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**MATPOWER**

# **MATPOWER Reference Manual**

***Release 8.0***

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# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Functions</b>	<b>2</b>
2.1	MATPOWER Installer . . . . .	2
2.2	Top-Level Simulation Functions . . . . .	4
2.3	Other Functions . . . . .	7
<b>3</b>	<b>Classes</b>	<b>8</b>
3.1	Task Classes . . . . .	8
3.2	Data Model Classes . . . . .	28
3.3	Data Model Converter Classes . . . . .	59
3.4	Network Model Classes . . . . .	72
3.5	Mathematical Model Classes . . . . .	122
3.6	Miscellaneous Classes . . . . .	157
3.7	MATPOWER Extension Classes . . . . .	171
<b>4</b>	<b>Tests</b>	<b>214</b>
4.1	MATPOWER Tests . . . . .	214
4.2	MATPOWER Test Data . . . . .	217
<b>5</b>	<b>Legacy</b>	<b>220</b>
5.1	Legacy Class . . . . .	220
5.2	Legacy Functions . . . . .	226
5.3	Legacy Tests . . . . .	372
<b>6</b>	<b>Previous Versions</b>	<b>385</b>
	<b>Index</b>	<b>386</b>

The purpose of this *Reference Manual* is to provide reference documentation on each class and function in MATPOWER. This documentation is automatically generated from the corresponding help text in the Matlab source for each function, class, property or method.

The GitHub icon in the upper right of each reference page links to the corresponding source file in the master branch on GitHub.

Currently, this manual includes *only* classes and functions that make up the new **MP-Core** and the **flexible** and **legacy** MATPOWER frameworks, but not the other legacy MATPOWER functions or the included packages [MP-Opt-Model](#), [MIPS](#), [MP-Test](#), or [MOST](#).

## 2.1 MATPOWER Installer

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**Note:** The `install_matpower()` (page 2) function is generally **not** in your MATLAB/Octave path, unless you change your current working directory to the MATPOWER install directory where it is located.

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### 2.1.1 install\_matpower

`install_matpower(modify, save_it, verbose, rm_oldpaths)`

`install_matpower()` (page 2) - Assist user in setting path to install MATPOWER.

```
install_matpower
install_matpower(modify)
install_matpower(modify, save_it)
install_matpower(modify, save_it, verbose)
install_matpower(modify, save_it, verbose, rm_oldpaths)
success = install_matpower(...)
```

Assists the user in setting up the proper MATLAB/Octave path to be able to use MATPOWER and run its tests. With no input arguments it prompts interactively to determine how to handle the paths.

---

**Note:** This function is generally **not** in your MATLAB/Octave path, unless you change your current working directory to the MATPOWER install directory where it is located.

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There are two main approaches for installing MATPOWER.

1. If you have a single version of MATPOWER, select the options to modify and save the path (interactive option 3). This will add MATPOWER to your default MATLAB/Octave path for all future sessions.
2. If you have multiple versions of MATPOWER, select the options to not modify the path (interactive option 1), but to save the `addpath()` commands to a file. Then execute the saved file to use this version of MATPOWER.

*All inputs and outputs are optional.*

## Inputs

- **modify** (*boolean*) – select how to set path
  - 0 (*default*) - generate relevant `addpath()` commands, but don't execute them; MATPOWER is not installed
  - 1 - modify the path by executing the relevant `addpath()` commands; MATPOWER is installed for this session
- **save\_it** (*integer or string*) – indicates whether or not to save the results
  - 0 or [] (*default*) - don't save any results
  - if `modify` is 0
    - \* `save_it = <string>` : the relevant `addpath()` commands are saved to a file whose name is provided in `save_it`; execute saved file in any session to make MATPOWER available for the session
    - \* `save_it = <other true value>` : the relevant `addpath()` commands are saved to a file named 'startup.m' in the current directory; MATPOWER is available in any session affected by this 'startup.m' file
    - \* *otherwise* : the commands are displayed, but not saved
  - if `modify` is 1
    - \* `save_it = <any true value>` : the path will be modified and saved with `savepath()`; MATPOWER is available in this and all future sessions
    - \* *otherwise* : the path will be modified but not saved
- **verbose** (*boolean*) – prints the relevant `addpath()` commands if true (*default*), silent otherwise
- **rm\_oldpaths** (*boolean*) – remove existing installation
  - 0 (*default*) - do **not** remove existing MATPOWER from path
  - 1 - remove existing MATPOWER paths first

## Output

**success** (*boolean*) – 1 if all commands succeeded, 0 otherwise

Examples:

```
install_matpower           % interactive mode, prompt for options
install_matpower(0);      % print the required addpath() commands
install_matpower(0, 1);   % save the commands to startup.m
install_matpower(1, 1);   % modify my path and save
install_matpower(1, 0, 0); % modify my path temporarily & silently
install_matpower(0, 'matpower8'); % save the commands to matpower8.m
install_matpower(0, 0, 1, 1); % uninstall MATPOWER from path (must
                             % call savepath() separately to make
                             % permanent)
```

See also `addpath`, `savepath`.

## 2.2 Top-Level Simulation Functions

These are top-level functions intended as user commands for running power flow (PF), continuation power flow (CPF), optimal power flow (OPF) and other custom simulation or optimization tasks.

### 2.2.1 run\_mp

**run\_mp**(*task\_class*, *d*, *mpopt*, *varargin*)

*run\_mp*() (page 4) - Run any MATPOWER simulation.

```
run_mp(task_class, d, mpopt)
run_mp(task_class, d, mpopt, ...)
task = run_mp(...)
```

This is **the** main function in the **flexible framework** for running MATPOWER. It creates the task object, applying any specified extensions, runs the task, and prints or saves the solution, if desired.

It is typically called from one of the wrapper functions such as *run\_pf*() (page 5), *run\_cpf*() (page 5), or *run\_opf*() (page 6).

#### Inputs

- **task\_class** (*function handle*) – handle to constructor of default task class for type of task to be run, e.g. *mp.task\_pf* (page 19) for power flow, *mp.task\_cpf* (page 21) for CPF, and *mp.task\_opf* (page 22) for OPF
- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct

Additional optional inputs can be provided as *<name>*, *<val>* pairs, with the following options:

- 'print\_fname' - file name for saving pretty-printed output
- 'soln\_fname' - file name for saving solved case
- 'mpx' - MATPOWER extension or cell array of MATPOWER extensions to apply

#### Output

**task** (*mp.task* (page 8)) – task object containing the solved run including the data, network, and mathematical model objects.

Solution results are available in the data model, and its elements, contained in the returned task object. For example:

```
task = run_opf('case9');
lam_p = task.dm.elements.bus.tab.lam_p % nodal price
pg = task.dm.elements.gen.tab.pg % generator active dispatch
```

See also *run\_pf*() (page 5), *run\_cpf*() (page 5), *run\_opf*() (page 6), *mp.task* (page 8).

## 2.2.2 run\_pf

**run\_pf**(*varargin*)

*run\_pf()* (page 5) - Run a power flow.

```
run_pf(d, mpopt)
run_pf(d, mpopt, ...)
task = run_pf(...)
```

This is the main function used to run power flow (PF) problems via the **flexible MATPOWER framework**.

This function is a simple wrapper around *run\_mp()* (page 4), calling it with the first argument set to `@mp.task_pf`.

### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **mpopt** (*struct*) – MATPOWER options struct

Additional optional inputs can be provided as `<name>`, `<val>` pairs, with the following options:

- `'print_fname'` - file name for saving pretty-printed output
- `'soln_fname'` - file name for saving solved case
- `'mpx'` - MATPOWER extension or cell array of MATPOWER extensions to apply

### Output

**task** (`mp.task_pf` (page 19)) – task object containing the solved run including the data, network, and mathematical model objects.

Solution results are available in the data model, and its elements, contained in the returned task object. For example:

```
task = run_pf('case9');
va = task.dm.elements.bus.tab.va    % bus voltage angles
pg = task.dm.elements.gen.tab.pg    % generator active dispatch
```

See also *run\_mp()* (page 4), *mp.task\_pf* (page 19).

## 2.2.3 run\_cpf

**run\_cpf**(*varargin*)

*run\_cpf()* (page 5) Run a continuation power flow.

```
run_cpf(d, mpopt)
run_cpf(d, mpopt, ...)
task = run_cpf(...)
```

This is the main function used to run continuation power flow (CPF) problems via the **flexible MATPOWER framework**.

This function is a simple wrapper around *run\_mp()* (page 4), calling it with the first argument set to `@mp.task_cpf`.



### Inputs

- **d** – data source specification, currently assumed to be a cell array of two MATPOWER case names or case structs (`mpc`), the first being the base case, the second the target case
- **mpopt** (*struct*) – MATPOWER options struct

Additional optional inputs can be provided as `<name>`, `<val>` pairs, with the following options:

- `'print_fname'` - file name for saving pretty-printed output
- `'soln_fname'` - file name for saving solved case
- `'mpx'` - MATPOWER extension or cell array of MATPOWER extensions to apply

### Output

**task** (`mp.task_cpf` (page 21)) – task object containing the solved run including the data, network, and mathematical model objects.

Solution results are available in the data model, and its elements, contained in the returned task object. For example:

```
task = run_cpf({'case9', 'case9target'});
vm = task.dm.elements.bus.tab.vm      % bus voltage magnitudes
pg = task.dm.elements.gen.tab.pg      % generator active dispatch
```

See also `run_mp()` (page 4), `mp.task_cpf` (page 21).

## 2.2.4 run\_opf

### `run_opf(varargin)`

`run_opf()` (page 6) Run an optimal power flow.

```
run_opf(d, mpopt)
run_opf(d, mpopt, ...)
task = run_opf(...)
```

This is the main function used to run optimal power flow (OPF) problems via the **flexible MATPOWER framework**.

This function is a simple wrapper around `run_mp()` (page 4), calling it with the first argument set to `@mp.task_opf`.

### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **mpopt** (*struct*) – MATPOWER options struct

Additional optional inputs can be provided as `<name>`, `<val>` pairs, with the following options:

- `'print_fname'` - file name for saving pretty-printed output
- `'soln_fname'` - file name for saving solved case
- `'mpx'` - MATPOWER extension or cell array of MATPOWER extensions to apply

**Output**

**task** (*mp.task\_opf* (page 22)) – task object containing the solved run including the data, network, and mathematical model objects.

Solution results are available in the data model, and its elements, contained in the returned task object. For example:

```
task = run_opf('case9');
lam_p = task.dm.elements.bus.tab.lam_p % nodal price
pg = task.dm.elements.gen.tab.pg % generator active dispatch
```

See also *run\_mp()* (page 4), *mp.task\_opf* (page 22).

## 2.3 Other Functions

### 2.3.1 mp\_table\_class

**mp\_table\_class()**

*mp\_table\_class()* (page 7) - Returns handle to constructor for `table` or *mp\_table* (page 157).

Returns a handle to `table` constructor, if it is available, otherwise to *mp\_table* (page 157) constructor. Useful for table-based code that is compatible with both MATLAB (using native tables) and Octave (using *mp\_table* (page 157) or the `table` implementation from Tablicious, if available).

```
% Works in MATLAB or Octave, which does not (yet) natively support table().
table_class = mp_table_class();
T = table_class(var1, var2, ...);
```

See also `table`, *mp\_table* (page 157).

## 3.1 Task Classes

### 3.1.1 Core Task Classes

#### `mp.task`

##### `class mp.task`

Bases: `handle`

`mp.task` (page 8) - MATPOWER task abstract base class.

Each task type (e.g. power flow, CPF, OPF) will inherit from `mp.task` (page 8).

Provides properties and methods related to the specific problem specification being solved (e.g. power flow, continuation power flow, optimal power flow, etc.). In particular, it coordinates all interactions between the 3 (data, network, mathematical) model layers.

The model objects, and indirectly their elements, as well as the solution success flag and messages from the mathematical model solver, are available in the properties of the task object.

##### **`mp.task` Properties:**

- `tag` (page 10) - task tag - e.g. 'PF', 'CPF', 'OPF'
- `name` (page 10) - task name - e.g. 'Power Flow', etc.
- `dmc` (page 10) - data model converter object
- `dm` (page 10) - data model object
- `nm` (page 10) - network model object
- `mm` (page 10) - mathematical model object
- `mm_opt` (page 10) - solve options for mathematical model
- `i_dm` (page 10) - iteration counter for data model loop
- `i_nm` (page 10) - iteration counter for network model loop

- *i\_mmm* (page 10) - iteration counter for math model loop
- *success* (page 10) - success flag, 1 - math model solved, 0 - didn't solve
- *message* (page 10) - output message
- *et* (page 10) - elapsed time (seconds) for *run()* (page 10) method

#### **mp.task Methods:**

- *run()* (page 10) - execute the task
- *next\_mmm()* (page 11) - controls iterations over mathematical models
- *next\_nm()* (page 11) - controls iterations over network models
- *next\_dm()* (page 11) - controls iterations over data models
- *run\_pre()* (page 12) - called at beginning of *run()* (page 10) method
- *run\_post()* (page 12) - called at end of *run()* (page 10) method
- *print\_soln()* (page 12) - display pretty-printed results
- *print\_soln\_header()* (page 12) - display success/failure, elapsed time
- *save\_soln()* (page 13) - save solved case to file
- *dm\_converter\_class()* (page 13) - get data model converter constructor
- *dm\_converter\_class\_mpc2\_default()* (page 13) - get default data model converter constructor
- *dm\_converter\_create()* (page 13) - create data model converter object
- *data\_model\_class()* (page 14) - get data model constructor
- *data\_model\_class\_default()* (page 14) - get default data model constructor
- *data\_model\_create()* (page 14) - create data model object
- *data\_model\_build()* (page 15) - create and build data model object
- *data\_model\_build\_pre()* (page 15) - called at beginning of *data\_model\_build()* (page 15)
- *data\_model\_build\_post()* (page 15) - called at end of *data\_model\_build()* (page 15)
- *network\_model\_class()* (page 15) - get network model constructor
- *network\_model\_class\_default()* (page 16) - get default network model constructor
- *network\_model\_create()* (page 16) - create network model object
- *network\_model\_build()* (page 16) - create and build network model object
- *network\_model\_build\_pre()* (page 16) - called at beginning of *network\_model\_build()* (page 16)
- *network\_model\_build\_post()* (page 17) - called at end of *network\_model\_build()* (page 16)
- *network\_model\_x\_soln()* (page 17) - update network model state from math model solution
- *network\_model\_update()* (page 17) - update net model state/soln from math model soln
- *math\_model\_class()* (page 17) - get mathematical model constructor
- *math\_model\_class\_default()* (page 18) - get default mathematical model constructor
- *math\_model\_create()* (page 18) - create mathematical model object
- *math\_model\_build()* (page 18) - create and build mathematical model object

- `math_model_opt()` (page 19) - get options struct to pass to `mm.solve()`

See the `sec_task` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.data_model` (page 28), `mp.net_model` (page 91), `mp.math_model` (page 122), `mp.dm_converter` (page 60).

### Property Summary

**tag**

(*char array*) task `tag` (page 10) - e.g. 'PF', 'CPF', 'OPF'

**name**

(*char array*) task `name` (page 10) - e.g. 'Power Flow', etc.

**dmc**

(*mp.dm\_converter* (page 60)) data model converter object

**dm**

(*mp.data\_model* (page 28)) data model object

**nm**

(*mp.net\_model* (page 91)) network model object

**mm**

(*mp.math\_model* (page 122)) mathematical model object

**mm\_opt**

(*struct*) solve options for mathematical model

**i\_dm**

(*integer*) iteration counter for data model loop

**i\_nm**

(*integer*) iteration counter for network model loop

**i\_mm**

(*integer*) iteration counter for math model loop

**success**

(*integer*) `success` (page 10) flag, 1 - math model solved, 0 - didn't solve

**message**

(*char array*) output `message` (page 10)

**et**

(*double*) elapsed time (seconds) for `run()` (page 10) method

### Method Summary

**run(d, mpopt, mpx)**

Execute the task.

```
task.run(d, mpopt)
task.run(d, mpopt, mpx)
```

**Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)

- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**task** (*mp.task* (page 8)) – task object containing the solved *run()* (page 10) including the data, network, and mathematical model objects.

Execute the task, creating the data model converter and the data, network and mathematical model objects, solving the math model and propagating the solution back to the data model.

See the `sec_task` section in the *MATPOWER Developer's Manual* for more information.

**next\_mm**(*mm, nm, dm, mpopt, mpx*)

Controls iterations over mathematical models.

```
[mm, nm, dm] = task.next_mm(mm, nm, dm, mpopt, mpx)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

- **mm** (*mp.math\_model* (page 122)) – new or updated mathematical model object, or empty matrix
- **nm** (*mp.net\_model* (page 91)) – potentially updated network model object
- **dm** (*mp.data\_model* (page 28)) – potentially updated data model object

Called automatically by *run()* (page 10) method. Subclasses can override this method to return a new or updated math model object for use in the next iteration or an empty matrix (the default) if finished.

**next\_nm**(*mm, nm, dm, mpopt, mpx*)

Controls iterations over network models.

```
[nm, dm] = task.next_nm(mm, nm, dm, mpopt, mpx)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

- **nm** (*mp.net\_model* (page 91)) – new or updated network model object, or empty matrix
- **dm** (*mp.data\_model* (page 28)) – potentially updated data model object

Called automatically by *run()* (page 10) method. Subclasses can override this method to return a new or updated network model object for use in the next iteration or an empty matrix (the default) if finished.

**next\_dm**(*mm, nm, dm, mpopt, mpx*)

Controls iterations over data models.

```
dm = task.next_dm(mm, nm, dm, mpopt, mpx)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**dm** (*mp.data\_model* (page 28)) – new or updated data model object, or empty matrix

Called automatically by `run()` (page 10) method. Subclasses can override this method to return a new or updated data model object for use in the next iteration or an empty matrix (the default) if finished.

**run\_pre**(*d, mpopt*)

Called at beginning of `run()` (page 10) method.

```
[d, mpopt] = task.run_pre(d, mpopt)
```

**Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct

**Outputs**

- **d** – updated value of corresponding input
- **mpopt** (*struct*) – updated value of corresponding input

Subclasses can override this method to update the input data or options before beginning the run.

**run\_post**(*mm, nm, dm, mpopt*)

Called at end of `run()` (page 10) method.

```
task.run_post(mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**task** (*mp.task* (page 8)) – task object

Subclasses can override this method to do any final processing after the run is complete.

**print\_soln**(*mpopt, fname*)

Display the pretty-printed results.

```
task.print_soln(mpop)
task.print_soln(mpop, fname)
```

**Inputs**

- **mpopt** (*struct*) – MATPOWER options struct
- **fname** (*char array*) – file name for saving pretty-printed output

Display to standard output and/or save to a file the pretty-printed solved case.

**print\_soln\_header**(*mpopt, fd*)

Display solution header information.

```
task.print_soln_header(mpop, fd)
```

**Inputs**

- **mpopt** (*struct*) – MATPOWER options struct
- **fd** (*integer*) – file identifier (1 for standard output)

Called by `print_soln()` (page 12) to print success/failure, elapsed time, etc. to a file identifier.

### **save\_soln**(*fname*)

Save the solved case to a file.

```
task.save_soln(fname)
```

#### **Input**

**fname** (*char array*) – file name for saving solved case

### **dm\_converter\_class**(*d*, *mpopt*, *mpx*)

Get data model converter constructor.

```
dmc_class = task.dm_converter_class(d, mpopt, mpx)
```

#### **Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

#### **Output**

**dmc\_class** (*function handle*) – handle to the constructor to be used to instantiate the data model converter object

Called by `dm_converter_create()` (page 13) to determine the class to use for the data model converter object. Handles any modifications specified by MATPOWER options or extensions.

### **dm\_converter\_class\_mpc2\_default**()

Get default data model converter constructor.

```
dmc_class = task.dm_converter_class_mpc2_default()
```

#### **Output**

**dmc\_class** (*function handle*) – handle to default constructor to be used to instantiate the data model converter object

Called by `dm_converter_class()` (page 13) to determine the default class to use for the data model converter object when the input is a version 2 MATPOWER case struct.

### **dm\_converter\_create**(*d*, *mpopt*, *mpx*)

Create data model converter object.

```
dmc = task.dm_converter_create(d, mpopt, mpx)
```

#### **Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

#### **Output**

**dmc** (*mp.dm\_converter* (page 60)) – data model converter object, ready to build

Called by `dm_converter_build()` (page 13) method to instantiate the data model converter object. Handles any modifications to data model converter elements specified by MATPOWER options or extensions.



**dm\_converter\_build**(*d*, *mpopt*, *mpx*)

Create and build data model converter object.

```
dmc = task.dm_converter_build(d, mpopt, mpx)
```

**Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**dmc** (*mp.dm\_converter* (page 60)) – data model converter object, ready for use

Called by *run()* (page 10) method to instantiate and build the data model converter object, including any modifications specified by MATPOWER options or extensions.

**data\_model\_class**(*d*, *mpopt*, *mpx*)

Get data model constructor.

```
dm_class = task.data_model_class(d, mpopt, mpx)
```

**Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**dm\_class** (*function handle*) – handle to the constructor to be used to instantiate the data model object

Called by *data\_model\_create()* (page 14) to determine the class to use for the data model object. Handles any modifications specified by MATPOWER options or extensions.

**data\_model\_class\_default**()

Get default data model constructor.

```
dm_class = task.data_model_class_default()
```

**Output**

**dm\_class** (*function handle*) – handle to default constructor to be used to instantiate the data model object

Called by *data\_model\_class()* (page 14) to determine the default class to use for the data model object.

**data\_model\_create**(*d*, *mpopt*, *mpx*)

Create data model object.

```
dm = task.data_model_create(d, mpopt, mpx)
```

**Inputs**

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**dm** (*mp.data\_model* (page 28)) – data model object, ready to build

Called by `data_model_build()` (page 15) to instantiate the data model object. Handles any modifications to data model elements specified by MATPOWER options or extensions.

**data\_model\_build**(*d*, *dmc*, *mpopt*, *mpx*)

Create and build data model object.

```
dm = task.data_model_create(d, dmc, mpopt, mpx)
```

#### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **dmc** (`mp.dm_converter` (page 60)) – data model converter object
- **mpopt** (`struct`) – MATPOWER options struct
- **mpx** (cell array of `mp.extension` (page 171)) – MATPOWER Extensions

#### Output

**dm** (`mp.data_model` (page 28)) – data model object, ready for use

Called by `run()` (page 10) method to instantiate and build the data model object, including any modifications specified by MATPOWER options or extensions.

**data\_model\_build\_pre**(*dm*, *d*, *dmc*, *mpopt*)

Called at beginning of `data_model_build()` (page 15).

```
[dm, d] = task.data_model_build_pre(dm, d, dmc, mpopt)
```

#### Inputs

- **dm** (`mp.data_model` (page 28)) – data model object
- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **dmc** (`mp.dm_converter` (page 60)) – data model converter object
- **mpopt** (`struct`) – MATPOWER options struct

#### Outputs

- **dm** (`mp.data_model` (page 28)) – updated data model object
- **d** – updated value of corresponding input

Called just *before* calling the data model's `build()` method. In this base class, this method does nothing.

**data\_model\_build\_post**(*dm*, *dmc*, *mpopt*)

Called at end of `data_model_build()` (page 15).

```
dm = task.data_model_build_post(dm, dmc, mpopt)
```

#### Inputs

- **dm** (`mp.data_model` (page 28)) – data model object
- **dmc** (`mp.dm_converter` (page 60)) – data model converter object
- **mpopt** (`struct`) – MATPOWER options struct

#### Output

**dm** (`mp.data_model` (page 28)) – updated data model object

Called just *after* calling the data model's `build()` method. In this base class, this method does nothing.

**network\_model\_class**(*dm*, *mpopt*, *mpx*)

Get network model constructor.

```
nm_class = task.network_model_class(dm, mpopt, mpx)
```

#### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**nm\_class** (*function handle*) – handle to the constructor to be used to instantiate the network model object

Called by *network\_model\_create()* (page 16) to determine the class to use for the network model object. Handles any modifications specified by MATPOWER options or extensions.

**network\_model\_class\_default**(*dm, mpopt*)

Get default network model constructor.

```
nm_class = task.network_model_class_default(dm, mpopt)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**nm\_class** (*function handle*) – handle to default constructor to be used to instantiate the network model object

Called by *network\_model\_class()* (page 15) to determine the default class to use for the network model object.

*Note: This is an abstract method that must be implemented by a subclass.*

**network\_model\_create**(*dm, mpopt, mpx*)

Create network model object.

```
nm = task.network_model_create(dm, mpopt, mpx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**nm** (*mp.net\_model* (page 91)) – network model object, ready to build

Called by *network\_model\_build()* (page 16) to instantiate the network model object. Handles any modifications to network model elements specified by MATPOWER options or extensions.

**network\_model\_build**(*dm, mpopt, mpx*)

Create and build network model object.

```
nm = task.network_model_build(dm, mpopt, mpx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**nm** (*mp.net\_model* (page 91)) – network model object, ready for use

Called by *run()* (page 10) method to instantiate and build the network model object, including any modifications specified by MATPOWER options or extensions.

**network\_model\_build\_pre**(*nm, dm, mpopt*)

Called at beginning of *network\_model\_build()* (page 16).

```
nm = task.network_model_build_pre(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**nm** (*mp.net\_model* (page 91)) – updated network model object

Called just *before* calling the network model's *build()* method. In this base class, this method does nothing.

**network\_model\_build\_post**(*nm, dm, mpopt*)

Called at end of *network\_model\_build()* (page 16).

```
nm = task.network_model_build_post(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**nm** (*mp.net\_model* (page 91)) – updated network model object

Called just *after* calling the network model's *build()* method. In this base class, this method does nothing.

**network\_model\_x\_soln**(*mm, nm*)

Update network model state from math model solution.

```
nm = task.network_model_x_soln(mm, nm)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object

**Output**

**nm** (*mp.net\_model* (page 91)) – updated network model object

Called by *network\_model\_update()* (page 17).

**network\_model\_update**(*mm, nm*)

Update network model state, solution values from math model solution.

```
nm = task.network_model_update(mm, nm)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object

**Output**

**nm** (*mp.net\_model* (page 91)) – updated network model object

Called by *run()* (page 10) method.

**math\_model\_class**(*nm, dm, mpopt, mpx*)

Get mathematical model constructor.

```
mm_class = task.math_model_class(nm, dm, mpopt, mpx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**mm\_class** (*function handle*) – handle to the constructor to be used to instantiate the mathematical model object

Called by *math\_model\_create()* (page 18) to determine the class to use for the mathematical model object. Handles any modifications specified by MATPOWER options or extensions.

**math\_model\_class\_default**(*nm, dm, mpopt*)

Get default mathematical model constructor.

```
mm_class = task.math_model_class_default(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**mm\_class** (*function handle*) – handle to the constructor to be used to instantiate the mathematical model object

Called by *math\_model\_class()* (page 17) to determine the default class to use for the mathematical model object.

*Note: This is an abstract method that must be implemented by a subclass.*

**math\_model\_create**(*nm, dm, mpopt, mpx*)

Create mathematical model object.

```
mm = task.math_model_create(nm, dm, mpopt, mpx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**mm** (*mp.math\_model* (page 122)) – mathematical model object, ready to build

Called by *math\_model\_build()* (page 18) to instantiate the mathematical model object. Handles any modifications to mathematical model elements specified by MATPOWER options or extensions.

**math\_model\_build**(*nm, dm, mpopt, mpx*)

Create and build mathematical model object.

```
mm = task.math_model_build(nm, dm, mpopt, mpx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct
- **mpx** (cell array of *mp.extension* (page 171)) – MATPOWER Extensions

**Output**

**mm** (*mp.math\_model* (page 122)) – mathematical model object, ready for use

Called by *run()* (page 10) method to instantiate and build the mathematical model object, including any modifications specified by MATPOWER options or extensions.

**math\_model\_opt**(*mm, nm, dm, mpopt*)

Get the options struct to pass to *mm.solve()*.

```
opt = task.math_model_opt(mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**opt** (*struct*) – options struct for mathematical model solve() method

Called by *run()* (page 10) method.

**mp.task\_pf**

**class mp.task\_pf**

Bases: *mp.task* (page 8)

*mp.task\_pf* (page 19) - MATPOWER task for power flow (PF).

Provides task implementation for the power flow problem.

This includes the handling of iterative runs to enforce generator reactive power limits, if requested.

**mp.task\_pf Properties:**

- *tag* (page 20) - task tag 'PF'
- *name* (page 20) - task name 'Power Flow'
- *dc* (page 20) - true if using DC network model
- *iterations* (page 20) - total number of power flow iterations
- *ref* (page 20) - current ref node indices
- *ref0* (page 20) - initial ref node indices
- *va\_ref0* (page 20) - initial ref node voltage angles
- *fixed\_q\_idx* (page 20) - indices of fixed Q gens
- *fixed\_q\_qty* (page 20) - Q output of fixed Q gens

**mp.task\_pf Methods:**

- *run\_pre()* (page 20) - set dc property

- `next_dm()` (page 20) - optionally iterate to enforce generator reactive limits
- `enforce_q_lims()` (page 20) - implementation of generator reactive limits
- `network_model_class_default()` (page 20) - select default network model constructor
- `network_model_build_post()` (page 20) - initialize properties for reactive limits
- `network_model_x_soln()` (page 20) - correct the voltage angles if necessary
- `math_model_class_default()` (page 21) - select default math model constructor

See also `mp.task` (page 8).

### Property Summary

**tag** = 'PF'

**name** = 'Power Flow'

**dc**

true if using DC network model (from `mpopt.model`, cached in `run_pre()` (page 20))

**iterations**

(integer) total number of power flow `iterations` (page 20)

**ref**

(integer) current `ref` (page 20) node indices

**ref0**

(integer) initial ref node indices

**va\_ref0**

(double) initial ref node voltage angles

**fixed\_q\_idx**

(integer) indices of fixed Q gens

**fixed\_q\_qty**

(double) Q output of fixed Q gens

### Method Summary

**run\_pre**(*d*, *mpopt*)

Set `dc` property after calling superclass `run_pre()` (page 12).

**next\_dm**(*nm*, *nm*, *dm*, *mpopt*, *mpx*)

Implement optional iterations to enforce generator reactive limits.

**enforce\_q\_lims**(*nm*, *dm*, *mpopt*)

Used by `next_dm()` (page 20) to implement enforcement of generator reactive limits.

**network\_model\_class\_default**(*dm*, *mpopt*)

Implement selector for default network model constructor depending on `mpopt.model` and `mpopt.pf.v_cartesian`.

**network\_model\_build\_post**(*nm*, *dm*, *mpopt*)

Initialize `mp.task_pf` (page 19) properties, if non-empty AC case with generator reactive limits enforced.

**network\_model\_x\_soln**(*mm, nm*)

Call superclass *network\_model\_x\_soln()* (page 17) then correct the voltage angle if the ref node has been changed.

**math\_model\_class\_default**(*nm, dm, mpopt*)

Implement selector for default mathematical model constructor depending on *mpopt.model*, *mpopt.pf.v\_cartesian*, and *mpopt.pf.current\_balance*.

**mp.task\_cpf****class mp.task\_cpf**

Bases: *mp.task\_pf* (page 19)

*mp.task\_cpf* (page 21) - MATPOWER task for continuation power flow (CPF).

Provides task implementation for the continuation power flow problem.

This includes the iterative solving of the mathematical model (using warm restarts) after updating the problem data, e.g. when enforcing certain limits.

**mp.task\_cpf Properties:**

- *warmstart* (page 21) - warm start data

**mp.task\_cpf Methods:**

- *task\_cpf()* (page 21) - constructor, inherits from *mp.task\_pf* (page 19) constructor
- *run\_pre()* (page 22) - call superclass *run\_pre()* (page 20) for base and target inputs
- *next\_mm()* (page 22) - handle warm start of continuation iterations
- *dm\_converter\_class()* (page 22) - select data model converter class
- *data\_model\_class\_default()* (page 22) - select default data model constructor
- *data\_model\_build()* (page 22) - build base and target data models
- *network\_model\_build()* (page 22) - build base and target network models
- *network\_model\_x\_soln()* (page 22) - update network model solution
- *network\_model\_update()* (page 22) - evaluate port injection solution
- *math\_model\_class\_default()* (page 22) - select default math model constructor
- *math\_model\_opt()* (page 22) - add warmstart parameters to math model solve options

See also *mp.task* (page 8), *mp.task\_pf* (page 19).

**Constructor Summary****task\_cpf()**

Constructor, inherits from *mp.task\_pf* (page 19) constructor.

**Property Summary****warmstart**

(*struct*) warm start data, with fields:

- *clam* - corrector parameter lambda
- *plam* - predictor parameter lambda



- *cV* - corrector complex voltage vector
- *pV* - predictor complex voltage vector

### Method Summary

**run\_pre**(*d, mpopt*)

Call superclass [run\\_pre\(\)](#) (page 20) for base and target inputs.

**next\_mm**(*mm, nm, dm, mpopt, mpx*)

Handle warm start of continuation iterations, after problem data update.

**dm\_converter\_class**(*d, mpopt, mpx*)

Implement selector for data model converter class based on superclass constructor.

**data\_model\_class\_default**()

Implement selector for default data model constructor.

**data\_model\_build**(*d, dmc, mpopt, mpx*)

Call superclass [data\\_model\\_build\(\)](#) for base and target models.

**network\_model\_build**(*dm, mpopt, mpx*)

Call superclass [network\\_model\\_build\(\)](#) for base and target models.

**network\_model\_x\_soln**(*mm, nm*)

Call superclass [network\\_model\\_x\\_soln\(\)](#) (page 20) then update solution in target network model.

**network\_model\_update**(*mm, nm*)

Call superclass [network\\_model\\_update\(\)](#) then update port injection solution by interpolating with parameter *lambda*.

**math\_model\_class\_default**(*nm, dm, mpopt*)

Implement selector for default mathematical model constructor depending on *mpopt.pf.v\_cartesian* and *mpopt.pf.current\_balance*.

**math\_model\_opt**(*mm, nm, dm, mpopt*)

Call superclass [math\\_model\\_opt\(\)](#) then add warmstart parameters, if available.

## mp.task\_opf

### class mp.task\_opf

Bases: [mp.task](#) (page 8)

[mp.task\\_opf](#) (page 22) - MATPOWER task for optimal power flow (OPF).

Provides task implementation for the optimal power flow problem.

#### mp.task\_opf Properties:

- *tag* - task tag 'OPF'
- *name* - task name 'Optimal Power Flow'
- *dc* (page 23) - true if using DC network model

#### mp.task\_opf Methods:

- [run\\_pre\(\)](#) (page 23) - set *dc* property
- [print\\_soln\\_header\(\)](#) (page 23) - add printout of objective function value

- `data_model_class_default()` (page 23) - select default data model constructor
- `data_model_build_post()` (page 23) - adjust bus voltage limits, if requested
- `network_model_class_default()` (page 23) - select default network model constructor
- `math_model_class_default()` (page 23) - select default math model constructor

See also `mp.task` (page 8).

### Property Summary

#### **dc**

true if using DC network model (from `mpopt.model`, cached in `run_pre()` (page 23))

### Method Summary

#### **run\_pre(*d*, *mpopt*)**

Set dc property after calling superclass `run_pre()` (page 12), then check for unsupported AC OPF solver selection.

#### **print\_soln\_header(*mpopt*, *fd*)**

Call superclass `print_soln_header()` (page 12) the print out the objective function value.

#### **data\_model\_class\_default()**

Implement selector for default data model constructor.

#### **data\_model\_build\_post(*dm*, *dmc*, *mpopt*)**

Call superclass `data_model_build_post()` (page 15) then adjust bus voltage magnitude limits based on generator `vm_setpoint`, if requested.

#### **network\_model\_class\_default(*dm*, *mpopt*)**

Implement selector for default network model constructor depending on `mpopt.model` and `mpopt.opf.v_cartesian`.

#### **math\_model\_class\_default(*nm*, *dm*, *mpopt*)**

Implement selector for default mathematical model constructor depending on `mpopt.model`, `mpopt.opf.v_cartesian`, and `mpopt.opf.current_balance`.

## 3.1.2 Legacy Task Classes

Used by MP-Core when called by the *legacy MATPOWER framework*.

### **mp.task\_pf\_legacy**

#### **class mp.task\_pf\_legacy**

Bases: `mp.task_pf` (page 19), `mp.task_shared_legacy` (page 27)

`mp.task_pf_legacy` (page 23) - MATPOWER task for legacy power flow (PF).

Adds functionality needed by the *legacy MATPOWER framework* to the task implementation for the power flow problem. This consists of pre-processing some input data and exporting and packaging result data.

#### **mp.task\_pf Methods:**

- `run_pre()` (page 24) - pre-process inputs that are for legacy framework only

- `run_post()` (page 24) - export results back to data model source
- `legacy_post_run()` (page 24) - post-process *legacy framework* outputs

See also `mp.task_pf` (page 19), `mp.task` (page 8), `mp.task_shared_legacy` (page 27).

### Method Summary

#### `run_pre(d, mpopt)`

Pre-process inputs that are for *legacy framework* only.

```
[d, mpopt] = task.run_pre(d, mpopt)
```

#### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **mpopt** (*struct*) – MATPOWER options struct

#### Outputs

- **d** – updated value of corresponding input
- **mpopt** (*struct*) – updated value of corresponding input

Call `run_pre_legacy()` (page 28) method before calling parent.

#### `run_post(mm, nm, dm, mpopt)`

Export results back to data model source.

```
task.run_post(mm, nm, dm, mpopt)
```

#### Inputs

- **mm** (`mp.math_model` (page 122)) – mathematical model object
- **nm** (`mp.net_model` (page 91)) – network model object
- **dm** (`mp.data_model` (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

#### Output

**task** (`mp.task` (page 8)) – task object

Calls `mp.dm_converter.export()` (page 61) and saves the result in the data model source property.

#### `legacy_post_run(mpopt)`

Post-process *legacy framework* outputs.

```
[results, success] = task.legacy_post_run(mpopt)
```

#### Input

**mpopt** (*struct*) – MATPOWER options struct

#### Outputs

- **results** (*struct*) – results struct for *legacy MATPOWER framework*, see Table 4.1 in *legacy MATPOWER User's Manual*.
- **success** (*integer*) – 1 - succeeded, 0 - failed

Extract results and success and save the task object in `results.task` before returning.

## mp.task\_cpf\_legacy

### class mp.task\_cpf\_legacy

Bases: [mp.task\\_cpf](#) (page 21), [mp.task\\_shared\\_legacy](#) (page 27)

[mp.task\\_cpf](#) (page 21) - MATPOWER task for legacy continuation power flow (CPF).

Adds functionality needed by the *legacy MATPOWER framework* to the task implementation for the continuation power flow problem. This consists of pre-processing some input data and exporting and packaging result data.

#### mp.task\_pf Methods:

- [run\\_pre\(\)](#) (page 25) - pre-process inputs that are for legacy framework only
- [run\\_post\(\)](#) (page 25) - export results back to data model source
- [legacy\\_post\\_run\(\)](#) (page 25) - post-process *legacy framework* outputs

See also [mp.task\\_cpf](#) (page 21), [mp.task](#) (page 8), [mp.task\\_shared\\_legacy](#) (page 27).

#### Method Summary

##### **run\_pre**(*d*, *mpopt*)

Pre-process inputs that are for *legacy framework* only.

```
[d, mpopt] = task.run_pre(d, mpopt)
```

##### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct

##### Outputs

- **d** – updated value of corresponding input
- **mpopt** (*struct*) – updated value of corresponding input

Call [run\\_pre\\_legacy\(\)](#) (page 28) method for both input cases before calling parent.

##### **run\_post**(*mm*, *nm*, *dm*, *mpopt*)

Export results back to data model source.

```
task.run_post(mm, nm, dm, mpopt)
```

##### Inputs

- **mm** ([mp.math\\_model](#) (page 122)) – mathematical model object
- **nm** ([mp.net\\_model](#) (page 91)) – network model object
- **dm** ([mp.data\\_model](#) (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

##### Output

**task** ([mp.task](#) (page 8)) – task object

Calls [mp.dm\\_converter.export\(\)](#) (page 61) and saves the result in the data model source property.

##### **legacy\_post\_run**(*mpopt*)

Post-process *legacy framework* outputs.

```
[results, success] = task.legacy_post_run(mpop)
```

##### Input

**mpopt** (*struct*) – MATPOWER options struct

##### Outputs

- **results** (*struct*) – results struct for *legacy MATPOWER framework*, see Table 5.1 in *legacy MATPOWER User’s Manual*.
- **success** (*integer*) – 1 - succeeded, 0 - failed

Extract results and success and save the task object in `results.task` before returning.

## mp.task\_opf\_legacy

### class mp.task\_opf\_legacy

Bases: *mp.task\_opf* (page 22), *mp.task\_shared\_legacy* (page 27)

*mp.task\_opf* (page 22) - MATPOWER task for legacy optimal power flow (OPF).

Adds functionality needed by the *legacy MATPOWER framework* to the task implementation for the optimal power flow problem. This consists of pre-processing some input data and exporting and packaging result data, as well as using some legacy specific model sub-classes.

#### mp.task\_pf Methods:

- *run\_pre()* (page 26) - pre-process inputs that are for legacy framework only
- *run\_post()* (page 26) - export results back to data model source
- *dm\_converter\_class\_mpc2\_default()* (page 27) - set to *mp.dm\_converter\_mpc2\_legacy* (page 63)
- *data\_model\_build\_post()* (page 27) - get data model converter to do more input pre-processing
- *math\_model\_class\_default()* (page 27) - use legacy math model subclasses
- *legacy\_post\_run()* (page 27) - post-process *legacy framework* outputs

See also *mp.task\_opf* (page 22), *mp.task* (page 8), *mp.task\_shared\_legacy* (page 27).

#### Method Summary

##### **run\_pre**(*d*, *mpopt*)

Pre-process inputs that are for *legacy framework* only.

```
[d, mpo] = task.run_pre(d, mpo)
```

##### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (*mpc*)
- **mpopt** (*struct*) – MATPOWER options struct

##### Outputs

- **d** – updated value of corresponding input
- **mpopt** (*struct*) – updated value of corresponding input

Call *run\_pre\_legacy()* (page 28) method before calling parent.

##### **run\_post**(*mm*, *nm*, *dm*, *mpopt*)

Export results back to data model source.

```
task.run_post(mm, nm, dm, mpo)
```

##### Inputs

- **mm** (*mp.math\_model* (page 122)) – mathematical model object

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**task** (*mp.task* (page 8)) – task object

Calls *mp.dm\_converter.export()* (page 61) and saves the result in the data model source property.

**dm\_converter\_class\_mpc2\_default()**

Set to *mp.dm\_converter\_mpc2\_legacy* (page 63).

```
dmc_class = task.dm_converter_class_mpc2_default()
```

**data\_model\_build\_post(dm, dmc, mpopt)**

Get data model converter to do more input pre-processing after calling superclass *data\_model\_build\_post()* (page 23).

**math\_model\_class\_default(nm, dm, mpopt)**

Use legacy math model subclasses to support legacy costs and callbacks.

Uses math model variations that inherit from *mp.mn\_shared\_opf\_legacy* (page 143) (compatible with the legacy *opf\_model* (page 220)), in order to support legacy cost functions and callback functions that expect to find the MATPOWER case struct in *mm.mpc*.

**legacy\_post\_run(mpop)**

Post-process *legacy framework* outputs.

```
[results, success, raw] = task.legacy_post_run(mpop)
```

**Input**

**mpopt** (*struct*) – MATPOWER options struct

**Outputs**

- **results** (*struct*) – results struct for *legacy MATPOWER framework*, see Table 6.1 in *legacy MATPOWER User's Manual*.
- **success** (*integer*) – 1 - succeeded, 0 - failed
- **raw** (*struct*) – see raw field in Table 6.1 in *legacy MATPOWER User's Manual*.

Extract results and success and save the task object in *results.task* before returning. This method also creates and populates numerous other fields expected in the legacy OPF results struct, such as *f*, *x*, *om*, *mu*, *g*, *dg*, *raw*, *var*, *nle*, *nli*, *lin*, and *cost*. Based on code from the legacy functions *opf\_execute()* (page 293), *dcopf\_solver()* (page 287), and *nlpopf\_solver()* (page 288).

**mp.task\_shared\_legacy****class mp.task\_shared\_legacy**

Bases: *handle*

*mp.task\_shared\_legacy* (page 27) - Shared legacy task functionality.

Provides legacy task functionality shared across different tasks (e.g. PF, CPF, OPF), specifically, the pre-processing of input data for the experimental system-wide ZIP load data.

**mp.task\_pf Methods:**

- *run\_pre\_legacy()* (page 28) - handle experimental system-wide ZIP load inputs

See also [mp.task](#) (page 8).

### Method Summary

**run\_pre\_legacy**(*d*, *mpopt*)

Handle experimental system-wide ZIP load inputs.

```
[d, mpopt] = task.run_pre_legacy(d, mpopt)
```

#### Inputs

- **d** – data source specification, currently assumed to be a MATPOWER case name or case struct (`mpc`)
- **mpopt** (*struct*) – MATPOWER options struct

#### Outputs

- **d** – updated value of corresponding input
- **mpopt** (*struct*) – updated value of corresponding input

Moves the legacy experimental system-wide ZIP load data from `mpopt.exp.sys_wide_zip_loads` to `d.sys_wide_zip_loads` to make it available to the data model converter ([mp.dmce\\_load\\_mpc2](#) (page 71)).

Called by [run\\_pre\(\)](#) (page 12).

## 3.2 Data Model Classes

### 3.2.1 Containers

#### mp.data\_model

**class mp.data\_model**

Bases: [mp.element\\_container](#) (page 166)

[mp.data\\_model](#) (page 28) - Base class for MATPOWER **data model** objects.

The data model object encapsulates the input data provided by the user for the problem of interest and the output data presented back to the user upon completion. It corresponds roughly to the `mpc` (MATPOWER case) and `results` structs used throughout the legacy MATPOWER implementation, but encapsulated in an object with additional functionality. It includes tables of data for each type of element in the system.

A data model object is primarily a container for data model element ([mp.dm\\_element](#) (page 36)) objects. Concrete data model classes may be specific to the task.

By convention, data model variables are named `dm` and data model class names begin with `mp.data_model`.

#### mp.data\_model Properties:

- [base\\_mva](#) (page 29) - system per unit MVA base
- [base\\_kva](#) (page 29) - system per unit kVA base
- [source](#) (page 29) - source of data, e.g. `mpc` (MATPOWER case struct)
- [userdata](#) (page 29) - arbitrary user data

#### mp.data\_model Methods:

- `data_model()` (page 29) - constructor, assign default data model element classes
- `copy()` (page 30) - make duplicate of object
- `build()` (page 30) - create, add, and build element objects
- `count()` (page 30) - count instances of each element and remove if count is zero
- `initialize()` (page 30) - initialize (online/offline) status of each element
- `update_status()` (page 30) - update (online/offline) status based on connectivity, etc
- `build_params()` (page 31) - extract/convert/calculate parameters for online elements
- `online()` (page 31) - get number of online elements of named type
- `display()` (page 31) - display the data model object
- `pretty_print()` (page 31) - pretty print data model to console or file
- `pp_flags()` (page 32) - from options, build flags to control pretty printed output
- `pp_section_label()` (page 32) - construct section header lines for output
- `pp_section_list()` (page 32) - return list of section tags
- `pp_have_section()` (page 33) - return true if section exists for object
- `pp_section()` (page 33) - pretty print the given section
- `pp_get_headers()` (page 33) - construct pretty printed lines for section headers
- `pp_get_headers_cnt()` (page 33) - construct pretty printed lines for **cnt** section headers
- `pp_get_headers_ext()` (page 34) - construct pretty printed lines for **ext** section headers
- `pp_data()` (page 34) - pretty print the data for the given section
- `set_bus_v_lims_via_vg()` (page 34) - set gen bus voltage limits based on gen voltage setpoints

See the `sec_data_model` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.task` (page 8), `mp.net_model` (page 91), `mp.math_model` (page 122), `mp.dm_converter` (page 60).

### Constructor Summary

#### `data_model()`

Constructor, assign default data model element classes.

```
dm = mp.data_model()
```

### Property Summary

#### `base_mva`

(*double*) system per unit MVA base, for balanced single-phase systems/sections, must be provided if system includes any 'bus' elements

#### `base_kva`

(*double*) system per unit kVA base, for unbalanced 3-phase systems/sections, must be provided if system includes any 'bus3p' elements

#### `source`

*source* (page 29) of data, e.g. `mpc` (MATPOWER case struct)



**userdata = struct()**

(*struct*) arbitrary user data

### Method Summary

**copy()**

Create a duplicate of the data model object, calling the `copy()` (page 41) method on each element.

```
new_dm = dm.copy()
```

**build(d, dmc)**

Create and add data model element objects.

```
dm.build(d, dmc)
```

#### Inputs

- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for `mp.dm_converter_mpc2` (page 62))
- **dmc** (`mp.dm_converter` (page 60)) – data model converter

Create the data model element objects by instantiating each class in the `element_classes` (page 166) property and adding the resulting object to the `elements` (page 166) property. Then proceed through the following additional `build()` (page 30) stages for each element.

- Import
- Count
- Initialize
- Update status
- Build parameters

See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* for more information.

**count()**

Count instances of each element and remove if `count()` (page 30) is zero.

```
dm.count()
```

Call each element's `count()` (page 41) method to determine the number of instances of that element in the data, and remove the element type from `elements` (page 166) if the count is 0.

Called by `build()` (page 30) to perform its **count** stage. See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* for more information.

**initialize()**

Initialize (online/offline) status of each element.

```
dm.initialize()
```

Call each element's `initialize()` (page 41) method to `initialize()` (page 30) statuses and create ID to row index mappings.

Called by `build()` (page 30) to perform its **initialize** stage. See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* for more information.

**update\_status()**

Update (online/offline) status based on connectivity, etc.

```
dm.update_status()
```

Call each element's `update_status()` (page 42) method to update statuses based on connectivity or other criteria and define element properties containing number and row indices of online elements, indices of offline elements, and mapping of row indices to indices in online and offline element lists.

Called by `build()` (page 30) to perform its **update status** stage. See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* for more information.

### **build\_params()**

Extract/convert/calculate parameters for online elements.

```
dm.build_params()
```

Call each element's `build_params()` (page 42) method to build parameters as necessary for online elements from the original data tables (e.g. p.u. conversion, initial state, etc.) and store them in element-specific properties.

Called by `build()` (page 30) to perform its **build parameters** stage. See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* more information.

### **online(name)**

Get number of online elements of named type.

```
n = dm.online(name)
```

#### **Input**

**name** (*char array*) – name of element type (e.g. 'bus', 'gen') as returned by the element's `name()` (page 38) method

#### **Output**

**n** (*integer*) – number of online elements

### **display()**

Display the data model object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the data model elements.

### **pretty\_print(mpop, fd)**

Pretty print data model to console or file.

```
dm.pretty_print(mpop)
dm.pretty_print(mpop, fd)
[dm, out] = dm.pretty_print(mpop, fd)
```

#### **Inputs**

- **mpopt** (*struct*) – MATPOWER options struct
- **fd** (*integer*) – (*optional, default = 1*) file identifier to use for printing, (1 for standard output, 2 for standard error)

#### **Outputs**

- **dm** (*mp.data\_model* (page 28)) – the data model object
- **out** (*struct*) – struct of output control flags

Displays the model parameters to a pretty-printed text format. The result can be output either to the console or to a file.

The output is organized into sections and each element type controls its own output for each section. The default sections are:

- **cnt** - counts, number of online, offline, and total elements of this type

- **sum** - summary, e.g. total amount of capacity, load, line loss, etc.
- **ext** - extremes, e.g. min and max voltages, nodal prices, etc.
- **det** - details, table of detailed data, e.g. voltages, prices for buses, dispatch, limits for generators, etc.

**pp\_flags**(mpopt)

From options, build flags to control pretty printed output.

```
[out, add] = dm.pp_flags(mpop)
```

**Input**

**mpopt** (*struct*) – MATPOWER options struct

**Outputs**

- **out** (*struct*) – struct of output control flags

```
out
.all      (-1, 0 or 1)
.any      (0 or 1)
.sec
.cnt
.all      (-1, 0 or 1)
.any      (0 or 1)
.sum      (same as cnt)
.ext      (same as cnt)
.det
.all      (-1, 0 or 1)
.any      (0 or 1)
.elm
.<name>   (0 or 1)
```

where <name> is the name of the corresponding element type.

- **add** (*struct*) – additional data for subclasses to use

```
add
.s0
.<name> = 0
.s1
.<name> = 1
.suppress (-1, 0 or 1)
.names    (cell array of element names)
.ne       (number of element names)
```

See also [pretty\\_print\(\)](#) (page 31).

**pp\_section\_label**(label, blank\_line)

Construct pretty printed lines for section label.

```
h = dm.pp_section_label(label, blank_line)
```

**Inputs**

- **label** (*char array*) – label for the section header
- **blank\_line** (*boolean*) – include a blank line before the section label if true

**Output**

**h** (*cell array of char arrays*) – individual lines of section label

See also [pretty\\_print\(\)](#) (page 31).

**pp\_section\_list**(*out*)

Return list of section tags.

```
sections = dm.pp_section_list(out)
```

**Input**

**out** (*struct*) – struct of output control flags (see [pp\\_flags\(\)](#) (page 32) for details)

**Output**

**sections** (*cell array of char arrays*) – e.g. {'cnt', 'sum', 'ext', 'det'}

See also [pretty\\_print\(\)](#) (page 31).

**pp\_have\_section**(*section, mpopt*)

Return true if section exists for object with given options.

```
TorF = dm.pp_have_section(section, mpopt)
```

**Inputs**

- **section** (*char array*) – e.g. 'cnt', 'sum', 'ext', or 'det'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**TorF** (*boolean*) – true if section exists

See also [pretty\\_print\(\)](#) (page 31).

**pp\_section**(*section, out\_s, mpopt, fd*)

Pretty print the given section.

```
dm.pp_section(section, out_s, mpopt, fd)
```

**Inputs**

- **section** (*char array*) – e.g. 'cnt', 'sum', 'ext', or 'det'
- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct
- **fd** (*integer*) – (*optional, default = 1*) file identifier to use for printing, (1 for standard output, 2 for standard error)

See also [pretty\\_print\(\)](#) (page 31).

**pp\_get\_headers**(*section, out\_s, mpopt*)

Construct pretty printed lines for section headers.

```
h = dm.pp_get_headers(section, out_s, mpopt)
```

**Inputs**

- **section** (*char array*) – e.g. 'cnt', 'sum', 'ext', or 'det'
- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**h** (*cell array of char arrays*) – individual lines of section headers

See also [pretty\\_print\(\)](#) (page 31).

**pp\_get\_headers\_cnt**(*out\_s, mpopt*)

Construct pretty printed lines for **cnt** section headers.

```
h = dm.pp_get_headers_cnt(out_s, mpopt)
```

**Inputs**

- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**h** (*cell array of char arrays*) – individual lines of **cnt** section headers

See also [pretty\\_print\(\)](#) (page 31), [pp\\_get\\_headers\(\)](#) (page 33).

**pp\_get\_headers\_ext**(*out\_s, mpopt*)

Construct pretty printed lines for **ext** section headers.

```
h = dm.pp_get_headers_ext(out_s, mpopt)
```

**Inputs**

- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**h** (*cell array of char arrays*) – individual lines of **ext** section headers

See also [pretty\\_print\(\)](#) (page 31), [pp\\_get\\_headers\(\)](#) (page 33).

**pp\_get\_headers\_other**(*section, out\_s, mpopt*)

Construct pretty printed lines for other section headers.

Returns nothing in base class, but subclasses can implement other section types (e.g. 'lim' for OPF).

```
h = dm.pp_get_headers_other(section, out_s, mpopt)
```

**Inputs**

- **section** (*char array*) – e.g. 'cnt', 'sum', 'ext', or 'det'
- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**h** (*cell array of char arrays*) – individual lines of **ext** section headers

See also [pretty\\_print\(\)](#) (page 31), [pp\\_get\\_headers\(\)](#) (page 33).

**pp\_data**(*section, out\_s, mpopt, fd*)

Pretty print the data for the given section.

```
dm.pp_data(section, out_s, mpopt, fd)
```

**Inputs**

- **section** (*char array*) – e.g. 'cnt', 'sum', 'ext', or 'det'
- **out\_s** (*struct*) – output control flags for the section, `out_s = out.sec.(section)`
- **mpopt** (*struct*) – MATPOWER options struct
- **fd** (*integer*) – (*optional, default = 1*) file identifier to use for printing, (1 for standard output, 2 for standard error)

See also [pretty\\_print\(\)](#) (page 31), [pp\\_section\(\)](#) (page 33).

**set\_bus\_v\_lims\_via\_vg**(*use\_vg*)

Set gen bus voltage limits based on gen voltage setpoints.

```
dm.set_bus_v_lims_via_vg(use_vg)
```

**Input**

**use\_vg** (*double*) – 1 if voltage setpoint should be used, 0 for original bus voltage bounds, or fractional value between 0 and 1 for bounds interpolated between the two.

## mp.data\_model\_cpf

### class mp.data\_model\_cpf

Bases: *mp.data\_model* (page 28)

*mp.data\_model\_cpf* (page 35) - MATPOWER **data model** for CPF tasks.

The purpose of this class is to include CPF-specific subclasses for the load and shunt elements, which need to be able to provide versions of their model parameters that are parameterized by the continuation parameter  $\lambda$ .

#### data\_model\_cpf Methods:

- *data\_model\_cpf()* (page 35) - constructor, assign default data model element classes

See also *mp.data\_model* (page 28).

#### Constructor Summary

##### data\_model\_cpf()

Constructor, assign default data model element classes.

Create an empty data model object and assign the default data model element classes, which are the same as those defined by the base class, except for loads and shunts.

```
dm = mp.data_model_cpf()
```

## mp.data\_model\_opf

### class mp.data\_model\_opf

Bases: *mp.data\_model* (page 28)

*mp.data\_model\_opf* (page 35) - MATPOWER **data model** for OPF tasks.

The purpose of this class is to include OPF-specific subclasses for its elements and to handle pretty-printing output for **lim** sections.

#### mp.data\_model\_opf Methods:

- *data\_model\_opf()* (page 35) - constructor, assign default data model element classes
- *pp\_flags()* (page 36) - add flags for **lim** sections
- *pp\_section\_list()* (page 36) - append 'lim' tag for **lim** sections to default list
- *pp\_get\_headers\_other()* (page 36) - construct headers for **lim** section headers

See also *mp.data\_model* (page 28).

#### Constructor Summary

##### data\_model\_opf()

Constructor, assign default data model element classes.

Create an empty data model object and assign the default data model element classes, each specific to OPF.

```
dm = mp.data_model_opf()
```

### Method Summary

#### **pp\_flags**(*mpopt*)

Add flags for **lim** sections.

See [mp.data\\_model.pp\\_flags\(\)](#) (page 32).

#### **pp\_section\_list**(*out*)

Append 'lim' tag for **lim** section to default list.

See [mp.data\\_model.pp\\_section\\_list\(\)](#) (page 32).

#### **pp\_get\_headers\_other**(*section, out\_s, mpop*)

Construct pretty printed lines for **lim** section headers.

See [mp.data\\_model.pp\\_get\\_headers\\_other\(\)](#) (page 34).

## 3.2.2 Elements

### mp.dm\_element

#### class mp.dm\_element

Bases: handle

[mp.dm\\_element](#) (page 36) - Abstract base class for MATPOWER **data model element** objects.

A data model element object encapsulates all of the input and output data for a particular element type. All data model element classes inherit from [mp.dm\\_element](#) (page 36) and each element type typically implements its own subclass. A given data model element object contains the data for all instances of that element type, stored in one or more table data structures.

Defines the following columns in the main data table, which are inherited by all subclasses:

Name	Type	Description
uid	<i>integer</i>	unique ID
name	<i>char</i> <i>array</i>	element name
status	<i>boolean</i>	true = online, false = offline
source_uid	<i>unde- fined</i>	intended for any info required to link back to element instance in source data

By convention, data model element variables are named `dme` and data model element class names begin with `mp.dme`.

In addition to being containers for the data itself, data model elements are responsible for handling the on/off status of each element, preparation of parameters needed by network and mathematical models, definition of connections with other elements, defining solution data to be updated when exporting, and pretty-printing of data to the console or file.

Elements that create nodes (e.g. buses) are called **junction** elements. Elements that define ports (e.g. generators, branches, loads) can connect the ports of a particular instance to the nodes of a particular instance of a junction element by specifying two pieces of information for each port:

- the **type** of junction element it connects to
- the **index** of the specific junction element

#### mp.dm\_element Properties:

- *tab* (page 38) - main data table
- *nr* (page 38) - total number of rows in table
- *n* (page 38) - number of online elements
- *ID2i* (page 38) - max(ID) x 1 vector, maps IDs to row indices
- *on* (page 38) - n x 1 vector of row indices of online elements
- *off* (page 38) - (nr-n) x 1 vector of row indices of offline elements
- *i2on* (page 38) - nr x 1 vector mapping row index to index in on/off respectively

#### mp.dm\_element Methods:

- *name()* (page 38) - get name of element type, e.g. 'bus', 'gen'
- *label()* (page 39) - get singular label for element type, e.g. 'Bus', 'Generator'
- *labels()* (page 39) - get plural label for element type, e.g. 'Buses', 'Generators'
- *cxn\_type()* (page 39) - type(s) of junction element(s) to which this element connects
- *cxn\_idx\_prop()* (page 39) - name(s) of property(ies) containing indices of junction elements
- *cxn\_type\_prop()* (page 40) - name(s) of property(ies) containing types of junction elements
- *table\_exists()* (page 40) - check for existence of data in main data table
- *main\_table\_var\_names()* (page 40) - names of variables (columns) in main data table
- *export\_vars()* (page 40) - names of variables to be exported by DMCE to data source
- *export\_vars\_offline\_val()* (page 41) - values of export variables for offline elements
- *dm\_converter\_element()* (page 41) - get corresponding data model converter element
- *copy()* (page 41) - create a duplicate of the data model element object
- *count()* (page 41) - determine number of instances of this element in the data
- *initialize()* (page 41) - initialize (online/offline) status of each element
- *ID()* (page 42) - return unique ID's for all or indexed rows
- *init\_status()* (page 42) - initialize status column
- *update\_status()* (page 42) - update (online/offline) status based on connectivity, etc
- *build\_params()* (page 42) - extract/convert/calculate parameters for online elements
- *rebuild()* (page 43) - rebuild object, calling *count()* (page 41), *initialize()* (page 41), *build\_params()* (page 42)
- *display()* (page 43) - display the data model element object
- *pretty\_print()* (page 43) - pretty-print data model element to console or file
- *pp\_have\_section()* (page 43) - true if pretty-printing for element has specified section



- `pp_rows()` (page 44) - indices of rows to include in pretty-printed output
- `pp_get_headers()` (page 44) - get pretty-printed headers for this element/section
- `pp_get_footers()` (page 44) - get pretty-printed footers for this element/section
- `pp_data()` (page 44) - pretty-print the data for this element/section
- `pp_have_section_cnt()` (page 44) - true if pretty-printing for element has **counts** section
- `pp_data_cnt()` (page 45) - pretty-print the **counts** data for this element
- `pp_have_section_sum()` (page 45) - true if pretty-printing for element has **summary** section
- `pp_data_sum()` (page 45) - pretty-print the **summary** data for this element
- `pp_have_section_ext()` (page 45) - true if pretty-printing for element has **extremes** section
- `pp_data_ext()` (page 45) - pretty-print the **extremes** data for this element
- `pp_have_section_det()` (page 45) - true if pretty-printing for element has **details** section
- `pp_get_title_det()` (page 45) - get title of **details** section for this element
- `pp_get_headers_det()` (page 46) - get pretty-printed **details** headers for this element
- `pp_get_footers_det()` (page 46) - get pretty-printed **details** footers for this element
- `pp_data_det()` (page 46) - pretty-print the **details** data for this element
- `pp_data_row_det()` (page 46) - get pretty-printed row of **details** data for this element

See the `sec_dm_element` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.data_model` (page 28).

### Property Summary

**tab**

*(table)* main data table

**nr**

*(integer)* total number of rows in table

**n**

*(integer)* number of online elements

**ID2i**

*(integer)* max(ID) x 1 vector, maps IDs to row indices

**on**

*(integer)* n x 1 vector of row indices of online elements

**off**

*(integer)* (nr-n) x 1 vector of row indices of offline elements

**i2on**

*(integer)* nr x 1 vector mapping row index to index in on/off respectively

### Method Summary

**name()**

Get name of element type, e.g. 'bus', 'gen'.

```
name = dme.name()
```

**Output**

**name** (*char array*) – name of element type, must be a valid struct field name

Implementation provided by an element type specific subclass.

**label()**

Get singular label for element type, e.g. 'Bus', 'Generator'.

```
label = dme.label()
```

**Output**

**label** (*char array*) – user-visible label for element type, when singular

Implementation provided by an element type specific subclass.

**labels()**

Get plural label for element type, e.g. 'Buses', 'Generators'.

```
label = dme.labels()
```

**Output**

**label** (*char array*) – user-visible label for element type, when plural

Implementation provided by an element type specific subclass.

**cxn\_type()**

Type(s) of junction element(s) to which this element connects.

```
name = dme.cxn_type()
```

**Output**

**name** (*char array or cell array of char arrays*) – name(s) of type(s) of junction elements, i.e. node-creating elements (e.g. 'bus'), to which this element connects

Assuming an element with *nc* connections, there are three options for the return value:

1. Single char array with one type that applies to all connections, `cxn_idx_prop()` (page 39) returns *empty*.
2. Cell array with *nc* elements, one for each connection, `cxn_idx_prop()` (page 39) returns *empty*.
3. Cell array of valid junction element types, `cxn_idx_prop()` (page 39) return value *not empty*.

See the `sec_dm_element_cxn` section in the *MATPOWER Developer's Manual* for more information.

Implementation provided by an element type specific subclass.

See also `cxn_idx_prop()` (page 39), `cxn_type_prop()` (page 40).

**cxn\_idx\_prop()**

Name(s) of property(ies) containing indices of junction elements.

```
name = dme.cxn_idx_prop()
```

**Output**

**name** (*char array or cell array of char arrays*) – name(s) of property(ies) containing indices of junction elements that define connections (e.g. {'fbus', 'tbus'})

See the `sec_dm_element_cxn` section in the *MATPOWER Developer's Manual* for more information.

Implementation provided by an element type specific subclass.

See also `cxn_type()` (page 39), `cxn_type_prop()` (page 40).

### `cxn_type_prop()`

Name(s) of property(ies) containing types of junction elements.

```
name = dme.cxn_type_prop()
```

#### Output

**name** (*char array or cell array of char arrays*) – name(s) of properties containing type of junction elements for each connection

*Note:* If not empty, dimension must match `cxn_idx_prop()` (page 39)

This is only used if the junction element type can vary by individual element, e.g. some elements of this type connect to one kind of bus, some to another kind. Otherwise, it returns an empty string and the junction element types for the connections are determined solely by `cxn_type()` (page 39).

See the `sec_dm_element_cxn` section in the *MATPOWER Developer's Manual* for more information.

Implementation provided by an element type specific subclass.

See also `cxn_type()` (page 39), `cxn_idx_prop()` (page 39).

### `table_exists()`

Check for existence of data in main data table.

```
TorF = dme.table_exists()
```

#### Output

**TorF** (*boolean*) – true if main data table is not empty

### `main_table_var_names()`

Names of variables (columns) in main data table.

```
names = dme.main_table_var_names()
```

#### Output

**names** (*cell array of char arrays*) – names of variables (columns) in main table

This base class includes the following variables {'uid', 'name', 'status', 'source\_uid'} which are common to all element types and should therefore be included in all subclasses. That is, subclass methods should append their additional fields to those returned by this parent method. For example, a subclass method would like something like the following:

```
function names = main_table_var_names(obj)
    names = horzcat( main_table_var_names@mp.dm_element(obj), ...
        {'subclass_var1', 'subclass_var2'} );
end
```

### `export_vars()`

Names of variables to be exported by DMCE to data source.

```
vars = dme.export_vars()
```

#### Output

**vars** (*cell array of char arrays*) – names of variables to export

Return the names of the variables the data model converter element needs to export to the data source. This is typically the list of variables updated by the solution process, e.g. bus voltages, line flows, etc.

### `export_vars_offline_val()`

Values of export variables for offline elements.

```
s = dme.export_vars_offline_val()
```

#### Output

`s` (*struct*) – keys are export variable names, values are the corresponding values to assign to these variables for offline elements.

Returns a struct defining the values of export variables for offline elements. Called by `mp.mm_element.data_model_update()` (page 146) to define how to set export variables for offline elements.

Export variables not found in the struct are not modified.

For example, `s = struct('va', 0, 'vm', 1)` would assign the value 0 to the `va` variable and 1 to the `vm` variable for any offline elements.

See also `export_vars()` (page 40).

### `dm_converter_element(dmc, name)`

Get corresponding data model converter element.

```
dmce = dme.dm_converter_element(dmc)
dmce = dme.dm_converter_element(dmc, name)
```

#### Inputs

- `dmc` (`mp.dm_converter` (page 60)) – data model converter object
- `name` (*char array*) – (optional) name of element type (default is name of this object)

#### Output

`dmce` (`mp.dmce_element` (page 63)) – data model converter element object

### `copy()`

Create a duplicate of the data model element object.

```
new_dme = dme.copy()
```

#### Output

`new_dme` (`mp.dm_element` (page 36)) – `copy()` (page 41) of data model element object

### `count(dm)`

Determine number of instances of this element in the data.

Store the count in the `nr` property.

```
nr = dme.count(dm);
```

#### Input

`dm` (`mp.data_model` (page 28)) – data model

#### Output

`nr` (*integer*) – number of instances (rows of data)

Called for each element by the `count()` (page 30) method of `mp.data_model` (page 28) during the `count` stage of a data model build.

See the `sec_building_data_model` section in the *MATPOWER Developer's Manual* for more information.

**initialize(dm)**

Initialize a newly created data model element object.

```
dme.initialize(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

Initialize the (online/offline) status of each element and create a mapping of ID to row index in the ID2i element property, then call *init\_status()* (page 42).

Called for each element by the *initialize()* (page 30) method of *mp.data\_model* (page 28) during the **initialize** stage of a data model build.

See the *sec\_building\_data\_model* section in the *MATPOWER Developer's Manual* for more information.

**ID(idx)**

Return unique ID's for all or indexed rows.

```
uid = dme.ID()  
uid = dme.ID(idx)
```

**Input**

**idx** (*integer*) – (*optional*) row index vector

Return an *nr* x 1 vector of unique IDs for all rows, i.e. a map of row index to unique ID or, if a row index vector is provided just the ID's of the indexed rows.

**init\_status(dm)**

Initialize status column.

```
dme.init_status(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

Called by *initialize()* (page 41). Does nothing in the base class.

**update\_status(dm)**

Update (online/offline) status based on connectivity, etc.

```
dme.update_status(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

Update status of each element based on connectivity or other criteria and define element properties containing number and row indices of online elements (*n* and *on*), indices of offline elements (*off*), and mapping (*i2on*) of row indices to corresponding entries in *on* or *off*.

Called for each element by the *update\_status()* (page 30) method of *mp.data\_model* (page 28) during the **update status** stage of a data model build.

See the *sec\_building\_data\_model* section in the *MATPOWER Developer's Manual* for more information.

**build\_params(dm)**

Extract/convert/calculate parameters for online elements.

```
dme.build_params(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

Extract/convert/calculate parameters as necessary for online elements from the original data tables (e.g. p.u. conversion, initial state, etc.) and store them in element-specific properties.

Called for each element by the *build\_params()* (page 31) method of *mp.data\_model* (page 28) during the **build parameters** stage of a data model build.

See the *sec\_building\_data\_model* section in the *MATPOWER Developer's Manual* for more information.

Does nothing in the base class.

**rebuild(dm)**

Rebuild object, calling *count()* (page 41), *initialize()* (page 41), *build\_params()* (page 42).

```
dme.rebuild(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

Typically used after modifying data in the main table.

**display()**

Display the data model element object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the elements, including total number of rows, number of online elements, and the main data table.

**pretty\_print(dm, section, out\_e, mpopt, fd, pp\_args)**

Pretty print data model element to console or file.

```
dme.pretty_print(dm, section, out_e, mpopt, fd, pp_args)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model
- **section** (*char array*) – section identifier, e.g. 'cnt', 'sum', 'ext', or 'det', for **counts**, **summary**, **extremes**, or **details** sections, respectively
- **out\_e** (*boolean*) – output control flag for this element/section
- **mpopt** (*struct*) – MATPOWER options struct
- **fd** (*integer*) – (*optional, default = 1*) file identifier to use for printing, (1 for standard output, 2 for standard error)
- **pp\_args** (*struct*) – arbitrary struct of additional pretty printing arguments passed to all sub-methods, allowing a single sub-method to be used for multiple output portions (e.g. for active and reactive power) by passing in a different argument; by convention, arguments for a branch element, for example, are passed in *pp\_args.branch*, etc.

**pp\_have\_section(section, mpopt, pp\_args)**

True if pretty-printing for element has specified section.

```
TorF = dme.pp_have_section(section, mpopt, pp_args)
```

**Inputs**

see *pretty\_print()* (page 43) for details

**Output**

**TorF** (*boolean*) – true if output includes specified section

Implementation handled by section-specific *pp\_have\_section* methods or *pp\_have\_section\_other()* (page 59).

See also *pp\_have\_section\_cnt()* (page 44), *pp\_have\_section\_sum()* (page 45), *pp\_have\_section\_ext()* (page 45), *pp\_have\_section\_det()* (page 45).

**pp\_rows**(*dm, section, out\_e, mpopt, pp\_args*)

Indices of rows to include in pretty-printed output.

```
rows = dme.pp_rows(dm, section, out_e, mpopt, pp_args)
```

**Inputs**

see *pretty\_print()* (page 43) for details

**Output**

**rows** (*integer*) – index vector of rows to be included in output

- 0 = no rows
- -1 = all rows

Includes all rows by default.

**pp\_get\_headers**(*dm, section, out\_e, mpopt, pp\_args*)

Get pretty-printed headers for this element/section.

```
h = dme.pp_get_headers(dm, section, out_e, mpopt, pp_args)
```

**Inputs**

see *pretty\_print()* (page 43) for details

**Output**

**h** (*cell array of char arrays*) – lines of pretty printed header output for this element/section

Empty by default for counts, summary and extremes sections, and handled by *pp\_get\_headers\_det()* (page 46) for details section.

**pp\_get\_footers**(*dm, section, out\_e, mpopt, pp\_args*)

Get pretty-printed footers for this element/section.

```
f = dme.pp_get_footers(dm, section, out_e, mpopt, pp_args)
```

**Inputs**

see *pretty\_print()* (page 43) for details

**Output**

**f** (*cell array of char arrays*) – lines of pretty printed footer output for this element/section

Empty by default for counts, summary and extremes sections, and handled by *pp\_get\_headers\_det()* (page 46) for details section.

**pp\_data**(*dm, section, rows, out\_e, mpopt, fd, pp\_args*)

Pretty-print the data for this element/section.

```
dme.pp_data(dm, section, rows, out_e, mpopt, fd, pp_args)
```

**Inputs**

- **rows** (*integer*) – indices of rows to include, from *pp\_rows()* (page 44)
- ... – see *pretty\_print()* (page 43) for details of other inputs

Implementation handled by section-specific *pp\_data* methods or *pp\_data\_other()* (page 59).

See also *pp\_data\_cnt()* (page 45), *pp\_data\_sum()* (page 45), *pp\_data\_ext()* (page 45), *pp\_data\_det()* (page 46).

**pp\_have\_section\_cnt**(*mpopt*, *pp\_args*)

True if pretty-printing for element has **counts** section.

```
TorF = dme.pp_have_section_cnt(mpop, pp_args)
```

Default is **true**.

See also [pp\\_have\\_section\(\)](#) (page 43).

**pp\_data\_cnt**(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)

Pretty-print the **counts** data for this element.

```
dme.pp_data_cnt(dm, rows, out_e, mpopt, fd, pp_args)
```

See also [pp\\_data\(\)](#) (page 44).

**pp\_have\_section\_sum**(*mpopt*, *pp\_args*)

True if pretty-printing for element has **summary** section.

```
TorF = dme.pp_have_section_sum(mpop, pp_args)
```

Default is **false**.

See also [pp\\_have\\_section\(\)](#) (page 43).

**pp\_data\_sum**(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)

Pretty-print the **summary** data for this element.

```
dme.pp_data_sum(dm, rows, out_e, mpopt, fd, pp_args)
```

Does nothing by default.

See also [pp\\_data\(\)](#) (page 44).

**pp\_have\_section\_ext**(*mpopt*, *pp\_args*)

True if pretty-printing for element has **extremes** section.

```
TorF = dme.pp_have_section_ext(mpop, pp_args)
```

Default is **false**.

See also [pp\\_have\\_section\(\)](#) (page 43).

**pp\_data\_ext**(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)

Pretty-print the **extremes** data for this element.

```
dme.pp_data_ext(dm, rows, out_e, mpopt, fd, pp_args)
```

Does nothing by default.

See also [pp\\_data\(\)](#) (page 44).

**pp\_have\_section\_det**(*mpopt*, *pp\_args*)

True if pretty-printing for element has **details** section.

```
TorF = dme.pp_have_section_det(mpop, pp_args)
```

Default is **false**.

See also [pp\\_have\\_section\(\)](#) (page 43).



**pp\_get\_title\_det**(*mpopt*, *pp\_args*)

Get title of **details** section for this element.

```
str = dme.pp_get_title_det(mpop, pp_args)
```

**Inputs**

see [pretty\\_print\(\)](#) (page 43) for details

**Output**

**str** (*char array*) – title of details section, e.g. 'Bus Data', 'Generator Data', etc.

Called by [pp\\_get\\_headers\\_det\(\)](#) (page 46) to insert title into detail section header.

**pp\_get\_headers\_det**(*dm*, *out\_e*, *mpopt*, *pp\_args*)

Get pretty-printed **details** headers for this element.

```
h = dme.pp_get_headers_det(dm, out_e, mpopt, pp_args)
```

See also [pp\\_get\\_headers\(\)](#) (page 44).

**pp\_get\_footers\_det**(*dm*, *out\_e*, *mpopt*, *pp\_args*)

Get pretty-printed **details** footers for this element.

```
f = dme.pp_get_footers_det(dm, out_e, mpopt, pp_args)
```

Empty by default.

See also [pp\\_get\\_footers\(\)](#) (page 44).

**pp\_data\_det**(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)

Pretty-print the **details** data for this element.

```
dme.pp_data_det(dm, rows, out_e, mpopt, fd, pp_args)
```

Calls [pp\\_data\\_row\\_det\(\)](#) (page 46) for each row.

See also [pp\\_data\(\)](#) (page 44), [pp\\_data\\_row\\_det\(\)](#) (page 46).

**pp\_data\_row\_det**(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)

Get pretty-printed row of **details** data for this element.

```
str = dme.pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)
```

**Inputs**

- **k** (*integer*) – index of row to print
- ... – see [pretty\\_print\(\)](#) (page 43) for details of other inputs

**Output**

**str** (*char array*) – row of data (*without newline*)

Called by [pp\\_data\\_det\(\)](#) (page 46) for each row.

**mp.dme\_branch****class mp.dme\_branch**

Bases: *mp.dm\_element* (page 36)

*mp.dme\_branch* (page 47) - Data model element for branch.

Implements the data element model for branch elements, including transmission lines and transformers.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus_fr</code>	<i>integer</i>	bus ID (uid) of “from” bus
<code>bus_to</code>	<i>integer</i>	bus ID (uid) of “to” bus
<code>r</code>	<i>double</i>	per unit series resistance
<code>x</code>	<i>double</i>	per unit series reactance
<code>g_fr</code>	<i>double</i>	per unit shunt conductance at “from” end
<code>b_fr</code>	<i>double</i>	per unit shunt susceptance at “from” end
<code>g_to</code>	<i>double</i>	per unit shunt conductance at “to” end
<code>b_to</code>	<i>double</i>	per unit shunt susceptance at “to” end
<code>sm_ub_a</code>	<i>double</i>	long term apparent power rating (MVA)
<code>sm_ub_b</code>	<i>double</i>	short term apparent power rating (MVA)
<code>sm_ub_c</code>	<i>double</i>	emergency apparent power rating (MVA)
<code>cm_ub_a</code>	<i>double</i>	long term current magnitude rating (MVA equivalent at 1 p.u. voltage)
<code>cm_ub_b</code>	<i>double</i>	short term current magnitude rating (MVA equivalent at 1 p.u. voltage)
<code>cm_ub_c</code>	<i>double</i>	emergency current magnitude rating (MVA equivalent at 1 p.u. voltage)
<code>vad_lb</code>	<i>double</i>	voltage angle difference lower bound
<code>vad_ub</code>	<i>double</i>	voltage angle difference upper bound
<code>tm</code>	<i>double</i>	transformer off-nominal turns ratio
<code>ta</code>	<i>double</i>	transformer phase-shift angle (degrees)
<code>pl_fr</code>	<i>double</i>	active power injection at “from” end
<code>ql_fr</code>	<i>double</i>	reactive power injection at “from” end
<code>pl_to</code>	<i>double</i>	active power injection at “to” end
<code>ql_to</code>	<i>double</i>	reactive power injection at “to” end

**Property Summary****fbus**

bus index vector for “from” port (port 1) (all branches)

**tbus**

bus index vector for “to” port (port 2) (all branches)

**r**

series resistance (p.u.) for branches that are on

**x**

series reactance (p.u.) for branches that are on

**g\_fr**

shunt conductance (p.u.) at “from” end for branches that are on

**g\_to**

shunt conductance (p.u.) at “to” end for branches that are on

**b\_fr**

shunt susceptance (p.u.) at “from” end for branches that are on

**b\_to**

shunt susceptance (p.u.) at “to” end for branches that are on

**tm**

transformer off-nominal turns ratio for branches that are on

**ta**

transformer phase-shift angle (radians) for branches that are on

**rate\_a**

long term flow limit (p.u.) for branches that are on

**Method Summary**

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**export\_vars()**

**export\_vars\_offline\_val()**

**initialize(*dm*)**

**update\_status(*dm*)**

**build\_params(*dm*)**

**pp\_data\_cnt(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**pp\_have\_section\_sum(*mpopt*, *pp\_args*)**

**pp\_data\_sum(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**pp\_get\_headers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_have\_section\_det(*mpopt*, *pp\_args*)**

**pp\_data\_row\_det(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**mp.dme\_branch\_opf****class mp.dme\_branch\_opf**

Bases: *mp.dme\_branch* (page 47), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_branch\_opf* (page 49) - Data model element for branch for OPF.

To parent class *mp.dme\_branch* (page 47), adds shadow prices on flow and angle difference limits, and pretty-printing for **lim** sections.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>mu_flow_fr_uk</code>	<i>double</i>	shadow price on flow constraint at “from” end ( $u/MVA$ ) <sup>1</sup>
<code>mu_flow_to_uk</code>	<i>double</i>	shadow price on flow constraint at “to” end ( $u/MVA$ ) <sup>1</sup>
<code>mu_vad_lb</code>	<i>double</i>	shadow price on lower bound of voltage angle difference constraint ( $u/degree$ ) <sup>1</sup>
<code>mu_vad_ub</code>	<i>double</i>	shadow price on upper bound of voltage angle difference constraint ( $u/degree$ ) <sup>1</sup>

**Method Summary**

`main_table_var_names()`

`export_vars()`

`export_vars_offline_val()`

`pretty_print(dm, section, out_e, mpopt, fd, pp_args)`

`pp_have_section_lim(mpop, pp_args)`

`pp_binding_rows_lim(dm, out_e, mpopt, pp_args)`

`pp_get_title_lim(mpop, pp_args)`

`pp_get_headers_lim(dm, out_e, mpopt, pp_args)`

`pp_data_row_lim(dm, k, out_e, mpopt, fd, pp_args)`

<sup>1</sup> Here  $u$  denotes the units of the objective function, e.g. USD.

## mp.dme\_bus

### class mp.dme\_bus

Bases: *mp.dm\_element* (page 36)

*mp.dme\_bus* (page 50) - Data model element for bus.

Implements the data element model for bus elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>base_kv</code>	<i>double</i>	base voltage ( <i>kV</i> )
<code>type</code>	<i>integer</i>	bus type (1 = PQ, 2 = PV, 3 = ref, 4 = isolated)
<code>area</code>	<i>integer</i>	area number
<code>zone</code>	<i>integer</i>	loss zone
<code>vm_lb</code>	<i>double</i>	voltage magnitude lower bound ( <i>p.u.</i> )
<code>vm_ub</code>	<i>double</i>	voltage magnitude upper bound ( <i>p.u.</i> )
<code>va</code>	<i>double</i>	voltage angle ( <i>degrees</i> )
<code>vm</code>	<i>double</i>	voltage magnitude ( <i>p.u.</i> )

### Property Summary

#### `type`

node *type* (page 50) vector for buses that are on

#### `vm_start`

initial voltage magnitudes (*p.u.*) for buses that are on

#### `va_start`

initial voltage angles (radians) for buses that are on

#### `vm_lb`

voltage magnitude lower bounds for buses that are on

#### `vm_ub`

voltage magnitude upper bounds for buses that are on

#### `vm_control`

true if voltage is controlled, for buses that are on

### Method Summary

`name()`

`label()`

`labels()`

`main_table_var_names()`

`export_vars()`

`export_vars_offline_val()`

`init_status(dm)`

```

update_status(dm)

build_params(dm)

pp_data_cnt(dm, rows, out_e, mpopt, fd, pp_args)

pp_have_section_ext(mpop, pp_args)

pp_data_ext(dm, rows, out_e, mpopt, fd, pp_args)

pp_have_section_det(mpop, pp_args)

pp_get_headers_det(dm, out_e, mpopt, pp_args)

pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)

set_bus_type_ref(dm, idx)

set_bus_type_pv(dm, idx)

set_bus_type_pq(dm, idx)

```

## mp.dme\_bus\_opf

**class** mp.dme\_bus\_opf

Bases: [mp.dme\\_bus](#) (page 50), [mp.dme\\_shared\\_opf](#) (page 59)

[mp.dme\\_bus\\_opf](#) (page 51) - Data model element for bus for OPF.

To parent class [mp.dme\\_bus](#) (page 50), adds shadow prices on power balance and voltage magnitude limits, and pretty-printing for **lim** sections.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
lam_p	<i>double</i>	active power nodal price, i.e. shadow price on active power balance constraint ( $u/MW$ ) <sup>1</sup>
lam_q	<i>double</i>	reactive power nodal price, i.e. shadow price on reactive power balance constraint ( $u/MVAr$ ) <sup>1</sup>
mu_vm_ll	<i>double</i>	shadow price on voltage magnitude lower bound ( $u/p.u.$ ) <sup>1</sup>
mu_vm_ul	<i>double</i>	shadow price on voltage magnitude upper bound ( $u/p.u.$ ) <sup>1</sup>

### Method Summary

```

main_table_var_names()

export_vars()

export_vars_offline_val()

```

<sup>1</sup> Here  $u$  denotes the units of the objective function, e.g. USD.

```

pp_data_ext(dm, rows, out_e, mpopt, fd, pp_args)
pp_get_headers_det(dm, out_e, mpopt, pp_args)
pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)
pp_have_section_lim(mpop, pp_args)
pp_binding_rows_lim(dm, out_e, mpopt, pp_args)
pp_get_headers_lim(dm, out_e, mpopt, pp_args)
pp_data_row_lim(dm, k, out_e, mpopt, fd, pp_args)

```

## mp.dme\_gen

**class mp.dme\_gen**

Bases: [mp.dm\\_element](#) (page 36)

[mp.dme\\_gen](#) (page 52) - Data model element for generator.

Implements the data element model for generator elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus</code>	<i>integer</i>	bus ID ( <code>uid</code> )
<code>vm_setpoint</code>	<i>double</i>	voltage magnitude setpoint ( <i>p.u.</i> )
<code>pg_lb</code>	<i>double</i>	active power output lower bound ( <i>MW</i> )
<code>pg_ub</code>	<i>double</i>	active power output upper bound ( <i>MW</i> )
<code>qg_lb</code>	<i>double</i>	reactive power output lower bound ( <i>MVA</i> )
<code>qg_ub</code>	<i>double</i>	reactive power output upper bound ( <i>MVA</i> )
<code>pg</code>	<i>double</i>	active power output ( <i>MW</i> )
<code>qg</code>	<i>double</i>	reactive power output ( <i>MVA</i> )
<code>startup_cost_cold</code>	<i>double</i>	cold startup cost ( <i>USD</i> )
<code>pc1</code>	<i>double</i>	lower active power output of PQ capability curve ( <i>MW</i> )
<code>pc2</code>	<i>double</i>	upper active power output of PQ capability curve ( <i>MW</i> )
<code>qc1_lb</code>	<i>double</i>	lower bound on reactive power output at <code>pc1</code> ( <i>MVA</i> )
<code>qc1_ub</code>	<i>double</i>	upper bound on reactive power output at <code>pc1</code> ( <i>MVA</i> )
<code>qc2_lb</code>	<i>double</i>	lower bound on reactive power output at <code>pc2</code> ( <i>MVA</i> )
<code>qc2_ub</code>	<i>double</i>	upper bound on reactive power output at <code>pc2</code> ( <i>MVA</i> )

### Property Summary

**bus**

[bus](#) (page 52) index vector (all gens)

**bus\_on**

vector of indices into online buses for gens that are on

**pg\_start**

initial active power (p.u.) for gens that are on

**qg\_start**

initial reactive power (p.u.) for gens that are on

**vm\_setpoint**

generator voltage setpoint for gens that are on

**pg\_lb**

active power lower bound (p.u.) for gens that are on

**pg\_ub**

active power upper bound (p.u.) for gens that are on

**qg\_lb**

reactive power lower bound (p.u.) for gens that are on

**qg\_ub**

reactive power upper bound (p.u.) for gens that are on

**Method Summary**

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**export\_vars()**

**export\_vars\_offline\_val()**

**have\_cost()**

**initialize(*dm*)**

**update\_status(*dm*)**

**apply\_vm\_setpoint(*dm*)**

**build\_params(*dm*)**

**violated\_q\_lims(*dm*, *mpopt*)**

**isload(*idx*)**

**pp\_have\_section\_sum(*mpopt*, *pp\_args*)**

**pp\_data\_sum(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**pp\_have\_section\_det(*mpopt*, *pp\_args*)**

**pp\_get\_headers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_get\_footers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_data\_row\_det(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**



**mp.dme\_gen\_opf****class mp.dme\_gen\_opf**

Bases: *mp.dme\_gen* (page 52), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_gen\_opf* (page 54) - Data model element for generator for OPF.

To parent class *mp.dme\_gen* (page 52), adds costs, shadow prices on active and reactive generation limits, and pretty-printing for **lim** sections.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>cost_pg</code>	<i>mp.cost_table</i>	active power cost ( $u/MW$ ) <sup>1</sup>
<code>cost_qg</code>	<i>mp.cost_table</i>	reactive power cost ( $u/MVAr$ ) <sup>1</sup>
<code>mu_pg_lb</code>	<i>double</i>	shadow price on active power output lower bound ( $u/MW$ ) <sup>1</sup>
<code>mu_pg_ub</code>	<i>double</i>	shadow price on active power output upper bound ( $u/MW$ ) <sup>1</sup>
<code>mu_qg_lb</code>	<i>double</i>	shadow price on reactive power output lower bound ( $u/MVAr$ ) <sup>1</sup>
<code>mu_qg_ub</code>	<i>double</i>	shadow price on reactive power output upper bound ( $u/MVAr$ ) <sup>1</sup>

The cost tables `cost_pg` and `cost_qg` are defined as tables with the following columns:

See also *mp.cost\_table* (page 162).

**Method Summary**

`main_table_var_names()`

`export_vars()`

`export_vars_offline_val()`

`have_cost()`

`build_cost_params(dm, dc)`

`max_pwl_gencost()`

`pretty_print(dm, section, out_e, mpopt, fd, pp_args)`

`pp_have_section_lim(mpop, pp_args)`

`pp_binding_rows_lim(dm, out_e, mpopt, pp_args)`

`pp_get_headers_lim(dm, out_e, mpopt, pp_args)`

`pp_data_row_lim(dm, k, out_e, mpopt, fd, pp_args)`

<sup>1</sup> Here  $u$  denotes the units of the objective function, e.g. USD.

**mp.dme\_load****class mp.dme\_load**

Bases: [mp.dm\\_element](#) (page 36)

[mp.dme\\_load](#) (page 55) - Data model element for load.

Implements the data element model for load elements, using a ZIP load model.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus</code>	<i>integer</i>	bus ID ( <code>uid</code> )
<code>pd</code>	<i>double</i>	$p_p$ , active constant power demand ( <i>MW</i> )
<code>qd</code>	<i>double</i>	$q_p$ , reactive constant power demand ( <i>MVA</i> r)
<code>pd_i</code>	<i>double</i>	$p_i$ , active nominal <sup>1</sup> constant current demand ( <i>MW</i> )
<code>qd_i</code>	<i>double</i>	$q_i$ , reactive nominal <sup>1</sup> constant current demand ( <i>MVA</i> r)
<code>pd_z</code>	<i>double</i>	$p_z$ , active nominal <sup>1</sup> constant impedance demand ( <i>MW</i> )
<code>qd_z</code>	<i>double</i>	$q_z$ , reactive nominal <sup>1</sup> constant impedance demand ( <i>MVA</i> r)
<code>p</code>	<i>double</i>	$p$ , total active demand ( <i>MW</i> )
<code>q</code>	<i>double</i>	$q$ , total reactive demand ( <i>MVA</i> r)

Implements a ZIP load model, where each load has three components, and total demand for the load  $i$  is given by

$$\begin{aligned} s &= s_p + s_i|v| + s_z|v|^2 \\ p + jq &= (p_p + jq_p) + (p_i + jq_i)|v| + (p_z + jq_z)|v|^2 \end{aligned} \quad (3.1)$$

**Property Summary****bus**

[bus](#) (page 55) index vector (all loads)

**pd**

active power demand (p.u.) for constant power loads that are on

**qd**

reactive power demand (p.u.) for constant power loads that are on

**pd\_i**

active power demand (p.u.) for constant current loads that are on

**qd\_i**

reactive power demand (p.u.) for constant current loads that are on

**pd\_z**

active power demand (p.u.) for constant impedance loads that are on

**qd\_z**

reactive power demand (p.u.) for constant impedance loads that are on

**Method Summary****name()**

<sup>1</sup> *Nominal* means for a voltage of 1 p.u.

`label()`  
`labels()`  
`cxn_type()`  
`cxn_idx_prop()`  
`main_table_var_names()`  
`count(dm)`  
`update_status(dm)`  
`build_params(dm)`  
`pp_have_section_sum(mpop, pp_args)`  
`pp_data_sum(dm, rows, out_e, mpop, fd, pp_args)`  
`pp_have_section_det(mpop, pp_args)`  
`pp_get_headers_det(dm, out_e, mpop, pp_args)`  
`pp_get_footers_det(dm, out_e, mpop, pp_args)`  
`pp_data_row_det(dm, k, out_e, mpop, fd, pp_args)`

### **mp.dme\_load\_cpf**

**class** `mp.dme_load_cpf`

Bases: `mp.dme_load` (page 55)

`mp.dme_load_cpf` (page 56) - Data model element for load for CPF.

To parent class `mp.dme_load` (page 55), adds method for adjusting model parameters based on value of continuation parameter  $\lambda$ , and overrides `export_vars` to export these updated parameter values.

#### **Method Summary**

`export_vars()`  
`parameterized(dm, dmb, dmt, lam)`

### **mp.dme\_load\_opf**

**class** `mp.dme_load_opf`

Bases: `mp.dme_load` (page 55), `mp.dme_shared_opf` (page 59)

`mp.dme_load_opf` (page 56) - Data model element for load for OPF.

To parent class `mp.dme_load` (page 55), adds pretty-printing for **lim** sections.

## mp.dme\_shunt\_cpf

### class mp.dme\_shunt\_cpf

Bases: [mp.dme\\_shunt](#) (page 57)

[mp.dme\\_shunt\\_cpf](#) (page 57) - Data model element for shunt for CPF.

To parent class [mp.dme\\_shunt](#) (page 57), adds method for adjusting model parameters based on value of continuation parameter  $\lambda$ , and overrides [export\\_vars\(\)](#) (page 57) to export these updated parameter values.

#### Method Summary

**export\_vars()**

**parameterized**(*dm, dmb, dmt, lam*)

## mp.dme\_shunt

### class mp.dme\_shunt

Bases: [mp.dm\\_element](#) (page 36)

[mp.dme\\_shunt](#) (page 57) - Data model element for shunt.

Implements the data element model for shunt elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
bus	<i>integer</i>	bus ID ( <code>uid</code> )
gs	<i>double</i>	$g_s$ , shunt conductance, specified as nominal <sup>1</sup> active power demand ( <i>MW</i> )
bs	<i>double</i>	$b_s$ , shunt susceptance, specified as nominal <sup>1</sup> reactive power injection ( <i>MVAR</i> )
p	<i>double</i>	$p$ , total active power absorbed ( <i>MW</i> )
q	<i>double</i>	$q$ , total reactive power absorbed ( <i>MVAR</i> )

#### Property Summary

##### bus

[bus](#) (page 57) index vector (all shunts)

##### gs

shunt conductance (p.u. active power demanded at

<sup>1</sup> *Nominal* means for a voltage of 1 p.u.

**bs**

V = 1.0 p.u.) for shunts that are on

#### Method Summary

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**count(*dm*)**

**update\_status(*dm*)**

**build\_params(*dm*)**

**pp\_have\_section\_sum(*mpopt*, *pp\_args*)**

**pp\_data\_sum(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**pp\_have\_section\_det(*mpopt*, *pp\_args*)**

**pp\_get\_headers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_get\_footers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_data\_row\_det(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

### **mp.dme\_shunt\_opf**

**class mp.dme\_shunt\_opf**

Bases: [mp.dme\\_shunt](#) (page 57), [mp.dme\\_shared\\_opf](#) (page 59)

[mp.dme\\_shunt\\_opf](#) (page 58) - Data model element for shunt for OPF.

To parent class [mp.dme\\_shunt](#) (page 57), adds pretty-printing for **lim** sections.

### **3.2.3 Element Mixins**

## mp.dme\_shared\_opf

class mp.dme\_shared\_opf

Bases: handle

*mp.dme\_shared\_opf* (page 59) - Mixin class for OPF **data model element** objects.

For all elements of *mp.data\_model\_opf* (page 35), adds shared functionality for pretty-printing of **lim** sections.

### Property Summary

**ctol**

constraint violation tolerance

**ptol**

shadow price tolerance

### Method Summary

**pp\_set\_tols\_lim**(mpopt)

**pp\_have\_section\_other**(section, mpopt, pp\_args)

**pp\_rows\_other**(dm, section, out\_e, mpopt, pp\_args)

**pp\_get\_headers\_other**(dm, section, out\_e, mpopt, pp\_args)

**pp\_get\_footers\_other**(dm, section, out\_e, mpopt, pp\_args)

**pp\_data\_other**(dm, section, rows, out\_e, mpopt, fd, pp\_args)

**pp\_have\_section\_lim**(mpopt, pp\_args)

**pp\_rows\_lim**(dm, out\_e, mpopt, pp\_args)

**pp\_binding\_rows\_lim**(dm, out\_e, mpopt, pp\_args)

**pp\_get\_title\_lim**(mpopt, pp\_args)

**pp\_get\_headers\_lim**(dm, out\_e, mpopt, pp\_args)

**pp\_get\_footers\_lim**(dm, out\_e, mpopt, pp\_args)

**pp\_data\_lim**(dm, rows, out\_e, mpopt, fd, pp\_args)

**pp\_data\_row\_lim**(dm, k, out\_e, mpopt, fd, pp\_args)

## 3.3 Data Model Converter Classes

### 3.3.1 Containers

## mp.dm\_converter

### class mp.dm\_converter

Bases: [mp.element\\_container](#) (page 166)

[mp.dm\\_converter](#) (page 60) - Abstract base class for MATPOWER **data model converter** objects.

A data model converter provides the ability to convert data between a data model and a specific data source or format, such as the PSS/E RAW format or version 2 of the MATPOWER case format. It is used, for example, during the import stage of the data model build process.

A data model converter object is primarily a container for data model converter element ([mp.dmc\\_element](#) (page 63)) objects. Concrete data model converter classes are specific to the type or format of the data source.

By convention, data model converter variables are named `dmc` and data model converter class names begin with `mp.dm_converter`.

#### mp.dm\_converter Methods:

- [format\\_tag\(\)](#) (page 60) - return char array identifier for data source/format
- [copy\(\)](#) (page 60) - make duplicate of object
- [build\(\)](#) (page 60) - create and add element objects
- [import\(\)](#) (page 60) - import data from a data source into a data model
- [export\(\)](#) (page 61) - export data from a data model to a data source
- [init\\_export\(\)](#) (page 61) - initialize a data source for export
- [save\(\)](#) (page 61) - save data source to a file
- [display\(\)](#) (page 61) - display the data model converter object

See the `sec_dm_converter` section in the *MATPOWER Developer's Manual* for more information.

See also [mp.data\\_model](#) (page 28), [mp.task](#) (page 8).

#### Method Summary

##### **format\_tag()**

Return a short char array identifier for data source/format.

```
tag = dmc.format_tag()
```

E.g. the subclass for the MATPOWER case format returns 'mpc2'.

*Note: This is an abstract method that must be implemented by a subclass.*

##### **copy()**

Create a duplicate of the data model converter object, calling the `copy()` method on each element.

```
new_dmc = dmc.copy()
```

##### **build()**

Create and add data model converter element objects.

```
dmc.build()
```

Create the data model converter element objects by instantiating each class in the [element\\_classes](#) (page 166) property and adding the resulting object to the [elements](#) (page 166) property.

**import**(*dm*, *d*)

Import data from a data source into a data model.

```
dm = dmc.import(dm, d)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Output**

**dm** (*mp.data\_model* (page 28)) – updated data model

Calls the *import()* (page 60) method for each data model converter element and its corresponding data model element.

**export**(*dm*, *d*)

Export data from a data model to a data source.

```
d = dmc.export(dm, d)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Output**

**d** – updated data source

Calls the *export()* (page 61) method for each data model converter element and its corresponding data model element.

**init\_export**(*dm*)

Initialize a data source for export.

```
d = dmc.export(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model

**Output**

**d** – new empty data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

Creates a new data source of the appropriate type in preparation for calling *export()* (page 61).

**save**(*fname*, *d*)

Save data source to a file.

```
fname_out = dmc.save(fname, d)
```

**Inputs**

- **fname** (*char array*)
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Output**

**fname\_out** (*char array*) – final file name after saving, possibly modified from input (e.g. extension added)

*Note: This is an abstract method that must be implemented by a subclass.*



**display()**

Display the data model converter object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the data model converter elements.

**mp.dm\_converter\_mpc2****class mp.dm\_converter\_mpc2**

Bases: *mp.dm\_converter* (page 60)

*mp.dm\_converter\_mpc2* (page 62) - MATPOWER **data model converter** for MATPOWER case v2.

This class implements importing/exporting of data models for version 2 of the classic MATPOWER case format. That is, the *data source d* for this class is expected to be a MATPOWER case struct.

**mp.dm\_converter\_mpc2 Methods:**

- *dm\_converter\_mpc2()* (page 62) - constructor
- *format\_tag()* (page 62) - return char array identifier for data source/format ('mpc2')
- *import()* (page 62) - import data from a MATPOWER case struct into a data model
- *export()* - export data from a data model to a MATPOWER case struct
- *save()* (page 62) - save MATPOWER case struct to a file

See also *mp.dm\_converter* (page 60).

**Constructor Summary****dm\_converter\_mpc2()**

Specify the element classes for handling MATPOWER case format.

**Method Summary****format\_tag()**

Return identifier tag 'mpc2' for version 2 MATPOWER case format.

**import(dm, d)**

Import data from a version 2 MATPOWER case struct into a data model.

**init\_export(dm)**

Initialize a MATPOWER case struct for export.

**save(fname, d)**

Save a MATPOWER case struct to a file.

### mp.dm\_converter\_mpc2\_legacy

**class** mp.dm\_converter\_mpc2\_legacy

Bases: *mp.dm\_converter\_mpc2* (page 62)

*mp.dm\_converter\_mpc2\_legacy* (page 63) - Legacy MATPOWER **data model converter** for MATPOWER case v2.

Adds to *mp.dm\_converter\_mpc2* (page 62) the ability to handle legacy user customization.

#### mp.dm\_converter\_mpc2\_legacy Methods:

- *legacy\_user\_mod\_inputs()* (page 63) - pre-process legacy inputs for use-defined customization
- *legacy\_user\_nln\_constraints()* (page 63) - pre-process legacy inputs for user-defined nonlinear constraints

See also *mp.dm\_converter* (page 60), *mp.dm\_converter\_mpc2* (page 62), *mp.taskopf\_legacy* (page 26).

#### Method Summary

**legacy\_user\_mod\_inputs**(*dm, mpop, dc*)

Handle pre-processing of inputs related to legacy user-defined variables, costs, and constraints. This includes optional mpc fields A, l, u, N, fparam, H1, Cw, z0, z1, zu and user\_constraints.

**legacy\_user\_nln\_constraints**(*dm, mpop*)

Handle pre-processing of inputs related to legacy user-defined non-linear constraints, specifically optional mpc fields user\_constraints.nle and user\_constraints.nli.

Called by *legacy\_user\_mod\_inputs()* (page 63) method.

## 3.3.2 Elements

### mp.dmc\_element

**class** mp.dmc\_element

Bases: handle

*mp.dmc\_element* (page 63)- Abstract base class for **data model converter element** objects.

A data model converter element object implements the functionality needed to import and export a particular element type from and to a given data format. All data model converter element classes inherit from *mp.dmc\_element* (page 63) and each element type typically implements its own subclass.

By convention, data model converter element variables are named dmce and data model converter element class names begin with mp.dmce.

Typically, much of the import/export functionality for a particular concrete subclass can be defined simply by implementing the *table\_var\_map()* (page 66) method.

#### mp.dmc\_element Methods:

- *name()* (page 64) - get name of element type, e.g. 'bus', 'gen'
- *data\_model\_element()* (page 64) - get corresponding data model element
- *data\_field()* (page 64) - get name of field in data source corresponding to default data table

- `data_subs()` (page 65) - get subscript reference struct for accessing data source
- `data_exists()` (page 65) - check if default field exists in data source
- `get_import_spec()` (page 65) - get import specification
- `get_export_spec()` (page 65) - get export specification
- `get_import_size()` (page 66) - get dimensions of data to be imported
- `get_export_size()` (page 66) - get dimensions of data to be exported
- `table_var_map()` (page 66) - get variable map for import/export
- `import()` (page 66) - import data from data source into data model element
- `import_table_values()` (page 67) - import table values for given import specification
- `get_input_table_values()` (page 67) - get values to insert in data model element table
- `import_col()` (page 67) - extract and optionally modify values from data source column
- `export()` (page 68) - export data from data model element to data source
- `export_table_values()` (page 68) - export table values for given import specification
- `init_export_data()` (page 68) - initialize data source for export from data model element
- `default_export_data_table()` (page 69) - create default (empty) data table for data source
- `default_export_data_nrows()` (page 69) - get number of rows  
`default_export_data_table()` (page 69)
- `export_col()` (page 69) - export a variable (table column) to the data source

See the `sec_dmc_element` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.dm_converter` (page 60).

### Method Summary

#### `name()`

Get name of element type, e.g. 'bus', 'gen'.

```
name = dmce.name()
```

#### Output

**name** (*char array*) – name of element type, must be a valid struct field name

Implementation provided by an element type specific subclass.

#### `data_model_element(dm, name)`

Get the corresponding data model element.

```
dme = dmce.data_model_element(dm)
dme = dmce.data_model_element(dm, name)
```

#### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **name** (*char array*) – (*optional*) name of element type (*default is name of this object*)

#### Output

**dme** (*mp.dm\_element* (page 36)) – data model element object

**data\_field()**

Get name of field in data source corresponding to default data table.

```
df = dmce.data_field()
```

**Output**

**df** (*char array*) – field name

**data\_subs()**

Get subscript reference struct for accessing data source.

```
s = dmce.data_subs()
```

**Output**

**s** (*struct*) – same as the **s** input argument to the built-in `suboref()`, to access this element's data in data source, with fields:

- **type** – character vector or string containing '()', '{}', or '.' specifying the subscript type
- **subs** – cell array, character vector, or string containing the actual subscripts

The default implementation in this base class uses the return value of the `data_field()` (page 64) method to access a field of the data source struct. That is:

```
s = struct('type', '.', 'subs', dmce.data_field());
```

**data\_exists(d)**

Check if default field exists in data source.

```
TorF = dmce.data_exists(d)
```

**Input**

**d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for `mp.dm_converter_mpc2` (page 62))

**Output**

**TorF** (*boolean*) – true if field exists

Check if value returned by `data_field()` (page 64) exists as a field in **d**.

**get\_import\_spec(dme, d)**

Get import specification.

```
spec = dmce.get_import_spec(dme, d)
```

**Inputs**

- **dme** (`mp.dm_element` (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for `mp.dm_converter_mpc2` (page 62))

**Output**

**spec** (*struct*) – import specification, with keys:

- 'subs' - subscript reference struct for accessing data source, as returned by `data_subs()` (page 65)
- 'nr', 'nc', 'r' - number of rows, number of columns, row index vector, as returned by `get_import_size()` (page 66)
- 'vmap' - variable map, as returned by `table_var_map()` (page 66)

See also `get_export_spec()` (page 65).

**get\_export\_spec**(*dme*, *d*)

Get export specification.

```
spec = dmce.get_export_spec(dme, d)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Output**

**spec** (*struct*) – export specification, see *get\_import\_spec()* (page 65)

See also *get\_import\_spec()* (page 65).

**get\_import\_size**(*d*)

Get dimensions of data to be imported.

```
[nr, nc, r] = dmce.get_import_size(d)
```

**Input**

**d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Outputs**

- **nr** (*integer*) – number of rows of data
- **nc** (*integer*) – number of columns of data
- **r** (*integer*) – optional index vector (*empty by default*) of rows in data source field that correspond to data to be imported

**get\_export\_size**(*dme*)

Get dimensions of data to be exported.

```
[nr, nc, r] = dmce.get_export_size(dme)
```

**Input**

**dme** (*mp.dm\_element* (page 36)) – data model element object

**Outputs**

- **nr** (*integer*) – number of rows of data
- **nc** (*integer*) – number of columns of data
- **r** (*integer*) – optional index vector (*empty by default*) of rows in main table of *dme* that correspond to data to be exported

**table\_var\_map**(*dme*, *d*)

Get variable map for import/export.

```
vmap = dmce.table_var_map(dme, d)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))

**Output**

**vmap** (*struct*) – variable map, see *tab\_var\_map* in the *MATPOWER Developer's Manual* for details

This method initializes each entry to {'col', []} by default, so subclasses only need to assign *vmap*.{vn}{2} for columns that map directly from a column of the data source.

**import**(*dme*, *d*, *var\_names*, *ridx*)

Import data from data source into data model element.

```
dme = dmce.import(dme, d, var_names, ridx)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **var\_names** (*cell array*) – (optional) list of names of variables (columns of main table) to import (*default is all variables*)
- **ridx** (*integer*) – (optional) vector of row indices of data to import (*default is all rows*)

**Output**

**dme** (*mp.dm\_element* (page 36)) – updated data model element object

See also *export()* (page 68).

**import\_table\_values**(*dme*, *d*, *spec*, *var\_names*, *ridx*)

Import table values for given import specification.

```
dme = dmce.import_table_values(dme, d, spec, var_names, ridx)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – import specification, see *get\_import\_spec()* (page 65)
- **var\_names** (*cell array*) – (optional) list of names of variables (columns of main table) to import (*default is all variables*)
- **ridx** (*integer*) – (optional) vector of row indices of data to import (*default is all rows*)

**Output**

**dme** (*mp.dm\_element* (page 36)) – updated data model element object

Called by *import()* (page 66).

**get\_input\_table\_values**(*d*, *spec*, *var\_names*, *ridx*)

Get values to insert in data model element table.

```
vals = dmce.get_input_table_values(d, spec, var_names, ridx)
```

**Inputs**

- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – import specification, see *get\_import\_spec()* (page 65)
- **var\_names** (*cell array*) – (optional) list of names of variables (columns of main table) to import (*default is all variables*)
- **ridx** (*integer*) – (optional) vector of row indices of data to import (*default is all rows*)

**Output**

**vals** (*cell array*) – values to assign to table columns in data model element

Called by *import\_table\_values()* (page 67).

**import\_col**(*d*, *spec*, *vn*, *c*, *sf*)

Extract and optionally modify values from data source column.

```
vals = dmce.import_col(d, spec, vn, c, sf)
```

**Inputs**

- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – import specification, see *get\_import\_spec()* (page 65)
- **vn** (*char array*) – variable name
- **c** (*integer*) – column index for data in data source
- **sf** (*double or function handle*) – (*optional*) scale factor, function is called as *sf(dmce, vn)*

**Output**

**vals** (*cell array*) – values to assign to table columns in data model element

Called by *get\_input\_table\_values()* (page 67).

**export**(*dme, d, var\_names, ridx*)

Export data from data model element to data source.

```
d = dmce.export(dme, d, var_names, ridx)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **var\_names** (*cell array*) – (*optional*) list of names of variables (columns of main table) to export (*default is all variables*)
- **ridx** (*integer*) – (*optional*) vector of row indices of data to export (*default is all rows*)

**Output**

**d** – updated data source

See also *import()* (page 66).

**export\_table\_values**(*dme, d, spec, var\_names, ridx*)

Export table values for given import specification.

```
d = dmce.export_table_values(dme, d, spec, var_names, ridx)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – export specification, see *get\_export\_spec()* (page 65)
- **var\_names** (*cell array*) – (*optional*) list of names of variables (columns of main table) to export (*default is all variables*)
- **ridx** (*integer*) – (*optional*) vector of row indices of data to export (*default is all rows*)

**Output**

**d** – updated data source

Called by *export()* (page 68).

**init\_export\_data**(*dme, d, spec*)

Initialize data source for export from data model element.

```
d = dmce.init_export_data(dme, d, spec)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – export specification, see *get\_export\_spec()* (page 65)

**Output****d** – updated data sourceCalled by `export_table_values()` (page 68).**default\_export\_data\_table**(*spec*)

Create default (empty) data table for data source.

```
dt = dmce.default_export_data_table(spec)
```

**Input****spec** (*struct*) – export specification, see `get_export_spec()` (page 65)**Output****dt** – data table for data source, type depends on implementing subclassCalled by `init_export_data()` (page 68).**default\_export\_data\_nrows**(*spec*)Get number of rows for `default_export_data_table()` (page 69).

```
nr = default_export_data_nrows(spec)
```

**Input****spec** (*struct*) – export specification, see `get_export_spec()` (page 65)**Output****nr** (*integer*) – number of rowsCalled by `default_export_data_table()` (page 69).**export\_col**(*dme, d, spec, vn, ridx, c, sf*)

Export a variable (table column) to the data source.

```
d = dmce.export_col(dme, d, spec, vn, ridx, c, sf)
```

**Inputs**

- **dme** (*mp.dm\_element* (page 36)) – data model element object
- **d** – data source, type depends on the implementing subclass (e.g. MATPOWER case struct for *mp.dm\_converter\_mpc2* (page 62))
- **spec** (*struct*) – export specification, see `get_export_spec()` (page 65)
- **vn** (*char array*) – variable name
- **ridx** (*integer*) – (*optional*) vector of row indices of data to export (*default is all rows*)
- **c** (*integer*) – column index for data in data source
- **sf** (*double or function handle*) – (*optional*) scale factor, function is called as `sf(dmce, vn)`

**Output****d** – updated data sourceCalled by `export_table_values()` (page 68).



### mp.dmce\_branch\_mpc2

**class** mp.dmce\_branch\_mpc2

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_branch\_mpc2* (page 70) - Data model converter element for branch for MATPOWER case v2.

#### Method Summary

**name()**  
**data\_field()**  
**table\_var\_map**(*dme, mpc*)  
**default\_export\_data\_table**(*spec*)

### mp.dmce\_bus\_mpc2

**class** mp.dmce\_bus\_mpc2

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_bus\_mpc2* (page 70) - Data model converter element for bus for MATPOWER case v2.

#### Method Summary

**name()**  
**data\_field()**  
**table\_var\_map**(*dme, mpc*)  
**init\_export\_data**(*dme, d, spec*)  
**default\_export\_data\_table**(*spec*)  
**bus\_name\_import**(*mpc, spec, vn, c*)  
**bus\_name\_export**(*dme, mpc, spec, vn, ridx, c*)  
**bus\_status\_import**(*mpc, spec, vn, c*)

### mp.dmce\_gen\_mpc2

**class** mp.dmce\_gen\_mpc2

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_gen\_mpc2* (page 70) - Data model converter element for generator for MATPOWER case v2.

#### Property Summary

**pw11**

indices of single-block piecewise linear costs, all gens (*automatically converted to linear cost*)

**Method Summary**

**name()**

**data\_field()**

**table\_var\_map**(*dme, mpc*)

**default\_export\_data\_table**(*spec*)

**start\_cost\_import**(*mpc, spec, vn*)

**start\_cost\_export**(*dme, mpc, spec, vn, ridx*)

**gen\_cost\_import**(*mpc, spec, vn, p\_or\_q*)

**gen\_cost\_export**(*dme, mpc, spec, vn, p\_or\_q, ridx*)

**static gencost2cost\_table**(*gencost*)

**static cost\_table2gencost**(*gencost0, cost, ridx*)

**mp.dmce\_load\_mpc2**

**class mp.dmce\_load\_mpc2**

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_load\_mpc2* (page 71) - Data model converter element for load for MATPOWER case v2.

**Property Summary**

**bus**

**Method Summary**

**name()**

**data\_field()**

**get\_import\_size**(*mpc*)

**get\_export\_size**(*dme*)

**table\_var\_map**(*dme, mpc*)

**scale\_factor\_fcn**(*vn, zip\_sf*)

**sys\_wide\_zip\_loads**(*mpc*)

## mp.dmce\_shunt\_mpc2

**class** mp.dmce\_shunt\_mpc2

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_shunt\_mpc2* (page 72) - Data model converter element for shunt for MATPOWER case v2.

### Property Summary

**bus**

### Method Summary

**name()**

**data\_field()**

**get\_import\_size(*mpc*)**

**get\_export\_size(*dme*)**

**table\_var\_map(*dme, mpc*)**

## 3.4 Network Model Classes

### 3.4.1 Containers

#### mp.form

**class** mp.form

Bases: handle

*mp.form* (page 72) - Abstract base class for MATPOWER **formulation**.

Used as a mix-in class for all **network model element** classes. That is, each concrete network model element class must inherit, at least indirectly, from both *mp.nm\_element* (page 108) and *mp.form* (page 72).

*mp.form* (page 72) provides properties and methods that are specific to the network model formulation (e.g. DC version, AC polar power version, etc.).

For more details, see the `sec_net_model_formulations` section in the *MATPOWER Developer's Manual* and the derivations in *MATPOWER Technical Note 5*.

#### mp.form Properties:

*subclasses provide properties for model parameters*

#### mp.form Methods:

- *form\_name()* (page 73) - get char array w/name of formulation
- *form\_tag()* (page 73) - get char array w/short label of formulation
- *model\_params()* (page 73) - get cell array of names of model parameters
- *model\_vvars()* (page 73) - get cell array of names of voltage state variables
- *model\_zvars()* (page 73) - get cell array of names of non-voltage state variables

- `get_params()` (page 74) - get network model element parameters
- `find_form_class()` (page 74) - get name of network element object's formulation subclass

See also `mp.nm_element` (page 108).

### Method Summary

#### `form_name()`

Get user-readable name of formulation, e.g. 'DC', 'AC-cartesian', 'AC-polar'.

```
name = nme.form_name()
```

#### Output

**name** (*char array*) – name of formulation

*Note: This is an abstract method that must be implemented by a subclass.*

#### `form_tag()`

Get short label of formulation, e.g. 'dc', 'acc', 'acp'.

```
tag = nme.form_tag()
```

#### Output

**tag** (*char array*) – short label of formulation

*Note: This is an abstract method that must be implemented by a subclass.*

#### `model_params()`

Get cell array of names of model parameters.

```
params = nme.model_params()
```

#### Output

**params** (*cell array of char arrays*) – names of object properties for model parameters

*Note: This is an abstract method that must be implemented by a subclass.*

#### `model_vvars()`

Get cell array of names of voltage state variables.

```
vtypes = nme.model_vvars()
```

#### Output

**vtypes** (*cell array of char arrays*) – names of network object properties for voltage state variables

The network model object, which inherits from `mp_idx_manager`, uses these values as set types for tracking its voltage state variables.

*Note: This is an abstract method that must be implemented by a subclass.*

#### `model_zvars()`

Get cell array of names of non-voltage state variables.

```
vtypes = nme.model_zvars()
```

#### Output

**vtypes** (*cell array of char arrays*) – names of network object properties for voltage state variables

The network model object, which inherits from `mp_idx_manager`, uses these values as set types for tracking its non-voltage state variables.

*Note: This is an abstract method that must be implemented by a subclass.*

**get\_params**(*idx, names*)

Get network model element parameters.

```
[p1, p2, ..., pN] = nme.get_params(idx)
pA = nme.get_params(idx, nameA)
[pA, pB, ...] = nme.get_params(idx, {nameA, nameB, ...})
```

**Inputs**

- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns parameters corresponding to all ports
- **names** (*char array or cell array of char arrays*) – (*optional*) name(s) of parameters to return

**Outputs**

- **p1, p2, ..., pN** – full set of parameters in canonical order
- **pA, pB** – parameters specified by names

If a particular parameter in the object is empty, this method returns a sparse zero matrix or vector of the appropriate size.

**find\_form\_class**()

Get name of network element object's formulation subclass.

```
form_class = nme.find_form_class()
```

**Output**

**form\_class** (*char array*)

Selects from this network model elements parent classes, the `mp.form` (page 72) subclass, that is not a subclass of `mp.nm_element` (page 108), with the longest inheritance path back to `mp.form` (page 72).

**mp.form\_ac**

**class mp.form\_ac**

Bases: `mp.form` (page 72)

`mp.form_ac` (page 74) - Abstract base class for MATPOWER AC **formulations**.

Used as a mix-in class for all **network model element** classes with an AC network model formulation. That is, each concrete network model element class with an AC formulation must inherit, at least indirectly, from both `mp.nm_element` (page 108) and `mp.form_ac` (page 74).

`mp.form_ac` (page 74) defines the complex port injections as functions of the state variables  $\mathbf{x}$ , that is, the complex voltages  $\mathbf{v}$  and non-voltage states  $\mathbf{z}$ . They are defined in terms of 3 components, the linear current injection and linear power injection components,

$$\begin{aligned} \mathbf{i}^{lin}(\mathbf{x}) &= \begin{bmatrix} \mathbf{Y} & \mathbf{L} \end{bmatrix} \mathbf{x} + \mathbf{i} \\ &= \mathbf{Y}\mathbf{v} + \mathbf{L}\mathbf{z} + \mathbf{i} \end{aligned} \tag{3.2}$$

$$\begin{aligned} \mathbf{s}^{lin}(\mathbf{x}) &= \begin{bmatrix} \mathbf{M} & \mathbf{N} \end{bmatrix} \mathbf{x} + \mathbf{s} \\ &= \mathbf{M}\mathbf{v} + \mathbf{N}\mathbf{z} + \mathbf{s}, \end{aligned} \tag{3.3}$$

and an arbitrary nonlinear injection component represented by  $\mathbf{s}^{nln}(\mathbf{x})$  or  $\mathbf{i}^{nln}(\mathbf{x})$ . The full complex power and current port injection functions implemented by `mp.form_ac` (page 74), are respectively

$$\begin{aligned} \mathbf{g}^S(\mathbf{x}) &= [\mathbf{v}] (\mathbf{i}^{lin}(\mathbf{x}))^* + \mathbf{s}^{lin}(\mathbf{x}) + \mathbf{s}^{nln}(\mathbf{x}) \\ &= [\mathbf{v}] (\mathbf{Y}\mathbf{v} + \mathbf{L}\mathbf{z} + \mathbf{i})^* + \mathbf{M}\mathbf{v} + \mathbf{N}\mathbf{z} + \mathbf{s} + \mathbf{s}^{nln}(\mathbf{x}) \end{aligned} \quad (3.4)$$

$$\begin{aligned} \mathbf{g}^I(\mathbf{x}) &= \mathbf{i}^{lin}(\mathbf{x}) + [\mathbf{s}^{lin}(\mathbf{x})]^* \mathbf{\Lambda}^* + \mathbf{i}^{nln}(\mathbf{x}) \\ &= \mathbf{Y}\mathbf{v} + \mathbf{L}\mathbf{z} + \mathbf{i} + [\mathbf{M}\mathbf{v} + \mathbf{N}\mathbf{z} + \mathbf{s}]^* \mathbf{\Lambda}^* + \mathbf{i}^{nln}(\mathbf{x}) \end{aligned} \quad (3.5)$$

where  $\mathbf{Y}$ ,  $\mathbf{L}$ ,  $\mathbf{M}$ ,  $\mathbf{N}$ ,  $\mathbf{i}$ , and  $\mathbf{s}$ , along with  $\mathbf{s}^{nln}(\mathbf{x})$  or  $\mathbf{i}^{nln}(\mathbf{x})$ , are the model parameters.

For more details, see the `sec_nm_formulations_ac` section in the *MATPOWER Developer's Manual* and the derivations in *MATPOWER Technical Note 5*.

#### mp.form\_dc Properties:

- $Y$  (page 76) -  $n_p n_k \times n_n$  matrix  $\mathbf{Y}$  of model parameters
- $L$  (page 76) -  $n_p n_k \times n_z$  matrix  $\mathbf{L}$  of model parameters
- $M$  (page 76) -  $n_p n_k \times n_n$  matrix  $\mathbf{M}$  of model parameters
- $N$  (page 76) -  $n_p n_k \times n_z$  matrix  $\mathbf{N}$  of model parameters
- $i$  (page 76) -  $n_p n_k \times 1$  vector  $\mathbf{i}$  of model parameters
- $s$  (page 76) -  $n_p n_k \times 1$  vector  $\mathbf{s}$  of model parameters
- `params_ncols` - specify number of columns for each parameter
- `inln` (page 76) - function to compute  $\mathbf{i}^{nln}(\mathbf{x})$
- `snln` (page 76) - function to compute  $\mathbf{s}^{nln}(\mathbf{x})$
- `inln_hess` (page 76) - function to compute Hessian of  $\mathbf{i}^{nln}(\mathbf{x})$
- `snln_hess` (page 76) - function to compute Hessian of  $\mathbf{s}^{nln}(\mathbf{x})$

#### mp.form\_dc Methods:

- `model_params()` (page 77) - get network model element parameters (`'Y'`, `'L'`, `'M'`, `'N'`, `'i'`, `'s'`)
- `model_zvars()` (page 77) - get cell array of names of non-voltage state variables (`'zr'`, `'zi'`)
- `port_inj_current()` (page 77) - compute port current injections from network state
- `port_inj_power()` (page 77) - compute port power injections from network state
- `port_inj_current_hess()` (page 78) - compute Hessian of port current injections
- `port_inj_power_hess()` (page 79) - compute Hessian of port power injections
- `port_inj_current_jac()` (page 79) - abstract method to compute voltage-related Jacobian terms
- `port_inj_current_hess_v()` (page 79) - abstract method to compute voltage-related Hessian terms
- `port_inj_current_hess_vz()` (page 79) - abstract method to compute voltage-related Hessian terms
- `port_inj_power_jac()` (page 79) - abstract method to compute voltage-related Jacobian terms
- `port_inj_power_hess_v()` (page 79) - abstract method to compute voltage-related Hessian terms
- `port_inj_power_hess_vz()` (page 80) - abstract method to compute voltage-related Hessian terms

- `port_apparent_power_lim_fcn()` (page 80) - compute port squared apparent power injection constraints
- `port_active_power_lim_fcn()` (page 80) - compute port active power injection constraints
- `port_active_power2_lim_fcn()` (page 80) - compute port squared active power injection constraints
- `port_current_lim_fcn()` (page 81) - compute port squared current injection constraints
- `port_apparent_power_lim_hess()` (page 81) - compute port squared apparent power injection Hessian
- `port_active_power_lim_hess()` (page 82) - compute port active power injection Hessian
- `port_active_power2_lim_hess()` (page 82) - compute port squared active power injection Hessian
- `port_current_lim_hess()` (page 82) - compute port squared current injection Hessian
- `aux_data_va_vm()` (page 83) - abstract method to return voltage angles/magnitudes from auxiliary data

See also `mp.form` (page 72), `mp.form_acc` (page 83), `mp.form_acp` (page 87), `mp.form_dc` (page 89), `mp.nm_element` (page 108).

### Property Summary

**Y** = []  
*(double)*  $n_p n_k \times n_n$  matrix **Y** of model parameter coefficients for **v**

**L** = []  
*(double)*  $n_p n_k \times n_z$  matrix **L** of model parameter coefficients for **z**

**M** = []  
*(double)*  $n_p n_k \times n_n$  matrix **M** of model parameter coefficients for **v**

**N** = []  
*(double)*  $n_p n_k \times n_z$  matrix **N** of model parameter coefficients for **z**

**i** = []  
*(double)*  $n_p n_k \times 1$  vector **i** of model parameters

**s** = []  
*(double)*  $n_p n_k \times 1$  vector **s** of model parameters

**param\_ncols** = `struct('Y',2,'L',3,'M',2,'N',3,'i',1,'s',1)`  
*(struct)* specify number of columns for each parameter, where

- 1 => single column (i.e. a vector)
- 2 =>  $n_p$  columns
- 3 =>  $n_z$  columns

**inln** = ''  
*(function handle)* function to compute  $\mathbf{i}^{nln}(\mathbf{x})$

**snln** = ''  
*(function handle)* function to compute  $\mathbf{s}^{nln}(\mathbf{x})$

**inln\_hess** = ''  
*(function handle)* function to compute Hessian of  $\mathbf{i}^{nln}(\mathbf{x})$

`snln_hess = ''`

(*function handle*) function to compute Hessian of  $s^{nln}(\mathbf{x})$

### Method Summary

#### `model_params()`

Get cell array of names of model parameters, i.e. {'Y', 'L', 'M', 'N', 'i', 's'}.

See `mp.form.model_params()` (page 73).

#### `model_zvars()`

Get cell array of names of non-voltage state variables, i.e. {'zr', 'zi'}.

See `mp.form.model_zvars()` (page 73).

#### `port_inj_current(x_, sysx, idx)`

Compute port complex current injections from network state.

```
I = nme.port_inj_current(x_, sysx)
I = nme.port_inj_current(x_, sysx, idx)
[I, Iv1, Iv2] = nme.port_inj_current(...)
[I, Iv1, Iv2, Izr, Izi] = nme.port_inj_current(...)
```

Compute the complex current injections for all or a selected subset of ports and, optionally, the components of the Jacobian, that is, the sparse matrices of partial derivatives with respect to each real component of the state. The voltage portion, which depends on the formulation (polar vs cartesian), is delegated to the `port_inj_current_jac()` method implemented by the appropriate subclass.

The state can be provided as a stacked aggregate of the state variables (port voltages and non-voltage states) for the full collection of network model elements of this type, or as the combined state for the entire network.

#### Inputs

- $\mathbf{x}_$  (*complex double*) – state vector  $\mathbf{x}$
- $\mathbf{sysx}$  (*0 or 1*) – which state is provided in  $\mathbf{x}_$ 
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- $\mathbf{idx}$  (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

#### Outputs

- $\mathbf{I}$  (*complex double*) – vector of port complex current injections,  $\mathbf{g}^I(\mathbf{x})$
- $\mathbf{Iv1}$  (*complex double*) – Jacobian of port complex current injections w.r.t 1st voltage component,  $\mathbf{g}_\theta^I$  (polar) or  $\mathbf{g}_u^I$  (cartesian)
- $\mathbf{Iv2}$  (*complex double*) – Jacobian of port complex current injections w.r.t 2nd voltage component,  $\mathbf{g}_\nu^I$  (polar) or  $\mathbf{g}_w^I$  (cartesian)
- $\mathbf{Izr}$  (*complex double*) – Jacobian of port complex current injections w.r.t real part of non-voltage state,  $\mathbf{g}_{z_r}^I$
- $\mathbf{Izi}$  (*complex double*) – Jacobian of port complex current injections w.r.t imaginary part of non-voltage state,  $\mathbf{g}_{z_i}^I$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_power()` (page 77).

#### `port_inj_power(x_, sysx, idx)`

Compute port complex power injections from network state.

```
S = nme.port_inj_power(x_, sysx)
S = nme.port_inj_power(x_, sysx, idx)
```

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```
[S, Sv1, Sv2] = nme.port_inj_power(...)
[S, Sv1, Sv2, Szr, Szi] = nme.port_inj_power(...)
```

Compute the complex power injections for all or a selected subset of ports and, optionally, the components of the Jacobian, that is, the sparse matrices of partial derivatives with respect to each real component of the state. The voltage portion, which depends on the formulation (polar vs cartesian), is delegated to the `port_inj_power_jac()` method implemented by the appropriate subclass.

The state can be provided as a stacked aggregate of the state variables (port voltages and non-voltage states) for the full collection of network model elements of this type, or as the combined state for the entire network.

**Inputs**

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **sysx** (*0 or 1*) – which state is provided in **x\_**
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Outputs**

- **S** (*complex double*) – vector of port complex power injections,  $\mathbf{g}^S(\mathbf{x})$
- **Sv1** (*complex double*) – Jacobian of port complex power injections w.r.t 1st voltage component,  $\mathbf{g}_\theta^S$  (polar) or  $\mathbf{g}_u^S$  (cartesian)
- **Sv2** (*complex double*) – Jacobian of port complex power injections w.r.t 2nd voltage component,  $\mathbf{g}_v^S$  (polar) or  $\mathbf{g}_w^S$  (cartesian)
- **Szr** (*complex double*) – Jacobian of port complex power injections w.r.t real part of non-voltage state,  $\mathbf{g}_{z_r}^S$
- **Szi** (*complex double*) – Jacobian of port complex power injections w.r.t imaginary part of non-voltage state,  $\mathbf{g}_{z_i}^S$ .

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_current()` (page 77).

**port\_inj\_current\_hess(x\_, lam, sysx, idx)**

Compute Hessian of port current injections from network state.

```
H = nme.port_inj_current_hess(x_, lam)
H = nme.port_inj_current_hess(x_, lam, sysx)
H = nme.port_inj_current_hess(x_, lam, sysx, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the port current injection Jacobian by a vector  $\lambda$ .

**Inputs**

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **lam** (*double*) – vector  $\lambda$  of multipliers, one for each port
- **sysx** (*0 or 1*) – which state is provided in **x\_**
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Outputs**

**H** (*complex double*) – sparse Hessian matrix of port complex current injections corresponding to specified  $\lambda$ , namely  $\mathbf{g}_{\mathbf{xx}}^I(\lambda)$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_current()` (page 77).

**port\_inj\_power\_hess**( $x_$ ,  $lam$ ,  $sysx$ ,  $idx$ )

Compute Hessian of port power injections from network state.

```
H = nme.port_inj_power_hess(x_, lam)
H = nme.port_inj_power_hess(x_, lam, sysx)
H = nme.port_inj_power_hess(x_, lam, sysx, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the port power injection Jacobian by a vector  $\lambda$ .

#### Inputs

- $x_$  (*complex double*) – state vector  $\mathbf{x}$
- $lam$  (*double*) – vector  $\lambda$  of multipliers, one for each port
- $sysx$  (*0 or 1*) – which state is provided in  $x_$ 
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- $idx$  (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

#### Outputs

$\mathbf{H}$  (*complex double*) – sparse Hessian matrix of port complex power injections corresponding to specified  $\lambda$ , namely  $\mathbf{g}_{\mathbf{xx}}^S(\lambda)$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_power()` (page 77).

**port\_inj\_current\_jac**( $n$ ,  $v_$ ,  $Y$ ,  $M$ ,  $invdiagvic$ ,  $diagSlineJ$ )

Abstract method to compute voltage-related Jacobian terms.

Called by `port_inj_current()` (page 77) to compute voltage-related Jacobian terms. See `mp.form_acc.port_inj_current_jac()` (page 84) and `mp.form_acp.port_inj_current_jac()` (page 88) for details.

**port\_inj\_current\_hess\_v**( $x_$ ,  $lam$ ,  $v_$ ,  $z_$ ,  $diaginvic$ ,  $Y$ ,  $M$ ,  $diagSlineJ$ ,  $diamJ$ )

Abstract method to compute voltage-related Hessian terms.

Called by `port_inj_current_hess()` (page 78) to compute voltage-related Hessian terms. See `mp.form_acc.port_inj_current_hess_v()` (page 84) and `mp.form_acp.port_inj_current_hess_v()` (page 88) for details.

**port\_inj\_current\_hess\_vz**( $x_$ ,  $lam$ ,  $v_$ ,  $z_$ ,  $diaginvic$ ,  $N$ ,  $diamJ$ )

Abstract method to compute voltage-related Hessian terms.

Called by `port_inj_current_hess()` (page 78) to compute voltage/non-voltage-related Hessian terms. See `mp.form_acc.port_inj_current_hess_vz()` (page 84) and `mp.form_acp.port_inj_current_hess_vz()` (page 88) for details.

**port\_inj\_power\_jac**( $n$ ,  $v_$ ,  $Y$ ,  $M$ ,  $diagv$ ,  $diagvi$ ,  $diagIlineJ$ )

Abstract method to compute voltage-related Jacobian terms.

Called by `port_inj_power()` (page 77) to compute voltage-related Jacobian terms. See `mp.form_acc.port_inj_power_jac()` (page 85) and `mp.form_acp.port_inj_power_jac()` (page 88) for details.

**port\_inj\_power\_hess\_v**( $x_$ ,  $lam$ ,  $v_$ ,  $z_$ ,  $diagvi$ ,  $Y$ ,  $M$ ,  $diagIlineJ$ ,  $diamJ$ )

Abstract method to compute voltage-related Hessian terms.

Called by `port_inj_power_hess()` (page 79) to compute voltage-related Hessian terms. See `mp.form_acc.port_inj_power_hess_v()` (page 85) and `mp.form_acp.port_inj_power_hess_v()` (page 88) for details.

**port\_inj\_power\_hess\_vz**(*x\_*, *lam*, *v\_*, *z\_*, *diagvi*, *L*, *dIamJ*)

Abstract method to compute voltage-related Hessian terms.

Called by `port_inj_power_hess()` (page 79) to compute voltage/non-voltage-related Hessian terms. See `mp.form_acc.port_inj_power_hess_vz()` (page 85) and `mp.form_acp.port_inj_power_hess_vz()` (page 89) for details.

**port\_apparent\_power\_lim\_fcn**(*x\_*, *nm*, *idx*, *hmax*)

Compute port squared apparent power injection constraints.

```
h = nme.port_apparent_power_lim_fcn(x_, nm, idx, hmax)
[h, dh] = nme.port_apparent_power_lim_fcn(x_, nm, idx, hmax)
```

Compute constraint function and optionally the Jacobian for the limit on port squared apparent power injections based on complex outputs of `port_inj_power()` (page 77).

**Inputs**

- *x\_* (*complex double*) – state vector *x*
- *nm* (*mp.net\_model* (page 91)) – network model object
- *idx* (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports
- *hmax* (*double*) – vector of squared apparent power limits

**Outputs**

- *h* (*double*) – constraint function,  $h^{\text{flow}}(\mathbf{x})$
- *dh* (*double*) – constraint Jacobian,  $h_x^{\text{flow}}$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_power()` (page 77).

**port\_active\_power\_lim\_fcn**(*x\_*, *nm*, *idx*, *hmax*)

Compute port active power injection constraints.

```
h = nme.port_active_power_lim_fcn(x_, nm, idx, hmax)
[h, dh] = nme.port_active_power_lim_fcn(x_, nm, idx, hmax)
```

Compute constraint function and optionally the Jacobian for the limit on port active power injections based on complex outputs of `port_inj_power()` (page 77).

**Inputs**

- *x\_* (*complex double*) – state vector *x*
- *nm* (*mp.net\_model* (page 91)) – network model object
- *idx* (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports
- *hmax* (*double*) – vector of active power limits

**Outputs**

- *h* (*double*) – constraint function,  $h^{\text{flow}}(\mathbf{x})$
- *dh* (*double*) – constraint Jacobian,  $h_x^{\text{flow}}$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_power()` (page 77).

**port\_active\_power2\_lim\_fcn**(*x\_*, *nm*, *idx*, *hmax*)

Compute port squared active power injection constraints.

```
h = nme.port_active_power2_lim_fcn(x_, nm, idx, hmax)
[h, dh] = nme.port_active_power2_lim_fcn(x_, nm, idx, hmax)
```

Compute constraint function and optionally the Jacobian for the limit on port squared active power injections based on complex outputs of `port_inj_power()` (page 77).

#### Inputs

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports
- **hmax** (*double*) – vector of squared active power limits

#### Outputs

- **h** (*double*) – constraint function,  $\mathbf{h}^{\text{flow}}(\mathbf{x})$
- **dh** (*double*) – constraint Jacobian,  $\mathbf{h}_x^{\text{flow}}$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_power()` (page 77).

### `port_current_lim_fcn(x_, nm, idx, hmax)`

Compute port squared current injection constraints.

```
h = nme.port_current_lim_fcn(x_, nm, idx, hmax)
[h, dh] = nme.port_current_lim_fcn(x_, nm, idx, hmax)
```

Compute constraint function and optionally the Jacobian for the limit on port squared current injections based on complex outputs of `port_inj_current()` (page 77).

#### Inputs

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports
- **hmax** (*double*) – vector of squared current limits

#### Outputs

- **h** (*double*) – constraint function,  $\mathbf{h}^{\text{flow}}(\mathbf{x})$
- **dh** (*double*) – constraint Jacobian,  $\mathbf{h}_x^{\text{flow}}$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also `port_inj_current()` (page 77).

### `port_apparent_power_lim_hess(x_, lam, nm, idx)`

Compute port squared apparent power injection Hessian.

```
d2H = nme.port_apparent_power_lim_hess(x_, lam, nm, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\boldsymbol{\mu}$ . Results are based on the complex outputs of `port_inj_power()` (page 77) and `port_inj_power_hess()` (page 79).

#### Inputs

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **lam** (*double*) – vector  $\boldsymbol{\mu}$  of multipliers, one for each port
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Output****d2H** (*double*) – sparse constraint Hessian matrix,  $h_{xx}^{\text{flow}}(\mu)$ For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.See also [port\\_inj\\_power\(\)](#) (page 77), [port\\_inj\\_power\\_hess\(\)](#) (page 79).**port\_active\_power\_lim\_hess**(*x\_*, *lam*, *nm*, *idx*)

Compute port active power injection Hessian.

```
d2H = nme.port_active_power_lim_hess(x_, lam, nm, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\mu$ . Results are based on the complex outputs of [port\\_inj\\_power\(\)](#) (page 77) and [port\\_inj\\_power\\_hess\(\)](#) (page 79).

**Inputs**

- **x\_** (*complex double*) – state vector  $x$
- **lam** (*double*) – vector  $\mu$  of multipliers, one for each port
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Output****d2H** (*double*) – sparse constraint Hessian matrix,  $h_{xx}^{\text{flow}}(\mu)$ For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.See also [port\\_inj\\_power\(\)](#) (page 77), [port\\_inj\\_power\\_hess\(\)](#) (page 79).**port\_active\_power2\_lim\_hess**(*x\_*, *lam*, *nm*, *idx*)

Compute port squared active power injection Hessian.

```
d2H = nme.port_active_power2_lim_hess(x_, lam, nm, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\mu$ . Results are based on the complex outputs of [port\\_inj\\_power\(\)](#) (page 77) and [port\\_inj\\_power\\_hess\(\)](#) (page 79).

**Inputs**

- **x\_** (*complex double*) – state vector  $x$
- **lam** (*double*) – vector  $\mu$  of multipliers, one for each port
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Output****d2H** (*double*) – sparse constraint Hessian matrix,  $h_{xx}^{\text{flow}}(\mu)$ For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.See also [port\\_inj\\_power\(\)](#) (page 77), [port\\_inj\\_power\\_hess\(\)](#) (page 79).**port\_current\_lim\_hess**(*x\_*, *lam*, *nm*, *idx*)

Compute port squared current injection Hessian.

```
d2H = nme.port_current_lim_hess(x_, lam, nm, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\mu$ . Results are based on the complex outputs of [port\\_inj\\_current\(\)](#) (page 77) and [port\\_inj\\_current\\_hess\(\)](#) (page 78).

**Inputs**

- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **lam** (*double*) – vector  $\boldsymbol{\mu}$  of multipliers, one for each port
- **nm** (*mp.net\_model* (page 91)) – network model object
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

**Output**

**d2H** (*double*) – sparse constraint Hessian matrix,  $\mathbf{h}_{xx}^{\text{flow}}(\boldsymbol{\mu})$

For details on the derivations of the formulas used, see *MATPOWER Technical Note 5*.

See also *port\_inj\_current()* (page 77), *port\_inj\_current\_hess()* (page 78).

**aux\_data\_va\_vm(ad)**

Abstract method to return voltage angles/magnitudes from auxiliary data.

```
[va, vm] = nme.aux_data_va_vm(ad)
```

**Input**

**ad** (*struct*) – struct of auxiliary data

**Outputs**

- **va** (*double*) – vector of voltage angles corresponding to voltage information stored in auxiliary data
- **vm** (*double*) – vector of voltage magnitudes corresponding to voltage information stored in auxiliary data

Implemented by *mp.form\_acc.aux\_data\_va\_vm()* (page 85) and *mp.form\_acp.aux\_data\_va\_vm()* (page 89).

**mp.form\_acc****class mp.form\_acc**

Bases: *mp.form\_ac* (page 74)

*mp.form\_acc* (page 83) - Base class for MATPOWER AC cartesian **formulations**.

Used as a mix-in class for all **network model element** classes with an AC network model formulation with a **cartesian** representation for voltages. That is, each concrete network model element class with an AC cartesian formulation must inherit, at least indirectly, from both *mp.nm\_element* (page 108) and *mp.form\_acc* (page 83).

Provides implementation of evaluation of voltage-related Jacobian and Hessian terms needed by some *mp.form\_ac* (page 74) methods.

**mp.form\_dc Methods:**

- *form\_name()* (page 84) - get char array w/name of formulation ('AC-cartesian')
- *form\_tag()* (page 84) - get char array w/short label of formulation ('acc')
- *model\_vvars()* (page 84) - get cell array of names of voltage state variables ({'vr', 'vi'})
- *port\_inj\_current\_jac()* (page 84) - compute voltage-related terms of current injection Jacobian
- *port\_inj\_current\_hess\_v()* (page 84) - compute voltage-related terms of current injection Hessian
- *port\_inj\_current\_hess\_vz()* (page 84) - compute voltage/non-voltage-related terms of current injection Hessian

- `port_inj_power_jac()` (page 85) - compute voltage-related terms of power injection Jacobian
- `port_inj_power_hess_v()` (page 85) - compute voltage-related terms of power injection Hessian
- `port_inj_power_hess_vz()` (page 85) - compute voltage/non-voltage-related terms of power injection Hessian
- `aux_data_va_vm()` (page 85) - return voltage angles/magnitudes from auxiliary data
- `va_fcn()` (page 85) - compute voltage angle constraints and Jacobian
- `va_hess()` (page 86) - compute voltage angle Hessian
- `vm2_fcn()` (page 86) - compute squared voltage magnitude constraints and Jacobian
- `vm2_hess()` (page 86) - compute squared voltage magnitude Hessian

For more details, see the `sec_nm_formulations_ac` section in the *MATPOWER Developer's Manual* and the derivations in *MATPOWER Technical Note 5*.

See also `mp.form` (page 72), `mp.form_ac` (page 74), `mp.form_acp` (page 87), `mp.nm_element` (page 108).

### Method Summary

#### `form_name()`

Get user-readable name of formulation, i.e. 'AC-cartesian'.

See `mp.form.form_name()` (page 73).

#### `form_tag()`

Get short label of formulation, i.e. 'acc'.

See `mp.form.form_tag()` (page 73).

#### `model_vvars()`

Get cell array of names of voltage state variables, i.e. {'vr', 'vi'}.

See `mp.form.model_vvars()` (page 73).

#### `port_inj_current_jac(n, v_, Y, M, invdiagvic, diagSlineJ)`

Compute voltage-related terms of current injection Jacobian.

```
[Iu, Iw] = nme.port_inj_current_jac(n, v_, Y, M, invdiagvic, diagSlineJ)
```

Called by `mp.form_ac.port_inj_current()` (page 77) to compute voltage-related Jacobian terms.

#### `port_inj_current_hess_v(x_, lam, v_, z_, diaginvic, Y, M, diagSlineJ, dlamJ)`

Compute voltage-related terms of current injection Hessian.

```
[Iuu, Iuw, Iww] = nme.port_inj_current_hess_v(x_, lam)
[Iuu, Iuw, Iww] = nme.port_inj_current_hess_v(x_, lam, sysx)
[Iuu, Iuw, Iww] = nme.port_inj_current_hess_v(x_, lam, sysx, idx)
[...] = nme.port_inj_current_hess_vz(x_, lam, v_, z_, diaginvic, Y, M,
↳diagSlineJ, dlamJ)
```

Called by `mp.form_ac.port_inj_current_hess()` (page 78) to compute voltage-related Hessian terms.

#### `port_inj_current_hess_vz(x_, lam, v_, z_, diaginvic, N, dlamJ)`

Compute voltage/non-voltage-related terms of current injection Hessian.



```
[Iuzr, Iuzi, Iwzr, Iwzi] = nme.port_inj_current_hess_vz(x_, lam)
[...] = nme.port_inj_current_hess_vz(x_, lam, sysx)
[...] = nme.port_inj_current_hess_vz(x_, lam, sysx, idx)
[...] = nme.port_inj_current_hess_vz(x_, lam, v_, z_, diaginvic, N, dlamJ)
```

Called by `mp.form_ac.port_inj_current_hess()` (page 78) to compute voltage/non-voltage-related Hessian terms.

**port\_inj\_power\_jac**(*n*, *v\_*, *Y*, *M*, *diagv*, *diagvi*, *diagIincJ*)

Compute voltage-related terms of power injection Jacobian.

```
[Su, Sw] = nme.port_inj_power_jac(...)
```

Called by `mp.form_ac.port_inj_power()` (page 77) to compute voltage-related Jacobian terms.

**port\_inj\_power\_hess\_v**(*x\_*, *lam*, *v\_*, *z\_*, *diagvi*, *Y*, *M*, *diagIincJ*, *dlamJ*)

Compute voltage-related terms of power injection Hessian.

```
[Suu, Suw, Sww] = nme.port_inj_power_hess_v(x_, lam)
[Suu, Suw, Sww] = nme.port_inj_power_hess_v(x_, lam, sysx)
[Suu, Suw, Sww] = nme.port_inj_power_hess_v(x_, lam, sysx, idx)
[...] = nme.port_inj_power_hess_v(x_, lam, v_, z_, diagvi, Y, M, diagIincJ,
↪ dlamJ)
```

Called by `mp.form_ac.port_inj_power_hess()` (page 79) to compute voltage-related Hessian terms.

**port\_inj\_power\_hess\_vz**(*x\_*, *lam*, *v\_*, *z\_*, *diagvi*, *L*, *dlamJ*)

Compute voltage/non-voltage-related terms of power injection Hessian.

```
[Suzr, Suzi, Swzr, Swzi] = nme.port_inj_power_hess_vz(x_, lam)
[...] = nme.port_inj_power_hess_vz(x_, lam, sysx)
[...] = nme.port_inj_power_hess_vz(x_, lam, sysx, idx)
[...] = nme.port_inj_power_hess_vz(x_, lam, v_, z_, diagvi, L, dlamJ)
```

Called by `mp.form_ac.port_inj_power_hess()` (page 79) to compute voltage/non-voltage-related Hessian terms.

**aux\_data\_va\_vm**(*ad*)

Return voltage angles/magnitudes from auxiliary data.

```
[va, vm] = nme.aux_data_va_vm(ad)
```

Converts from cartesian voltage data stored in `ad.vr` and `ad.vi`.

**Input**

**ad** (*struct*) – struct of auxiliary data

**Outputs**

- **va** (*double*) – vector of voltage angles corresponding to voltage information stored in auxiliary data
- **vm** (*double*) – vector of voltage magnitudes corresponding to voltage information stored in auxiliary data

**va\_fcn**(*xx*, *idx*, *lim*)

Compute voltage angle constraints and Jacobian.



```
g = nme.va_fcn(xx, idx, lim)
[g, dg] = nme.va_fcn(xx, idx, lim)
```

Compute constraint function and optionally the Jacobian for voltage angle limits.

#### Inputs

- **xx** (*1 x 2 cell array*) – real part of complex voltage in **xx{1}**, imaginary part in **xx{2}**
- **idx** (*integer*) – index of subset of voltages of interest to include in constraint; if empty, include all
- **lim** (*double or cell array of double*) – constraint bound(s), can be a vector, for equality constraints or an upper bound, or a cell array with {**va\_lb**, **va\_ub**} for dual-bound constraints

#### Outputs

- **g** (*double*) – constraint function,  $g(x)$
- **dg** (*double*) – constraint Jacobian,  $g_x$

**va\_hess**(*xx, lam, idx*)

Compute voltage angle Hessian.

```
d2G = nme.va_hess(xx, lam, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of voltages. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\lambda$ .

#### Inputs

- **xx** (*1 x 2 cell array*) – real part of complex voltage in **xx{1}**, imaginary part in **xx{2}**
- **lam** (*double*) – vector  $\lambda$  of multipliers, one for each constraint
- **idx** (*integer*) – index of subset of voltages of interest to include in constraint; if empty, include all

#### Output

- **d2G** (*double*) – sparse constraint Hessian,  $g_{xx}(\lambda)$

**vm2\_fcn**(*xx, idx, lim*)

Compute squared voltage magnitude constraints and Jacobian.

```
g = nme.vm2_fcn(xx, idx, lim)
[g, dg] = nme.vm2_fcn(xx, idx, lim)
```

Compute constraint function and optionally the Jacobian for squared voltage magnitude limits.

#### Inputs

- **xx** (*1 x 2 cell array*) – real part of complex voltage in **xx{1}**, imaginary part in **xx{2}**
- **idx** (*integer*) – index of subset of voltages of interest to include in constraint; if empty, include all
- **lim** (*double or cell array of double*) – constraint bound(s), can be a vector, for equality constraints or an upper bound, or a cell array with {**vm2\_lb**, **vm2\_ub**} for dual-bound constraints

#### Outputs

- **g** (*double*) – constraint function,  $g(x)$
- **dg** (*double*) – constraint Jacobian,  $g_x$

**vm2\_hess**(*xx, lam, idx*)

Compute squared voltage magnitude Hessian.

```
d2G = nme.vm2_hess(xx, lam, idx)
```

Compute a sparse Hessian matrix for all or a selected subset of voltages. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\lambda$ .

**Inputs**

- **xx** (*1 x 2 cell array*) – real part of complex voltage in `xx{1}`, imaginary part in `xx{2}`
- **lam** (*double*) – vector  $\lambda$  of multipliers, one for each constraint
- **idx** (*integer*) – index of subset of voltages of interest to include in constraint; if empty, include all

**Output**

**d2G** (*double*) – sparse constraint Hessian,  $g_{xx}(\lambda)$

## mp.form\_acp

### class mp.form\_acp

Bases: *mp.form\_ac* (page 74)

*mp.form\_acp* (page 87) - Base class for MATPOWER AC polar **formulations**.

Used as a mix-in class for all **network model element** classes with an AC network model formulation with a **polar** representation for voltages. That is, each concrete network model element class with an AC polar formulation must inherit, at least indirectly, from both *mp.nm\_element* (page 108) and *mp.form\_acp* (page 87).

Provides implementation of evaluation of voltage-related Jacobian and Hessian terms needed by some *mp.form\_ac* (page 74) methods.

#### mp.form\_dc Methods:

- *form\_name()* (page 87) - get char array w/name of formulation ('AC-polar')
- *form\_tag()* (page 88) - get char array w/short label of formulation ('acp')
- *model\_vvars()* (page 88) - get cell array of names of voltage state variables ({'va', 'vm'})
- *port\_inj\_current\_jac()* (page 88) - compute voltage-related terms of current injection Jacobian
- *port\_inj\_current\_hess\_v()* (page 88) - compute voltage-related terms of current injection Hessian
- *port\_inj\_current\_hess\_vz()* (page 88) - compute voltage/non-voltage-related terms of current injection Hessian
- *port\_inj\_power\_jac()* (page 88) - compute voltage-related terms of power injection Jacobian
- *port\_inj\_power\_hess\_v()* (page 88) - compute voltage-related terms of power injection Hessian
- *port\_inj\_power\_hess\_vz()* (page 89) - compute voltage/non-voltage-related terms of power injection Hessian
- *aux\_data\_va\_vm()* (page 89) - return voltage angles/magnitudes from auxiliary data

For more details, see the `sec_nm_formulations_ac` section in the *MATPOWER Developer's Manual* and the derivations in *MATPOWER Technical Note 5*.

See also *mp.form* (page 72), *mp.form\_ac* (page 74), *mp.form\_acc* (page 83), *mp.nm\_element* (page 108).

#### Method Summary

**form\_name()**

Get user-readable name of formulation, i.e. 'AC-polar'.

See *mp.form.form\_name()* (page 73).

**form\_tag()**

Get short label of formulation, i.e. 'acp'.

See *mp.form.form\_tag()* (page 73).

**model\_vvars()**

Get cell array of names of voltage state variables, i.e. {'va', 'vm'}.

See *mp.form.model\_vvars()* (page 73).

**port\_inj\_current\_jac**(*n, v\_, Y, M, invdiagvic, diagSlineJ*)

Compute voltage-related terms of current injection Jacobian.

```
[Iva, Ivvm] = nme.port_inj_current_jac(n, v_, Y, M, invdiagvic, diagSlineJ)
```

Called by *mp.form\_ac.port\_inj\_current()* (page 77) to compute voltage-related Jacobian terms.

**port\_inj\_current\_hess\_v**(*x\_, lam, v\_, z\_, diaginvic, Y, M, diagSlineJ, dlamJ*)

Compute voltage-related terms of current injection Hessian.

```
[Ivava, Ivavm, Ivvmv] = nme.port_inj_current_hess_v(x_, lam)
[Ivava, Ivavm, Ivvmv] = nme.port_inj_current_hess_v(x_, lam, sysx)
[Ivava, Ivavm, Ivvmv] = nme.port_inj_current_hess_v(x_, lam, sysx, idx)
[...] = nme.port_inj_current_hess_vz(x_, lam, v_, z_, diaginvic, Y, M,
↳diagSlineJ, dlamJ)
```

Called by *mp.form\_ac.port\_inj\_current\_hess()* (page 78) to compute voltage-related Hessian terms.

**port\_inj\_current\_hess\_vz**(*x\_, lam, v\_, z\_, diaginvic, N, dlamJ*)

Compute voltage/non-voltage-related terms of current injection Hessian.

```
[Ivazr, Ivazi, Ivvmzr, Ivvmzi] = nme.port_inj_current_hess_vz(x_, lam)
[...] = nme.port_inj_current_hess_vz(x_, lam, sysx)
[...] = nme.port_inj_current_hess_vz(x_, lam, sysx, idx)
[...] = nme.port_inj_current_hess_vz(x_, lam, v_, z_, diaginvic, N, dlamJ)
```

Called by *mp.form\_ac.port\_inj\_current\_hess()* (page 78) to compute voltage/non-voltage-related Hessian terms.

**port\_inj\_power\_jac**(*n, v\_, Y, M, diagv, diagvi, diagIlineJ*)

Compute voltage-related terms of power injection Jacobian.

```
[Sva, Svvm] = nme.port_inj_power_jac(...)
```

Called by *mp.form\_ac.port\_inj\_power()* (page 77) to compute voltage-related Jacobian terms.

**port\_inj\_power\_hess\_v**(*x\_, lam, v\_, z\_, diagvi, Y, M, diagIlineJ, dlamJ*)

Compute voltage-related terms of power injection Hessian.

```
[Svava, Svavm, Svmvm] = nme.port_inj_power_hess_v(x_, lam)
[Svava, Svavm, Svmvm] = nme.port_inj_power_hess_v(x_, lam, sysx)
[Svava, Svavm, Svmvm] = nme.port_inj_power_hess_v(x_, lam, sysx, idx)
[...] = nme.port_inj_power_hess_v(x_, lam, v_, z_, diagvi, Y, M, diagIlinec],
↪ dlamJ)
```

Called by `mp.form_ac.port_inj_power_hess()` (page 79) to compute voltage-related Hessian terms.

**port\_inj\_power\_hess\_vz**(*x\_*, *lam*, *v\_*, *z\_*, *diagvi*, *L*, *dlamJ*)

Compute voltage/non-voltage-related terms of power injection Hessian.

```
[Svazr, Svazi, Svmzr, Svmzi] = nme.port_inj_power_hess_vz(x_, lam)
[...] = nme.port_inj_power_hess_vz(x_, lam, sysx)
[...] = nme.port_inj_power_hess_vz(x_, lam, sysx, idx)
[...] = nme.port_inj_power_hess_vz(x_, lam, v_, z_, diagvi, L, dlamJ)
```

Called by `mp.form_ac.port_inj_power_hess()` (page 79) to compute voltage/non-voltage-related Hessian terms.

**aux\_data\_va\_vm**(*ad*)

Return voltage angles/magnitudes from auxiliary data.

```
[va, vm] = nme.aux_data_va_vm(ad)
```

Simply returns voltage data stored in `ad.va` and `ad.vm`.

**Input**

**ad** (*struct*) – struct of auxiliary data

**Outputs**

- **va** (*double*) – vector of voltage angles corresponding to voltage information stored in auxiliary data
- **vm** (*double*) – vector of voltage magnitudes corresponding to voltage information stored in auxiliary data

## mp.form\_dc

**class mp.form\_dc**

Bases: `mp.form` (page 72)

`mp.form_dc` (page 89) - Base class for MATPOWER DC formulations.

Used as a mix-in class for all **network model element** classes with a DC network model formulation. That is, each concrete network model element class with a DC formulation must inherit, at least indirectly, from both `mp.nm_element` (page 108) and `mp.form_dc` (page 89).

`mp.form_dc` (page 89) defines the port active power injection as a linear function of the state variables  $\mathbf{x}$ , that is, the voltage angles  $\theta$  and non-voltage states  $\mathbf{z}$ , as

$$\begin{aligned} \mathbf{g}^P(\mathbf{x}) &= \begin{bmatrix} \mathbf{B} & \mathbf{K} \end{bmatrix} \mathbf{x} + \underline{\mathbf{p}} \\ &= \underline{\mathbf{B}}\theta + \underline{\mathbf{K}}\mathbf{z} + \underline{\mathbf{p}}, \end{aligned} \tag{3.6}$$

where  $\underline{\mathbf{B}}$ ,  $\underline{\mathbf{K}}$ , and  $\underline{\mathbf{p}}$  are the model parameters.

For more details, see the `sec_nm_formulations_dc` section in the *MATPOWER Developer's Manual* and the derivations in *MATPOWER Technical Note 5*.

#### **mp.form\_dc Properties:**

- $B$  (page 90) -  $n_p n_k \times n_n$  matrix  $\underline{B}$  of model parameters
- $K$  (page 90) -  $n_p n_k \times n_z$  matrix  $\underline{K}$  of model parameters
- $p$  (page 90) -  $n_p n_k \times 1$  vector  $\underline{p}$  of model parameters
- `params_ncols` - specify number of columns for each parameter

#### **mp.form\_dc Methods:**

- `form_name()` (page 90) - get char array w/name of formulation ('DC')
- `form_tag()` (page 90) - get char array w/short label of formulation ('dc')
- `model_params()` (page 90) - get network model element parameters ({'B', 'K', 'p'})
- `model_vvars()` (page 90) - get cell array of names of voltage state variables ({'va'})
- `model_zvars()` (page 91) - get cell array of names of non-voltage state variables ({'z'})
- `port_inj_power()` (page 91) - compute port power injections from network state

See also `mp.form` (page 72), `mp.form_ac` (page 74), `mp.nm_element` (page 108).

#### **Property Summary**

**B** = []

(double)  $n_p n_k \times n_n$  matrix  $\underline{B}$  of model parameter coefficients for  $\theta$

**K** = []

(double)  $n_p n_k \times n_z$  matrix  $\underline{K}$  of model parameter coefficients for  $z$

**p** = []

(double)  $n_p n_k \times 1$  vector  $\underline{p}$  of model parameters

**param\_ncols** = `struct('B',2,'K',3,'p',1)`

(struct) specify number of columns for each parameter, where

- 1 => single column (i.e. a vector)
- 2 =>  $n_p$  columns
- 3 =>  $n_z$  columns

#### **Method Summary**

**form\_name()**

Get user-readable name of formulation, i.e. 'DC'.

See `mp.form.form_name()` (page 73).

**form\_tag()**

Get short label of formulation, i.e. 'dc'.

See `mp.form.form_tag()` (page 73).

**model\_params()**

Get cell array of names of model parameters, i.e. {'B', 'K', 'p'}.

See `mp.form.model_params()` (page 73).

**model\_vvars()**

Get cell array of names of voltage state variables, i.e. {'va'}.

See *mp.form.model\_vvars()* (page 73).

**model\_zvars()**

Get cell array of names of non-voltage state variables, i.e. {'z'}.

See *mp.form.model\_zvars()* (page 73).

**port\_inj\_power(x, sysx, idx)**

Compute port power injections from network state.

```
P = nme.port_inj_power(x, sysx, idx)
```

Compute the active power injections for all or a selected subset of ports.

The state can be provided as a stacked aggregate of the state variables (port voltages and non-voltage states) for the full collection of network model elements of this type, or as the combined state for the entire network.

**Inputs**

- **x** (*double*) – state vector  $x$
- **sysx** (*0 or 1*) – which state is provided in  $x$ 
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns injections corresponding to all ports

**Outputs**

**P** (*double*) – vector of port power injections,  $g^P(x)$

**mp.net\_model****class mp.net\_model**

Bases: *mp.nm\_element* (page 108), *mp.element\_container* (page 166), *mp\_idx\_manager*

*mp.net\_model* (page 91) - Abstract base class for MATPOWER **network model** objects.

The network model defines the states of and connections between network elements, as well as the parameters and functions defining the relationships between states and port injections. A given network model implements a specific network model **formulation**, and defines sets of **nodes**, **ports**, and **states**.

A network model object is primarily a container for network model element (*mp.nm\_element* (page 108)) objects and *is itself* a network model element. All network model classes inherit from *mp.net\_model* (page 91) and therefore also from *mp.element\_container* (page 166), *mp\_idx\_manager*, and *mp.nm\_element* (page 108). Concrete network model classes are also formulation-specific, inheriting from a corresponding subclass of *mp.form* (page 72).

By convention, network model variables are named *nm* and network model class names begin with *mp.net\_model*.

**mp.net\_model Properties:**

- *the\_np* (page 93) - total number of ports
- *the\_nz* (page 93) - total number of non-voltage states
- *nv* (page 93) - total number of (real) voltage variables

- *node* (page 93) - `mp_idx_manager` data for nodes
- *port* (page 93) - `mp_idx_manager` data for ports
- *state* (page 93) - `mp_idx_manager` data for non-voltage states

**mp.net\_model Methods:**

- *name()* (page 93) - return name of this network element type ('network')
- *np()* (page 93) - return number of ports for this network element
- *nz()* (page 93) - return number of (*possibly complex*) non-voltage states for this network element
- *build()* (page 93) - create, add, and build network model element objects
- *add\_nodes()* (page 93) - elements add nodes, then add corresponding voltage variables
- *add\_states()* (page 94) - elements add states, then add corresponding state variables
- *build\_params()* (page 94) - build incidence matrices, parameters, add ports for each element
- *stack\_matrix\_params()* (page 94) - form network matrix parameter by stacking corresponding element parameters
- *stack\_vector\_params()* (page 94) - form network vector parameter by stacking corresponding element parameters
- *add\_vvars()* (page 95) - add voltage variable(s) for each network node
- *add\_zvars()* (page 95) - add non-voltage state variable(s) for each network state
- *def\_set\_types()* (page 95) - define node, state, and port set types for `mp_idx_manager`
- *init\_set\_types()* (page 95) - initialize structures for tracking/indexing nodes, states, ports
- *display()* (page 95) - display the network model object
- *add\_node()* (page 96) - add named set of nodes
- *add\_port()* (page 96) - add named set of ports
- *add\_state()* (page 96) - add named set of states
- *set\_type\_idx\_map()* (page 96) - map node/port/state index back to named set & index within set
- *set\_type\_label()* (page 97) - create a user-readable label to identify a node, port, or state
- *add\_var()* (page 97) - add a set of variables to the model
- *params\_var()* (page 98) - return initial value, bounds, and variable type for variables
- *get\_node\_idx()* (page 99) - get index information for named node set
- *get\_port\_idx()* (page 99) - get index information for named port set
- *get\_state\_idx()* (page 99) - get index information for named state set
- *node\_types()* (page 99) - get node type information
- *ensure\_ref\_node()* (page 100) -
- *set\_node\_type\_ref()* (page 100) - make the specified node a reference node
- *set\_node\_type\_pv()* (page 101) - make the specified node a PV node
- *set\_node\_type\_pq()* (page 101) - make the specified node a PQ node

See the `sec_net_model` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.form` (page 72), `mp.nm_element` (page 108), `mp.task` (page 8), `mp.data_model` (page 28), `mp.math_model` (page 122).

### Property Summary

**the\_np = 0**

(integer) total number of ports

**the\_nz = 0**

(integer) total number of non-voltage states

**nv = 0**

(integer) total number of (real) voltage variables

**node = []**

(struct) `mp_idx_manager` data for nodes

**port = []**

(struct) `mp_idx_manager` data for ports

**state = []**

(struct) `mp_idx_manager` data for non-voltage states

### Method Summary

**name()**

Return the name of this network element type ('network').

```
name = nm.name()
```

**np()**

Return the number of ports for this network element.

```
np = nm.np()
```

**nz()**

Return the number of (possibly complex) non-voltage states for this network element.

```
nz = nm.nz()
```

**build(dm)**

Create, add, and `build()` (page 93) network model element objects.

```
nm.build(dm)
```

#### Input

**dm** (`mp.data_model` (page 28)) – data model object

Create and add network model element objects, add nodes and states, and build the parameters for all elements.

See also `add_nodes()` (page 93), `add_states()` (page 94), `build_params()` (page 94).

**add\_nodes(nm, dm)**

Elements add nodes, then add corresponding voltage variables.



```
nm.add_nodes(nm, dm)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Each element can add its nodes, then the network model itself can add additional nodes, and finally corresponding voltage variables are added for each node.

See also *add\_vvars()* (page 95), *add\_states()* (page 94).

**add\_states(nm, dm)**

Elements add states, then add corresponding state variables.

```
nm.add_states(nm, dm)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Each element can add its states, then corresponding non-voltage state variables are added for each state.

See also *add\_zvars()* (page 95), *add\_nodes()* (page 93).

**build\_params(nm, dm)**

Build incidence matrices and parameters, and add ports for each element.

```
nm.build_params(nm, dm)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

For each element, build connection and state variable incidence matrices and element parameters, and add ports. Then construct the full network connection and state variable incidence matrices.

**stack\_matrix\_params(name, vnotz)**

Form network matrix parameter by stacking corresponding element parameters.

```
M = nm.stack_matrix_params(name, vnotz)
```

**Inputs**

- **name** (*char array*) – name of the parameter of interest
- **vnotz** (*boolean*) – true if columns of parameter correspond to voltage variables, false otherwise

**Output**

**M** (*double*) – matrix parameter of interest for the full network

A given matrix parameter (e.g. **Y**) for the full network is formed by stacking the corresponding matrix parameters for each element along the matrix block diagonal.

**stack\_vector\_params(name)**

Form network vector parameter by stacking corresponding element parameters.

```
v = nm.stack_vector_params(name)
```

**Input**

**name** (*char array*) – name of the parameter of interest

**Output**

**v** (*double*) – vector parameter of interest for the full network

A given vector parameter (e.g. *s*) for the full network is formed by vertically stacking the corresponding vector parameters for each element.

**add\_vvars**(*nm, dm, idx*)

Add voltage variable(s) for each network node.

```
nm.add_vvars(nm, dm)
nm.add_vvars(nm, dm, idx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index for name and indexed variables (*currently unused here*)

Also updates the *nv* property.

See also [add\\_zvars\(\)](#) (page 95), [add\\_nodes\(\)](#) (page 93).

**add\_zvars**(*nm, dm, idx*)

Add non-voltage state variable(s) for each network state.

```
nm.add_zvars(nm, dm)
nm.add_zvars(nm, dm, idx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*cell array*) – indices for named and indexed variables (*currently unused here*)

See also [add\\_vvars\(\)](#) (page 95), [add\\_states\(\)](#) (page 94).

**def\_set\_types**()

Define node, state, and port set types for *mp\_idx\_manager*.

```
nm.def_set_types()
```

Define the following set types:

- 'node' - NODES
- 'state' - STATES
- 'port' - PORTS

See also *mp\_idx\_manager*.

**init\_set\_types**()

Initialize structures for tracking/indexing nodes, states, ports.

```
nm.init_set_types()
```

See also *mp\_idx\_manager*.

**display**()

Display the network model object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the nodes, ports, states, voltage variables, non-voltage state variables, and network model elements.

See also `mp_idx_manager`.

**add\_node**(*name, idx, N*)

Add named set of nodes.

```
nm.add_node(name, N)
nm.add_node(name, idx, N)
```

#### Inputs

- **name** (*char array*) – name for set of nodes
- **idx** (*cell array*) – indices for named, indexed set of nodes
- **N** (*integer*) – number of nodes in set

See also `mp_idx_manager.add_named_set()`.

**add\_port**(*name, idx, N*)

Add named set of ports.

```
nm.add_port(name, N)
nm.add_port(name, idx, N)
```

#### Inputs

- **name** (*char array*) – name for set of ports
- **idx** (*cell array*) – indices for named, indexed set of ports
- **N** (*integer*) – number of ports in set

See also `mp_idx_manager.add_named_set()`.

**add\_state**(*name, idx, N*)

Add named set of states.

```
nm.add_state(name, N)
nm.add_state(name, idx, N)
```

#### Inputs

- **name** (*char array*) – name for set of states
- **idx** (*cell array*) – indices for named, indexed set of states
- **N** (*integer*) – number of states in set

See also `mp_idx_manager.add_named_set()`.

**set\_type\_idx\_map**(*set\_type, idxs, dm, group\_by\_name*)

Map node/port/state index back to named set & index within set.

```
s = obj.set_type_idx_map(set_type)
s = obj.set_type_idx_map(set_type, idxs)
s = obj.set_type_idx_map(set_type, idxs, dm)
s = obj.set_type_idx_map(set_type, idxs, dm, group_by_name)
```

#### Inputs

- **set\_type** (*char array*) – 'node', 'port', or 'state'
- **idxs** (*integer*) – vector of indices, defaults to `[1:ns]'`, where `ns` is the full dimension of the set corresponding to the all elements for the specified set type (i.e. node, port, or state)
- **dm** (*mp.data\_model* (page 28)) – data model object

- **group\_by\_name** (*boolean*) – if true, results are consolidated, with a single entry in *s* for each unique name/idx pair, where the *i* and *j* fields are vectors

**Output**

*s* (*struct*) – index map of same dimensions as *idxs*, unless *group\_by\_name* is true, in which case it is 1 dimensional

Returns a struct of same dimensions as *idxs* specifying, for each index, the corresponding named set and element within the named set for the specified *set\_type*. The return struct has the following fields:

- **name** : name of corresponding set
- **idx** : cell array of indices for the name, if named set is indexed
- **i** : index of element within the set
- **e** : external index (i.e. corresponding row in data model)
- **ID** : external ID (i.e. corresponding element ID in data model)
- **j** : (only if *group\_by\_name* == 1), corresponding index of set type, equal to a particular element of *idxs*

Examples:

```
s = nm.set_type_idx_map('node', 87, dm);
s = nm.set_type_idx_map('port', [38; 49; 93], dm);
s = nm.set_type_idx_map('state');
s = nm.set_type_idx_map('node', [], dm, 1);
```

**set\_type\_label**(*set\_type*, *idxs*, *dm*)

Create a user-readable label to identify a node, port, or state.

```
label = nm.set_type_label(set_type, idxs)
label = nm.set_type_label(set_type, idxs, dm)
```

**Inputs**

- **set\_type** (*char array*) – 'node', 'port', or 'state'
- **idxs** (*integer*) – vector of indices
- **dm** (*mp.data\_model* (page 28)) – data model object

**Output**

**label** (*cell array*) – same dimensions as *idxs*, where each entry is a char array

Example:

```
labels = nm.set_type_label('port', [1;6;15;20], dm)

labels =

4x1 cell array

    {'gen 1'      }
    {'load 3'     }
    {'branch(1) 9'}
    {'branch(2) 5'}
```

**add\_var**(*vtype*, *name*, *idx*, *varargin*)

Add a set of variables to the model.

```
nm.add_var(vtype, name, N, v0, v1, vu, vt)
nm.add_var(vtype, name, N, v0, v1, vu)
nm.add_var(vtype, name, N, v0, v1)
```

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```

nm.add_var(vtype, name, N, v0)
nm.add_var(vtype, name, N)
nm.add_var(vtype, name, idx_list, N, v0, vl, vu, vt)
nm.add_var(vtype, name, idx_list, N, v0, vl, vu)
nm.add_var(vtype, name, idx_list, N, v0, vl)
nm.add_var(vtype, name, idx_list, N, v0)
nm.add_var(vtype, name, idx_list, N)

```

**Inputs**

- **vtype** (*char array*) – variable type, must be a valid struct field name
- **name** (*char array*) – name of variable set
- **idx\_list** (*cell array*) – optional index list
- **N** (*integer*) – number of variables in the set
- **v0** (*double*) – N x 1 col vector, initial value of variables, default is 0
- **vl** (*double*) – N x 1 col vector, lower bounds, default is -Inf
- **vu** (*double*) – N x 1 col vector, upper bounds, default is Inf
- **vt** (*char*) – scalar or 1 x N row vector, variable type, default is 'C', valid element values are:
  - 'C' - continuous
  - 'I' - integer
  - 'B' - binary

Essentially identical to the `add_var()` method from `opt_model` of MP-Opt-Model, with the addition of a variable type (`vtype`).

See also `opt_model.add_var()`.

**params\_var**(*vtype, name, idx*)

Return initial value, bounds, and variable type for variables.

```

[v0, vl, vu] = nm.params_var(vtype)
[v0, vl, vu] = nm.params_var(vtype, name)
[v0, vl, vu] = nm.params_var(vtype, name, idx_list)
[v0, vl, vu, vt] = nm.params_var(...)

```

**Inputs**

- **vtype** (*char array*) – variable type, must be a valid struct field name
- **name** (*char array*) – name of variable set
- **idx\_list** (*cell array*) – optional index list

**Outputs**

- **v0** (*double*) – N x 1 col vector, initial value of variables
- **vl** (*double*) – N x 1 col vector, lower bounds
- **vu** (*double*) – N x 1 col vector, upper bounds
- **vt** (*char*) – scalar or 1 x N row vector, variable type, valid element values are:
  - 'C' - continuous
  - 'I' - integer
  - 'B' - binary

Essentially identical to the `params_var()` method from `opt_model` of MP-Opt-Model, with the addition of a variable type (`vtype`).

Returns the initial value `v0`, lower bound `vl` and upper bound `vu` for the full variable vector, or for a specific named or named and indexed variable set. Optionally also returns a corresponding char vector `vt` of variable types, where 'C', 'I' and 'B' represent continuous, integer, and binary variables, respectively.

Examples:

```
[vr0, vrmin, vrmax] = obj.params_var('vr');
[pg0, pg_lb, pg_ub] = obj.params_var('zr', 'pg');
[zij0, zij_lb, zij_ub, ztype] = obj.params_var('zi', 'z', {i, j});
```

See also `opt_model.params_var()`.

#### **get\_node\_idx**(name)

Get index information for named node set.

```
[i1 iN] = nm.get_node_idx(name)
nidx = nm.get_node_idx(name)
```

##### **Input**

**name** (*char array*) – name of node set

##### **Outputs**

- **i1** (*integer*) – index of first node for name
- **iN** (*integer*) – index of last node for name
- **nidx** (*integer or cell array*) – indices of nodes for name, equal to either `[i1:iN]'` or `{[i1(1):iN(1)]', ..., [i1(n):iN(n)]'}`

#### **get\_port\_idx**(name)

Get index information for named port set.

```
[i1 iN] = nm.get_port_idx(name)
pidx = nm.get_port_idx(name)
```

##### **Input**

**name** (*char array*) – name of port set

##### **Outputs**

- **i1** (*integer*) – index of first port for name
- **iN** (*integer*) – index of last port for name
- **pidx** (*integer or cell array*) – indices of ports for name, equal to either `[i1:iN]'` or `{[i1(1):iN(1)]', ..., [i1(n):iN(n)]'}`

#### **get\_state\_idx**(name)

Get index information for named state set.

```
[i1 iN] = nm.get_state_idx(name)
sidx = nm.get_state_idx(name)
```

##### **Input**

**name** (*char array*) – name of state set

##### **Outputs**

- **i1** (*integer*) – index of first state for name
- **iN** (*integer*) – index of last state for name
- **sidx** (*integer or cell array*) – indices of states for name, equal to either `[i1:iN]'` or `{[i1(1):iN(1)]', ..., [i1(n):iN(n)]'}`

#### **node\_types**(nm, dm, idx, skip\_ensure\_ref)

Get node type information.

```
ntv = nm.node_types(nm, dm)
[ntv, by_elm] = nm.node_types(nm, dm)
```

(continues on next page)

(continued from previous page)

```
[ref, pv, pq] = nm.node_types(nm, dm)
[ref, pv, pq, by_elm] = nm.node_types(nm, dm)
... = nm.node_types(nm, dm, idx)
... = nm.node_types(nm, dm, idx, skip_ensure_ref)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index (*not used in base method*)
- **skip\_ensure\_ref** (*boolean*) – unless true, if there is no reference node, the first PV node will be converted to a new reference

**Outputs**

- **ntv** (*integer*) – node type vector, valid element values are:
  - *mp.NODE\_TYPE.REF* (page 170)
  - *mp.NODE\_TYPE.PV* (page 170)
  - *mp.NODE\_TYPE.PQ* (page 170)
- **ref** (*integer*) – vector of indices of reference nodes
- **pv** (*integer*) – vector of indices of PV nodes
- **pq** (*integer*) – vector of indices of PQ nodes
- **by\_elm** (*struct*) – *by\_elm(k)* is struct for k-th node-creating element type, with fields:
  - 'name' - name of corresponding node-creating element type
  - 'ntv' - node type vector (if *by\_elm* is 2nd output arg)
  - 'ref'/'pv'/'pq' - index vectors into elements of corresponding node-creating element type (if *by\_elm* is 4th output arg)

See also *mp.NODE\_TYPE* (page 170), *ensure\_ref\_node()* (page 100).

**ensure\_ref\_node(dm, ref, pv, pq)**

Ensure there is at least one reference node.

```
[ref, pv, pq] = nm.ensure_ref_node(dm, ref, pv, pq)
ntv = nm.ensure_ref_node(dm, ntv)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **ref** (*integer*) – vector of indices of reference nodes
- **pv** (*integer*) – vector of indices of PV nodes
- **pq** (*integer*) – vector of indices of PQ nodes
- **ntv** (*integer*) – node type vector, valid element values are:
  - *mp.NODE\_TYPE.REF* (page 170)
  - *mp.NODE\_TYPE.PV* (page 170)
  - *mp.NODE\_TYPE.PQ* (page 170)

**Outputs**

- **ref** (*integer*) – updated vector of indices of reference nodes
- **pv** (*integer*) – updated vector of indices of PV nodes
- **pq** (*integer*) – updated vector of indices of PQ nodes
- **ntv** (*integer*) – updated node type vector

**set\_node\_type\_ref(dm, idx)**

Make the specified node a reference node.

```
nm.set_node_type_ref(dm, idx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.REF* (page 170).

**set\_node\_type\_pv**(*dm, idx*)

Make the specified node a PV node.

```
nm.set_node_type_pv(dm, idx)
```

#### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.PV* (page 170).

**set\_node\_type\_pq**(*dm, idx*)

Make the specified node a PQ node.

```
nm.set_node_type_pq(dm, idx)
```

#### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.PQ* (page 170).

## mp.net\_model\_ac

**class mp.net\_model\_ac**

Bases: *mp.net\_model* (page 91)

*mp.net\_model\_ac* (page 101) - Abstract base class for MATPOWER AC **network model** objects.

Explicitly a subclass of *mp.net\_model* (page 91) and implicitly assumed to be a subclass of *mp.form\_ac* (page 74) as well.

#### mp.net\_model\_ac Properties:

- **zr** - vector of real part of complex non-voltage states,  $z_r$
- **zi** - vector of imaginary part of complex non-voltage states,  $z_i$

#### mp.net\_model\_ac Methods:

- *def\_set\_types()* (page 102) - add non-voltage state variable set types for *mp\_idx\_manager*
- *build\_params()* (page 102) - build incidence matrices, parameters, add ports for each element
- *port\_inj\_nln()* (page 102) - compute general nonlinear port injection functions and Jacobians
- *port\_inj\_nln\_hess()* (page 103) - compute general nonlinear port injection Hessian
- *nodal\_complex\_current\_balance()* (page 103) - compute nodal complex current balance constraints
- *nodal\_complex\_power\_balance()* (page 103) - compute nodal complex power balance constraints
- *nodal\_complex\_current\_balance\_hess()* (page 104) - compute nodal complex current balance Hessian



- `nodal_complex_power_balance_hess()` (page 104) - compute nodal complex power balance Hessian
- `port_inj_soln()` (page 104) - compute the network port power injections at the solution
- `get_va()` (page 104) - get node voltage angle vector

See also `mp.net_model` (page 91), `mp.form` (page 72), `mp.form_ac` (page 74), `mp.nm_element` (page 108).

### Method Summary

#### `def_set_types()`

Add non-voltage state variable set types for `mp_idx_manager`.

```
nm.def_set_types()
```

Add the following set types:

- 'zr' - NON-VOLTAGE VARS REAL (zr)
- 'zi' - NON-VOLTAGE VARS IMAG (zi)

See also `mp.net_model.def_set_types()` (page 95), `mp_idx_manager`.

#### `build_params(nm, dm)`

Build incidence matrices and parameters, and add ports for each element.

```
nm.build_params(nm, dm)
```

#### Inputs

- **nm** (`mp.net_model` (page 91)) – network model object
- **dm** (`mp.data_model` (page 28)) – data model object

Call the parent method to do most () of the work, then build the aggregate network model parameters and add the general nonlinear function terms,  $s^{nl_n}(\mathbf{x})$  or  $i^{nl_n}(\mathbf{x})$ , for any elements that define them.

#### `port_inj_nln(si, x_, sysx, idx)`

Compute general nonlinear port injection functions and Jacobians

```
g = nm.port_inj_nln(si, x_, sysx, idx)
[g, gv1, gv2] = nm.port_inj_nln(si, x_, sysx, idx)
[g, gv1, gv2, gvr, gvri] = nm.port_inj_nln(si, x_, sysx, idx)
```

Compute and assemble the functions, and optionally Jacobians, for the general nonlinear injection functions  $s^{nl_n}(\mathbf{x})$  and  $i^{nl_n}(\mathbf{x})$  for the full aggregate network model, for all or a selected subset of ports.

#### Inputs

- **si** ('S' or 'I') – select power or current injection function:
  - 'S' for complex power  $s^{nl_n}(\mathbf{x})$
  - 'I' for complex current  $i^{nl_n}(\mathbf{x})$
- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **sysx** (0 or 1) – which state is provided in **x\_**
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

#### Outputs

- **g** (*complex double*) – nonlinear injection function,  $s^{nl_n}(\mathbf{x})$  (or  $i^{nl_n}(\mathbf{x})$ )
- **gv1** (*complex double*) – Jacobian w.r.t. 1st voltage variable,  $s_{\theta}^{nl_n}$  or  $s_u^{nl_n}$  (or  $i_{\theta}^{nl_n}$  or  $i_u^{nl_n}$ )
- **gv2** (*complex double*) – Jacobian w.r.t. 2nd voltage variable,  $s_v^{nl_n}$  or  $s_w^{nl_n}$  (or  $i_v^{nl_n}$  or  $i_w^{nl_n}$ )

- **g<sub>zr</sub>** (*complex double*) – Jacobian w.r.t. real non-voltage variable,  $s_{z_r}^{nl}$  (or  $i_{z_r}^{nl}$ )
- **g<sub>zi</sub>** (*complex double*) – Jacobian w.r.t. imaginary non-voltage variable,  $s_{z_i}^{nl}$  (or  $i_{z_i}^{nl}$ )

See also [port\\_inj\\_nln\\_hess\(\)](#) (page 103).

### port\_inj\_nln\_hess(si, x\_, lam, sysx, idx)

Compute general nonlinear port injection Hessian.

```
H = nm.port_inj_nln_hess(si, x_, lam)
H = nm.port_inj_nln_hess(si, x_, lam, sysx)
H = nm.port_inj_nln_hess(si, x_, lam, sysx, idx)
```

Compute and assemble the Hessian for the general nonlinear injection functions  $s^{nl}(\mathbf{x})$  and  $i^{nl}(\mathbf{x})$  for the full aggregate network model, for all or a selected subset of ports. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the corresponding Jacobian by a vector  $\lambda$ .

#### Inputs

- **si** ('S' or 'I') – select power or current injection function:
  - 'S' for complex power  $s^{nl}(\mathbf{x})$
  - 'I' for complex current  $i^{nl}(\mathbf{x})$
- **x\_** (*complex double*) – state vector  $\mathbf{x}$
- **lam** (*double*) – vector  $\lambda$  of multipliers, one for each port
- **sysx** (0 or 1) – which state is provided in **x\_**
  - 0 – class aggregate state
  - 1 – (*default*) full system state
- **idx** (*integer*) – (*optional*) vector of indices of ports of interest, if empty or missing, returns results corresponding to all ports

#### Output

**H** (*complex double*) – sparse Hessian matrix,  $s_{xx}^{nl}(\lambda)$  or  $i_{xx}^{nl}(\lambda)$

See also [port\\_inj\\_nln\(\)](#) (page 102).

### nodal\_complex\_current\_balance(x\_)

Compute nodal complex current balance constraints.

```
G = nm.nodal_complex_current_balance(x_)
[G, Gv1, Gv2, Gzr, Gzi] = nm.nodal_complex_current_balance(x_)
```

Compute constraint function and optionally the Jacobian for the complex current balance equality constraints based on outputs of [mp.form\\_ac.port\\_inj\\_current\(\)](#) (page 77) and the node incidence matrix.

#### Input

**x\_** (*complex double*) – state vector  $\mathbf{x}$  (full system state)

#### Outputs

- **G** (*complex double*) – nodal complex current balance constraint function,  $\mathbf{g}^{kcl}(\mathbf{x})$
- **Gv1** (*complex double*) – Jacobian w.r.t. 1st voltage variable,  $\mathbf{g}_{\theta}^{kcl}$  or  $\mathbf{g}_u^{kcl}$
- **Gv2** (*complex double*) – Jacobian w.r.t. 2nd voltage variable,  $\mathbf{g}_v^{kcl}$  or  $\mathbf{g}_w^{kcl}$
- **Gzr** (*complex double*) – Jacobian w.r.t. real non-voltage variable,  $\mathbf{g}_{z_r}^{kcl}$
- **Gzi** (*complex double*) – Jacobian w.r.t. imaginary non-voltage variable,  $\mathbf{g}_{z_i}^{kcl}$

See also [mp.form\\_ac.port\\_inj\\_current\(\)](#) (page 77), [nodal\\_complex\\_current\\_balance\\_hess\(\)](#) (page 104).

### nodal\_complex\_power\_balance(x\_)

Compute nodal complex power balance constraints.

```
G = nm.nodal_complex_power_balance(x_)
[G, Gv1, Gv2, Gzr, Gzi] = nm.nodal_complex_power_balance(x_)
```

Compute constraint function and optionally the Jacobian for the complex power balance equality constraints based on outputs of `mp.form_ac.port_inj_power()` (page 77) and the node incidence matrix.

**Input**

`x_` (*complex double*) – state vector  $\mathbf{x}$  (full system state)

**Outputs**

- **G** (*complex double*) – nodal complex power balance constraint function,  $\mathbf{g}^{\text{kcl}}(\mathbf{x})$
- **Gv1** (*complex double*) – Jacobian w.r.t. 1st voltage variable,  $\mathbf{g}_{\theta}^{\text{kcl}}$  or  $\mathbf{g}_u^{\text{kcl}}$
- **Gv2** (*complex double*) – Jacobian w.r.t. 2nd voltage variable,  $\mathbf{g}_v^{\text{kcl}}$  or  $\mathbf{g}_w^{\text{kcl}}$
- **Gzr** (*complex double*) – Jacobian w.r.t. real non-voltage variable,  $\mathbf{g}_{z_r}^{\text{kcl}}$
- **Gzi** (*complex double*) – Jacobian w.r.t. imaginary non-voltage variable,  $\mathbf{g}_{z_i}^{\text{kcl}}$

See also `mp.form_ac.port_inj_power()` (page 77), `nodal_complex_power_balance_hess()` (page 104).

**nodal\_complex\_current\_balance\_hess(x\_, lam)**

Compute nodal complex current balance Hessian.

`d2G = nm.nodal_complex_current_balance_hess(x_, lam)`

Compute the Hessian of the nodal complex current balance constraint. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\lambda$ . Based on `mp.form_ac.port_inj_current_hess()` (page 78).

**Inputs**

- `x_` (*complex double*) – state vector  $\mathbf{x}$  (full system state)
- `lam` (*double*) – vector  $\lambda$  of multipliers, one for each node

**Output**

**d2G** (*complex double*) – sparse Hessian matrix,  $\mathbf{g}_{\mathbf{x}\mathbf{x}}^{\text{kcl}}(\lambda)$

See also `mp.form_ac.port_inj_current_hess()` (page 78), `nodal_complex_current_balance()` (page 103).

**nodal\_complex\_power\_balance\_hess(x\_, lam)**

Compute nodal complex power balance Hessian.

`d2G = nm.nodal_complex_power_balance_hess(x_, lam)`

Compute the Hessian of the nodal complex power balance constraint. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\lambda$ . Based on `mp.form_ac.port_inj_power_hess()` (page 79).

**Inputs**

- `x_` (*complex double*) – state vector  $\mathbf{x}$  (full system state)
- `lam` (*double*) – vector  $\lambda$  of multipliers, one for each node

**Output**

**d2G** (*complex double*) – sparse Hessian matrix,  $\mathbf{g}_{\mathbf{x}\mathbf{x}}^{\text{kcl}}(\lambda)$

See also `mp.form_ac.port_inj_power_hess()` (page 79), `nodal_complex_power_balance()` (page 103).

**port\_inj\_soln()**

Compute the network port power injections at the solution.

`nm.port_inj_soln()`

Takes the solved network state, computes the port power injections, and saves them in `nm.soln.gs_`.

**get\_va(idx)**

Get node voltage angle vector.

```
va = nm.get_va()
va = nm.get_va(idx)
```

Get vector of node voltage angles for all or a selected subset of nodes. Values come from the solution if available, otherwise from the provided initial voltages.

**Input**

**idx** (*integer*) – index of subset of voltages of interest; if missing or empty, include all

**Output**

**va** (*double*) – vector of voltage angles

## mp.net\_model\_acc

### class mp.net\_model\_acc

Bases: [mp.net\\_model\\_ac](#) (page 101), [mp.form\\_acc](#) (page 83)

[mp.net\\_model\\_acc](#) (page 105) - Concrete class for MATPOWER AC cartesian **network model** objects.

This network model class and all of its network model element classes are specific to the AC cartesian formulation and therefore inherit from [mp.form\\_acc](#) (page 83).

#### mp.net\_model\_acc Properties:

- **vr** - vector of real part of complex voltage state variables, *u*
- **vi** - vector of imaginary part of complex voltage state variables, *w*

#### mp.net\_model\_acc Methods:

- [net\\_model\\_acc\(\)](#) (page 105) - constructor, assign default network model element classes
- [def\\_set\\_types\(\)](#) (page 105) - add voltage state variable set types for `mp_idx_manager`
- [initial\\_voltage\\_angle\(\)](#) (page 106) - get vector of initial node voltage angles

See also [mp.net\\_model\\_ac](#) (page 101), [mp.net\\_model](#) (page 91), [mp.form\\_acc](#) (page 83), [mp.form\\_ac](#) (page 74), [mp.form](#) (page 72), [mp.nm\\_element](#) (page 108).

#### Constructor Summary

##### net\_model\_acc()

Constructor, assign default network model element classes.

```
nm = net_model_acc()
```

This network model class and all of its network model element classes are specific to the AC cartesian formulation and therefore inherit from [mp.form\\_acc](#) (page 83).

#### Method Summary

##### def\_set\_types()

Add voltage state variable set types for `mp_idx_manager`.

```
nm.def_set_types()
```

Add the following set types:

- 'vr' - REAL VOLTAGE VARS (vr)
- 'vi' - IMAG VOLTAGE VARS (vi)

See also [mp.net\\_model\\_ac.def\\_set\\_types\(\)](#) (page 102), [mp.net\\_model.def\\_set\\_types\(\)](#) (page 95), [mp\\_idx\\_manager](#).

### **initial\_voltage\_angle**(*idx*)

Get vector of initial node voltage angles.

```
va = nm.initial_voltage_angle()
va = nm.initial_voltage_angle(idx)
```

Get vector of initial node voltage angles for all or a selected subset of nodes.

#### **Input**

**idx** (*integer*) – index of subset of voltages of interest; if missing or empty, include all

#### **Output**

**va** (*double*) – vector of initial voltage angles

## **mp.net\_model\_acp**

### **class mp.net\_model\_acp**

Bases: [mp.net\\_model\\_ac](#) (page 101), [mp.form\\_acp](#) (page 87)

[mp.net\\_model\\_acp](#) (page 106) - Concrete class for MATPOWER AC polar **network model** objects.

This network model class and all of its network model element classes are specific to the AC polar formulation and therefore inherit from [mp.form\\_acp](#) (page 87).

#### **mp.net\_model\_acp Properties:**

- **va** - vector of angles of complex voltage state variables,  $\theta$
- **vm** - vector of magnitudes of complex voltage state variables,  $\nu$

#### **mp.net\_model\_acp Methods:**

- [net\\_model\\_acp\(\)](#) (page 106) - constructor, assign default network model element classes
- [def\\_set\\_types\(\)](#) (page 106) - add voltage state variable set types for [mp\\_idx\\_manager](#)
- [initial\\_voltage\\_angle\(\)](#) (page 107) - get vector of initial node voltage angles

See also [mp.net\\_model\\_ac](#) (page 101), [mp.net\\_model](#) (page 91), [mp.form\\_acp](#) (page 87), [mp.form\\_ac](#) (page 74), [mp.form](#) (page 72), [mp.nm\\_element](#) (page 108).

#### **Constructor Summary**

##### **net\_model\_acp()**

Constructor, assign default network model element classes.

```
nm = net_model_acp()
```

This network model class and all of its network model element classes are specific to the AC polar formulation and therefore inherit from [mp.form\\_acp](#) (page 87).

#### **Method Summary**

##### **def\_set\_types()**

Add voltage state variable set types for [mp\\_idx\\_manager](#).

```
nm.def_set_types()
```

Add the following set types:

- 'va' - VOLTAGE ANG VARS (va)
- 'vm' - VOLTAGE MAG VARS (vm)

See also [mp.net\\_model\\_ac.def\\_set\\_types\(\)](#) (page 102), [mp.net\\_model.def\\_set\\_types\(\)](#) (page 95), [mp\\_idx\\_manager](#).

### **initial\_voltage\_angle**(idx)

Get vector of initial node voltage angles.

```
va = nm.initial_voltage_angle()
va = nm.initial_voltage_angle(idx)
```

Get vector of initial node voltage angles for all or a selected subset of nodes.

#### **Input**

**idx** (*integer*) – index of subset of voltages of interest; if missing or empty, include all

#### **Output**

**va** (*double*) – vector of initial voltage angles

## **mp.net\_model\_dc**

### **class mp.net\_model\_dc**

Bases: [mp.net\\_model](#) (page 91), [mp.form\\_dc](#) (page 89)

[mp.net\\_model\\_dc](#) (page 107) - Concrete class for MATPOWER DC **network model** objects.

This network model class and all of its network model element classes are specific to the DC formulation and therefore inherit from [mp.form\\_dc](#) (page 89).

#### **mp.net\_model\_dc Properties:**

- **va** (page 108) - vector of voltage states (voltage angles  $\theta$ )
- **z** (page 108) - vector of non-voltage states  $z$

#### **mp.net\_model\_dc Methods:**

- [net\\_model\\_dc\(\)](#) (page 107) - constructor, assign default network model element classes
- [def\\_set\\_types\(\)](#) (page 108) - add voltage and non-voltage variable set types for [mp\\_idx\\_manager](#)
- [build\\_params\(\)](#) (page 108) - build incidence matrices, parameters, add ports for each element
- [port\\_inj\\_soln\(\)](#) (page 108) - compute the network port injections at the solution

See also [mp.net\\_model](#) (page 91), [mp.form\\_dc](#) (page 89), [mp.form](#) (page 72), [mp.nm\\_element](#) (page 108).

#### **Constructor Summary**

##### **net\_model\_dc()**

Constructor, assign default network model element classes.

```
nm = net_model_dc()
```

This network model class and all of its network model element classes are specific to the DC formulation and therefore inherit from [mp.form\\_dc](#) (page 89).

### Property Summary

**va** = []

(*double*) vector of voltage states (voltage angles  $\theta$ )

**z** = []

(*double*) vector of non-voltage states  $z$

### Method Summary

#### **def\_set\_types()**

Add voltage and non-voltage variable set types for `mp_idx_manager`.

```
nm.def_set_types()
```

Add the following set types:

- 'va' - VOLTAGE VARS (va)
- 'z' - NON-VOLTAGE VARS (z)

See also `mp.net_model.def_set_types()` (page 95), `mp_idx_manager`.

#### **build\_params(nm, dm)**

Build incidence matrices and parameters, and add ports for each element.

```
nm.build_params(nm, dm)
```

#### **Inputs**

- **nm** (`mp.net_model` (page 91)) – network model object
- **dm** (`mp.data_model` (page 28)) – data model object

Call the parent method to do most () of the work, then build the aggregate network model parameters.

#### **port\_inj\_soln()**

Compute the network port injections at the solution.

```
nm.port_inj_soln()
```

Takes the solved network state, computes the port power injections, and saves them in `nm.soln.gp`.

## 3.4.2 Elements

### `mp.nm_element`

#### **class mp.nm\_element**

Bases: `handle`

`mp.nm_element` (page 108) - Abstract base class for MATPOWER **network model element** objects.

A network model element object encapsulates all of the network model parameters for a particular element type. All network model element classes inherit from `mp.nm_element` (page 108) and also, like the container, from a formulation-specific subclass of `mp.form` (page 72). Each element type typically implements its own subclasses, which are further subclassed per formulation. A given network model element object contains the aggregate network model parameters for all online instances of that element type, stored in the set of matrices and vectors that correspond to the formulation.

By convention, network model element variables are named `nme` and network model element class names begin with `mp.nme`.

#### **mp.mm\_element Properties:**

- `nk` (page 109) - number of elements of this type
- `C` (page 109) - stacked sparse element-node incidence matrices
- `D` (page 110) - stacked sparse incidence matrices for  $z$ -variables
- `soln` (page 110) - struct for storing solved states, quantities

#### **mp.mm\_element Methods:**

- `name()` (page 110) - get name of element type, e.g. 'bus', 'gen'
- `np()` (page 110) - number of ports per element of this type
- `nn()` (page 110) - number of nodes per element, created by this element type
- `nz()` (page 110) - number of non-voltage state variables per element of this type
- `data_model_element()` (page 110) - get the corresponding data model element
- `math_model_element()` (page 111) - get the corresponding math model element
- `count()` (page 111) - get number of online elements in `dm`, set `nk`
- `add_nodes()` (page 111) - add nodes to network model
- `add_states()` (page 111) - add non-voltage states to network model
- `add_vvars()` (page 111) - add real-valued voltage variables to network object
- `add_zvars()` (page 112) - add real-valued non-voltage state variables to network object
- `build_params()` (page 112) - build model parameters from data model
- `get_nv_()` (page 112) - get number of (*possibly complex*) voltage variables
- `x2vz()` (page 112) - get port voltages and non-voltage states from combined state vector
- `node_indices()` (page 113) - construct node indices from data model element connection info
- `incidence_matrix()` (page 113) - construct stacked incidence matrix from set of index vectors
- `node_types()` (page 114) - get node type information
- `set_node_type_ref()` (page 114) - make the specified node a reference node
- `set_node_type_pv()` (page 114) - make the specified node a PV node
- `set_node_type_pq()` (page 115) - make the specified node a PQ node
- `display()` (page 115) - display the network model element object

See the `sec_nm_element` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.net_model` (page 91).

#### **Property Summary**

**`nk = 0`**

(*integer*) number of elements of this type



**C** = []

(*sparse integer matrix*) stacked element-node incidence matrices, where  $C(i, kk)$  is 1 if port  $j$  of element  $k$  is connected to node  $i$ , and  $kk = k + (j-1)*np$

**D** = []

(*sparse integer matrix*) stacked incidence matrices for  $z$ -variables (non-voltage state variables), where  $D(i, kk)$  is 1 if  $z$ -variable  $j$  of element  $k$  is the  $i$ -th system  $z$ -variable and  $kk = k + (j-1)*nz$

**soln**

(*struct*) for storing solved states, quantities

## Method Summary

**name()**

Get name of element type, e.g. 'bus', 'gen'.

```
name = nme.name()
```

### Output

**name** (*char array*) – name of element type, must be a valid struct field name

Implementation provided by an element type specific subclass.

**np()**

Number of ports per element of this type.

```
np = nme.np()
```

### Output

**np** (*integer*) – number of ports per element of this type

**nn()**

Number of nodes per element, created by this element type.

```
nn = nme.nn()
```

### Output

**nn** (*integer*) – number of ports per element of this type

**nz()**

Number of non-voltage state variables per element of this type.

```
nz = nme.nz()
```

### Output

**nz** (*integer*) – number of non-voltage state variables per element of this type

**data\_model\_element(dm, name)**

Get the corresponding data model element.

```
dme = nme.data_model_element(dm)
dme = nme.data_model_element(dm, name)
```

### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **name** (*char array*) – (*optional*) name of element type (*default is name of this object*)

### Output

**dme** (*mp.dm\_element* (page 36)) – data model element object

**math\_model\_element**(*mm*, *name*)

Get the corresponding math model element.

```
nme = nme.math_model_element(mm)
nme = nme.math_model_element(mm, name)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – math model object
- **name** (*char array*) – (optional) name of element type (default is name of this object)

**Output**

**nme** (*mp.mm\_element* (page 144)) – math model element object

**count**(*dm*)

Get number of online elements of this type in *dm*, set *nk*.

```
nk = nme.count(dm)
```

**Input**

**dm** (*mp.data\_model* (page 28)) – data model object

**Output**

**nk** (*integer*) – number of online elements of this type

**add\_nodes**(*nm*, *dm*)

Add nodes to network model for this element.

```
nme.add_nodes(nm, dm)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Add nodes to the network model object, based on value *nm* returned by *nn()* (page 110). Calls the network model's *add\_node()* (page 96) *nm* times.

**add\_states**(*nm*, *dm*)

Add non-voltage states to network model for this element.

```
nme.add_states(nm, dm)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Add non-voltage states to the network model object, based on value *nz* returned by *nz()* (page 110). Calls the network model's *add\_state()* (page 96) *nz* times.

**add\_vvars**(*nm*, *dm*, *idx*)

Add real-valued voltage variables to network object.

```
nme.add_vvars(nm, dm, idx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Add real-valued voltage variables (*v*-variables) to the network model object, for each port. Implementation depends on the specific formulation (i.e. subclass of *mp.form* (page 72)).

For example, consider an element with  $np$  ports and an AC formulation with polar voltage representation. The actual port voltages are complex, but this method would call the network model's `add_var()` (page 97) twice for each port, once for the voltage angle variables and once for the voltage magnitude variables.

Implemented by a formulation-specific subclass.

#### **add\_zvars**(*nm, dm, idx*)

Add real-valued non-voltage state variables to network object.

```
nme.add_zvars(nm, dm, idx)
```

##### **Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*cell array*) – indices for named and indexed variables

Add real-valued non-voltage state variables ( $z$ -variables) to the network model object. Implementation depends on the specific formulation (i.e. subclass of *mp.form* (page 72)).

For example, consider an element with  $nz$   $z$ -variables and a formulation in which these are complex. This method would call the network model's `add_var()` (page 97) twice for each complex  $z$ -variable, once for the variables representing the real part and once for the imaginary part.

Implemented by a formulation-specific subclass.

#### **build\_params**(*nm, dm*)

Build model parameters from data model.

```
nme.build_params(nm, dm)
```

##### **Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object

Construction of incidence matrices C and D are handled in this base class. Building of the formulation-specific model parameters must be implemented by a formulation-specific subclass. The subclass should call its parent in order to construct the incidence matrices.

See also `incidence_matrix()` (page 113), `node_indices()` (page 113).

#### **get\_nv\_**(*sysx*)

Get number of (*possibly complex*) voltage variables.

```
nv_ = nme.get_nv_(sysx)
```

##### **Input**

**sysx** (*boolean*) – if true the state  $x_$  refers to the full (*possibly complex*) system state (*all node voltages and system non-voltage states*), otherwise it is the state vector for this specific element type (*port voltages and element non-voltage states*)

##### **Output**

**nv\_** (*integer*) – number of (*possibly complex*) voltage variables in the state variable  $x_$ , whose meaning depends on the `sysx` input

#### **x2vz**(*x\_, sysx, idx*)

Get port voltages and non-voltage states from combined state vector.

```
[v_, z_, vi_] = nme.x2vz(x_, sysx, idx)
```

**Inputs**

- **x\_** (*double*) – possibly complex state vector
- **sysx** (*boolean*) – if true the state **x\_** refers to the full (*possibly complex*) system state (*all node voltages and system non-voltage states*), otherwise it is the state vector for this specific element type (*port voltages and element non-voltage states*)
- **idx** (*integer*) – vector of port indices of interest

**Outputs**

- **v\_** (*double*) – vector of (*possibly complex*) port voltages
- **z\_** (*double*) – vector of (*possibly complex*) non-voltage state variables
- **vi\_** (*double*) – vector of (*possibly complex*) port voltages for selected ports only, as indexed by **idx**

This method extracts voltage and non-voltage states from a combined state vector, optionally with voltages for specific ports only.

Note, that this method can operate on multiple state vectors simultaneously, by specifying **x\_** as a matrix. In this case, each output will have the same number of columns, one for each column of the input **x\_**.

**node\_indices**(*nm, dm, cxn\_type, cxn\_idx\_prop, cxn\_type\_prop*)

Construct node indices from data model element connection info.

```
nidxs = nme.node_indices(nm, dm)
nidxs = nme.node_indices(nm, dm, cxn_type, cxn_idx_prop)
nidxs = nme.node_indices(nm, dm, cxn_type, cxn_idx_prop, cxn_type_prop)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **cxn\_type** (*char array or cell array of char arrays*) – name(s) of type(s) of junction elements, i.e. node-creating elements (e.g. 'bus'), to which this element connects; see *mp.dm\_element.cxn\_type()* (page 39) for more info
- **cxn\_idx\_prop** (*char array or cell array of char arrays*) – name(s) of property(ies) containing indices of junction elements that define connections (e.g. {'fbus', 'tbus'}); see *mp.dm\_element.cxn\_idx\_prop()* (page 39) for more info
- **cxn\_type\_prop** (*char array or cell array of char arrays*) – name(s) of properties containing type of junction elements for each connection, defaults to '' if **cxn\_type** and **cxn\_type\_prop** are provided, but not **cxn\_type\_prop**; see *mp.dm\_element.cxn\_type\_prop()* (page 40) for more info

**Output**

**nidxs** (*cell array*) – 1 x *np* cell array of node index vectors for each port

This method constructs the node index vectors for each port. That is, element *p* of **nidxs** is the vector of indices of the nodes to which port *p* of these elements are connected. These node indices can be used to construct the element-node incidence matrices that form **C**.

By default, the connection information is obtained from the corresponding data model element, as described in the *sec\_dm\_element\_cxn* section in the *MATPOWER Developer's Manual*.

See also *incidence\_matrix()* (page 113), *mp.dm\_element.cxn\_type()* (page 39), *mp.dm\_element.cxn\_idx\_prop()* (page 39), *mp.dm\_element.cxn\_type\_prop()* (page 40).

**incidence\_matrix**(*m, varargin*)

Construct stacked incidence matrix from set of index vectors.

```
CD = nme.incidence_matrix(m, idx1, idx2, ...)
```

**Inputs**

- **m** (*integer*) – total number of nodes or states
- **idx1** (*integer*) – index vector for nodes corresponding to this element’s first port, or state variables corresponding to this element’s first non-voltage state
- **idx2** (*integer*) – same as **idx1** for second port or non-voltage state, and so on

**Output**

**CD** (*sparse matrix*) – stacked incidence matrix (C for ports, D for states)

Forms an  $m \times n$  incidence matrix for each input index vector **idx**, where  $n$  is the dimension of **idx**, and column  $j$  of the corresponding incidence matrix consists of all zeros with a 1 in row **idx**( $j$ ).

These incidence matrices are then stacked horizontally to form a single matrix return value.

**node\_types**(*nm, dm, idx*)

Get node type information.

```
ntv          = nme.node_types(nm, dm)
[ref, pv, pq] = nme.node_types(nm, dm)
...          = nme.node_types(nm, dm, idx)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index (*not used in base method*)

**Outputs**

- **ntv** (*integer*) – node type vector, valid element values are:
  - *mp.NODE\_TYPE.REF* (page 170)
  - *mp.NODE\_TYPE.PV* (page 170)
  - *mp.NODE\_TYPE.PQ* (page 170)
- **ref** (*integer*) – vector of indices of reference nodes
- **pv** (*integer*) – vector of indices of PV nodes
- **pq** (*integer*) – vector of indices of PQ nodes

See also *mp.NODE\_TYPE* (page 170).

**set\_node\_type\_ref**(*dm, idx*)

Make the specified node a reference node.

```
nme.set_node_type_ref(dm, idx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.REF* (page 170).

Implementation provided by node-creating subclass.

**set\_node\_type\_pv**(*dm, idx*)

Make the specified node a PV node.

```
nme.set_node_type_pv(dm, idx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.PV* (page 170).

Implementation provided by node-creating subclass.

**set\_node\_type\_pq**(*dm*, *idx*)

Make the specified node a PQ node.

```
nme.set_node_type_pq(dm, idx)
```

**Inputs**

- **dm** (*mp.data\_model* (page 28)) – data model object
- **idx** (*integer*) – index of node to modify, this is the internal network model element index

Set the specified node to type *mp.NODE\_TYPE.PQ* (page 170).

Implementation provided by node-creating subclass.

**display**()

Display the network model element object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the elements, including total number of elements, nodes per element, ports per element, non-voltage state per element, formulation name, tag, and class, and names and dimensions of the model parameters.

## mp.nme\_branch

**class mp.nme\_branch**

Bases: *mp.nm\_element* (page 108)

*mp.nme\_branch* (page 115) - Network model element abstract base class for branch.

Implements the network model element for branch elements, including transmission lines and transformers, with 2 ports per branch.

**Method Summary**

**name**()

**np**()

## mp.nme\_branch\_ac

**class mp.nme\_branch\_ac**

Bases: *mp.nme\_branch* (page 115)

*mp.nme\_branch\_ac* (page 115) - Network model element abstract base class for branch for AC formulations.

Implements building of the admittance parameter  $\underline{Y}$  for branches.

**Method Summary**

**build\_params**(*nm, dm*)

Builds the admittance parameter  $\underline{Y}$  for branches.

### **mp.nme\_branch\_acc**

**class** mp.nme\_branch\_acc

Bases: *mp.nme\_branch\_ac* (page 115), *mp.form\_acc* (page 83)

*mp.nme\_branch\_acc* (page 116) - Network model element for branch for AC cartesian voltage formulations.

Implements functions for the voltage angle difference limits and their derivatives and inherits from *mp.form\_acc* (page 83).

#### **Method Summary**

**ang\_diff\_fcn**(*xx, Aang, lang, uang*)

**ang\_diff\_hess**(*xx, lambda, Aang*)

### **mp.nme\_branch\_acp**

**class** mp.nme\_branch\_acp

Bases: *mp.nme\_branch\_ac* (page 115), *mp.form\_acp* (page 87)

*mp.nme\_branch\_acp* (page 116) - Network model element for branch for AC polar voltage formulations.

Inherits from *mp.form\_acp* (page 87).

### **mp.nme\_branch\_dc**

**class** mp.nme\_branch\_dc

Bases: *mp.nme\_branch* (page 115), *mp.form\_dc* (page 89)

*mp.nme\_branch\_dc* (page 116) - Network model element for branch for DC formulations.

Implements building of the branch parameters  $\underline{B}$  and  $\underline{p}$ , and inherits from *mp.form\_dc* (page 89).

#### **Method Summary**

**build\_params**(*nm, dm*)

## mp.nme\_bus

### class mp.nme\_bus

Bases: *mp.nm\_element* (page 108)

*mp.nme\_bus* (page 117) - Network model element abstract base class for bus.

Implements the network model element for bus elements, with 1 node per bus.

Implements node type methods.

#### Method Summary

**name()**

**nn()**

**node\_types**(*nm, dm, idx*)

**set\_node\_type\_ref**(*nm, dm, idx*)

**set\_node\_type\_pv**(*nm, dm, idx*)

**set\_node\_type\_pq**(*nm, dm, idx*)

## mp.nme\_bus\_acc

### class mp.nme\_bus\_acc

Bases: *mp.nme\_bus* (page 117), *mp.form\_acc* (page 83)

*mp.nme\_bus\_acc* (page 117) - Network model element for bus for AC cartesian voltage formulations.

Adds voltage variables  $V_r$  and  $V_i$  to the network model and inherits from *mp.form\_acc* (page 83).

#### Method Summary

**add\_vvars**(*nm, dm, idx*)

## mp.nme\_bus\_acp

### class mp.nme\_bus\_acp

Bases: *mp.nme\_bus* (page 117), *mp.form\_acp* (page 87)

*mp.nme\_bus\_acp* (page 117) - Network model element for bus for AC cartesian polar formulations.

Adds voltage variables  $V_a$  and  $V_m$  to the network model and inherits from *mp.form\_acp* (page 87).

#### Method Summary

**add\_vvars**(*nm, dm, idx*)



## mp.nme\_bus\_dc

### class mp.nme\_bus\_dc

Bases: [mp.nme\\_bus](#) (page 117), [mp.form\\_dc](#) (page 89)

[mp.nme\\_bus\\_dc](#) (page 118) - Network model element for bus for DC formulations.

Adds voltage variable  $V_a$  to the network model and inherits from [mp.form\\_dc](#) (page 89).

#### Method Summary

**add\_vvars**(*nm, dm, idx*)

## mp.nme\_gen

### class mp.nme\_gen

Bases: [mp.nm\\_element](#) (page 108)

[mp.nme\\_gen](#) (page 118) - Network model element abstract base class for generator.

Implements the network model element for generator elements, with 1 port and 1 non-voltage state per generator.

#### Method Summary

**name**()

**np**()

**nz**()

## mp.nme\_gen\_ac

### class mp.nme\_gen\_ac

Bases: [mp.nme\\_gen](#) (page 118)

[mp.nme\\_gen\\_ac](#) (page 118) - Network model element abstract base class for generator for AC formulations.

Adds non-voltage state variables  $P_g$  and  $Q_g$  to the network model and builds the parameter  $\underline{N}$ .

#### Method Summary

**add\_zvars**(*nm, dm, idx*)

**build\_params**(*nm, dm*)

### mp.nme\_gen\_acc

#### class mp.nme\_gen\_acc

Bases: [mp.nme\\_gen\\_ac](#) (page 118), [mp.form\\_acc](#) (page 83)

[mp.nme\\_gen\\_acc](#) (page 119) - Network model element for generator for AC cartesian voltage formulations.

Inherits from [mp.form\\_acc](#) (page 83).

### mp.nme\_gen\_acp

#### class mp.nme\_gen\_acp

Bases: [mp.nme\\_gen\\_ac](#) (page 118), [mp.form\\_acp](#) (page 87)

[mp.nme\\_gen\\_acp](#) (page 119) - Network model element for generator for AC polar voltage formulations.

Inherits from [mp.form\\_acp](#) (page 87).

### mp.nme\_gen\_dc

#### class mp.nme\_gen\_dc

Bases: [mp.nme\\_gen](#) (page 118), [mp.form\\_dc](#) (page 89)

[mp.nme\\_gen\\_dc](#) (page 119) - Network model element for generator for DC formulations.

Adds non-voltage state variable  $P_g$  to the network model, builds the parameter  $\underline{K}$ , and inherits from [mp.form\\_dc](#) (page 89).

#### Method Summary

**add\_zvars**(*nm*, *dm*, *idx*)

**build\_params**(*nm*, *dm*)

### mp.nme\_load

#### class mp.nme\_load

Bases: [mp.nm\\_element](#) (page 108)

[mp.nme\\_load](#) (page 119) - Network model element abstract base class for load.

Implements the network model element for load elements, with 1 port per load.

#### Method Summary

**name**()

**np**()

### mp.nme\_load\_ac

#### class mp.nme\_load\_ac

Bases: [mp.nme\\_load](#) (page 119)

[mp.nme\\_load\\_ac](#) (page 120) - Network model element abstract base class for load for AC formulations.

Builds the parameters  $\underline{s}$  and  $\underline{Y}$  and nonlinear functions  $s^{nl_n}(\mathbf{x})$  and  $\mathbf{i}^{nl_n}(\mathbf{x})$ .

#### Method Summary

**build\_params**(*nm, dm*)

**port\_inj\_current\_nln**(*Sd, x\_, sysx, idx*)

**port\_inj\_power\_nln**(*Sd, x\_, sysx, idx*)

### mp.nme\_load\_acc

#### class mp.nme\_load\_acc

Bases: [mp.nme\\_load\\_ac](#) (page 120), [mp.form\\_acc](#) (page 83)

[mp.nme\\_load\\_acc](#) (page 120) - Network model element for load for AC cartesian voltage formulations.

Inherits from [mp.form\\_acc](#) (page 83).

### mp.nme\_load\_acp

#### class mp.nme\_load\_acp

Bases: [mp.nme\\_load\\_ac](#) (page 120), [mp.form\\_acp](#) (page 87)

[mp.nme\\_load\\_acp](#) (page 120) - Network model element for load for AC polar voltage formulations.

Inherits from [mp.form\\_acp](#) (page 87).

### mp.nme\_load\_dc

#### class mp.nme\_load\_dc

Bases: [mp.nme\\_load](#) (page 119), [mp.form\\_dc](#) (page 89)

[mp.nme\\_load\\_dc](#) (page 120) - Network model element for load for DC formulations.

Builds the parameter  $\underline{p}$  and inherits from [mp.form\\_dc](#) (page 89).

#### Method Summary

**build\_params**(*nm, dm*)

**mp.nme\_shunt****class mp.nme\_shunt**

Bases: *mp.nm\_element* (page 108)

*mp.nme\_shunt* (page 121) - Network model element abstract base class for shunt.

Implements the network model element for shunt elements, with 1 port per shunt.

**Method Summary**

**name()**

**np()**

**mp.nme\_shunt\_ac****class mp.nme\_shunt\_ac**

Bases: *mp.nme\_shunt* (page 121)

*mp.nme\_shunt\_ac* (page 121) - Network model element abstract base class for shunt for AC formulations.

Builds the parameter Y.

**Method Summary**

**build\_params**(*nm, dm*)

**mp.nme\_shunt\_acc****class mp.nme\_shunt\_acc**

Bases: *mp.nme\_shunt\_ac* (page 121), *mp.form\_acc* (page 83)

*mp.nme\_shunt\_acc* (page 121) - Network model element for shunt for AC cartesian voltage formulations.

Inherits from *mp.form\_acc* (page 83).

**mp.nme\_shunt\_acp****class mp.nme\_shunt\_acp**

Bases: *mp.nme\_shunt\_ac* (page 121), *mp.form\_acp* (page 87)

*mp.nme\_shunt\_acp* (page 121) - Network model element for shunt for AC polar voltage formulations.

Inherits from *mp.form\_acp* (page 87).

## mp.nme\_shunt\_dc

### class mp.nme\_shunt\_dc

Bases: [mp.nme\\_shunt](#) (page 121), [mp.form\\_dc](#) (page 89)

[mp.nme\\_shunt\\_dc](#) (page 122) - Network model element for shunt for DC formulations.

Builds the parameter  $p$  and inherits from [mp.form\\_dc](#) (page 89).

#### Method Summary

`build_params(nm, dm)`

## 3.5 Mathematical Model Classes

### 3.5.1 Containers

#### mp.math\_model

##### class mp.math\_model

Bases: [mp.element\\_container](#) (page 166), `opt_model`

[mp.math\\_model](#) (page 122) - Abstract base class for MATPOWER **mathematical model** objects.

The mathematical model, or math model, formulates and defines the mathematical problem to be solved. That is, it determines the variables, constraints, and objective that define the problem. This takes on different forms depending on the task (e.g. *power flow*, *optimal power flow*, etc.) and the formulation (e.g. *DC*, *AC-polar-power*, etc.).

A math model object is a container for math model element ([mp.mm\\_element](#) (page 144)) objects and it is also an MP-Opt-Model (`opt_model`) object. All math model classes inherit from [mp.math\\_model](#) (page 122) and therefore also from [mp.element\\_container](#) (page 166), `opt_model`, and `mp_idx_manager`. Concrete math model classes are task and formulation specific. They also sometimes inherit from abstract mix-in classes that are shared across tasks or formulations.

By convention, math model variables are named `mm` and math model class names begin with `mp.math_model`.

#### mp.math\_model Properties:

- [aux\\_data](#) (page 123) - auxiliary data relevant to the model

#### mp.math\_model Methods:

- [task\\_tag\(\)](#) (page 123) - returns task tag, e.g. 'PF', 'OPF'
- [task\\_name\(\)](#) (page 123) - returns task name, e.g. 'Power Flow', 'Optimal Power Flow'
- [form\\_tag\(\)](#) (page 123) - returns network formulation tag, e.g. 'dc', 'acps'
- [form\\_name\(\)](#) (page 123) - returns network formulation name, e.g. 'DC', 'AC-polar-power'
- [build\(\)](#) (page 123) - create, add, and build math model element objects
- [display\(\)](#) (page 124) - display the math model object
- [add\\_aux\\_data\(\)](#) (page 124) - builds auxiliary data and adds it to the model

- `build_base_aux_data()` (page 124) - builds base auxiliary data, including node types & variable initial values
- `add_vars()` (page 124) - add variables to the model
- `add_system_vars()` (page 124) - add system variables to the model
- `add_constraints()` (page 125) - add constraints to the model
- `add_system_constraints()` (page 125) - add system constraints to the model
- `add_node_balance_constraints()` (page 125) - add node balance constraints to the model
- `add_costs()` (page 125) - add costs to the model
- `add_system_costs()` (page 126) - add system costs to the model
- `solve_opts()` (page 126) - return an options struct to pass to the solver
- `update_nm_vars()` (page 126) - update network model variables from math model solution
- `data_model_update()` (page 127) - update data model from math model solution
- `network_model_x_soln()` (page 127) - convert solved state from math model to network model solution

See the `sec_math_model` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.task` (page 8), `mp.data_model` (page 28), `mp.net_model` (page 91).

### Property Summary

#### `aux_data`

(*struct*) auxiliary data relevant to the model, e.g. can be passed to model constraint functions

### Method Summary

#### `task_tag()`

Returns task tag, e.g. 'PF', 'OPF'.

```
tag = mm.task_tag()
```

#### `task_name()`

Returns task name, e.g. 'Power Flow', 'Optimal Power Flow'.

```
name = mm.task_name()
```

#### `form_tag()`

Returns network formulation tag, e.g. 'dc', 'acps'.

```
tag = mm.form_tag()
```

#### `form_name()`

Returns network formulation name, e.g. 'DC', 'AC-polar-power'.

```
name = mm.form_name()
```

#### `build(nm, dm, mpopt)`

Create, add, and `build()` (page 123) math model element objects.

```
mm.build(nm, dm, mpopt);
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Create and add network model objects, create and add auxiliary data, and add variables, constraints, and costs.

**display()**

Display the math model object.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

Displays the details of the variables, constraints, costs, and math model elements.

See also `mp_idx_manager`.

**add\_aux\_data(nm, dm, mpopt)**

Builds auxiliary data and adds it to the model.

```
mm.add_aux_data(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Calls the `build_aux_data()` method and assigns the result to the `aux_data` property. The base `build_aux_data()` method, which simply calls `build_base_aux_data()` (page 124), is defined in `mp.mm_shared_pfcpf` (page 139) (and in `mp.math_model_opf` (page 132)) allowing it to be shared across math models for different tasks (PF and CPF).

**build\_base\_aux\_data(nm, dm, mpopt)**

Builds base auxiliary data, including node types & variable initial values.

```
ad = mm.build_base_aux_data(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**ad** (*struct*) – struct of auxiliary data

**add\_vars(nm, dm, mpopt)**

Add variables to the model.

```
mm.add_vars(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Adds system variables, then calls the `add_vars()` (page 145) method for each math model element.

**add\_system\_vars**(*nm, dm, mpopt*)

Add system variables to the model.

```
mm.add_system_vars(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Variables which correspond to a specific math model element should be added by that element's *add\_vars()* (page 145) method. Other variables can be added by *add\_system\_vars()* (page 124). In this base class this method does nothing.

**add\_constraints**(*nm, dm, mpopt*)

Add constraints to the model.

```
mm.add_constraints(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Adds system constraints, then calls the *add\_constraints()* (page 145) method for each math model element.

**add\_system\_constraints**(*nm, dm, mpopt*)

Add system constraints to the model.

```
mm.add_system_constraints(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Constraints which correspond to a specific math model element should be added by that element's *add\_constraints()* (page 145) method. Other constraints can be added by *add\_system\_constraints()* (page 125). In this base class, it simply calls *add\_node\_balance\_constraints()* (page 125).

**add\_node\_balance\_constraints**(*nm, dm, mpopt*)

Add node balance constraints to the model.

```
mm.add_node_balance_constraints(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

In this base class this method does nothing.

**add\_costs**(*nm, dm, mpopt*)

Add costs to the model.



```
mm.add_costs(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Adds system costs, then calls the `add_costs()` (page 146) method for each math model element.

```
add_system_costs(nm, dm, mpopt)
```

Add system costs to the model.

```
mm.add_system_costs(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Costs which correspond to a specific math model element should be added by that element's `add_costs()` (page 146) method. Other variables can be added by `add_system_costs()` (page 126). In this base class this method does nothing.

```
solve_opts(nm, dm, mpopt)
```

Return an options struct to pass to the solver.

```
opt = mm.solve_opts(nm, dm, mpopt)
```

**Inputs**

- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**opt** (*struct*) – options struct for solver

In this base class, returns an empty struct.

```
update_nm_vars(mmx, nm)
```

Update network model variables from math model solution.

```
nm_vars = mm.update_nm_vars(mmx, nm)
```

**Inputs**

- **mmx** (*double*) – vector of math model variable  $x$
- **nm** (*mp.net\_model* (page 91)) – network model object

**Output**

**nm\_vars** (*struct*) – updated network model variables

Returns a struct with the network model variables as fields. The `mm.aux_data.var_map` cell array is used to track mappings of math model variables back to network model variables. Each entry is itself a 7-element cell array of the form

```
{nm_var_type, nm_i1, nm_iN, nm_idx, mm_i1, mm_iN, mm_idx}
```

where

- **nm\_var\_type** - network model variable type (e.g. va, vm, zr, zi)
- **nm\_i1** - starting index for network model variable type
- **nm\_iN** - ending index for network model variable type

- `nm_idx` - vector of indices for network model variable type
- `mm_i1` - starting index for math model variable
- `mm_iN` - ending index for math model variable
- `mm_idx` - vector of indices for math model variable

Uses either `i1:iN` (if `i1` is not empty) or `idx` as the indices, unless both are empty, in which case it uses `':'`.

#### `data_model_update(nm, dm, mpopt)`

Update data model from math model solution.

```
dm = mm.data_model_update(nm, dm, mpopt)
```

##### Inputs

- `nm` (*mp.net\_model* (page 91)) – network model object
- `dm` (*mp.data\_model* (page 28)) – data model object
- `mpopt` (*struct*) – MATPOWER options struct

##### Output

`dm` (*mp.data\_model* (page 28)) – updated data model object

Calls the `data_model_update()` (page 146) method for each math model element.

#### `network_model_x_soln(nm)`

Convert solved state from math model to network model solution.

```
nm = mm.network_model_x_soln(nm)
```

##### Input

`nm` (*mp.net\_model* (page 91)) – network model object

##### Output

`nm` (*mp.net\_model* (page 91)) – updated network model object

Calls `convert_x_m2n()` to which is defined in a subclass of in *mp.mm\_shared\_pfcopf* (page 139) (and of *mp.math\_model\_opf* (page 132)) allowing it to be shared across math models for different tasks (PF and CPF).

## `mp.math_model_pf`

### `class mp.math_model_pf`

Bases: *mp.math\_model* (page 122)

*mp.math\_model\_pf* (page 127) - Abstract base class for power flow (PF) **math model** objects.

Implements setting up of solver options from MATPOWER options struct.

#### Method Summary

`task_tag()`

`task_name()`

`add_costs(nm, dm, mpopt)`

`add_system_vars(nm, dm, mpopt)`

`solve_opts`(*nm*, *dm*, *mpopt*)

### `mp.math_model_pf_ac`

**class** `mp.math_model_pf_ac`

Bases: `mp.math_model_pf` (page 127)

`mp.math_model_pf_ac` (page 128) - Power flow (PF) **math model** for AC formulations.

Provides AC-specific and PF-specific subclasses for elements.

#### Constructor Summary

`math_model_pf_ac`()

### `mp.math_model_pf_acci`

**class** `mp.math_model_pf_acci`

Bases: `mp.math_model_pf_ac` (page 128), `mp.mm_shared_pfcpf_acci` (page 141)

`mp.math_model_pf_acci` (page 128) - Power flow (PF) **math model** for AC-cartesian-current formulation.

Implements formulation-specific node balance constraints and inherits from formulation-specific class for shared PF/CPF code.

#### Method Summary

`form_tag`()

`form_name`()

`add_node_balance_constraints`(*nm*, *dm*, *mpopt*)

### `mp.math_model_pf_accs`

**class** `mp.math_model_pf_accs`

Bases: `mp.math_model_pf_ac` (page 128), `mp.mm_shared_pfcpf_accs` (page 141)

`mp.math_model_pf_accs` (page 128) - Power flow (PF) **math model** for AC-cartesian-power formulation.

Implements formulation-specific node balance constraints and inherits from formulation-specific class for shared PF/CPF code.

#### Method Summary

`form_tag`()

`form_name`()

`add_node_balance_constraints(nm, dm, mpopt)`

### **mp.math\_model\_pf\_acpi**

**class** `mp.math_model_pf_acpi`

Bases: `mp.math_model_pf_ac` (page 128), `mp.mm_shared_pfcpi_acpi` (page 142)

`mp.math_model_pf_acpi` (page 129) - Power flow (PF) **math model** for AC-polar-current formulation.

Implements formulation-specific node balance constraints and inherits from formulation-specific class for shared PF/CPF code.

#### **Method Summary**

`form_tag()`

`form_name()`

`add_node_balance_constraints(nm, dm, mpopt)`

### **mp.math\_model\_pf\_acps**

**class** `mp.math_model_pf_acps`

Bases: `mp.math_model_pf_ac` (page 128), `mp.mm_shared_pfcpi_acps` (page 142)

`mp.math_model_pf_acps` (page 129) - Power flow (PF) **math model** for AC-polar-power formulation.

Implements formulation-specific node balance constraints and inherits from formulation-specific class for shared PF/CPF code.

Also includes implementations of methods specific to fast-decoupled power flow.

#### **Method Summary**

`form_tag()`

`form_name()`

`add_node_balance_constraints(nm, dm, mpopt)`

`gs_x_update(x, f, nm, dm, mpopt)`

`zg_x_update(x, f, nm, dm, mpopt)`

`fd_jac_approx(nm, dm, mpopt)`

`fdpf_B_matrix_models(dm, alg)`

## mp.math\_model\_pf\_dc

### class mp.math\_model\_pf\_dc

Bases: [mp.math\\_model\\_pf](#) (page 127), [mp.mm\\_shared\\_pfcpf\\_dc](#) (page 142)

[mp.math\\_model\\_pf\\_dc](#) (page 130) - Power flow (PF) **math model** for DC formulation.

Provides formulation-specific and PF-specific subclasses for elements and implements formulation-specific node balance constraints.

Overrides the default [solve\\_opts\(\)](#) (page 130) method.

#### Constructor Summary

**math\_model\_pf\_dc()**

#### Method Summary

**form\_tag()**

**form\_name()**

**add\_node\_balance\_constraints**(*nm, dm, mpopt*)

**solve\_opts**(*nm, dm, mpopt*)

## mp.math\_model\_cpf\_acc

### class mp.math\_model\_cpf\_acc

Bases: [mp.math\\_model\\_cpf](#)

[mp.math\\_model\\_cpf\\_acc](#) (page 130) - Abstract base class for AC cartesian CPF **math model** objects.

Provides formulation-specific and CPF-specific subclasses for elements.

#### Constructor Summary

**math\_model\_cpf\_acc()**

Constructor, assign default network model element classes.

```
mm = math_model_cpf_acc()
```

## mp.math\_model\_cpf\_acci

### class mp.math\_model\_cpf\_acci

Bases: [mp.math\\_model\\_cpf\\_acc](#) (page 130), [mp.mm\\_shared\\_pfcpf\\_acci](#) (page 141)

[mp.math\\_model\\_cpf\\_acci](#) (page 130) - CPF **math model** for AC-cartesian-current formulation.

Implements formulation-specific and CPF-specific node balance constraint.

#### Method Summary

```

form_tag()
form_name()
add_node_balance_constraints(nm, dm, mpopt)

```

### **mp.math\_model\_cpf\_accs**

**class** `mp.math_model_cpf_accs`

Bases: [mp.math\\_model\\_cpf\\_acc](#) (page 130), [mp.mm\\_shared\\_pfcopf\\_accs](#) (page 141)

[mp.math\\_model\\_cpf\\_accs](#) (page 131) - CPF **math model** for AC-cartesian-power formulation.

Implements formulation-specific and CPF-specific node balance constraint.

#### **Method Summary**

```

form_tag()
form_name()
add_node_balance_constraints(nm, dm, mpopt)

```

### **mp.math\_model\_cpf\_acp**

**class** `mp.math_model_cpf_acp`

Bases: `mp.math_model_cpf`

[mp.math\\_model\\_cpf\\_acp](#) (page 131) - Abstract base class for AC polar CPF **math model** objects.

Provides formulation-specific and CPF-specific subclasses for elements and implementations of event and call-back functions for handling voltage limits.

#### **Constructor Summary**

```

math_model_cpf_acp()
    Constructor, assign default network model element classes.

```

```

mm = math_model_cpf_acp()

```

#### **Method Summary**

```

event_vlim(cx, opt, nm, dm, mpopt)
callback_vlim(k, nx, cx, px, s, opt, nm, dm, mpopt)

```

### mp.math\_model\_cpf\_acpi

**class** mp.math\_model\_cpf\_acpi

Bases: [mp.math\\_model\\_cpf\\_acp](#) (page 131), [mp.mm\\_shared\\_pfcpi\\_acpi](#) (page 142)  
[mp.math\\_model\\_cpf\\_acpi](#) (page 132) - CPF **math model** for AC-polar-current formulation.  
Implements formulation-specific and CPF-specific node balance constraint.

#### Method Summary

**form\_tag()**  
**form\_name()**  
**add\_node\_balance\_constraints**(*nm, dm, mpop*)

### mp.math\_model\_cpf\_acps

**class** mp.math\_model\_cpf\_acps

Bases: [mp.math\\_model\\_cpf\\_acp](#) (page 131), [mp.mm\\_shared\\_pfcpi\\_acps](#) (page 142)  
[mp.math\\_model\\_cpf\\_acps](#) (page 132) - CPF **math model** for AC-polar-power formulation.  
Implements formulation-specific and CPF-specific node balance constraint.  
Provides methods for warm-starting solver with updated data.

#### Method Summary

**form\_tag()**  
**form\_name()**  
**add\_node\_balance\_constraints**(*nm, dm, mpop*)  
**expand\_z\_warmstart**(*nm, ad, varargin*)  
**solve\_opts\_warmstart**(*opt, ws, nm*)

### mp.math\_model\_opf

**class** mp.math\_model\_opf

Bases: [mp.math\\_model](#) (page 122)  
[mp.math\\_model\\_opf](#) (page 132) - Abstract base class for optimal power flow (OPF) **math model** objects.  
Provide implementations for adding system variables to the mathematical model and creating an interior starting point.

#### Method Summary

**task\_tag()**

```

task_name()
build_aux_data(nm, dm, mpopt)
add_system_vars(nm, dm, mpopt)
interior_x0(mm, nm, dm, x0)
interior_va(nm, dm)

```

### mp.math\_model\_opf\_ac

**class** mp.math\_model\_opf\_ac

Bases: *mp.math\_model\_opf* (page 132)

*mp.math\_model\_opf\_ac* (page 133) - Abstract base class for AC OPF **math model** objects.

Provide implementation of nodal current and power balance functions and their derivatives, and setup of solver options.

#### Method Summary

```

nodal_current_balance_fcn(x, nm)
nodal_power_balance_fcn(x, nm)
nodal_current_balance_hess(x, lam, nm)
nodal_power_balance_hess(x, lam, nm)
solve_opts(nm, dm, mpopt)

```

### mp.math\_model\_opf\_acc

**class** mp.math\_model\_opf\_acc

Bases: *mp.math\_model\_opf\_ac* (page 133)

*mp.math\_model\_opf\_acc* (page 133) - Abstract base class for AC cartesian OPF **math model** objects.

Provides formulation-specific and OPF-specific subclasses for elements.

Implements *convert\_x\_m2n()* (page 133) to convert from math model state to network model state.

#### Constructor Summary

```

math_model_opf_acc()

```

#### Method Summary

```

convert_x_m2n(mmx, nm)
interior_va(nm, dm)

```



## mp.math\_model\_opf\_acci

**class** mp.math\_model\_opf\_acci

Bases: [mp.math\\_model\\_opf\\_acc](#) (page 133)

[mp.math\\_model\\_opf\\_acci](#) (page 134) - OPF **math model** for AC-cartesian-current formulation.

Implements formulation-specific and OPF-specific node balance constraint and node balance price methods.

### Method Summary

**form\_tag()**

**form\_name()**

**add\_node\_balance\_constraints**(*nm, dm, mpopt*)

**node\_power\_balance\_prices**(*nm*)

## mp.math\_model\_opf\_acci\_legacy

**class** mp.math\_model\_opf\_acci\_legacy

Bases: [mp.math\\_model\\_opf\\_acci](#) (page 134), [mp.mm\\_shared\\_opf\\_legacy](#) (page 143)

[mp.math\\_model\\_opf\\_acci\\_legacy](#) (page 134) - OPF **math model** for AC-cartesian-current formulation w/legacy extensions.

Provides formulation-specific methods for handling legacy user customization of OPF problem.

### Constructor Summary

**math\_model\_opf\_acci\_legacy()**

### Method Summary

**add\_named\_set**(*varargin*)

**def\_set\_types()**

**init\_set\_types()**

**build**(*nm, dm, mpopt*)

**add\_vars**(*nm, dm, mpopt*)

**add\_system\_costs**(*nm, dm, mpopt*)

**add\_system\_constraints**(*nm, dm, mpopt*)

**legacy\_user\_var\_names()**

**mp.math\_model\_opf\_accs****class** mp.math\_model\_opf\_accsBases: [mp.math\\_model\\_opf\\_acc](#) (page 133)[mp.math\\_model\\_opf\\_accs](#) (page 135) - OPF **math model** for AC-cartesian-power formulation.

Implements formulation-specific and OPF-specific node balance constraint and node balance price methods.

**Method Summary****form\_tag()****form\_name()****add\_node\_balance\_constraints**(*nm, dm, mpopt*)**node\_power\_balance\_prices**(*nm*)**mp.math\_model\_opf\_accs\_legacy****class** mp.math\_model\_opf\_accs\_legacyBases: [mp.math\\_model\\_opf\\_accs](#) (page 135), [mp.mm\\_shared\\_opf\\_legacy](#) (page 143)[mp.math\\_model\\_opf\\_accs\\_legacy](#) (page 135) - OPF **math model** for AC-cartesian-power formulation w/legacy extensions.

Provides formulation-specific methods for handling legacy user customization of OPF problem.

**Constructor Summary****math\_model\_opf\_accs\_legacy()****Method Summary****add\_named\_set**(*varargin*)**def\_set\_types()****init\_set\_types()****build**(*nm, dm, mpopt*)**add\_vars**(*nm, dm, mpopt*)**add\_system\_costs**(*nm, dm, mpopt*)**add\_system\_constraints**(*nm, dm, mpopt*)**legacy\_user\_var\_names()**

### mp.math\_model\_opf\_acp

**class** mp.math\_model\_opf\_acp

Bases: *mp.math\_model\_opf\_ac* (page 133)

*mp.math\_model\_opf\_acp* (page 136) - Abstract base class for AC polar OPF **math model** objects.

Provides formulation-specific and OPF-specific subclasses for elements.

Implements *convert\_x\_m2n()* (page 136) to convert from math model state to network model state.

#### Constructor Summary

**math\_model\_opf\_acp()**

#### Method Summary

**convert\_x\_m2n**(*mmx, nm*)

### mp.math\_model\_opf\_acpi

**class** mp.math\_model\_opf\_acpi

Bases: *mp.math\_model\_opf\_acp* (page 136)

*mp.math\_model\_opf\_acpi* (page 136) - OPF **math model** for AC-polar-current formulation.

Implements formulation-specific and OPF-specific node balance constraint and node balance price methods.

#### Method Summary

**form\_tag()**

**form\_name()**

**add\_node\_balance\_constraints**(*nm, dm, mpopt*)

**node\_power\_balance\_prices**(*nm*)

### mp.math\_model\_opf\_acpi\_legacy

**class** mp.math\_model\_opf\_acpi\_legacy

Bases: *mp.math\_model\_opf\_acpi* (page 136), *mp.mm\_shared\_opf\_legacy* (page 143)

*mp.math\_model\_opf\_acpi\_legacy* (page 136) - OPF **math model** for AC-polar-current formulation w/legacy extensions.

Provides formulation-specific methods for handling legacy user customization of OPF problem.

#### Constructor Summary

**math\_model\_opf\_acpi\_legacy()**

#### Method Summary

```

add_named_set(varargin)
def_set_types()
init_set_types()
build(nm, dm, mpop)
add_vars(nm, dm, mpop)
add_system_costs(nm, dm, mpop)
add_system_constraints(nm, dm, mpop)
legacy_user_var_names()

```

### **mp.math\_model\_opf\_acps**

**class** `mp.math_model_opf_acps`

Bases: [mp.math\\_model\\_opf\\_acp](#) (page 136)

[mp.math\\_model\\_opf\\_acps](#) (page 137) - OPF **math model** for AC-polar-power formulation.

Implements formulation-specific and OPF-specific node balance constraint and node balance price methods.

#### **Method Summary**

```

form_tag()
form_name()
add_node_balance_constraints(nm, dm, mpop)
node_power_balance_prices(nm)

```

### **mp.math\_model\_opf\_acps\_legacy**

**class** `mp.math_model_opf_acps_legacy`

Bases: [mp.math\\_model\\_opf\\_acps](#) (page 137), [mp.mm\\_shared\\_opf\\_legacy](#) (page 143)

[mp.math\\_model\\_opf\\_acps\\_legacy](#) (page 137) - OPF **math model** for AC-polar-power formulation w/legacy extensions.

Provides formulation-specific methods for handling legacy user customization of OPF problem.

#### **Constructor Summary**

```

math_model_opf_acps_legacy()

```

#### **Method Summary**

```

add_named_set(varargin)

```

```
def_set_types()  
init_set_types()  
build(nm, dm, mpopt)  
add_vars(nm, dm, mpopt)  
add_system_costs(nm, dm, mpopt)  
add_system_constraints(nm, dm, mpopt)  
legacy_user_var_names()
```

### **mp.math\_model\_opf\_dc**

**class** mp.math\_model\_opf\_dc

Bases: [mp.math\\_model\\_opf](#) (page 132)

[mp.math\\_model\\_opf\\_dc](#) (page 138) - Optimal Power flow (OPF) **math model** for DC formulation.

Provides formulation-specific and OPF-specific subclasses for elements.

Provides implementation of nodal balance constraint method and setup of solver options.

Implements [convert\\_x\\_m2n\(\)](#) (page 138) to convert from math model state to network model state.

#### **Constructor Summary**

```
math_model_opf_dc()
```

#### **Method Summary**

```
form_tag()
```

```
form_name()
```

```
convert_x_m2n(mmx, nm)
```

```
add_node_balance_constraints(nm, dm, mpopt)
```

```
solve_opts(nm, dm, mpopt)
```

### **mp.math\_model\_opf\_dc\_legacy**

**class** mp.math\_model\_opf\_dc\_legacy

Bases: [mp.math\\_model\\_opf\\_dc](#) (page 138), [mp.mm\\_shared\\_opf\\_legacy](#) (page 143)

[mp.math\\_model\\_opf\\_dc](#) (page 138) - OPF **math model** for DC formulation w/legacy extensions.

Provides formulation-specific methods for handling legacy user customization of OPF problem.

#### **Constructor Summary**

`math_model_opf_dc_legacy(mpc)`

#### Method Summary

`add_named_set(varargin)`

`def_set_types()`

`init_set_types()`

`build(nm, dm, mpopt)`

`add_vars(nm, dm, mpopt)`

`add_system_costs(nm, dm, mpopt)`

`add_system_constraints(nm, dm, mpopt)`

`legacy_user_var_names()`

### 3.5.2 Container Mixins

#### `mp.mm_shared_pfcpf`

`class mp.mm_shared_pfcpf`

Bases: `handle`

`mp.mm_shared_pfcpf` (page 139) - Mixin class for PF/CPF **math model** objects.

An abstract mixin class inherited by all power flow (PF) and continuation power flow (CPF) **math model** objects.

#### Method Summary

`build_aux_data(nm, dm, mpopt)`

#### `mp.mm_shared_pfcpf_ac`

`class mp.mm_shared_pfcpf_ac`

Bases: `mp.mm_shared_pfcpf` (page 139)

`mp.mm_shared_pfcpf_ac` (page 139) - Mixin class for AC PF/CPF **math model** objects.

An abstract mixin class inherited by all AC power flow (PF) and continuation power flow (CPF) **math model** objects.

#### Method Summary

`add_system_varset_pf(nm, vvar, typ)`

**update\_z**(*nm, v\_, z\_, ad, Sinj, idx*)

*update\_z()* (page 139) - Update/allocate active/reactive injections at slack/PV nodes.

Update/allocate slack know active power injections and slack/PV node reactive power injections.

### **mp.mm\_shared\_pfcpf\_ac\_i**

**class** mp.mm\_shared\_pfcpf\_ac\_i

Bases: handle

*mp.mm\_shared\_pfcpf\_ac\_i* (page 140) - Mixin class for AC-current PF/CPF **math model** objects.

An abstract mixin class inherited by all AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a current balance formulation.

Code shared between AC cartesian and polar formulations with current balance belongs in this class.

#### **Method Summary**

**build\_aux\_data\_i**(*nm, ad*)

### **mp.mm\_shared\_pfcpf\_acc**

**class** mp.mm\_shared\_pfcpf\_acc

Bases: *mp.mm\_shared\_pfcpf\_ac* (page 139)

*mp.mm\_shared\_pfcpf\_acc* (page 140) - Mixin class for AC cartesian PF/CPF **math model** objects.

An abstract mixin class inherited by all AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a cartesian voltage formulation.

#### **Method Summary**

**convert\_x\_m2n**(*mmx, nm, only\_v*)

*convert\_x\_m2n()* (page 140) - Convert math model state to network model state.

```
x = mm.pf_convert(mmx, nm)
[v, z] = mm.pf_convert(mmx, nm)
[v, z, x] = mm.pf_convert(mmx, nm,)
... = mm.pf_convert(mmx, nm, only_v)
```

### mp.mm\_shared\_pfcpf\_acci

#### class mp.mm\_shared\_pfcpf\_acci

Bases: *mp.mm\_shared\_pfcpf\_acc* (page 140), *mp.mm\_shared\_pfcpf\_ac\_i* (page 140)

*mp.mm\_shared\_pfcpf\_acci* (page 141) - Mixin class for AC-cartesian-current PF/CPF **math model** objects.

An abstract mixin class inherited by AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a cartesian voltage and current balance formulation.

#### Method Summary

```

build_aux_data(nm, dm, mpopt)
add_system_vars_pf(nm, dm, mpopt)
node_balance_equations(x, nm)

```

### mp.mm\_shared\_pfcpf\_accs

#### class mp.mm\_shared\_pfcpf\_accs

Bases: *mp.mm\_shared\_pfcpf\_acc* (page 140)

*mp.mm\_shared\_pfcpf\_accs* (page 141) - Mixin class for AC-cartesian-power PF/CPF **math model** objects.

An abstract mixin class inherited by AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a cartesian voltage and power balance formulation.

#### Method Summary

```

add_system_vars_pf(nm, dm, mpopt)
node_balance_equations(x, nm)

```

### mp.mm\_shared\_pfcpf\_acp

#### class mp.mm\_shared\_pfcpf\_acp

Bases: *mp.mm\_shared\_pfcpf\_ac* (page 139)

*mp.mm\_shared\_pfcpf\_acp* (page 141) - Mixin class for AC polar PF/CPF **math model** objects.

An abstract mixin class inherited by all AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a polar voltage formulation.

#### Method Summary

```

convert_x_m2n(mmx, nm, only_v)
convert_x_m2n() (page 141) - Convert math model state to network model state.

```

```

x = mm.pf_convert(mmx, nm)
[v, z] = mm.pf_convert(mmx, nm)
[v, z, x] = mm.pf_convert(mmx, nm)
... = mm.pf_convert(mmx, nm, only_v)

```



### mp.mm\_shared\_pfcpf\_acpi

**class** mp.mm\_shared\_pfcpf\_acpi

Bases: *mp.mm\_shared\_pfcpf\_acp* (page 141), *mp.mm\_shared\_pfcpf\_ac\_i* (page 140)

*mp.mm\_shared\_pfcpf\_acpi* (page 142) - Mixin class for AC-polar-current PF/CPF **math model** objects.

An abstract mixin class inherited by AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a polar voltage and current balance formulation.

#### Method Summary

**build\_aux\_data**(*nm, dm, mpopt*)

**add\_system\_vars\_pf**(*nm, dm, mpopt*)

**node\_balance\_equations**(*x, nm*)

### mp.mm\_shared\_pfcpf\_acps

**class** mp.mm\_shared\_pfcpf\_acps

Bases: *mp.mm\_shared\_pfcpf\_acp* (page 141)

*mp.mm\_shared\_pfcpf\_acps* (page 142) - Mixin class for AC-polar-power PF/CPF **math model** objects.

An abstract mixin class inherited by AC power flow (PF) and continuation power flow (CPF) **math model** objects that use a polar voltage and power balance formulation.

#### Method Summary

**build\_aux\_data**(*nm, dm, mpopt*)

**add\_system\_vars\_pf**(*nm, dm, mpopt*)

**node\_balance\_equations**(*x, nm, fdpf*)

### mp.mm\_shared\_pfcpf\_dc

**class** mp.mm\_shared\_pfcpf\_dc

Bases: *mp.mm\_shared\_pfcpf* (page 139)

*mp.mm\_shared\_pfcpf\_dc* (page 142) - Mixin class for DC power flow (PF) **math model** objects.

An abstract mixin class inherited by DC power flow (PF) **math model** objects.

#### Method Summary

**build\_aux\_data**(*nm, dm, mpopt*)

**add\_system\_vars\_pf**(*nm, dm, mpopt*)

**convert\_x\_m2n**(*mmx, nm, only\_v*)

[convert\\_x\\_m2n\(\)](#) (page 143) - Convert math model state to network model state.

```
x = mm.pf_convert(mmx, nm)
[v, z] = mm.pf_convert(mmx, nm)
[v, z, x] = mm.pf_convert(mmx, nm)
... = mm.pf_convert(mmx, nm, only_v)
```

**update\_z**(*nm, v, z, ad*)

[update\\_z\(\)](#) (page 143) - Update/allocate slack node active power injections.

### mp.mm\_shared\_opf\_legacy

**class** mp.mm\_shared\_opf\_legacy

Bases: handle

[mp.mm\\_shared\\_opf\\_legacy](#) (page 143) - Mixin class for legacy optimal power flow (OPF) **math model** objects.

An abstract mixin class inherited by optimal power flow (OPF) **math model** objects that need to handle legacy user customization mechanisms.

#### Method Summary

**def\_set\_types\_legacy**()

**init\_set\_types\_legacy**()

**get\_mpc**(*om*)

**build\_legacy**(*nm, dm, mpopt*)

**add\_legacy\_user\_vars**(*nm, dm, mpopt*)

**add\_legacy\_user\_costs**(*nm, dm, dc*)

**add\_legacy\_user\_constraints**(*nm, dm, mpopt*)

**add\_legacy\_user\_constraints\_ac**(*nm, dm, mpopt*)

**add\_legacy\_cost**(*om, name, idx, varargin*)

[add\\_legacy\\_cost\(\)](#) (page 143) - Add a set of user costs to the model

```
mm.add_legacy_cost(name, cp)
mm.add_legacy_cost(name, idx, varsets)
mm.add_legacy_cost(name, idx_list, cp)
mm.add_legacy_cost(name, idx_list, cp, varsets)
```

**eval\_legacy\_cost**(*om, x, name, idx*)

[eval\\_legacy\\_cost\(\)](#) (page 143) - Evaluate individual or full set of legacy user costs.

```
f = mm.eval_legacy_cost(x ...)
[f, df] = mm.eval_legacy_cost(x ...)
[f, df, d2f] = mm.eval_legacy_cost(x ...)
[f, df, d2f] = mm.eval_legacy_cost(x, name)
[f, df, d2f] = mm.eval_legacy_cost(x, name, idx_list)
```

**params\_legacy\_cost**(*om, name, idx*)

[params\\_legacy\\_cost\(\)](#) (page 144) - Return cost parameters for legacy user-defined costs.

```
cp = mm.params_legacy_cost()
cp = mm.params_legacy_cost(name)
cp = mm.params_legacy_cost(name, idx)
[cp, vs] = mm.params_legacy_cost(...)
[cp, vs, i1, iN] = mm.params_legacy_cost(...)
```

### 3.5.3 Elements

#### mp.mm\_element

**class** mp.mm\_element

Bases: handle

[mp.mm\\_element](#) (page 144) - Abstract base class for MATPOWER **mathematical model element** objects.

A math model element object typically does not contain any data, but only the methods that are used to build the math model and update the corresponding data model element once the math model has been solved.

All math model element classes inherit from [mp.mm\\_element](#) (page 144). Each element type typically implements its own subclasses, which are further subclassed where necessary per task and formulation, as with the container class.

By convention, math model element variables are named `mme` and math model element class names begin with `mp.mme`.

#### mp.mm\_element Methods:

- [name\(\)](#) (page 145) - get name of element type, e.g. 'bus', 'gen'
- [data\\_model\\_element\(\)](#) (page 145) - get corresponding data model element
- [network\\_model\\_element\(\)](#) (page 145) - get corresponding network model element
- [add\\_vars\(\)](#) (page 145) - add math model variables for this element
- [add\\_constraints\(\)](#) (page 145) - add math model constraints for this element
- [add\\_costs\(\)](#) (page 146) - add math model costs for this element
- [data\\_model\\_update\(\)](#) (page 146) - update the corresponding data model element
- [data\\_model\\_update\\_off\(\)](#) (page 146) - update offline elements in corresponding data model element
- [data\\_model\\_update\\_on\(\)](#) (page 146) - update online elements in corresponding data model element

See the `sec_mm_element` section in the *MATPOWER Developer's Manual* for more information.

See also `mp.math_model` (page 122).

### Method Summary

#### `name()`

Get name of element type, e.g. 'bus', 'gen'.

```
name = mme.name()
```

#### Output

**name** (*char array*) – name of element type, must be a valid struct field name

Implementation provided by an element type specific subclass.

#### `data_model_element(dm, name)`

Get corresponding data model element.

```
dme = mme.data_model_element(dm)
dme = mme.data_model_element(dm, name)
```

#### Inputs

- **dm** (*mp.data\_model* (page 28)) – data model object
- **name** (*char array*) – (optional) name of element type (default is name of this object)

#### Output

**dme** (*mp.dm\_element* (page 36)) – data model element object

#### `network_model_element(nm, name)`

Get corresponding network model element.

```
nme = mme.network_model_element(nm)
nme = mme.network_model_element(nm, name)
```

#### Inputs

- **nm** (*mp.net\_model* (page 91)) – network model object
- **name** (*char array*) – (optional) name of element type (default is name of this object)

#### Output

**nme** (*mp.nm\_element* (page 108)) – network model element object

#### `add_vars(mm, nm, dm, mpopt)`

Add math model variables for this element.

```
mme.add_vars(mm, nm, dm, mpopt)
```

#### Inputs

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Implementation provided by a subclass.

#### `add_constraints(mm, nm, dm, mpopt)`

Add math model constraints for this element.

```
mme.add_constraints(obj, mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Implementation provided by a subclass.

**add\_costs**(*mm, nm, dm, mpopt*)

Add math model costs for this element.

```
mme.add_costs(obj, mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Implementation provided by a subclass.

**data\_model\_update**(*mm, nm, dm, mpopt*)

Update the corresponding data model element.

```
mme.data_model_update(mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Call *data\_model\_update\_off()* (page 146) then *data\_model\_update\_on()* (page 146) to update the data model for this element based on the math model solution.

See also *data\_model\_update\_off()* (page 146), *data\_model\_update\_on()* (page 146).

**data\_model\_update\_off**(*mm, nm, dm, mpopt*)

Update offline elements in the corresponding data model element.

```
mme.data_model_update_off(mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Set export variables for offline elements based on specs returned by *mp.dm\_element.export\_vars\_offline\_val()* (page 41).

See also *data\_model\_update()* (page 146), *data\_model\_update\_on()* (page 146).

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

Update online elements in the corresponding data model element.

```
mme.data_model_update_on(mm, nm, dm, mpopt)
```

**Inputs**

- **mm** (*mp.math\_model* (page 122)) – mathematical model object
- **nm** (*mp.net\_model* (page 91)) – network model object
- **dm** (*mp.data\_model* (page 28)) – data model object
- **mpopt** (*struct*) – MATPOWER options struct

Extract the math model solution relevant to this particular element and update the corresponding data model element for online elements accordingly.

Implementation provided by a subclass.

See also *data\_model\_update()* (page 146), *data\_model\_update\_off()* (page 146).

## mp.mme\_branch

### class mp.mme\_branch

Bases: *mp.mm\_element* (page 144)

*mp.mme\_branch* (page 147) - Math model element abstract base class for branch.

Abstract math model element base class for branch elements, including transmission lines and transformers.

#### Method Summary

**name()**

## mp.mme\_branch\_pf\_ac

### class mp.mme\_branch\_pf\_ac

Bases: *mp.mme\_branch* (page 147)

*mp.mme\_branch\_pf\_ac* (page 147) - Math model element for branch for AC power flow.

Math model element class for branch elements, including transmission lines and transformers, for AC power flow problems.

Implements updating the output data in the corresponding data model element for in-service branches from the math model solution.

#### Method Summary

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

### mp.mme\_branch\_pf\_dc

#### class mp.mme\_branch\_pf\_dc

Bases: [mp.mme\\_branch](#) (page 147)

[mp.mme\\_branch\\_pf\\_dc](#) (page 148) - Math model element for branch for DC power flow.

Math model element class for branch elements, including transmission lines and transformers, for DC power flow problems.

Implements updating the output data in the corresponding data model element for in-service branches from the math model solution.

#### Method Summary

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

### mp.mme\_branch\_opf

#### class mp.mme\_branch\_opf

Bases: [mp.mme\\_branch](#) (page 147)

[mp.mme\\_branch\\_opf](#) (page 148) - Math model element abstract base class for branch for OPF.

Math model element abstract base class for branch elements, including transmission lines and transformers, for OPF problems.

Implements methods to prepare data required for angle difference limit constraints and to extract shadow prices for these constraints from the math model solution.

#### Method Summary

**ang\_diff\_params**(*dm, ignore*)

**ang\_diff\_prices**(*mm, nme*)

### mp.mme\_branch\_opf\_ac

#### class mp.mme\_branch\_opf\_ac

Bases: [mp.mme\\_branch\\_opf](#) (page 148)

[mp.mme\\_branch\\_opf\\_ac](#) (page 148) - Math model element abstract base class for branch for AC OPF.

Math model element abstract base class for branch elements, including transmission lines and transformers, for AC OPF problems.

Implements methods for adding of branch flow constraints and for updating the output data in the corresponding data model element for in-service branches from the math model solution.

#### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

`data_model_update_on(mm, nm, dm, mpop)`

### **mp.mme\_branch\_opf\_acc**

**class** `mp.mme_branch_opf_acc`

Bases: `mp.mme_branch_opf_ac` (page 148)

`mp.mme_branch_opf_acc` (page 149) - Math model element for branch for AC cartesian voltage OPF.

Math model element class for branch elements, including transmission lines and transformers, for AC cartesian voltage OPF problems.

Implements method for adding branch angle difference constraints and overrides method to extract shadow prices for these constraints from the math model solution.

#### **Method Summary**

`add_constraints(mm, nm, dm, mpop)`

`ang_diff_prices(mm, nme)`

### **mp.mme\_branch\_opf\_acp**

**class** `mp.mme_branch_opf_acp`

Bases: `mp.mme_branch_opf_ac` (page 148)

`mp.mme_branch_opf_acp` (page 149) - Math model element for branch for AC polar voltage OPF.

Math model element class for branch elements, including transmission lines and transformers, for AC polar voltage OPF problems.

Implements method for adding branch angle difference constraints.

#### **Method Summary**

`add_constraints(mm, nm, dm, mpop)`

### **mp.mme\_branch\_opf\_dc**

**class** `mp.mme_branch_opf_dc`

Bases: `mp.mme_branch_opf` (page 148)

`mp.mme_branch_opf_dc` (page 149) - Math model element for branch for DC OPF.

Math model element class for branch elements, including transmission lines and transformers, for DC OPF problems.

Implements methods for adding of branch flow and angle difference constraints and for updating the output data in the corresponding data model element for in-service branches from the math model solution.



### Method Summary

`add_constraints(mm, nm, dm, mpopt)`

`data_model_update_on(mm, nm, dm, mpopt)`

## mp.mme\_bus

### class mp.mme\_bus

Bases: [mp.mm\\_element](#) (page 144)

[mp.mme\\_bus](#) (page 150) - Math model element abstract base class for bus.

Abstract math model element base class for bus elements.

### Method Summary

`name()`

## mp.mme\_bus\_pf\_ac

### class mp.mme\_bus\_pf\_ac

Bases: [mp.mme\\_bus](#) (page 150)

[mp.mme\\_bus\\_pf\\_ac](#) (page 150) - Math model element for bus for AC power flow.

Math model element class for bus elements for AC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service buses from the math model solution.

### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

## mp.mme\_bus\_pf\_dc

### class mp.mme\_bus\_pf\_dc

Bases: [mp.mme\\_bus](#) (page 150)

[mp.mme\\_bus\\_pf\\_dc](#) (page 150) - Math model element for bus for DC power flow.

Math model element class for bus elements for DC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service buses from the math model solution.

### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

### mp.mme\_bus\_opf\_ac

**class** `mp.mme_bus_opf_ac`

Bases: `mp.mme_bus` (page 150)

`mp.mme_bus_opf_ac` (page 151) - Math model element abstract base class for bus for AC OPF.

Abstract math model element class for bus elements for AC OPF problems.

Implements method for forming an interior initial point for voltage magnitudes.

#### Method Summary

**interior\_vm**(*mm, nm, dm*)

return vm equal to avg of clipped limits

### mp.mme\_bus\_opf\_acc

**class** `mp.mme_bus_opf_acc`

Bases: `mp.mme_bus_opf_ac` (page 151)

`mp.mme_bus_opf_acc` (page 151) - Math model element for bus for AC cartesian voltage OPF.

Math model element class for bus elements for AC cartesian voltage OPF problems.

Implements methods for adding constraints for reference voltage angle, fixed voltage magnitudes and voltage magnitude limits, for forming an interior initial point and for updating the output data in the corresponding data model element for in-service buses from the math model solution.

#### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

**interior\_x0**(*mm, nm, dm, x0*)

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

### mp.mme\_bus\_opf\_acp

**class** `mp.mme_bus_opf_acp`

Bases: `mp.mme_bus_opf_ac` (page 151)

`mp.mme_bus_opf_acp` (page 151) - Math model element for bus for AC polar voltage OPF.

Math model element class for bus elements for AC polar voltage OPF problems.

Implements methods for forming an interior initial point and for updating the output data in the corresponding data model element for in-service buses from the math model solution.

**Method Summary**`interior_x0(mm, nm, dm, x0)``data_model_update_on(mm, nm, dm, mpopt)`**mp.mme\_bus\_opf\_dc****class mp.mme\_bus\_opf\_dc**Bases: [mp.mme\\_bus](#) (page 150)[mp.mme\\_bus\\_opf\\_dc](#) (page 152) - Math model element for bus for DC OPF.

Math model element class for bus elements for DC OPF problems.

Implements methods for forming an interior initial point and for updating the output data in the corresponding data model element for in-service buses from the math model solution.

**Method Summary**`interior_x0(mm, nm, dm, x0)``data_model_update_on(mm, nm, dm, mpopt)`**mp.mme\_gen****class mp.mme\_gen**Bases: [mp.mme\\_element](#) (page 144)[mp.mme\\_gen](#) (page 152) - Math model element abstract base class for generator.

Abstract math model element base class for generator elements.

**Method Summary**`name()`**mp.mme\_gen\_pf\_ac****class mp.mme\_gen\_pf\_ac**Bases: [mp.mme\\_gen](#) (page 152)[mp.mme\\_gen\\_pf\\_ac](#) (page 152) - Math model element for generator for AC power flow.

Math model element class for generator elements for AC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service generators from the math model solution.

**Method Summary**

`data_model_update_on(mm, nm, dm, mpop)`

## mp.mme\_gen\_pf\_dc

**class** `mp.mme_gen_pf_dc`

Bases: `mp.mme_gen` (page 152)

`mp.mme_gen_pf_dc` (page 153) - Math model element for generator for DC power flow.

Math model element class for generator elements for DC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service generators from the math model solution.

### Method Summary

`data_model_update_on(mm, nm, dm, mpop)`

## mp.mme\_gen\_opf

**class** `mp.mme_gen_opf`

Bases: `mp.mme_gen` (page 152)

`mp.mme_gen_opf` (page 153) - Math model element abstract base class for generator for OPF.

Math model element abstract base class for generator elements for OPF problems.

Implements methods to add costs, including piecewise linear cost variables, and to form an interior initial point for cost variables.

### Property Summary

#### **cost**

struct for `cost` (page 153) parameters with fields:

- `poly_p` - polynomial costs for active power, struct returned by `mp.cost_table.poly_params()` (page 163), with fields:
  - `have_quad_cost`
  - `i0, i1, i2, i3`
  - `k, c, Q`
- `poly_q` - polynomial costs for reactive power (*same struct as poly\_p*)
- `pwl` - piecewise linear costs for active & reactive struct returned by `mp.cost_table.pwl_params()` (page 164), with fields:
  - `n, i, A, b`

### Method Summary

`add_vars(mm, nm, dm, mpop)`

`add_costs(mm, nm, dm, mpop)`

`interior_x0(mm, nm, dm, x0)`

## mp.mme\_gen\_opf\_ac

**class** mp.mme\_gen\_opf\_ac

Bases: [mp.mme\\_gen\\_opf](#) (page 153)

[mp.mme\\_gen\\_opf\\_ac](#) (page 154) - Math model element for generator for AC OPF.

Math model element class for generator elements for AC OPF problems.

Implements methods for building and adding PQ capability constraints, dispatchable load power factor constraints, polynomial costs, and for updating the output data in the corresponding data model element for in-service generators from the math model solution.

### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

**add\_costs**(*mm, nm, dm, mpopt*)

**pq\_capability\_constraint**(*dme, base\_mva*)

from legacy [makeApq\(\)](#) (page 289)

**has\_pq\_cap**(*gen, upper\_lower*)

from legacy [hasPQcap\(\)](#) (page 339)

**disp\_load\_constant\_pf\_constraint**(*dm*)

from legacy [makeAvl\(\)](#) (page 290)

**build\_cost\_params**(*dm*)

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

## mp.mme\_gen\_opf\_dc

**class** mp.mme\_gen\_opf\_dc

Bases: [mp.mme\\_gen\\_opf](#) (page 153)

[mp.mme\\_gen\\_opf\\_dc](#) (page 154) - Math model element for generator for DC OPF.

Math model element class for generator elements for DC OPF problems.

Implements methods for building cost parameters, adding piecewise linear cost constraints, and for updating the output data in the corresponding data model element for in-service generators from the math model solution.

### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

**build\_cost\_params**(*dm*)

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

## mp.mme\_load

### class mp.mme\_load

Bases: *mp.mm\_element* (page 144)

*mp.mme\_load* (page 155) - Math model element abstract base class for load.

Abstract math model element base class for load elements.

#### Method Summary

**name()**

## mp.mme\_load\_pf\_ac

### class mp.mme\_load\_pf\_ac

Bases: *mp.mme\_load* (page 155)

*mp.mme\_load\_pf\_ac* (page 155) - Math model element for load for AC power flow.

Math model element class for load elements for AC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service loads from the math model solution.

#### Method Summary

**data\_model\_update\_on**(*mm, nm, dm, mpop*)

## mp.mme\_load\_pf\_dc

### class mp.mme\_load\_pf\_dc

Bases: *mp.mme\_load* (page 155)

*mp.mme\_load\_pf\_dc* (page 155) - Math model element for load for DC power flow.

Math model element class for load elements for DC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service loads from the math model solution.

#### Method Summary

**data\_model\_update\_on**(*mm, nm, dm, mpop*)

## mp.mme\_load\_cpf

### class mp.mme\_load\_cpf

Bases: *mp.mme\_load\_pf\_ac* (page 155)

*mp.mme\_load\_cpf* (page 156) - Math model element for load for CPF.

Math model element class for load elements for AC CPF problems.

Implements method for updating the output data in the corresponding data model element for in-service loads from the math model solution.

#### Method Summary

`data_model_update_on(mm, nm, dm, mpop)`

## mp.mme\_shunt

### class mp.mme\_shunt

Bases: *mp.mm\_element* (page 144)

*mp.mme\_shunt* (page 156) - Math model element abstract base class for shunt.

Abstract math model element base class for shunt elements.

#### Method Summary

`name()`

## mp.mme\_shunt\_pf\_ac

### class mp.mme\_shunt\_pf\_ac

Bases: *mp.mme\_shunt* (page 156)

*mp.mme\_shunt\_pf\_ac* (page 156) - Math model element for shunt for AC power flow.

Math model element class for shunt elements for AC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service shunts from the math model solution.

#### Method Summary

`data_model_update_on(mm, nm, dm, mpop)`

## mp.mme\_shunt\_pf\_dc

### class mp.mme\_shunt\_pf\_dc

Bases: [mp.mme\\_shunt](#) (page 156)

[mp.mme\\_shunt\\_pf\\_dc](#) (page 157) - Math model element for shunt for DC power flow.

Math model element class for shunt elements for DC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service shunts from the math model solution.

#### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

## mp.mme\_shunt\_cpf

### class mp.mme\_shunt\_cpf

Bases: [mp.mme\\_shunt\\_pf\\_ac](#) (page 156)

[mp.mme\\_shunt\\_cpf](#) (page 157) - Math model element for shunt for CPF.

Math model element class for shunt elements for AC CPF problems.

Implements method for updating the output data in the corresponding data model element for in-service shunts from the math model solution.

#### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

## 3.6 Miscellaneous Classes

### 3.6.1 mp\_table

#### class mp\_table

[mp\\_table](#) (page 157) - Very basic table-compatible class for Octave or older Matlab.

```
T = mp_table(var1, var2, ...);
T = mp_table(..., 'VariableNames', {name1, name2, ...});
T = mp_table(..., 'RowNames', {name1, name2, ...});
T = mp_table(..., 'DimensionNames', {name1, name2, ...});
```

Implements a very basic table array class focused the ability to store and access named variables of different types in a way that is compatible with MATLAB's built-in table class. Other features, such as table joining, etc., are not implemented.



---

**Important:** Since the dot syntax `T.<var_name>` is used to access table variables, you must use a functional syntax `<method>(T, ...)`, as opposed to the object-oriented `T.<method>(...)`, to call `mp_table` methods.

---

### **mp\_table Methods:**

- `mp_table()` (page 158) - construct object
- `istable()` (page 158) - true for `mp_table` (page 157) objects
- `size()` (page 158) - dimensions of table
- `isempty()` (page 158) - true if table has no columns or no rows
- `end()` (page 159) - used to index last row or variable/column
- `subsref()` (page 159) - indexing a table to retrieve data
- `subsasgn()` (page 159) - indexing a table to assign data
- `horzcat()` (page 160) - concatenate tables horizontally
- `vertcat()` (page 160) - concatenate tables vertically
- `display()` (page 160) - display table contents

See also `table`.

### **Constructor Summary**

#### **mp\_table**(*varargin*)

Constructs the object.

```
T = mp_table(var1, var2, ...)
T = mp_table(..., 'VariableNames', {name1, name2, ...})
T = mp_table(..., 'RowNames', {name1, name2, ...})
T = mp_table(..., 'DimensionNames', {name1, name2, ...})
```

### **Method Summary**

#### **istable**()

Returns true.

```
TorF = istable(T)
```

Unfortunately, this is not really useful until Octave implements a built-in `istable()` (page 158) that this can override.

#### **size**(*dim*)

Returns dimensions of table.

```
[m, n] = size(T)
m = size(T, 1)
n = size(T, 2)
```

#### **isempty**()

Returns true if the table has no columns or no rows.

```
TorF = isempty(T)
```

**end**(*k, n*)

Used to index the last row or column of the table.

```
last_var = T{:, end}
last_row = T(end, :)
```

**subsref**(*s*)

Called when indexing a table to retrieve data.

```
sub_T = T(i, *)
sub_T = T(i1:iN, *)
sub_T = T(:, *)
sub_T = T(*, j)
sub_T = T(*, j1:jN)
sub_T = T(*, :)
sub_T = T(*, <str>)
sub_T = T(*, <cell>)
var_<name> = T.<name>
val = T.<name>(i)
val = T.<name>(i1:iN)
val = T.<name>{i}
val = T.<name>{i1:iN}
val = T.<name>(*, :)
val = T.<name>(*, j)
var_<j> = T{:, j}
var_<str> = T{:, <str>}
val = T{i, *}
val = T{i1:iN, *}
val = T{:, *}
val = T{* , j}
val = T{* , j1:jN}
val = T{* , :}
val = T{* , <str>}
val = T{* , <cell>}
```

**subsasgn**(*s, b*)

Called when indexing a table to assign data.

```
T(i, *) = sub_T
T(i1:iN, *) = sub_T
T(:, *) = sub_T
T(*, j) = sub_T
T(*, j1:jN) = sub_T
T(*, :) = sub_T
T(*, <str>) = sub_T
T(*, <cell>) = sub_T
T.<name> = val
T.<name>(i) = val
T.<name>(i1:iN) = val
T.<name>{i} = val
T.<name>{i1:iN} = val
```

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```

T.<name>(*, :) = val
T.<name>(*, j) = val
T{:, j} = var_<j>
T{:, <str>} = var_<str>
T{i, *} = val
T{i1:iN, *} = val
T{:, *} = val
T{* , j} = val
T{* , j1:jN} = val
T{* , :} = val
T{* , <str>} = val
T{* , <cell>} = val

```

**horzcat**(*varargin*)

Concatenate tables horizontally.

```
T = [T1 T2]
```

**vertcat**(*varargin*)

Concatenate tables vertically.

```
T = [T1; T2]
```

**display()**

Display the table contents.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

By default it displays only the first and last 10 rows if there are more than 25 rows.

Does not currently display the contents of any nested tables.

**static extract\_named\_args**(*args*)

Extracts special named constructor arguments.

```

[var_names, row_names, dim_names, args] = extract_named_args(var1, var2, ...
↪)
[...] = extract_named_args(..., 'VariableNames', {name1, name2, ...})
[...] = extract_named_args(..., 'RowNames', {name1, name2, ...})
[...] = extract_named_args(..., 'DimensionNames', {name1, name2, ...})

```

Used to extract named arguments, 'VariableNames', 'RowNames', and 'DimensionNames', to pass to constructor.

### 3.6.2 mp\_table\_subclass

#### class mp\_table\_subclass

*mp\_table\_subclass* (page 161) - Class that acts like a table but isn't one.

Addresses two issues with inheriting from **table** classes (**table**) or *mp\_table* (page 157)).

1. In MATLAB, **table** is a sealed class, so you cannot inherit from it. You can, however, use a subclass of *mp\_table* (page 157), but that can result in the next issue under Octave.
2. While nesting of tables works just fine in general, when using *mp\_table* (page 157) in Octave (at least up through 8.4.0), you cannot nest a subclass of *mp\_table* (page 157) inside another *mp\_table* (page 157) object because of this bug: <https://savannah.gnu.org/bugs/index.php?65037>.

To work around these issues, your “table subclass” can inherit from **this** class. An object of this class **isn't** a **table** or *mp\_table* (page 157) object, but rather it **contains** one and attempts to act like one. That is, it delegates method calls (currently only those available in *mp\_table* (page 157), listed below) to the contained table object.

The class of the contained table object is either **table** or *mp\_table* (page 157) and is determined by *mp\_table\_class()* (page 7).

---

#### Limitations

1. The Octave bug mentioned above also affects tables that inherit from *mp\_table\_subclass* (page 161). That is, such tables can be nested inside tables of type **table** or *mp\_table* (page 157), but not inside tables that are or inherit from *mp\_table\_subclass* (page 161).
2. In MATLAB, when nesting an *mp\_table\_subclass* (page 161) object within another *mp\_table\_subclass* (page 161) object, one cannot use multi-level indexing directly. E.g. If T2 is a variable in T1 and x is a variable in T2, attempting `x = T1.T2.x` will result in an error. The indexing must be done in multiple steps `T2 = T1.T2; x = T2.x`. Note: This only applies to MATLAB, where the contained table is a **table**. It works just fine in Octave, where the contained table is an *mp\_table* (page 157).

---

**Important:** Since the dot syntax `T.<var_name>` is used to access table variables, you must use a functional syntax `<method>(T, ...)`, as opposed to the object-oriented `T.<method>(...)`, to call methods of this class or subclasses, as with *mp\_table*.

---

#### mp.mp\_table\_subclass Properties:

- `tab` - (*table* or *mp\_table*) contained table object this class emulates

#### mp.cost\_table Methods:

- `mp_table_subclass()` - construct object
- `get_table()` (page 162) - return the table stored in `tab`
- `set_table()` (page 162) - assign a table to `tab`
- `istable()` - true for *mp\_table* (page 157) objects
- `size()` - dimensions of table
- `isempty()` - true if table has no columns or no rows
- `end()` - used to index last row or variable/column
- `subsref()` - indexing a table to retrieve data

- `subsasgn()` - indexing a table to assign data
- `horzcat()` - concatenate tables horizontally
- `vertcat()` - concatenate tables vertically
- `display()` - display table contents

See also [`mp\_table`](#) (page 157), [`mp\_table\_class\(\)`](#) (page 7).

### Method Summary

#### `get_table()`

```
T = get_table(obj)
```

#### `set_table(T)`

```
set_table(obj, T)
```

## 3.6.3 `mp.cost_table`

### class `mp.cost_table`

Bases: [`mp\_table\_subclass`](#) (page 161)

[`mp.cost\_table`](#) (page 162) - Table for (polynomial and piecewise linear) cost parameters.

```
T = cost_table(poly_n, poly_coef, pwl_n, pwl_qty, pwl_cost);
```

---

**Important:** Since the dot syntax `T.<var_name>` is used to access table variables, you must use a functional syntax `<method>(T, ...)`, as opposed to the object-oriented `T.<method>(...)`, to call standard `mp.cost_table` methods.

---

Standard table subscripting syntax is not available within methods of this class (references built-in `subsref()` and `subsasgn()` rather than the versions overridden by the table class). For this reason, some method implementations are delegated to static methods in [`mp.cost\_table\_utils`](#) (page 165) where that syntax is available, making the code more readable.

#### `mp.cost_table` Methods:

- [`cost\_table\(\)`](#) (page 163) - construct object
- [`poly\_params\(\)`](#) (page 163) - create struct of polynomial parameters from [`mp.cost\_table`](#) (page 162)
- [`pwl\_params\(\)`](#) (page 164) - create struct of piecewise linear parameters from [`mp.cost\_table`](#) (page 162)
- [`max\_pwl\_cost\(\)`](#) (page 164) - get maximum cost component used to specify pwl costs

An [`mp.cost\_table`](#) (page 162) has the following columns:

Name	Type	Description
<code>poly_n</code>	<i>integer</i>	$n_{\text{poly}}$ , number of coefficients in polynomial cost curve, $f_{\text{poly}}(x) = c_0 + c_1x + \dots + c_Nx^N$ , where $n_{\text{poly}} = N + 1$
<code>poly_coef</code>	<i>double</i>	matrix of coefficients $c_j$ , of polynomial cost $f_{\text{poly}}(x)$ , where $c_j$ is found in column $j + 1$
<code>pwl_n</code>	<i>double</i>	$n_{\text{pwl}}$ , number of data points $(x_1, f_1), (x_2, f_2), \dots, (x_N, f_N)$ defining a piecewise linear cost curve, $f_{\text{pwl}}(x)$ where $N = n_{\text{pwl}}$
<code>pwl_qty</code>	<i>double</i>	matrix of <i>quantity</i> coordinates $x_j$ for piecewise linear cost $f_{\text{pwl}}(x)$ , where $x_j$ is found in column $j$
<code>pwl_cost</code>	<i>double</i>	matrix of <i>cost</i> coordinates $f_j$ for piecewise linear cost $f_{\text{pwl}}(x)$ , where $f_j$ is found in column $j$

See also [mp.cost\\_table\\_utils](#) (page 165), [mp\\_table\\_subclass](#) (page 161).

### Constructor Summary

`cost_table(varargin)`

```
T = cost_table()
T = cost_table(poly_n, poly_coef, pwl_n, pwl_qty, pwl_cost)
```

For descriptions of the inputs, see the corresponding column in the class documentation above.

#### Inputs

- **poly\_n** (*col vector of integers*)
- **poly\_coef** (*matrix of doubles*)
- **pwl\_n** (*col vector of integers*)
- **pwl\_qty** (*matrix of doubles*)
- **pwl\_cost** (*matrix of doubles*)

#### Outputs

**T** ([mp.cost\\_table](#) (page 162)) – the cost table object

### Method Summary

`poly_params(idx, pu_base)`

```
p = poly_params(obj, idx, pu_base)
```

#### Inputs

- **obj** ([mp.cost\\_table](#) (page 162)) – the cost table
- **idx** – (*integer*) : index vector of rows of interest, empty for all rows
- **pu\_base** (*double*) – base used to scale quantities to per unit

#### Outputs

**p** (*struct*) – polynomial cost parameters, struct with fields:

- **have\_quad\_cost** - true if any polynomial costs have order quadratic or less
- **i0** - row indices for constant costs
- **i1** - row indices for linear costs
- **i2** - row indices for quadratic costs
- **i3** - row indices for order 3 or higher costs
- **k** - constant term for all quadratic and lower order costs
- **c** - linear term for all quadratic and lower order costs
- **Q** - quadratic term for all quadratic and lower order costs

Implementation in `mp.cost_table_utils.poly_params()` (page 165).

`pwl_params(idx, pu_base, varargin)`

```
p = pwl_params(obj, idx, pu_base)
p = pwl_params(obj, idx, pu_base, ng, dc)
```

#### Inputs

- **obj** (`mp.cost_table` (page 162)) – the cost table
- **idx** – (integer) : index vector of rows of interest, empty for all rows
- **pu\_base** (*double*) – base used to scale quantities to per unit
- **ng** (*integer*) – number of units, default is # of rows in cost
- **dc** (*boolean*) – true if DC formulation (ng variables), otherwise AC formulation (2\*ng variables), default is 1

#### Outputs

- p** (*struct*) – piecewise linear cost parameters, struct with fields:
- **n** - number of piecewise linear costs
  - **i** - row indices for piecewise linear costs
  - **A** - constraint coefficient matrix for CCV formulation
  - **b** - constraint RHS vector for CCV formulation

Implementation in `mp.cost_table_utils.pwl_params()` (page 166).

`max_pwl_cost()`

```
maxc = max_pwl_cost(obj)
```

#### Input

- **obj** (`mp.cost_table` (page 162)) – the cost table

#### Output

- **maxc** (*double*) – maximum cost component of all breakpoints used to specify piecewise linear costs

Implementation in `mp.cost_table_utils.max_pwl_cost()` (page 166).

`static poly_cost_fcn(xx, x_scale, ccm, idx)`

```
f = mp.cost_table.poly_cost_fcn(xx, x_scale, ccm, idx)
[f, df] = mp.cost_table.poly_cost_fcn(...)
[f, df, d2f] = mp.cost_table.poly_cost_fcn(...)
```

Evaluates the sum of a set of polynomial cost functions  $f(x) = \sum_{i \in I} f_i(x_i)$ , and optionally the gradient and Hessian.

#### Inputs

- **xx** (*single element cell array of double*) – first element is a vector of the pre-scaled quantities  $x/\alpha$  used to compute the costs
- **x\_scale** (*double*) – scalar  $\alpha$  used to scale the quantity value before evaluating the polynomial cost
- **ccm** (*double*) – cost coefficient matrix, element  $(i,j)$  is the coefficient of the  $(j-1)$  order term for cost  $i$
- **idx** (*integer*) – index vector of subset  $I$  of rows of `xx{1}` and `ccm` of interest

#### Outputs

- **f** (*double*) – value of cost function  $f(x)$
- **df** (*vector of double*) – (optional) gradient of cost function
- **d2f** (*matrix of double*) – (optional) Hessian of cost function

**static eval\_poly\_fcn**(*c*, *x*)

```
f = mp.cost_table.eval_poly_fcn(c, x)
```

Evaluate a vector of polynomial functions, where ...

```
f = c(:,1) + c(:,2) .* x + c(:,3) .* x^2 + ...
```

**Inputs**

- *c* (*matrix of double*) – coefficient matrix, element (*i,j*) is the coefficient of the (*j-1*) order term for *i*-th element of *f*
- *x* (*vector of double*) – vector of input values

**Outputs**

*f* (*vector of double*) – value of functions

**static diff\_poly\_fcn**(*c*)

```
c = mp.cost_table.diff_poly_fcn(c)
```

Compute the coefficient matrix for the derivatives of a set of polynomial functions from the coefficients of the functions.

**Inputs**

*c* (*matrix of double*) – coefficient matrix for the functions, element (*i,j*) is the coefficient of the (*j-1*) order term of the *i*-th function

**Outputs**

*c* (*matrix of double*) – coefficient matrix for the derivatives of the functions, element (*i,j*) is the coefficient of the (*j-1*) order term of the derivative of the *i*-th function

### 3.6.4 mp.cost\_table\_utils

**class mp.cost\_table\_utils**

*mp.cost\_table\_utils* (page 165) - Static methods for *mp.cost\_table* (page 162).

Contains the implementation of some methods that would ideally belong in *mp.cost\_table* (page 162).

Within classes that inherit from *mp\_table\_subclass* (page 161), such as *mp.cost\_table* (page 162), any subscripting to access the elements of the table must be done through explicit calls to the table's *subsref()* and *subsasgn()* methods. That is, the normal table subscripting syntax will not work, so working with the table becomes extremely cumbersome.

This purpose of this class is to provide the implementation for *mp.cost\_table* (page 162) methods that **do** allow access to that table via normal table subscripting syntax.

**mp.cost\_table\_util Methods:**

- *poly\_params()* (page 165) - create struct of polynomial parameters from *mp.cost\_table* (page 162)
- *pwl\_params()* (page 166) - create struct of piecewise linear parameters from *mp.cost\_table* (page 162)
- *max\_pwl\_cost()* (page 166) - get maximum cost component used to specify pwl costs

See also *mp.cost\_table* (page 162).

**Method Summary**



**static poly\_params**(*cost, idx, pu\_base*)

```
p = mp.cost_table_utils.poly_params(cost, idx, pu_base)
```

Implementation for `mp.cost_table.poly_params()` (page 163). See `mp.cost_table.poly_params()` (page 163) for details.

**static pwl\_params**(*cost, idx, pu\_base, ng, dc*)

```
p = mp.cost_table_utils.pwl_params(cost, idx, pu_base)
p = mp.cost_table_utils.pwl_params(cost, idx, pu_base, ng, dc)
```

Implementation for `mp.cost_table.pwl_params()` (page 164). See `mp.cost_table.pwl_params()` (page 164) for details.

**static max\_pwl\_cost**(*cost*)

```
maxc = mp.cost_table_utils.max_pwl_cost(cost)
```

Implementation for `mp.cost_table.max_pwl_cost()` (page 164). See `mp.cost_table.max_pwl_cost()` (page 164) for details.

### 3.6.5 mp.element\_container

**class mp.element\_container**

Bases: `handle`

`mp.element_container` (page 166) - Mix-in class to handle named/ordered element object array.

Implements an element container that is used for MATPOWER model and data model converter objects. Provides the properties to store the constructors for each element and the elements themselves. Also provides a method to modify an existing set of element constructors.

**mp.element\_container Properties:**

- `element_classes` (page 166) - cell array of element constructors
- `elements` (page 166) - a `mp.mapped_array` (page 167) to hold the element objects

**mp.element\_container Methods:**

- `modify_element_classes()` (page 166) - modify an existing set of element constructors

See also `mp.mapped_array` (page 167).

**Property Summary**

**element\_classes**

Cell array of function handles of constructors for individual elements, filled by constructor of subclass.

**elements**

A mapped array (`mp.mapped_array` (page 167)) to hold the element objects included inside this container object.

**Method Summary**

**modify\_element\_classes**(*class\_list*)

Modify an existing set of element constructors.

```
obj.modify_element_classes(class_list)
```

**Input**

**class\_list** (*cell array*) – list of **element class modifiers**, where each modifier is one of the following:

1. a handle to a constructor to **append** to `obj.element_classes`, *or*
2. a char array B, indicating to **remove** any element E in the list for which `isa(E(), B)` is `true`, *or*
3. a 2-element cell array {A,B} where A is a handle to a constructor to **replace** any element E in the list for which `isa(E(), B)` is `true`, i.e. B is a char array

Also accepts a single element class modifier of type 1 or 2 (*A single type 3 modifier has to be enclosed in a single-element cell array to keep it from being interpreted as a list of 2 modifiers*).

Can be used to modify the list of element constructors in the `element_classes` property by appending, removing, or replacing entries. See `tab_element_class_modifiers` in the *MATPOWER Developer's Manual* for more information.

### 3.6.6 mp.mapped\_array

#### class mp.mapped\_array

Bases: handle

*mp.mapped\_array* (page 167) - Cell array indexed by name as well as numeric index.

Currently, arrays are only 1-D.

Example usage:

```
% create a mapped array object
ma = mp.mapped_array({30, 40, 50}, {'width', 'height', 'depth'});

% treat it like a cell array
ma{3} = 60;
height = ma{2};
for i = 1:length(ma)
    disp( ma{i} );
end

% treat it like a struct
ma.width = 20;
depth = ma.depth;

% add elements
ma.add_elements({'red', '25 lbs'}, {'color', 'weight'});

% delete elements
ma.delete_elements([3 5]);
ma.delete_elements('height');
```

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```
% check for named element
ma.has_name('color');
```

**mp.mapped\_array Methods:**

- *mapped\_array()* (page 168) - constructor
- *copy()* (page 168) - create a duplicate of the mapped array object
- *length()* (page 168) - return number of elements in mapped array
- *size()* (page 168) - return dimensions of mapped array
- *add\_names()* (page 169) - add or modify names of elements
- *add\_elements()* (page 169) - append elements to the end of the mapped array
- *delete\_elements()* (page 169) - delete elements from the mapped array
- *has\_name()* (page 169) - return true if the name exists in the mapped array
- *name2idx()* (page 169) - return the index corresponding to a name
- *subsref()* (page 169) - called when indexing a mapped array to retrieve data
- *subsasgn()* (page 170) - called when indexing a mapped array to assign data
- *display()* (page 170) - display the mapped array structure

**Constructor Summary****mapped\_array**(varargin)

```
obj = mp.mapped_array(vals)
obj = mp.mapped_array(vals, names)
```

**Inputs**

- **vals** (*cell array*) – values to be stored
- **names** (*cell array of char arrays*) – names for each element in **vals**, where a valid name is any valid variable name that is not one of the methods of this class. If names are not provided, it is equivalent to a cell array, except that names can be added later.

**Method Summary****copy()**

Create a duplicate of the mapped array object.

```
new_obj = obj.copy();
```

**length()**

Return number of elements in mapped array.

```
num_elements = obj.length();
```

**size(dim)**

Return dimensions of mapped array. First dimension is 1, second matches the length.

```
[m, n] = obj.size();
m = obj.size(1);
n = obj.size(2);
```

**add\_names**(*i0, names*)

Add or modify names of elements.

```
obj.add_names(i0, names)
```

**Inputs**

- **i0** (*cell array*) – index of element corresponding to first name provided in **names**
- **names** (*char array or cell array of char arrays*) – the names to assign

Adds or overwrites the names for elements starting at the specified index.

**add\_elements**(*vals, names*)

Append elements to the end of the mapped array.

```
obj.add_elements(vals);
obj.add_elements(vals, names);
```

**Inputs**

- **vals** – single value or cell array of values
- **names** (*char array or cell array of char arrays*) – (optional) corresponding names

The two arguments must be both cell arrays of the same dimension or a single value and single name.

See also [delete\\_elements\(\)](#) (page 169).

**delete\_elements**(*refs*)

Delete elements from the mapped array.

```
obj.delete_elements(idx);
obj.delete_elements(names);
```

**Inputs**

- **idx** (*scalar or vector integer*) – index(indices) of element(s) to delete
- **names** (*char array or cell array of char arrays*) – name(s) of element(s) to delete

See also [add\\_elements\(\)](#) (page 169).

**has\_name**(*name*)

Return true if the name exists in the mapped array.

```
TorF = obj.has_name(name);
```

**Input**

**name** (*char array*) – name to check

**name2idx**(*name*)

Return the numerical index in the array corresponding to a name.

```
idx = obj.name2idx(name);
```

**Input**

**name** (*char array*) – name corresponding to desired index

**subsref(*s*)**

Called when indexing a table to retrieve data.

```
val = obj.<name>;  
val = obj{idx};
```

**subsasgn(*s*, *b*)**

Called when indexing a table to assign data.

```
obj.<name> = val;  
obj{idx} = val;
```

**display()**

Display the mapped array structure.

This method is called automatically when omitting a semicolon on a line that returns an object of this class.

### 3.6.7 mp.NODE\_TYPE

**class mp.NODE\_TYPE**

*mp.NODE\_TYPE* (page 170) - Defines enumerated type for node types.

**mp.NODE\_TYPE Properties:**

- *PQ* (page 170) - PQ node (= 1)
- *PV* (page 170) - PV node (= 2)
- *REF* (page 170) - reference node (= 3)
- *NONE* (page 170) - isolated node (= 4)

**mp.NODE\_TYPE Methods:**

- *is\_valid()* (page 170) - returns true if the value is a valid node type

All properties are Constant properties and the class is a Sealed class. So the properties function as global constants which do not create an instance of the class, e.g. *mp.NODE\_TYPE.REF* (page 170).

**Property Summary**

**PQ = 1**

PQ node

**PV = 2**

PV node

**REF = 3**

reference node

**NONE = 4**

isolated node

**Method Summary**

**static is\_valid(val)**

Returns true if the value is a valid node type.

```
TorF = mp.NODE_TYPE.is_valid(val)
```

**Input**

**val** (*integer*) – node type value to check for validity

**Output**

**TorF** (*boolean*) – true if val is a valid node type

## 3.7 MATPOWER Extension Classes

### 3.7.1 Base

#### mp.extension

**class mp.extension**

Bases: `handle`

[mp.extension](#) (page 171) - Abstract base class for MATPOWER extensions.

This class serves as the framework for the **MATPOWER extension** API, providing a way to bundle a set of class additions and modifications together into a single named package.

By default the methods in this class do nothing, but they can be overridden to customize essentially any aspect of a MATPOWER run. The first 5 methods are used to modify the default classes used to construct the task, data model converter, data, network, and/or mathematical model objects. The last 4 methods are used to add to or modify the classes used to construct the elements for each of the container types.

By convention, MATPOWER extension objects (or cell arrays of them) are named `mpx` and MATPOWER extension class names begin with `mp.xt`.

#### mp.extension Methods:

- [task\\_class\(\)](#) (page 172) - return handle to constructor for task object
- [dmc\\_class\(\)](#) - return handle to constructor for data model converter object
- [dm\\_class\(\)](#) - return handle to constructor for data model object
- [nm\\_class\(\)](#) - return handle to constructor for network model object
- [mm\\_class\(\)](#) - return handle to constructor for mathematical object
- [dmc\\_element\\_classes\(\)](#) (page 173) - return element class modifiers for data model converter elements
- [dm\\_element\\_classes\(\)](#) (page 173) - return element class modifiers for data model elements
- [nm\\_element\\_classes\(\)](#) (page 173) - return element class modifiers for network model elements
- [mm\\_element\\_classes\(\)](#) (page 173) - return element class modifiers for mathematical model elements

See the `sec_customizing` and `sec_extensions` sections in the *MATPOWER Developer's Manual* for more information, and specifically the `sec_element_classes` section and the `tab_element_class_modifiers` table for details on *element class modifiers*.

Example MATPOWER extensions:

- `mp.xt_reserves` (page 174) - adds fixed zonal reserves to OPF
- `mp.xt_3p` (page 179) - adds example prototype unbalanced three-phase elements for AC PF, CPF, and OPF

See also `mp.task` (page 8), `mp.dm_converter` (page 60), `mp.data_model` (page 28), `mp.net_model` (page 91), `mp.math_model` (page 122), `mp.dmc_element` (page 63), `mp.dm_element` (page 36), `mp.nm_element` (page 108), `mp.mm_element` (page 144).

## Method Summary

**task\_class**(*task\_class*, *mpopt*)

Return handle to constructor for task object.

```
task_class = mpx.task_class(task_class, mpopt)
```

### Inputs

- **task\_class** (*function handle*) – default task constructor
- **mpopt** (*struct*) – MATPOWER options struct

### Output

**task\_class** (*function handle*) – updated task constructor

**dm\_converter\_class**(*dmc\_class*, *fmt*, *mpopt*)

Return handle to constructor for data model converter object.

```
dmc_class = mpx.dm_converter_class(dmc_class, fmt, mpopt)
```

### Inputs

- **dmc\_class** (*function handle*) – default data model converter constructor
- **fmt** (*char array*) – data format tag, e.g. 'mpc2'
- **mpopt** (*struct*) – MATPOWER options struct

### Output

**dmc\_class** (*function handle*) – updated data model converter constructor

**data\_model\_class**(*dm\_class*, *task\_tag*, *mpopt*)

Return handle to constructor for data model object.

```
dm_class = mpx.data_model_class(dm_class, task_tag, mpopt)
```

### Inputs

- **dm\_class** (*function handle*) – default data model constructor
- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

### Output

**dm\_class** (*function handle*) – updated data model constructor

**network\_model\_class**(*nm\_class*, *task\_tag*, *mpopt*)

Return handle to constructor for network model object.

```
nm_class = mpx.network_model_class(nm_class, task_tag, mpopt)
```

### Inputs

- **nm\_class** (*function handle*) – default network model constructor

- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**nm\_class** (*function handle*) – updated network model constructor

**math\_model\_class**(*mm\_class, task\_tag, mpopt*)

Return handle to constructor for mathematical model object.

```
mm_class = mpx.math_model_class(mm_class, task_tag, mpopt)
```

**Inputs**

- **mm\_class** (*function handle*) – default math model constructor
- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**mm\_class** (*function handle*) – updated math model constructor

**dmc\_element\_classes**(*dmc\_class, fmt, mpopt*)

Return element class modifiers for data model converter elements.

```
dmc_elements = mpx.dmc_element_classes(dmc_class, fmt, mpopt)
```

**Inputs**

- **dmc\_class** (*function handle*) – data model converter constructor
- **fmt** (*char array*) – data format tag, e.g. 'mpc2'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**dmc\_elements** (*cell array*) – element class modifiers (see `tab_element_class_modifiers` in the *MATPOWER Developer's Manual*)

**dm\_element\_classes**(*dm\_class, task\_tag, mpopt*)

Return element class modifiers for data model elements.

```
dm_elements = mpx.dm_element_classes(dm_class, task_tag, mpopt)
```

**Inputs**

- **dm\_class** (*function handle*) – data model constructor
- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**dm\_elements** (*cell array*) – element class modifiers (see `tab_element_class_modifiers` in the *MATPOWER Developer's Manual*)

**nm\_element\_classes**(*nm\_class, task\_tag, mpopt*)

Return element class modifiers for network model elements.

```
nm_elements = mpx.nm_element_classes(nm_class, task_tag, mpopt)
```

**Inputs**

- **nm\_class** (*function handle*) – network model constructor
- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

**Output**

**nm\_elements** (*cell array*) – element class modifiers (see `tab_element_class_modifiers` in the *MATPOWER Developer's Manual*)



**mm\_element\_classes**(*mm\_class*, *task\_tag*, *mpopt*)

Return element class modifiers for mathematical model elements.

```
mm_elements = mpx.mm_element_classes(mm_class, task_tag, mpopt)
```

#### Inputs

- **mm\_class** (*function handle*) – mathematical model constructor
- **task\_tag** (*char array*) – task tag, e.g. 'PF', 'CPF', 'OPF'
- **mpopt** (*struct*) – MATPOWER options struct

#### Output

**mm\_elements** (*cell array*) – element class modifiers (see `tab_element_class_modifiers` in the *MATPOWER Developer's Manual*)

## 3.7.2 OPF Fixed Zonal Reserves Extension

### mp.xt\_reserves

**class mp.xt\_reserves**

Bases: *mp.extension* (page 171)

*mp.xt\_reserves* (page 174) - MATPOWER extension for OPF with fixed zonal reserves.

For OPF problems, this extension adds two types of elements to the data and mathematical model containers, as well as the data model converter.

The 'reserve\_gen' element handles all of the per-generator aspects, such as reserve cost and quantity limit parameters, reserve variables, and constraints on reserve capacity.

The 'reserve\_zone' element handles the per-zone aspects, such as generator/zone mappings, zonal reserve requirement parameters and constraints, and zonal reserve prices.

#### mp.xt\_reserves Methods:

- *dmc\_element\_classes*() (page 174) - add two classes to data model converter elements
- *dm\_element\_classes*() (page 174) - add two classes to data model elements
- *mm\_element\_classes*() (page 175) - add two classes to mathematical model elements

See the `sec_customizing` and `sec_extensions` sections in the *MATPOWER Developer's Manual* for more information, and specifically the `sec_element_classes` section and the `tab_element_class_modifiers` table for details on *element class modifiers*.

See also *mp.extension* (page 171).

#### Method Summary

**dmc\_element\_classes**(*dmc\_class*, *fmt*, *mpopt*)

Add two classes to data model converter elements.

For 'mpc2' data formats, adds the classes:

- *mp.dmce\_reserve\_gen\_mpc2* (page 175)
- *mp.dmce\_reserve\_zone\_mpc2* (page 176)

**dm\_element\_classes**(*dm\_class, task\_tag, mpopt*)

Add two classes to data model elements.

For 'OPF' tasks, adds the classes:

- *mp.dme\_reserve\_gen* (page 176)
- *mp.dme\_reserve\_zone* (page 177)

**mm\_element\_classes**(*mm\_class, task\_tag, mpopt*)

Add two classes to mathematical model elements.

For 'OPF' tasks, adds the classes:

- *mp.mme\_reserve\_gen* (page 178)
- *mp.mme\_reserve\_zone* (page 179)

Other classes belonging to *mp.xt\_reserves* (page 174) extension:

### **mp.dmce\_reserve\_gen\_mpc2**

**class** *mp.dmce\_reserve\_gen\_mpc2*

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_reserve\_gen\_mpc2* (page 175) - Data model converter element for reserve generator for MATPOWER case v2.

#### **Method Summary**

**name**()

**data\_field**()

**data\_subs**()

**get\_import\_size**(*mpc*)

**get\_export\_size**(*dme*)

**table\_var\_map**(*dme, mpc*)

**import\_cost**(*mpc, spec, vn*)

**import\_qty**(*mpc, spec, vn*)

**import\_ramp**(*mpc, spec, vn*)

**import**(*dme, mpc, varargin*)

### mp.dmce\_reserve\_zone\_mpc2

**class** mp.dmce\_reserve\_zone\_mpc2

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_reserve\_zone\_mpc2* (page 176) - Data model converter element for reserve zone for MATPOWER case v2.

#### Method Summary

**name()**  
**data\_field()**  
**data\_subs()**  
**table\_var\_map**(*dme, mpc*)  
**import\_req**(*mpc, spec, vn*)  
**import\_zones**(*mpc, spec, vn*)

### mp.dme\_reserve\_gen

**class** mp.dme\_reserve\_gen

Bases: *mp.dm\_element* (page 36), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_reserve\_gen* (page 176) - Data model element for reserve generator.

Implements the data element model for reserve generator elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
gen	<i>integer</i>	ID (uid) of corresponding generator
cost	<i>double</i>	reserve cost ( $u/MW$ ) <sup>1</sup>
qty	<i>double</i>	available reserve quantity ( $MW$ )
ramp10	<i>double</i>	10-minute ramp rate ( $MW$ )
r	<i>double</i>	$r$ , reserve allocation ( $MW$ )
r_lb	<i>double</i>	lower bound on reserve allocation ( $MW$ )
r_ub	<i>double</i>	upper bound on reserve allocation ( $MW$ )
total_cost	<i>double</i>	total cost of allocated reserves ( $u$ ) <sup>1</sup>
prc	<i>double</i>	reserve price ( $u/MVA_r$ ) <sup>1</sup>
mu_lb	<i>double</i>	shadow price on $r$ lower bound ( $u/MW$ ) <sup>1</sup>
mu_ub	<i>double</i>	shadow price on $r$ upper bound ( $u/MW$ ) <sup>1</sup>
mu_pg_ub	<i>double</i>	shadow price on capacity constraint ( $u/MW$ ) <sup>1</sup>

#### Property Summary

**gen**  
 index of online gens (for online reserve gens)

---

<sup>1</sup> Here  $u$  denotes the units of the objective function, e.g. USD.

**r\_ub**

upper bound on reserve qty (p.u.) for units that are on

**Method Summary****name()****label()****labels()****main\_table\_var\_names()****export\_vars()****export\_vars\_offline\_val()****update\_status(dm)****build\_params(dm)****pp\_have\_section\_sum(mpop, pp\_args)****pp\_data\_sum(dm, rows, out\_e, pop, fd, pp\_args)****pp\_have\_section\_det(mpop, pp\_args)****pp\_get\_headers\_det(dm, out\_e, pop, pp\_args)****pp\_data\_row\_det(dm, k, out\_e, pop, fd, pp\_args)****pp\_have\_section\_lim(mpop, pp\_args)****pp\_binding\_rows\_lim(dm, out\_e, pop, pp\_args)****pp\_get\_headers\_lim(dm, out\_e, pop, pp\_args)****pp\_data\_row\_lim(dm, k, out\_e, pop, fd, pp\_args)****pp\_get\_footers\_det(dm, out\_e, pop, pp\_args)****mp.dme\_reserve\_zone****class mp.dme\_reserve\_zone**Bases: *mp.dm\_element* (page 36), *mp.dme\_shared\_opf* (page 59)*mp.dme\_reserve\_zone* (page 177) - Data model element for reserve zone.

Implements the data element model for reserve zone elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
req	double	zonal reserve requirement (MW)
zones	integer	matrix defining generators included in the zone
prc	double	zonal reserve price (u/MW) <sup>1</sup>

**Property Summary****zones**zone map for online *zones* (page 178) / gens**req**

reserve requirement in p.u. for each active zone

**Method Summary****name()****label()****labels()****main\_table\_var\_names()****export\_vars()****export\_vars\_offline\_val()****update\_status(*dm*)****build\_params(*dm*)****pp\_have\_section\_det(*mpopt, pp\_args*)****pp\_get\_headers\_det(*dm, out\_e, mpopt, pp\_args*)****pp\_data\_row\_det(*dm, k, out\_e, mpopt, fd, pp\_args*)****mp.mme\_reserve\_gen****class mp.mme\_reserve\_gen**Bases: *mp.mm\_element* (page 144)*mp.mme\_reserve\_gen* (page 178) - Mathematical model element for reserve generator.

Math model element class for reserve generator elements.

Implements methods for adding reserve variables, costs, and per-generator reserve constraints, and for updating the output data in the corresponding data model element for in-service reserve generators from the math model solution.

**Method Summary****name()****add\_vars(*mm, nm, dm, mpopt*)****add\_costs(*mm, nm, dm, mpopt*)****add\_constraints(*mm, nm, dm, mpopt*)****data\_model\_update\_on(*mm, nm, dm, mpopt*)**

---

<sup>1</sup> Here *u* denotes the units of the objective function, e.g. USD.

## mp.mme\_reserve\_zone

### class mp.mme\_reserve\_zone

Bases: *mp.mm\_element* (page 144)

*mp.mme\_reserve\_zone* (page 179) - Mathematical model element for reserve zone.

Math model element class for reserve zone elements.

Implements methods for adding reserve zone constraints, and for updating the output data in the corresponding data model element for in-service reserve zones from the math model solution.

#### Method Summary

**name()**

**add\_constraints**(*mm, nm, dm, mpopt*)

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

## 3.7.3 Three-Phase Prototype Extension

### mp.xt\_3p

#### class mp.xt\_3p

Bases: *mp.extension* (page 171)

*mp.xt\_3p* (page 179) - MATPOWER extension to add unbalanced three-phase elements.

For AC power flow, continuation power flow, and optimal power flow problems, adds six new element types:

- 'bus3p' - 3-phase bus
- 'gen3p' - 3-phase generator
- 'load3p' - 3-phase load
- 'line3p' - 3-phase distribution line
- 'xfmr3p' - 3-phase transformer
- 'buslink' - 3-phase to single phase linking element

No changes are required for the task or container classes, so only the `..._element_classes` methods are overridden.

The set of data model element classes depends on the task, with each OPF class inheriting from the corresponding class used for PF and CPF.

The set of network model element classes depends on the formulation, specifically whether cartesian or polar representations are used for voltages.

And the set of mathematical model element classes depends on both the task and the formulation.

#### mp.xt\_3p Methods:

- *dmc\_element\_classes()* (page 180) - add six classes to data model converter elements
- *dm\_element\_classes()* (page 180) - add six classes to data model elements

- `nm_element_classes()` (page 180) - add six classes to network model elements
- `mm_element_classes()` (page 181) - add six classes to mathematical model elements

See the `sec_customizing` and `sec_extensions` sections in the *MATPOWER Developer's Manual* for more information, and specifically the `sec_element_classes` section and the `tab_element_class_modifiers` table for details on *element class modifiers*.

See also `mp.extension` (page 171).

### Method Summary

#### **dmc\_element\_classes**(*dmc\_class, fmt, mpopt*)

Add six classes to data model converter elements.

For 'mpc2' data formats, adds the classes:

- `mp.dmce_bus3p_mpc2` (page 181)
- `mp.dmce_gen3p_mpc2` (page 181)
- `mp.dmce_load3p_mpc2` (page 182)
- `mp.dmce_line3p_mpc2` (page 182)
- `mp.dmce_xfmr3p_mpc2` (page 183)
- `mp.dmce_buslink_mpc2` (page 183)

#### **dm\_element\_classes**(*dm\_class, task\_tag, mpopt*)

Add six classes to data model elements.

For 'PF' and 'CPF' tasks, adds the classes:

- `mp.dme_bus3p` (page 183)
- `mp.dme_gen3p` (page 185)
- `mp.dme_load3p` (page 186)
- `mp.dme_line3p` (page 188)
- `mp.dme_xfmr3p` (page 190)
- `mp.dme_buslink` (page 191)

For 'OPF' tasks, adds the classes:

- `mp.dme_bus3p_opf` (page 192)
- `mp.dme_gen3p_opf` (page 192)
- `mp.dme_load3p_opf` (page 193)
- `mp.dme_line3p_opf` (page 193)
- `mp.dme_xfmr3p_opf` (page 193)
- `mp.dme_buslink_opf` (page 193)

#### **nm\_element\_classes**(*nm\_class, task\_tag, mpopt*)

Add six classes to network model elements.

For *cartesian* voltage formulations, adds the classes:

- `mp.nme_bus3p_acc` (page 194)
- `mp.nme_gen3p_acc` (page 195)
- `mp.nme_load3p` (page 195)
- `mp.nme_line3p` (page 196)
- `mp.nme_xfmr3p` (page 196)
- `mp.nme_buslink_acc` (page 197)

For *polar* voltage formulations, adds the classes:

- `mp.nme_bus3p_acp` (page 194)
- `mp.nme_gen3p_acp` (page 195)
- `mp.nme_load3p` (page 195)
- `mp.nme_line3p` (page 196)
- `mp.nme_xfmr3p` (page 196)
- `mp.nme_buslink_acp` (page 197)

**mm\_element\_classes**(*mm\_class, task\_tag, mpop*)

Add five classes to mathematical model elements.

For 'PF' and 'CPF' tasks, adds the classes:

- *mp.mme\_bus3p* (page 197)
- *mp.mme\_gen3p* (page 198)
- *mp.mme\_line3p* (page 198)
- *mp.mme\_xfmr3p* (page 198)
- *mp.mme\_buslink\_pf\_acc* (page 199) (*cartesian*) or *mp.mme\_buslink\_pf\_acp* (page 200) (*polar*)

For 'OPF' tasks, adds the classes:

- *mp.mme\_bus3p\_opf\_acc* (page 200) (*cartesian*) or *mp.mme\_bus3p\_opf\_acp* (page 200) (*polar*)
- *mp.mme\_gen3p\_opf* (page 201)
- *mp.mme\_line3p\_opf* (page 201)
- *mp.mme\_xfmr3p\_opf* (page 201)
- *mp.mme\_buslink\_opf\_acc* (page 202) (*cartesian*) or *mp.mme\_buslink\_opf\_acp* (page 202) (*polar*)

**Data model converter element classes belonging to *mp.xt\_3p* (page 179) extension:**

### **mp.dmce\_bus3p\_mpc2**

**class** *mp.dmce\_bus3p\_mpc2*

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_bus3p\_mpc2* (page 181) - Data model converter element for 3-phase bus for MATPOWER case v2.

#### **Method Summary**

**name**()

**data\_field**()

**table\_var\_map**(*dme, mpc*)

**bus\_status\_import**(*mpc, spec, vn, c*)

### **mp.dmce\_gen3p\_mpc2**

**class** *mp.dmce\_gen3p\_mpc2*

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_gen3p\_mpc2* (page 181) - Data model converter element for 3-phase generator for MATPOWER case v2.

#### **Method Summary**

**name**()

**data\_field**()



`table_var_map(dme, mpc)`

### **mp.dmce\_load3p\_mpc2**

**class** `mp.dmce_load3p_mpc2`

Bases: `mp.dmc_element` (page 63)

`mp.dmce_load3p_mpc2` (page 182) - Data model converter element for 3-phase load for MATPOWER case v2.

#### **Property Summary**

**bus**

#### **Method Summary**

**name()**

**data\_field()**

**table\_var\_map(dme, mpc)**

### **mp.dmce\_line3p\_mpc2**

**class** `mp.dmce_line3p_mpc2`

Bases: `mp.dmc_element` (page 63)

`mp.dmce_line3p_mpc2` (page 182) - Data model converter element for 3-phase line for MATPOWER case v2.

#### **Method Summary**

**name()**

**data\_field()**

**table\_var\_map(dme, mpc)**

**create\_line\_construction\_table(dme, lc)**

**import(dme, mpc, varargin)**

**mp.dmce\_xfmr3p\_mpc2****class** mp.dmce\_xfmr3p\_mpc2Bases: *mp.dmc\_element* (page 63)*mp.dmce\_xfmr3p\_mpc2* (page 183) - Data model converter element for 3-phase transformer for MATPOWER case v2.**Method Summary****name()****data\_field()****table\_var\_map**(*dme, mpc*)**mp.dmce\_buslink\_mpc2****class** mp.dmce\_buslink\_mpc2Bases: *mp.dmc\_element* (page 63)*mp.dmce\_buslink\_mpc2* (page 183) - Data model converter element for 1-to-3-phase buslink for MATPOWER case v2.**Method Summary****name()****data\_field()****table\_var\_map**(*dme, mpc*)**Data model element classes belonging to *mp.xt\_3p* (page 179) extension:****mp.dme\_bus3p****class** mp.dme\_bus3pBases: *mp.dm\_element* (page 36)*mp.dme\_bus3p* (page 183) - Data model element for 3-phase bus.

Implements the data element model for 3-phase bus elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>type</code>	<i>integer</i>	bus type (1 = PQ, 2 = PV, 3 = ref, 4 = isolated)
<code>base_kv</code>	<i>double</i>	base voltage ( <i>kV</i> )
<code>vm1</code>	<i>double</i>	phase 1 voltage magnitude ( <i>p.u.</i> )
<code>vm2</code>	<i>double</i>	phase 2 voltage magnitude ( <i>p.u.</i> )
<code>vm3</code>	<i>double</i>	phase 3 voltage magnitude ( <i>p.u.</i> )
<code>va1</code>	<i>double</i>	phase 1 voltage angle ( <i>degrees</i> )
<code>va2</code>	<i>double</i>	phase 2 voltage angle ( <i>degrees</i> )
<code>va3</code>	<i>double</i>	phase 3 voltage angle ( <i>degrees</i> )

### Property Summary

#### `type`

node *type* (page 184) vector for buses that are on

#### `vm1_start`

initial phase 1 voltage magnitudes (*p.u.*) for buses that are on

#### `vm2_start`

initial phase 2 voltage magnitudes (*p.u.*) for buses that are on

#### `vm3_start`

initial phase 3 voltage magnitudes (*p.u.*) for buses that are on

#### `va1_start`

initial phase 1 voltage angles (radians) for buses that are on

#### `va2_start`

initial phase 2 voltage angles (radians) for buses that are on

#### `va3_start`

initial phase 3 voltage angles (radians) for buses that are on

#### `vm_control`

true if voltage is controlled, for buses that are on

### Method Summary

`name()`

`label()`

`labels()`

`main_table_var_names()`

`init_status(dm)`

`update_status(dm)`

`build_params(dm)`

`pp_have_section_det(mppopt, pp_args)`

`pp_get_headers_det(dm, out_e, mppopt, pp_args)`

`pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)`

## mp.dme\_gen3p

### class mp.dme\_gen3p

Bases: *mp.dm\_element* (page 36)

*mp.dme\_gen3p* (page 185) - Data model element for 3-phase generator.

Implements the data element model for 3-phase generator elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus</code>	<i>integer</i>	bus ID (uid) of 3-phase bus
<code>vm1_setpoint</code>	<i>double</i>	phase 1 voltage magnitude setpoint ( <i>p.u.</i> )
<code>vm2_setpoint</code>	<i>double</i>	phase 2 voltage magnitude setpoint ( <i>p.u.</i> )
<code>vm3_setpoint</code>	<i>double</i>	phase 3 voltage magnitude setpoint ( <i>p.u.</i> )
<code>pg1</code>	<i>double</i>	phase 1 active power output ( <i>kW</i> )
<code>pg2</code>	<i>double</i>	phase 2 active power output ( <i>kW</i> )
<code>pg3</code>	<i>double</i>	phase 3 active power output ( <i>kW</i> )
<code>qg1</code>	<i>double</i>	phase 1 reactive power output ( <i>kVAr</i> )
<code>qg2</code>	<i>double</i>	phase 2 reactive power output ( <i>kVAr</i> )
<code>qg3</code>	<i>double</i>	phase 3 reactive power output ( <i>kVAr</i> )

### Property Summary

#### **bus**

*bus* (page 185) index vector (all gens)

#### **bus\_on**

vector of indices into online buses for gens that are on

#### **pg1\_start**

initial phase 1 active power (p.u.) for gens that are on

#### **pg2\_start**

initial phase 2 active power (p.u.) for gens that are on

#### **pg3\_start**

initial phase 3 active power (p.u.) for gens that are on

#### **qg1\_start**

initial phase 1 reactive power (p.u.) for gens that are on

#### **qg2\_start**

initial phase 2 reactive power (p.u.) for gens that are on

#### **qg3\_start**

initial phase 3 reactive power (p.u.) for gens that are on

#### **vm1\_setpoint**

phase 1 generator voltage setpoint for gens that are on

**vm2\_setpoint**

phase 2 generator voltage setpoint for gens that are on

**vm3\_setpoint**

phase 3 generator voltage setpoint for gens that are on

**Method Summary**

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**initialize(dm)**

**update\_status(dm)**

**apply\_vm\_setpoint(dm)**

**build\_params(dm)**

**pp\_have\_section\_sum(mpop, pp\_args)**

**pp\_data\_sum(dm, rows, out\_e, mpop, fd, pp\_args)**

**pp\_have\_section\_det(mpop, pp\_args)**

**pp\_get\_headers\_det(dm, out\_e, mpop, pp\_args)**

**pp\_data\_row\_det(dm, k, out\_e, mpop, fd, pp\_args)**

**mp.dme\_load3p**

**class mp.dme\_load3p**

Bases: [mp.dm\\_element](#) (page 36)

[mp.dme\\_load3p](#) (page 186) - Data model element for 3-phase load.

Implements the data element model for 3-phase load elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
bus	<i>integer</i>	bus ID (uid) of 3-phase bus
pd1	<i>double</i>	phase 1 active power demand ( <i>kW</i> )
pd2	<i>double</i>	phase 2 active power demand ( <i>kW</i> )
pd3	<i>double</i>	phase 3 active power demand ( <i>kW</i> )
pf1	<i>double</i>	phase 1 power factor
pf2	<i>double</i>	phase 2 power factor
pf3	<i>double</i>	phase 3 power factor

**Property Summary****bus***bus* (page 187) index vector (all loads)**pd1**

phase 1 active power demand (p.u.) for loads that are on

**pd2**

phase 2 active power demand (p.u.) for loads that are on

**pd3**

phase 3 active power demand (p.u.) for loads that are on

**pf1**

phase 1 power factor for loads that are on

**pf2**

phase 2 power factor for loads that are on

**pf3**

phase 3 power factor for loads that are on

**Method Summary****name()****label()****labels()****cxn\_type()****cxn\_idx\_prop()****main\_table\_var\_names()****initialize(*dm*)****update\_status(*dm*)****build\_params(*dm*)****pp\_have\_section\_sum(*mpopt*, *pp\_args*)****pp\_data\_sum(*dm*, *rows*, *out\_e*, *mpopt*, *fd*, *pp\_args*)****pp\_have\_section\_det(*mpopt*, *pp\_args*)****pp\_get\_headers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)****pp\_data\_row\_det(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

**mp.dme\_line3p**

**class mp.dme\_line3p**

Bases: *mp.dm\_element* (page 36)

*mp.dme\_line3p* (page 188) - Data model element for 3-phase line.

Implements the data element model for 3-phase distribution line elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus_fr</code>	<i>integer</i>	bus ID ( <code>uid</code> ) of “from” 3-phase bus
<code>bus_to</code>	<i>integer</i>	bus ID ( <code>uid</code> ) of “to” 3-phase bus
<code>lc</code>	<i>double</i>	index into line construction table
<code>len</code>	<i>double</i>	line length ( <i>miles</i> )
<code>p11_fr</code>	<i>double</i>	phase 1 active power injection at “from” end ( <i>kW</i> )
<code>q11_fr</code>	<i>double</i>	phase 1 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p12_fr</code>	<i>double</i>	phase 2 active power injection at “from” end ( <i>kW</i> )
<code>q12_fr</code>	<i>double</i>	phase 2 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p13_fr</code>	<i>double</i>	phase 3 active power injection at “from” end ( <i>kW</i> )
<code>q13_fr</code>	<i>double</i>	phase 3 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p11_to</code>	<i>double</i>	phase 1 active power injection at “to” end ( <i>kW</i> )
<code>q11_to</code>	<i>double</i>	phase 1 reactive power injection at “to” end ( <i>kVAr</i> )
<code>p12_to</code>	<i>double</i>	phase 2 active power injection at “to” end ( <i>kW</i> )
<code>q12_to</code>	<i>double</i>	phase 2 reactive power injection at “to” end ( <i>kVAr</i> )
<code>p13_to</code>	<i>double</i>	phase 3 active power injection at “to” end ( <i>kW</i> )
<code>q13_to</code>	<i>double</i>	phase 3 reactive power injection at “to” end ( <i>kVAr</i> )

The line construction table in the `lc_tab` property is defined as a table with the following columns:

Name	Type	Description
<code>id</code>	<i>integer</i>	unique line construction ID, referenced from <code>lc</code> column of main data table
<code>r</code>	<i>double</i>	6 resistance parameters for forming symmetric 3x3 series impedance matrix ( <i>p.u. per mile</i> )
<code>x</code>	<i>double</i>	6 reactance parameters for forming symmetric 3x3 series impedance matrix ( <i>p.u. per mile</i> )
<code>c</code>	<i>double</i>	6 susceptance parameters for forming symmetric 3x3 shunt susceptance matrix ( <i>nF per mile</i> )

**Property Summary**

**fbus**

bus index vector for “from” bus (all lines)

**tbus**

bus index vector for “to” bus (all lines)

**freq**

system frequency, in Hz

**lc**  
index into `lc_tab` for lines that are on

**len**  
length for lines that are on

**lc\_tab**  
line construction table

**ys**  
cell array of 3x3 series admittance matrices for lc rows

**yc**  
cell array of 3x3 shunt admittance matrices for lc rows

### Method Summary

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**lc\_table\_var\_names()**

**create\_line\_construction\_table(*id, r, x, c*)**

**initialize(*dm*)**

**update\_status(*dm*)**

**build\_params(*dm*)**

**vec2symmat(*v*)**  
Make a symmetric matrix from a vector of 6 values.

**symmat2vec(*M*)**  
Extract a vector of 6 values from a matrix assumed to be symmetric.

**pretty\_print(*dm, section, out\_e, mpopt, fd, pp\_args*)**

**pp\_have\_section\_sum(*mpopt, pp\_args*)**

**pp\_data\_sum(*dm, rows, out\_e, mpopt, fd, pp\_args*)**

**pp\_have\_section\_det(*mpopt, pp\_args*)**

**pp\_get\_headers\_det(*dm, out\_e, mpopt, pp\_args*)**

**pp\_data\_row\_det(*dm, k, out\_e, mpopt, fd, pp\_args*)**



**mp.dme\_xfmr3p****class mp.dme\_xfmr3p**

Bases: *mp.dm\_element* (page 36)

*mp.dme\_xfmr3p* (page 190) - Data model element for 3-phase transformer.

Implements the data element model for 3-phase transformer elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus_fr</code>	<i>integer</i>	bus ID (uid) of “from” 3-phase bus
<code>bus_to</code>	<i>integer</i>	bus ID (uid) of “to” 3-phase bus
<code>r</code>	<i>double</i>	series resistance ( <i>p.u.</i> )
<code>x</code>	<i>double</i>	series reactance ( <i>p.u.</i> )
<code>base_kva</code>	<i>double</i>	transformer kVA base ( <i>kVA</i> )
<code>base_kv</code>	<i>double</i>	transformer kV base ( <i>kV</i> )
<code>p11_fr</code>	<i>double</i>	phase 1 active power injection at “from” end ( <i>kW</i> )
<code>q11_fr</code>	<i>double</i>	phase 1 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p12_fr</code>	<i>double</i>	phase 2 active power injection at “from” end ( <i>kW</i> )
<code>q12_fr</code>	<i>double</i>	phase 2 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p13_fr</code>	<i>double</i>	phase 3 active power injection at “from” end ( <i>kW</i> )
<code>q13_fr</code>	<i>double</i>	phase 3 reactive power injection at “from” end ( <i>kVAr</i> )
<code>p11_to</code>	<i>double</i>	phase 1 active power injection at “to” end ( <i>kW</i> )
<code>q11_to</code>	<i>double</i>	phase 1 reactive power injection at “to” end ( <i>kVAr</i> )
<code>p12_to</code>	<i>double</i>	phase 2 active power injection at “to” end ( <i>kW</i> )
<code>q12_to</code>	<i>double</i>	phase 2 reactive power injection at “to” end ( <i>kVAr</i> )
<code>p13_to</code>	<i>double</i>	phase 3 active power injection at “to” end ( <i>kW</i> )
<code>q13_to</code>	<i>double</i>	phase 3 reactive power injection at “to” end ( <i>kVAr</i> )

**Property Summary****fbus**

bus index vector for “from” bus (all transformers)

**tbus**

bus index vector for “to” bus (all transformers)

**r**

series resistance (*p.u.*) for transformers that are on

**x**

series reactance (*p.u.*) for transformers that are on

**Method Summary**

`name()`

`label()`

`labels()`

`cxn_type()`

`cxn_idx_prop()`

```

main_table_var_names()
initialize(dm)
update_status(dm)
build_params(dm)
pretty_print(dm, section, out_e, mpopt, fd, pp_args)
pp_have_section_sum(mpopt, pp_args)
pp_data_sum(dm, rows, out_e, mpopt, fd, pp_args)
pp_have_section_det(mpopt, pp_args)
pp_get_headers_det(dm, out_e, mpopt, pp_args)
pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)

```

### mp.dme\_buslink

**class** `mp.dme_buslink`

Bases: `mp.dm_element` (page 36)

`mp.dme_buslink` (page 191) - Data model element for 1-to-3-phase buslink.

Implements the data element model for 1-to-3-phase buslink elements.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus</code>	<i>integer</i>	bus ID ( <code>uid</code> ) of single phase bus
<code>bus3p</code>	<i>integer</i>	bus ID ( <code>uid</code> ) of 3-phase bus

### Property Summary

#### **bus**

`bus` (page 191) index vector (all buslinks)

#### **bus3p**

`bus3p` (page 191) index vector (all buslinks)

#### **pg1\_start**

initial phase 1 active power (p.u.) for buslinks that are on

#### **pg2\_start**

initial phase 2 active power (p.u.) for buslinks that are on

#### **pg3\_start**

initial phase 3 active power (p.u.) for buslinks that are on

#### **qg1\_start**

initial phase 1 reactive power (p.u.) for buslinks that are on

**qg2\_start**

initial phase 2 reactive power (p.u.) for buslinks that are on

**qg3\_start**

initial phase 3 reactive power (p.u.) for buslinks that are on

### Method Summary

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**initialize(*dm*)**

**update\_status(*dm*)**

**build\_params(*dm*)**

**pp\_have\_section\_det(*mpopt*, *pp\_args*)**

**pp\_get\_headers\_det(*dm*, *out\_e*, *mpopt*, *pp\_args*)**

**pp\_data\_row\_det(*dm*, *k*, *out\_e*, *mpopt*, *fd*, *pp\_args*)**

### **mp.dme\_bus3p\_opf**

**class mp.dme\_bus3p\_opf**

Bases: [mp.dme\\_bus3p](#) (page 183), [mp.dme\\_shared\\_opf](#) (page 59)

[mp.dme\\_bus3p\\_opf](#) (page 192) - Data model element for 3-phase bus for OPF.

To parent class [mp.dme\\_bus3p](#) (page 183), adds pretty-printing for **lim** sections.

### **mp.dme\_gen3p\_opf**

**class mp.dme\_gen3p\_opf**

Bases: [mp.dme\\_gen3p](#) (page 185), [mp.dme\\_shared\\_opf](#) (page 59)

[mp.dme\\_gen3p\\_opf](#) (page 192) - Data model element for 3-phase generator for OPF.

To parent class [mp.dme\\_gen3p](#) (page 185), adds pretty-printing for **lim** sections.

**mp.dme\_load3p\_opf****class mp.dme\_load3p\_opf**

Bases: *mp.dme\_load3p* (page 186), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_load3p\_opf* (page 193) - Data model element for 3-phase load for OPF.

To parent class *mp.dme\_load3p* (page 186), adds pretty-printing for **lim** sections.

**mp.dme\_line3p\_opf****class mp.dme\_line3p\_opf**

Bases: *mp.dme\_line3p* (page 188), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_line3p\_opf* (page 193) - Data model element for 3-phase line for OPF.

To parent class *mp.dme\_line3p* (page 188), adds pretty-printing for **lim** sections.

**mp.dme\_xfmr3p\_opf****class mp.dme\_xfmr3p\_opf**

Bases: *mp.dme\_xfmr3p* (page 190), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_xfmr3p\_opf* (page 193) - Data model element for 3-phase transformer for OPF.

To parent class *mp.dme\_xfmr3p* (page 190), adds pretty-printing for **lim** sections.

**mp.dme\_buslink\_opf****class mp.dme\_buslink\_opf**

Bases: *mp.dme\_buslink* (page 191), *mp.dme\_shared\_opf* (page 59)

*mp.dme\_buslink\_opf* (page 193) - Data model element for 1-to-3-phase buslink for OPF.

To parent class *mp.dme\_buslink* (page 191), adds pretty-printing for **lim** sections.

Network model element classes belonging to *mp.xt\_3p* (page 179) extension:

**mp.nme\_bus3p****class mp.nme\_bus3p**

Bases: *mp.nm\_element* (page 108)

*mp.nme\_bus3p* (page 193) - Network model element abstract base class for 3-phase bus.

Implements the network model element for 3-phase bus elements, with 3 nodes per 3-phase bus.

Implements *node\_types()* (page 194) method.

**Method Summary**

`name()`

`nn()`

`node_types(nm, dm, idx)`

```
ntv = nme.node_types(nm, dm, idx)
[ref, pv, pq] = nme.node_types(nm, dm, idx)
```

Called by the `node_types()` (page 99) method of `mp.net_model` (page 91).

### `mp.nme_bus3p_acc`

**class** `mp.nme_bus3p_acc`

Bases: `mp.nme_bus3p` (page 193), `mp.form_acc` (page 83)

`mp.nme_bus3p_acc` (page 194) - Network model element for 3-phase bus, AC cartesian voltage formulation.

Adds voltage variables  $V_{r3}$  and  $V_{i3}$  to the network model and inherits from `mp.form_acc` (page 83).

#### Method Summary

`add_vvars(nm, dm, idx)`

### `mp.nme_bus3p_acp`

**class** `mp.nme_bus3p_acp`

Bases: `mp.nme_bus3p` (page 193), `mp.form_acp` (page 87)

`mp.nme_bus3p_acp` (page 194) - Network model element for 3-phase bus, AC polar voltage formulation.

Adds voltage variables  $V_{a3}$  and  $V_{m3}$  to the network model and inherits from `mp.form_acp` (page 87).

#### Method Summary

`add_vvars(nm, dm, idx)`

### `mp.nme_gen3p`

**class** `mp.nme_gen3p`

Bases: `mp.nm_element` (page 108)

`mp.nme_gen3p` (page 194) - Network model element abstract base class for 3-phase generator.

Implements the network model element for 3-phase generator elements, with 3 ports and 3 non-voltage states per 3-phase generator.

Adds non-voltage state variables  $P_{g3}$  and  $Q_{g3}$  to the network model and builds the parameter  $\underline{N}$ .

**Method Summary**

**name()**  
**np()**  
**nz()**  
**add\_zvars**(*nm, dm, idx*)  
**build\_params**(*nm, dm*)

**mp.nme\_gen3p\_acc****class mp.nme\_gen3p\_acc**

Bases: *mp.nme\_gen3p* (page 194), *mp.form\_acc* (page 83)

*mp.nme\_gen3p\_acc* (page 195) - Network model element for 3-phase generator, AC cartesian voltage formulation.

Inherits from *mp.form\_acc* (page 83).

**mp.nme\_gen3p\_acp****class mp.nme\_gen3p\_acp**

Bases: *mp.nme\_gen3p* (page 194), *mp.form\_acp* (page 87)

*mp.nme\_gen3p\_acp* (page 195) - Network model element for 3-phase generator, AC polar voltage formulation.

Inherits from *mp.form\_acp* (page 87).

**mp.nme\_load3p****class mp.nme\_load3p**

Bases: *mp.nm\_element* (page 108), *mp.form\_acp* (page 87)

*mp.nme\_load3p* (page 195) - Network model element for 3-phase load.

Implements the network model element for 3-phase load elements, with 3 ports per 3-phase load.

Builds the parameter *s* and inherits from *mp.form\_acp* (page 87).

**Method Summary**

**name()**  
**np()**  
**build\_params**(*nm, dm*)

## mp.nme\_line3p

### class mp.nme\_line3p

Bases: *mp.nm\_element* (page 108), *mp.form\_acp* (page 87)

*mp.nme\_line3p* (page 196) - Network model element for 3-phase line.

Implements the network model element for 3-phase line elements, with 6 ports per 3-phase line.

Implements building of the admittance parameter  $\underline{Y}$  for 3-phase lines and inherits from *mp.form\_acp* (page 87).

#### Method Summary

**name()**

**np()**

**build\_params**(*nm, dm*)

**vec2symmat\_stacked**(*vv*)

## mp.nme\_xfmr3p

### class mp.nme\_xfmr3p

Bases: *mp.nm\_element* (page 108), *mp.form\_acp* (page 87)

*mp.nme\_xfmr3p* (page 196) - Network model element for 3-phase transformer.

Implements the network model element for 3-phase transformer elements, with 6 ports per transformer.

Implements building of the admittance parameter  $\underline{Y}$  for 3-phase transformers and inherits from *mp.form\_acp* (page 87).

#### Method Summary

**name()**

**np()**

**build\_params**(*nm, dm*)

## mp.nme\_buslink

### class mp.nme\_buslink

Bases: *mp.nm\_element* (page 108)

*mp.nme\_buslink* (page 196) - Network model element abstract base class for 1-to-3-phase buslink.

Implements the network model element for 1-to-3-phase buslink elements, with 4 ports and 3 non-voltage states per buslink.

Adds non-voltage state variables  $\underline{Plink}$  and  $\underline{Qlink}$  to the network model, builds the parameter  $\underline{N}$ , and constructs voltage constraints.

**Method Summary**

**name()**  
**np()**  
**nz()**  
**add\_zvars**(*nm, dm, idx*)  
**build\_params**(*nm, dm*)  
**voltage\_constraints()**

**mp.nme\_buslink\_acc**

**class** mp.nme\_buslink\_acc

Bases: *mp.nme\_buslink* (page 196), *mp.form\_acc* (page 83)

*mp.nme\_buslink\_acc* (page 197) - Network model element for 1-to-3-phase buslink, AC cartesian voltage formulation.

Inherits from *mp.form\_acc* (page 83).

**mp.nme\_buslink\_acp**

**class** mp.nme\_buslink\_acp

Bases: *mp.nme\_buslink* (page 196), *mp.form\_acp* (page 87)

*mp.nme\_buslink\_acp* (page 197) - Network model element for 1-to-3-phase buslink, AC polar voltage formulation.

Inherits from *mp.form\_acp* (page 87).

**Mathematical model element classes belonging to *mp.xt\_3p* (page 179) extension:**

**mp.mme\_bus3p**

**class** mp.mme\_bus3p

Bases: *mp.mm\_element* (page 144)

*mp.mme\_bus3p* (page 197) - Math model element for 3-phase bus.

Math model element base class for 3-phase bus elements.

Implements method for updating the output data in the corresponding data model element for in-service 3-phase buses from the math model solution.

**Method Summary**

**name()**



`data_model_update_on(mm, nm, dm, mpop)`

### **mp.mme\_gen3p**

**class** `mp.mme_gen3p`

Bases: `mp.mm_element` (page 144)

`mp.mme_gen3p` (page 198) - Math model element for 3-phase generator.

Math model element base class for 3-phase generator elements.

Implements method for updating the output data in the corresponding data model element for in-service 3-phase generators from the math model solution.

#### **Method Summary**

`name()`

`data_model_update_on(mm, nm, dm, mpop)`

### **mp.mme\_line3p**

**class** `mp.mme_line3p`

Bases: `mp.mm_element` (page 144)

`mp.mme_line3p` (page 198) - Math model element for 3-phase line.

Math model element base class for 3-phase line elements.

Implements method for updating the output data in the corresponding data model element for in-service 3-phase lines from the math model solution.

#### **Method Summary**

`name()`

`data_model_update_on(mm, nm, dm, mpop)`

### **mp.mme\_xfmr3p**

**class** `mp.mme_xfmr3p`

Bases: `mp.mm_element` (page 144)

`mp.mme_xfmr3p` (page 198) - Math model element for 3-phase transformer.

Math model element base class for 3-phase transformer elements.

Implements method for updating the output data in the corresponding data model element for in-service 3-phase transformers from the math model solution.

#### **Method Summary**

**name()**

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

## mp.mme\_buslink

**class** mp.mme\_buslink

Bases: *mp.mm\_element* (page 144)

*mp.mme\_buslink* (page 199) - Math model element abstract base class for 1-to-3-phase buslink.

Abstract math model element base class for 1-to-3-phase buslink elements.

### Method Summary

**name()**

## mp.mme\_buslink\_pf\_ac

**class** mp.mme\_buslink\_pf\_ac

Bases: *mp.mme\_buslink* (page 199)

*mp.mme\_buslink\_pf\_ac* (page 199) - Math model element abstract base class for 1-to-3-phase buslink for AC PF/CPF.

Abstract math model element base class for 1-to-3-phase buslink elements for AC power flow and CPF problems.

Implements methods for adding per-phase active and reactive power variables and for forming and adding voltage and reactive power constraints.

### Method Summary

**add\_vars**(*mm, nm, dm, mpopt*)

**add\_constraints**(*mm, nm, dm, mpopt*)

**voltage\_constraints**(*nme, ad*)

## mp.mme\_buslink\_pf\_acc

**class** mp.mme\_buslink\_pf\_acc

Bases: *mp.mme\_buslink\_pf\_ac* (page 199)

*mp.mme\_buslink\_pf\_acc* (page 199) - Math model element for 1-to-3-phase buslink for AC cartesian voltage PF/CPF.

Math model element class for 1-to-3-phase buslink elements for AC cartesian power flow and CPF problems.

Implements methods for adding constraints to match voltages across each buslink.

**Method Summary**

**add\_constraints**(*mm, nm, dm, mpopt*)

**pf\_va\_fcn**(*nme, xx, A, b*)

**pf\_vm\_fcn**(*nme, xx, A, b*)

**mp.mme\_buslink\_pf\_acp**

**class** mp.mme\_buslink\_pf\_acp

Bases: [mp.mme\\_buslink\\_pf\\_ac](#) (page 199)

[mp.mme\\_buslink\\_pf\\_acp](#) (page 200) - Math model element for 1-to-3-phase buslink for AC polar voltage PF/CPF.

Math model element class for 1-to-3-phase buslink elements for AC polar power flow and CPF problems.

Implements method for adding constraints to match voltages across each buslink.

**Method Summary**

**add\_constraints**(*mm, nm, dm, mpopt*)

**mp.mme\_bus3p\_opf\_acc**

**class** mp.mme\_bus3p\_opf\_acc

Bases: [mp.mme\\_bus3p](#) (page 197)

[mp.mme\\_bus3p\\_opf\\_acc](#) (page 200) - Math model element for 3-phase bus for AC cartesian voltage OPF.

Math model element class for 3-phase bus elements for AC cartesian voltage OPF problems.

Implements method for forming an interior initial point.

**Method Summary**

**interior\_x0**(*mm, nm, dm, x0*)

**mp.mme\_bus3p\_opf\_acp**

**class** mp.mme\_bus3p\_opf\_acp

Bases: [mp.mme\\_bus3p](#) (page 197)

[mp.mme\\_bus3p\\_opf\\_acp](#) (page 200) - Math model element for 3-phase bus for AC polar voltage OPF.

Math model element class for 3-phase bus elements for AC polar voltage OPF problems.

Implements method for forming an interior initial point.

**Method Summary**

`interior_x0(mm, nm, dm, x0)`

### `mp.mme_gen3p_opf`

**class** `mp.mme_gen3p_opf`

Bases: `mp.mme_gen3p` (page 198)

`mp.mme_gen3p_opf` (page 201) - Math model element for 3-phase generator for OPF.

Math model element class for 1-to-3-phase generator elements for OPF problems.

Implements (currently empty) method for forming an interior initial point.

#### Method Summary

`interior_x0(mm, nm, dm, x0)`

### `mp.mme_line3p_opf`

**class** `mp.mme_line3p_opf`

Bases: `mp.mme_line3p` (page 198)

`mp.mme_line3p_opf` (page 201) - Math model element for 3-phase line for OPF.

Math model element class for 3-phase line elements for OPF problems.

Implements (currently empty) method for forming an interior initial point.

#### Method Summary

`interior_x0(mm, nm, dm, x0)`

### `mp.mme_xfmr3p_opf`

**class** `mp.mme_xfmr3p_opf`

Bases: `mp.mme_xfmr3p` (page 198)

`mp.mme_xfmr3p_opf` (page 201) - Math model element for 3-phase transformer for OPF.

Math model element class for 3-phase transformer elements for OPF problems.

Implements (currently empty) method for forming an interior initial point.

#### Method Summary

`interior_x0(mm, nm, dm, x0)`

### mp.mme\_buslink\_opf

#### class mp.mme\_buslink\_opf

Bases: [mp.mme\\_buslink](#) (page 199)

[mp.mme\\_buslink\\_opf](#) (page 202) - Math model element abstract base class for 1-to-3-phase buslink for OPF.

Abstract math model element base class for 1-to-3-phase buslink elements for OPF problems.

Implements (currently empty) method for forming an interior initial point.

#### Method Summary

**interior\_x0**(*mm, nm, dm, x0*)

### mp.mme\_buslink\_opf\_acc

#### class mp.mme\_buslink\_opf\_acc

Bases: [mp.mme\\_buslink\\_opf](#) (page 202)

[mp.mme\\_buslink\\_opf\\_acc](#) (page 202) - Math model element for 1-to-3-phase buslink for AC cartesian voltage OPF.

Math model element class for 1-to-3-phase buslink elements for AC cartesian OPF problems.

Implements methods for adding constraints to match voltages across each buslink.

#### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

**va\_fcn**(*nme, xx, A, b*)

**va\_hess**(*nme, xx, lam, A*)

**vm2\_fcn**(*nme, xx, A, b*)

**vm2\_hess**(*nme, xx, lam, A*)

### mp.mme\_buslink\_opf\_acp

#### class mp.mme\_buslink\_opf\_acp

Bases: [mp.mme\\_buslink\\_opf](#) (page 202)

[mp.mme\\_buslink\\_opf\\_acp](#) (page 202) - Math model element for 1-to-3-phase buslink for AC polar voltage OPF.

Math model element class for 1-to-3-phase buslink elements for AC polar OPF problems.

Implements method for adding constraints to match voltages across each buslink.

#### Method Summary

**add\_constraints**(*mm, nm, dm, mpopt*)

### 3.7.4 Legacy DC Line Extension

For more details, see `howto_element`.

#### `mp.xt_legacy_dcline`

##### class `mp.xt_legacy_dcline`

Bases: `mp.extension` (page 171)

`mp.xt_legacy_dcline` (page 203) - MATPOWER extension to add legacy DC line elements.

For AC and DC power flow, continuation power flow, and optimal power flow problems, adds a new element type:

- 'legacy\_dcline' - legacy DC line

No changes are required for the task or container classes, so only the `..._element_classes` methods are overridden.

The set of data model element classes depends on the task, with each OPF class inheriting from the corresponding class used for PF and CPF.

The set of network model element classes depends on the formulation, specifically whether cartesian or polar representations are used for voltages.

And the set of mathematical model element classes depends on both the task and the formulation.

##### `mp.xt_legacy_dcline` Methods:

- `dmc_element_classes()` (page 203) - add a class to data model converter elements
- `dm_element_classes()` (page 203) - add a class to data model elements
- `nm_element_classes()` (page 203) - add a class to network model elements
- `mm_element_classes()` (page 204) - add a class to mathematical model elements

See the `sec_customizing` and `sec_extensions` sections in the *MATPOWER Developer's Manual* for more information, and specifically the `sec_element_classes` section and the `tab_element_class_modifiers` table for details on *element class modifiers*.

See also `mp.extension` (page 171).

##### Method Summary

**`dmc_element_classes`**(*dmc\_class*, *fmt*, *mpopt*)

Add a class to data model converter elements.

For 'mpc2' data formats, adds the classes:

- `mp.dmce_legacy_dcline_mpc2` (page 204)

**`dm_element_classes`**(*dm\_class*, *task\_tag*, *mpopt*)

Add a class to data model elements.

For 'PF' and 'CPF' tasks, adds the class:

- `mp.dme_legacy_dcline` (page 205)

For 'OPF' tasks, adds the class:

- `mp.dme_legacy_dcline_opf` (page 207)

**nm\_element\_classes**(*nm\_class, task\_tag, mpopt*)

Add a class to network model elements.

For DC formulations, adds the class:

- *mp.nme\_legacy\_dcline\_dc* (page 209)

For AC *cartesian* voltage formulations, adds the class:

- *mp.nme\_legacy\_dcline\_acc* (page 209)

For AC *polar* voltage formulations, adds the class:

- *mp.nme\_legacy\_dcline\_acp* (page 209)

**mm\_element\_classes**(*mm\_class, task\_tag, mpopt*)

Add a class to mathematical model elements.

For 'PF' and 'CPF' tasks, adds the class:

- *mp.mme\_legacy\_dcline\_pf\_dc* (page 210) (*DC formulation*) or
- *mp.mme\_legacy\_dcline\_pf\_ac* (page 210) (*AC formulation*)

For 'OPF' tasks, adds the class:

- *mp.mme\_legacy\_dcline\_opf\_dc* (page 211) (*DC formulation*) or
- *mp.mme\_legacy\_dcline\_opf\_ac* (page 211) (*AC formulation*)

Data model converter element class belonging to *mp.xt\_legacy\_dcline* (page 203) extension:

### **mp.dmce\_legacy\_dcline\_mpc2**

**class** *mp.dmce\_legacy\_dcline\_mpc2*

Bases: *mp.dmc\_element* (page 63)

*mp.dmce\_legacy\_dcline\_mpc2* (page 204) - Data model converter element for legacy DC line for MATPOWER case v2.

#### **Method Summary**

**name**()

**data\_field**()

**table\_var\_map**(*dme, mpc*)

**default\_export\_data\_table**(*spec*)

**dcline\_cost\_import**(*mpc, spec, vn*)

**dcline\_cost\_export**(*dme, mpc, spec, vn, ridx*)

Data model element classes belonging to *mp.xt\_legacy\_dcline* (page 203) extension:

**mp.dme\_legacy\_dcline**

**class mp.dme\_legacy\_dcline**

Bases: *mp.dm\_element* (page 36)

*mp.dme\_legacy\_dcline* (page 205) - Data model element for legacy DC line.

Implements the data element model for legacy DC line elements, with linear line losses.

$$p_{\text{loss}} = l_0 + l_1 p_{\text{fr}}$$

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>bus_fr</code>	<i>integer</i>	bus ID (uid) of “from” bus
<code>bus_to</code>	<i>integer</i>	bus ID (uid) of “to” bus
<code>loss0</code>	<i>double</i>	$l_0$ , constant term of loss function (MW)
<code>loss1</code>	<i>double</i>	$l_1$ , linear coefficient of loss function (MW/MW)
<code>vm_setpoint_fr</code>	<i>double</i>	per unit “from” bus voltage magnitude setpoint
<code>vm_setpoint_to</code>	<i>double</i>	per unit “to” bus voltage magnitude setpoint
<code>p_fr_lb</code>	<i>double</i>	lower bound on MW flow at “from” port
<code>p_fr_ub</code>	<i>double</i>	upper bound on MW flow at “from” port
<code>q_fr_lb</code>	<i>double</i>	lower bound on MVar injection into “from” bus
<code>q_fr_ub</code>	<i>double</i>	upper bound on MVar injection into “from” bus
<code>q_to_lb</code>	<i>double</i>	lower bound on MVar injection into “to” bus
<code>q_to_ub</code>	<i>double</i>	upper bound on MVar injection into “to” bus
<code>p_fr</code>	<i>double</i>	MW flow at “from” end (“from” → “to”)
<code>q_fr</code>	<i>double</i>	MVar injection into “from” bus
<code>p_to</code>	<i>double</i>	MW flow at “to” end (“from” → “to”)
<code>q_to</code>	<i>double</i>	MVar injection into “to” bus

**Property Summary**

**fbus**

bus index vector for “from” port (port 1) (all DC lines)

**tbus**

bus index vector for “to” port (port 2) (all DC lines)

**fbus\_on**

vector of “from” bus indices into online buses (in-service DC lines)

**tbus\_on**

vector of “to” bus indices into online buses (in-service DC lines)

**loss0**

constant term of loss function (p.u.) (in-service DC lines)

**loss1**

linear coefficient of loss function (in-service DC lines)

**p\_fr\_start**

initial active power (p.u.) at “from” port (in-service DC lines)

**p\_to\_start**

initial active power (p.u.) at “to” port (in-service DC lines)



**q\_fr\_start**

initial reactive power (p.u.) at “from” port (in-service DC lines)

**q\_to\_start**

initial reactive power (p.u.) at “to” port (in-service DC lines)

**vm\_setpoint\_fr**

from bus voltage magnitude setpoint (p.u.) (in-service DC lines)

**vm\_setpoint\_to**

to bus voltage magnitude setpoint (p.u.) (in-service DC lines)

**p\_fr\_lb**

p.u. lower bound on active power flow at “from” port (in-service DC lines)

**p\_fr\_ub**

p.u. upper bound on active power flow at “from” port (in-service DC lines)

**q\_fr\_lb**

p.u. lower bound on reactive power flow at “from” port (in-service DC lines)

**q\_fr\_ub**

p.u. upper bound on reactive power flow at “from” port (in-service DC lines)

**q\_to\_lb**

p.u. lower bound on reactive power flow at “to” port (in-service DC lines)

**q\_to\_ub**

p.u. upper bound on reactive power flow at “to” port (in-service DC lines)

**Method Summary**

**name()**

**label()**

**labels()**

**cxn\_type()**

**cxn\_idx\_prop()**

**main\_table\_var\_names()**

**export\_vars()**

**export\_vars\_offline\_val()**

**have\_cost()**

**initialize(*dm*)**

**update\_status(*dm*)**

**apply\_vm\_setpoints(*dm*)**

**build\_params(*dm*)**

**pp\_have\_section\_sum(*mpopt*, *pp\_args*)**

```

pp_data_sum(dm, rows, out_e, mpopt, fd, pp_args)
pp_get_headers_det(dm, out_e, mpopt, pp_args)
pp_have_section_det(mpop, pp_args)
pp_data_row_det(dm, k, out_e, mpopt, fd, pp_args)

```

### mp.dme\_legacy\_dcline\_opf

**class** mp.dme\_legacy\_dcline\_opf

Bases: [mp.dme\\_legacy\\_dcline](#) (page 205), [mp.dme\\_shared\\_opf](#) (page 59)

[mp.dme\\_legacy\\_dcline\\_opf](#) (page 207) - Data model element for legacy DC line for OPF.

To parent class [mp.dme\\_legacy\\_dcline](#) (page 205), adds costs, shadow prices on active and reactive flow limits, and pretty-printing for **lim** sections.

Adds the following columns in the main data table, found in the `tab` property:

Name	Type	Description
<code>cost_pg</code>	<code>mp.cost_table</code>	cost of active power flow ( $u/MW$ ) <sup>1</sup>
<code>mu_p_fr_lb</code>	<code>double</code>	shadow price on MW flow lower bound at “from” end ( $u/MW$ ) <sup>1</sup>
<code>mu_p_fr_ub</code>	<code>double</code>	shadow price on MW flow upper bound at “from” end ( $u/MW$ ) <sup>1</sup>
<code>mu_q_fr_lb</code>	<code>double</code>	shadow price on lower bound of MVar injection at “from” bus ( $u/degree$ ) <sup>1</sup>
<code>mu_q_fr_ub</code>	<code>double</code>	shadow price on upper bound of MVar injection at “from” bus ( $u/degree$ ) <sup>1</sup>
<code>mu_q_to_lb</code>	<code>double</code>	shadow price on lower bound of MVar injection at “to” bus ( $u/degree$ ) <sup>1</sup>
<code>mu_q_to_ub</code>	<code>double</code>	shadow price on upper bound of MVar injection at “to” bus ( $u/degree$ ) <sup>1</sup>

### Method Summary

```

main_table_var_names()
export_vars()
export_vars_offline_val()
have_cost()
build_cost_params(dm)
pretty_print(dm, section, out_e, mpopt, fd, pp_args)
pp_have_section_lim(mpop, pp_args)
pp_binding_rows_lim(dm, out_e, mpopt, pp_args)

```

<sup>1</sup> Here  $u$  denotes the units of the objective function, e.g. USD.

```
pp_get_headers_lim(dm, out_e, mpopt, pp_args)
```

```
pp_data_row_lim(dm, k, out_e, mpopt, fd, pp_args)
```

Network model element classes belonging to [mp.xt\\_legacy\\_dcline](#) (page 203) extension:

### **mp.nme\_legacy\_dcline**

**class** mp.nme\_legacy\_dcline

Bases: [mp.nm\\_element](#) (page 108)

[mp.nme\\_legacy\\_dcline](#) (page 208) - Network model element abstract base class for legacy DC line.

Implements the network model element for legacy DC line elements, with 2 ports and 2 non-voltage states per DC line.

#### **Method Summary**

**name()**

**np()**

**nz()**

### **mp.nme\_legacy\_dcline\_ac**

**class** mp.nme\_legacy\_dcline\_ac

Bases: [mp.nme\\_legacy\\_dcline](#) (page 208)

[mp.nme\\_legacy\\_dcline\\_ac](#) (page 208) - Network model element abstract base class for legacy DC line for AC formulation.

Adds non-voltage state variables Pdcf, Qdcf, Pdct, and Qdct to the network model and builds the parameter  $\underline{N}$ .

#### **Method Summary**

**add\_zvars(nm, dm, idx)**

**build\_params(nm, dm)**

**mp.nme\_legacy\_dcline\_acc****class** mp.nme\_legacy\_dcline\_accBases: *mp.nme\_legacy\_dcline\_ac* (page 208), *mp.form\_acc* (page 83)*mp.nme\_legacy\_dcline\_acc* (page 209) - Network model element for legacy DC line for for AC cartesian voltage formulations.Inherits from *mp.form\_acc* (page 83).**mp.nme\_legacy\_dcline\_acp****class** mp.nme\_legacy\_dcline\_acpBases: *mp.nme\_legacy\_dcline\_ac* (page 208), *mp.form\_acp* (page 87)*mp.nme\_legacy\_dcline\_acp* (page 209) - Network model element for legacy DC line for for AC polar voltage formulations.Inherits from *mp.form\_acp* (page 87).**mp.nme\_legacy\_dcline\_dc****class** mp.nme\_legacy\_dcline\_dcBases: *mp.nme\_legacy\_dcline* (page 208), *mp.form\_dc* (page 89)*mp.nme\_legacy\_dcline\_dc* (page 209) - Network model element for legacy DC line for DC formulation.Adds non-voltage state variables Pdcf and Pdct to the network model and builds the parameter *K*.**Method Summary****add\_zvars**(*nm, dm, idx*)**build\_params**(*nm, dm*)Mathematical model element classes belonging to *mp.xt\_legacy\_dcline* (page 203) extension:**mp.mme\_legacy\_dcline****class** mp.mme\_legacy\_dclineBases: *mp.mm\_element* (page 144)*mp.mme\_legacy\_dcline* (page 209) - Math model element abstract base class for legacy DC line.

Abstract math model element base class for legacy DC line elements.

**Method Summary****name**()

### **mp.mme\_legacy\_dcline\_pf\_ac**

**class** mp.mme\_legacy\_dcline\_pf\_ac

Bases: *mp.mme\_legacy\_dcline* (page 209)

*mp.mme\_legacy\_dcline\_pf\_ac* (page 210) - Math model element for legacy DC line for AC power flow.

Math model element class for legacy DC line elements for AC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service DC lines from the math model solution.

#### **Method Summary**

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

### **mp.mme\_legacy\_dcline\_pf\_dc**

**class** mp.mme\_legacy\_dcline\_pf\_dc

Bases: *mp.mme\_legacy\_dcline* (page 209)

*mp.mme\_legacy\_dcline\_pf\_dc* (page 210) - Math model element for legacy DC line for DC power flow.

Math model element class for legacy DC line elements for DC power flow problems.

Implements method for updating the output data in the corresponding data model element for in-service DC lines from the math model solution.

#### **Method Summary**

**data\_model\_update\_on**(*mm, nm, dm, mpopt*)

### **mp.mme\_legacy\_dcline\_opf**

**class** mp.mme\_legacy\_dcline\_opf

Bases: *mp.mme\_legacy\_dcline* (page 209)

*mp.mme\_legacy\_dcline\_opf* (page 210) - Math model element abstract base class for legacy DC line for OPF.

Math model element abstract base class for legacy DC line elements for OPF problems.

Implements methods to add costs, including piecewise linear cost variables, and to form an interior initial point for cost variables.

#### **Property Summary**

##### **cost**

struct for *cost* (page 210) parameters with fields:

- *poly* - polynomial costs for active power, struct with fields:
  - *have\_quad\_cost*
  - *i0, i1, i2, i3*
  - *k, c, Q*

- `pwl` - piecewise linear costs for active power, struct with fields:
  - `n`, `i`, `A`, `b`

### Method Summary

`build_cost_params(dm)`

`add_vars(mm, nm, dm, mpopt)`

`add_constraints(mm, nm, dm, mpopt)`

`add_costs(mm, nm, dm, mpopt)`

`interior_x0(mm, nm, dm, x0)`

### `mp.mme_legacy_dcline_opf_ac`

**class** `mp.mme_legacy_dcline_opf_ac`

Bases: `mp.mme_legacy_dcline_opf` (page 210)

`mp.mme_legacy_dcline_opf_ac` (page 211) - Math model element for legacy DC line for AC OPF.

Math model element class for legacy DC line elements for AC OPF problems.

Implements method for updating the output data in the corresponding data model element for in-service DC lines from the math model solution.

### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

### `mp.mme_legacy_dcline_opf_dc`

**class** `mp.mme_legacy_dcline_opf_dc`

Bases: `mp.mme_legacy_dcline_opf` (page 210)

`mp.mme_legacy_dcline_opf_dc` (page 211) - Math model element for legacy DC line for DC OPF.

Math model element class for legacy DC line elements for DC OPF problems.

Implements method for updating the output data in the corresponding data model element for in-service DC lines from the math model solution.

### Method Summary

`data_model_update_on(mm, nm, dm, mpopt)`

### 3.7.5 Example User Constraint Extension

For more details, see `howto_add_constraint`.

#### `mp.xt_oval_cap_curve`

**class** `mp.xt_oval_cap_curve`

Bases: `mp.extension` (page 171)

`mp.xt_oval_cap_curve` (page 212) - MATPOWER extension for OPF with oval gen PQ capability curves.

For OPF problems, this extension restricts the output of each generator to lie within the half-oval-shaped region centered at (P<sub>MIN</sub>, Q<sub>0</sub>) and passing through (P<sub>MAX</sub>, Q<sub>0</sub>), (P<sub>MIN</sub>, Q<sub>MIN</sub>) and (P<sub>MIN</sub>, Q<sub>MAX</sub>).

#### `mp.xt_oval_cap_curve` Methods:

- `mm_element_classes()` (page 212) - replace a class in mathematical model elements

See the `sec_customizing` and `sec_extensions` sections in the *MATPOWER Developer's Manual* for more information, and specifically the `sec_element_classes` section and the `tab_element_class_modifiers` table for details on *element class modifiers*.

See also `mp.extension` (page 171), `mp.mme_gen_opf_ac_oval` (page 212).

#### Method Summary

`mm_element_classes(mm_class, task_tag, mpopt)`

Replace a class in mathematical model elements.

For 'OPF' tasks, replaces `mp.gen_opf_ac` with `mp.gen_opf_ac_oval`.

Mathematical model element class belonging to `mp.xt_oval_cap_curve` (page 212) extension:

#### `mp.mme_gen_opf_ac_oval`

**class** `mp.mme_gen_opf_ac_oval`

Bases: `mp.mme_gen_opf_ac` (page 154)

`mp.mme_gen_opf_ac_oval` (page 212) - Math model element for generator for AC OPF w/oval cap curve.

Math model element class for generator elements for AC OPF problems, implementing an oval, as opposed to rectangular, PQ capability curve.

#### Method Summary

`add_constraints(mm, nm, dm, mpopt)`

Set up the nonlinear constraint for gen oval PQ capability curves.

```
mm.add_constraints(mm, nm, dm, mpopt)
```

`oval_pq_capability_fcn(xx, idx, p0, q0, a2, b2)`

Compute oval PQ capability constraints and Jacobian.

```
h = mme.oval_pq_capability_fcn(xx, idx, p0, q0, a2, b2)
[h, dh] = mme.oval_pq_capability_fcn(xx, idx, p0, q0, a2, b2)
```

Compute constraint function and optionally the Jacobian for oval PQ capability limits.

**Inputs**

- **xx** (*1 x 2 cell array*) – active power injection in **xx**{1}, reactive injection in **xx**{2}
- **idx** (*integer*) – index of subset of generators of interest to include in constraint; if empty, include all
- **p0** (*double*) – vector of horizontal (p) centers
- **q0** (*double*) – vector of vertical (q) centers
- **a2** (*double*) – vector of squares of horizontal (p) radii
- **b2** (*double*) – vector of squares of vertical (q) radii

**Outputs**

- **h** (*double*) – constraint function,  $h(x)$
- **dh** (*double*) – constraint Jacobian,  $h_x$

Note that the oval specs **p0**, **q0**, **a2**, **b2** are assumed to have dimension corresponding to **idx**.

**oval\_pq\_capability\_hess**(*xx, lam, idx, p0, q0, a2, b2*)

Compute oval PQ capability constraint Hessian.

```
d2H = mme.oval_pq_capability_hess(xx, lam, idx, p0, q0, a2, b2)
```

Compute a sparse Hessian matrix for oval PQ capability limits. Rather than a full, 3-dimensional Hessian, it computes the Jacobian of the vector obtained by multiplying the transpose of the constraint Jacobian by a vector  $\mu$ .

**Inputs**

- **xx** (*1 x 2 cell array*) – active power injection in **xx**{1}, reactive injection in **xx**{2}
- **lam** (*double*) – vector  $\mu$  of multipliers
- **idx** (*integer*) – index of subset of generators of interest to include in constraint; if empty, include all
- **p0** (*double*) – vector of horizontal (p) centers
- **q0** (*double*) – vector of vertical (q) centers
- **a2** (*double*) – vector of squares of horizontal (p) radii
- **b2** (*double*) – vector of squares of vertical (q) radii

**Output**

**d2H** (*double*) – sparse constraint Hessian matrix

Note that the oval specs **p0**, **q0**, **a2**, **b2** are assumed to have dimension corresponding to **idx**.



## 4.1 MATPOWER Tests

### 4.1.1 test\_matpower

**test\_matpower**(*verbose*, *exit\_on\_fail*)

*test\_matpower*() (page 214) - Run all MATPOWER tests.

```
test_matpower
test_matpower(verbose)
test_matpower(verbose, exit_on_fail)
success = test_matpower(...)
```

Runs all of the MATPOWER tests. If *verbose* is true (*false by default*), it prints the details of the individual tests. If *exit\_on\_fail* is true (*false by default*), it will exit MATLAB or Octave with a status of 1 unless *t\_run\_tests*() returns *all\_ok* true.

See also *t\_run\_tests*().

### 4.1.2 t\_mp\_mapped\_array

**t\_mp\_mapped\_array**(*quiet*)

*t\_mp\_mapped\_array*() (page 214) - Tests for *mp.mapped\_array* (page 167).

### 4.1.3 t\_mp\_table

**t\_mp\_table**(*quiet*)

*t\_mp\_table*() (page 215) - Tests for *mp\_table* (page 157) (and *table*).

### 4.1.4 t\_mp\_data\_model

**t\_mp\_data\_model**(*quiet*)

*t\_mp\_data\_model*() (page 215) - Tests for *mp.data\_model* (page 28).

### 4.1.5 t\_dmc\_element

**t\_dmc\_element**(*quiet*)

*t\_dmc\_element*() (page 215) - Tests for *mp.dmc\_element* (page 63).

### 4.1.6 t\_mp\_dm\_converter\_mpc2

**t\_mp\_dm\_converter\_mpc2**(*quiet*)

*t\_mp\_dm\_converter\_mpc2*() (page 215) - Tests for *mp.dm\_converter\_mpc2* (page 62).

### 4.1.7 t\_nm\_element

**t\_nm\_element**(*quiet, out\_ac*)

*t\_nm\_element*() (page 215) - Tests for *mp.nm\_element* (page 108).

### 4.1.8 t\_port\_inj\_current\_acc

**t\_port\_inj\_current\_acc**(*quiet*)

*t\_port\_inj\_current\_acc*() (page 215) - Tests of *mp.form\_ac.port\_inj\_current*() (page 77) derivatives wrt cartesian V.

### 4.1.9 t\_port\_inj\_current\_acp

**t\_port\_inj\_current\_acp**(*quiet*)

*t\_port\_inj\_current\_acp*() (page 216) - Tests of *mp.form\_ac.port\_inj\_current*() (page 77) derivatives wrt polar V.

### 4.1.10 t\_port\_inj\_power\_acc

**t\_port\_inj\_power\_acc**(*quiet*)

*t\_port\_inj\_power\_acc*() (page 216) - Tests of *mp.form\_ac.port\_inj\_power*() (page 77) derivatives wrt cartesian V.

### 4.1.11 t\_port\_inj\_power\_acp

**t\_port\_inj\_power\_acp**(*quiet*)

*t\_port\_inj\_power\_acp*() (page 216) - Tests of *mp.form\_ac.port\_inj\_power*() (page 77) derivatives wrt polar V.

### 4.1.12 t\_node\_test

**t\_node\_test**(*quiet*)

*t\_node\_test*() (page 216) - Tests for network model with multiple node-creating elements.

### 4.1.13 t\_run\_mp

**t\_run\_mp**(*quiet*)

*t\_run\_mp*() (page 216) - Tests for *run\_mp*() (page 4) and simple creation and solve of models.

### 4.1.14 t\_run\_mp\_3p

**t\_run\_mp\_3p**(*quiet*)

*t\_run\_mp\_3p*() (page 216) - Tests for *run\_pf*() (page 5), *run\_cpf*() (page 5), *run\_opf*() (page 6) for 3-phase and hybrid test cases.

### 4.1.15 `t_run_opf_default`

`t_run_opf_default(quiet)`

`t_run_opf_default()` (page 217) - Tests for AC optimal power flow using `run_opf()` (page 6) w/default solver.

### 4.1.16 `t_pretty_print`

`t_pretty_print(quiet)`

`t_pretty_print()` (page 217) - Tests for pretty printed output.

### 4.1.17 `t_mpxt_legacy_dcline`

`t_mpxt_legacy_dcline(quiet)`

`t_mpxt_legacy_dcline()` (page 217) - Tests for legacy DC line extension in `mp.xt_legacy_dcline` (page 203).

### 4.1.18 `t_mpxt_reserves`

`t_mpxt_reserves(quiet)`

`t_mpxt_reserves()` (page 217) - Tests `mp.xt_reserves` (page 174) extension.

## 4.2 MATPOWER Test Data

### 4.2.1 `mp_foo_table`

`class mp_foo_table`

Bases: `mp_table_subclass` (page 161)

`mp_foo_table` (page 217) - Subclass of `mp_table_subclass` (page 161) for testing.

## 4.2.2 `t_case3p_a`

### `t_case3p_a()`

`t_case3p_a()` (page 218) - Four bus, unbalanced 3-phase test case.

This data comes from `4Bus-YY-UnB.DSS`, a modified version (with unbalanced load) of `4Bus-YY-Bal.DSS` [1], the OpenDSS 4 bus IEEE test case with grounded-wye to grounded-wye transformer.

[1] <https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Distrib/IEEETestCases/4Bus-YY-Bal/4Bus-YY-Bal.DSS>

## 4.2.3 `t_case3p_b`

### `t_case3p_b()`

`t_case3p_b()` (page 218) - Six bus hybrid test case, 2 single-phase buses, 4 3-phase buses.

One bus is a hybrid PQ bus. Three phase bus solution should match `t_case3p_a()` (page 218).

## 4.2.4 `t_case3p_c`

### `t_case3p_c()`

`t_case3p_c()` (page 218) - Six bus hybrid test case, 2 single-phase buses, 4 3-phase buses.

One bus is a hybrid PV bus (PV on single-phase side). Three phase bus solution should match `t_case3p_a()` (page 218).

## 4.2.5 `t_case3p_d`

### `t_case3p_d()`

`t_case3p_d()` (page 218) - Six bus hybrid test case, 2 single-phase buses, 4 3-phase buses.

One bus is a hybrid PV bus (PV on 3-phase side). Three phase bus solution should match `t_case3p_a()` (page 218).

## 4.2.6 `t_case3p_e`

### `t_case3p_e()`

`t_case3p_e()` (page 218) - Five bus hybrid test case, 1 single-phase bus, 4 3-phase buses.

One bus is a hybrid REF bus (REF on single-phase side). Three phase bus solution should match `t_case3p_a()` (page 218).

### 4.2.7 t\_case3p\_f

#### t\_case3p\_f()

*t\_case3p\_f()* (page 219) - 21 bus hybrid test case, 9 single-phase buses, 12 3-phase buses.

Three buses are hybrid PQ buses.

### 4.2.8 t\_case3p\_g

#### t\_case3p\_g()

*t\_case3p\_g()* (page 219) - 21 bus hybrid test case, 9 single-phase buses, 12 3-phase buses.

Three buses are hybrid buses, one REF-PQ, one PV-PQ and the other PQ-PQ. Solutions of three-phase portions should match *t\_case3p\_a()* (page 218).

### 4.2.9 t\_case3p\_h

#### t\_case3p\_h()

*t\_case3p\_h()* (page 219) - 21 bus hybrid test case, 9 single-phase buses, 12 3-phase buses.

Same as *t\_case3p\_g()* (page 219), except the PV hybrid bus has the PV on the 3-phase side. Three buses are hybrid buses, one REF-PQ, one PQ-PV and the other PQ-PQ. Solutions of three-phase portions should match *t\_case3p\_a()* (page 218).

### 4.2.10 t\_case9\_gizmo

#### t\_case9\_gizmo()

*t\_case9\_gizmo()* (page 219) - Power flow data for 9 bus, 3 generator case, with gizmo data.

Please see caseformat for details on the case file format.

This section contains reference documentation for the **legacy MATPOWER framework** (see `sec_two_frameworks` in the *MATPOWER Developer's Manual*) and the rest of the legacy codebase inherited from MATPOWER 7 and earlier.

## 5.1 Legacy Class

### 5.1.1 `opf_model`

**class `opf_model`**

Bases: `opt_model`

*opf\_model* (page 220) - Legacy MATPOWER OPF model class.

```
OM = OPF_MODEL(MPC)
```

This `class` implements the OPF model object used to encapsulate a given OPF problem formulation. It allows `for` access to optimization variables, constraints `and` costs in named blocks, keeping track of the ordering `and` indexing of the blocks as variables, constraints `and` costs are added to the problem.

This `class` is a subclass of `OPT_MODEL` that adds the `'mpc'` field `for` storing the MATPOWER `case struct` used to build the object along with the `get_mpc()` method.

It also adds the `'cost'` field `and` the following three `methods for` implementing the legacy user-defined OPF costs:

```
add_legacy_cost
params_legacy_cost
eval_legacy_cost
```

The following is the structure of the data in the OPF model object.

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```

om
<opt_model fields> - see OPT_MODEL for details
.cost           - data for legacy user-defined costs
  .idx
    .i1 - starting row index within full N matrix
    .iN - ending row index within full N matrix
    .N  - number of rows in this cost block in full N matrix
  .N           - total number of rows in full N matrix
  .NS          - number of cost blocks
  .data        - data for each user-defined cost block
    .N         - see help for ADD_LEGACY_COST for details
    .H         - "
    .Cw        - "
    .dd        - "
    .rr        - "
    .kk        - "
    .mm        - "
    .vs        - cell array of variable sets that define xx for this
                  cost block, where the N for this block multiplies xx
  .order       - struct array of names/indices for cost blocks in the
                  order they appear in the rows of the full N matrix
    .name      - name of the block, e.g. R
    .idx       - indices for name, {2,3} => R(2,3)
.mpc           - MATPOWER case struct used to create this model object
  .baseMVA
  .bus
  .branch
  .gen
  .gencost
  .A (if present, must have l, u)
  .l
  .u
  .N (if present, must have fparm, H, Cw)
  .fparm
  .H
  .Cw

```

See also `opt_model`.

### Constructor Summary

`opf_model(mpc)`

Constructor.

```

om = opf_model()
om = opf_model(mpc)

```

### Property Summary

`cost = []`

data for legacy user-defined costs



**mpc = struct()**

MATPOWER case struct from which om was built

**Method Summary**

**def\_set\_types(om)**

Define set types var, lin, nle, nli, qdc, nlc, cost.

**init\_set\_types(om)**

Initialize data structures for each set type.

**set\_mpc(om, mpc)**

[set\\_mpc\(\)](#) (page 222) - Sets the MATPOWER case struct.

OM.SET\_MPC(MPC)

See also [opt\\_model](#).

**display(om)**

[display\(\)](#) (page 222) - Displays the object.

Called when semicolon is omitted at the command-line. Displays the details of the variables, constraints, costs included in the model.

See also [opt\\_model](#).

**get\_mpc(om)**

[get\\_mpc\(\)](#) (page 222) - Returns the MATPOWER case struct.

MPC = OM.GET\_MPC()

See also [opt\\_model](#).

**eval\_legacy\_cost(om, x, name, idx)**

[eval\\_legacy\\_cost\(\)](#) (page 222) - Evaluates individual or full set of legacy user costs.

```
F = OM.EVAL_LEGACY_COST(X ...)
[F, DF] = OM.EVAL_LEGACY_COST(X ...)
[F, DF, D2F] = OM.EVAL_LEGACY_COST(X ...)
[F, DF, D2F] = OM.EVAL_LEGACY_COST(X, NAME)
[F, DF, D2F] = OM.EVAL_LEGACY_COST(X, NAME, IDX_LIST)
Evaluates an individual named set or the full set of legacy user
costs and their derivatives for a given value of the optimization vector
X, based on costs added by ADD_LEGACY_COST.
```

Example:

```
[f, df, d2f] = om.eval_legacy_cost(x)
[f, df, d2f] = om.eval_legacy_cost(x, name)
[f, df, d2f] = om.eval_legacy_cost(x, name, idx)
```

See also [opt\\_model](#), [add\\_legacy\\_cost\(\)](#) (page 224), [params\\_legacy\\_cost\(\)](#) (page 222).

**params\_legacy\_cost(om, name, idx)**

[params\\_legacy\\_cost\(\)](#) (page 222) - Returns cost parameters for legacy user-defined costs.

```

CP = OM.PARAMS_LEGACY_COST()
CP = OM.PARAMS_LEGACY_COST(NAME)
CP = OM.PARAMS_LEGACY_COST(NAME, IDX_LIST)
[CP, VS] = OM.PARAMS_LEGACY_COST(...)
[CP, VS, I1, IN] = OM.PARAMS_LEGACY_COST(...)

```

With no **input** parameters, it assembles **and** returns the parameters **for** the aggregate legacy user-defined cost from **all** legacy cost sets added using `ADD_LEGACY_COST`. The values of these parameters are cached **for** subsequent calls. The parameters are contained in the **struct** `CP`, described below.

If a `NAME` is provided then it simply returns parameter **struct** `CP` **for** the corresponding named **set**. Likewise **for** indexed named sets specified by `NAME` **and** `IDX_LIST`.

An optional 2nd output argument `VS` indicates the variable sets used by this cost **set**. The **size** of `CP.N` will be consistent with `VS`.

If `NAME` is provided, optional 3rd **and** 4th output arguments `I1` **and** `IN` indicate the starting **and** ending row indices of the corresponding cost **set** in the **full** aggregate cost matrix `CP.N`.

Let `X` refer to the vector formed by combining the corresponding varsets `VS`, **and** `F_U(X, CP)` be the cost at `X` corresponding to the cost parameters contained in `CP`, where `CP` is a **struct** with the following fields:

```

N      - nw x nx sparse matrix (optional, identity matrix by default)
Cw     - nw x 1 vector
H      - nw x nw sparse matrix (optional, all zeros by default)
dd, mm - nw x 1 vectors (optional, all ones by default)
rh, kk - nw x 1 vectors (optional, all zeros by default)

```

These parameters are used as follows to compute `F_U(X, CP)`

```

R = N*X - rh

      /  kk(i),  R(i) < -kk(i)
K(i) = <  0,    -kk(i) <= R(i) <= kk(i)
      \ -kk(i), R(i) > kk(i)

RR = R + K

U(i) = /  0, -kk(i) <= R(i) <= kk(i)
      \  1, otherwise

DDL(i) = /  1, dd(i) = 1
        \  0, otherwise

DDQ(i) = /  1, dd(i) = 2
        \  0, otherwise

Dl = diag(mm) * diag(U) * diag(DDL)
Dq = diag(mm) * diag(U) * diag(DDQ)

```

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$$w = (Dl + Dq * \text{diag}(RR)) * RR$$

$$F_U(X, CP) = 1/2 * w' * H * w + Cw' * w$$

See also `opt_model`, `add_legacy_cost()` (page 224), `eval_legacy_cost()` (page 222).

**add\_named\_set**(*om, set\_type, name, idx, N, varargin*)

`add_named_set()` (page 224) - Adds a named set of variables/constraints/costs to the model.

```
----- PRIVATE METHOD -----

This method is intended to be a private method, used internally by
the public methods ADD_VAR, ADD_LIN_CONSTRAINT, ADD_NLN_CONSTRAINT
ADD_QUAD_COST, ADD_NLN_COST and ADD_LEGACY_COST.

Variable Set
    OM.ADD_NAMED_SET('var', NAME, IDX_LIST, N, V0, VL, VU, VT);

Linear Constraint Set
    OM.ADD_NAMED_SET('lin', NAME, IDX_LIST, N, A, L, U, VARSETS);

Nonlinear Inequality Constraint Set
    OM.ADD_NAMED_SET('nle', NAME, IDX_LIST, N, FCN, HESS, COMPUTED_BY,
    ↪VARSETS);

Nonlinear Inequality Constraint Set
    OM.ADD_NAMED_SET('nli', NAME, IDX_LIST, N, FCN, HESS, COMPUTED_BY,
    ↪VARSETS);

Quadratic Cost Set
    OM.ADD_NAMED_SET('qdc', NAME, IDX_LIST, N, CP, VARSETS);

General Nonlinear Cost Set
    OM.ADD_NAMED_SET('nlc', NAME, IDX_LIST, N, FCN, VARSETS);

Legacy Cost Set
    OM.ADD_NAMED_SET('cost', NAME, IDX_LIST, N, CP, VARSETS);
```

See also `opt_model`, `add_var`, `add_lin_constraint`, `add_nln_constraint`, `add_quad_cost`, `add_nln_cost`, `add_legacy_cost()` (page 224).

**add\_legacy\_cost**(*om, name, idx, varargin*)

`add_legacy_cost()` (page 224) - Adds a set of user costs to the model.

```
OM.ADD_LEGACY_COST(NAME, CP);
OM.ADD_LEGACY_COST(NAME, CP, VARSETS);
OM.ADD_LEGACY_COST(NAME, IDX_LIST, CP);
OM.ADD_LEGACY_COST(NAME, IDX_LIST, CP, VARSETS);
```

Adds a named block of user-defined costs to the model. Each **set** is defined by the CP **struct** described below. All user-defined sets of costs are combined together into a **single set** of cost parameters in

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a **single CP struct** by BULD\_COST\_PARAMS. This **full aggregate set** of cost parameters can be retrieved from the model by GET\_COST\_PARAMS.

Examples:

```
cp1 = struct('N', N1, 'Cw', Cw1);
cp2 = struct('N', N2, 'Cw', Cw2, 'H', H, 'dd', dd, ...
            'rh', rh, 'kk', kk, 'mm', mm);
om.add_legacy_cost('usr1', cp1, {'Pg', 'Qg', 'z'});
om.add_legacy_cost('usr2', cp2, {'Vm', 'Pg', 'Qg', 'z'});

om.init_indexed_name('c', {2, 3});
for i = 1:2
    for j = 1:3
        om.add_legacy_cost('c', {i, j}, cp(i,j), ...);
    end
end
```

Let  $x$  refer to the vector formed by combining the specified VARSETS, and  $f_u(x, CP)$  be the cost at  $x$  corresponding to the cost parameters contained in  $CP$ , where  $CP$  is a **struct** with the following fields:

```
N      - nw x nx sparse matrix (optional, identity matrix by default)
Cw     - nw x 1 vector
H      - nw x nw sparse matrix (optional, all zeros by default)
dd, mm - nw x 1 vectors (optional, all ones by default)
rh, kk - nw x 1 vectors (optional, all zeros by default)
```

These parameters are used as follows to compute  $f_u(x, CP)$

```
R = N*x - rh

      /  kk(i),  R(i) < -kk(i)
K(i) = <  0,    -kk(i) <= R(i) <= kk(i)
      \ -kk(i),  R(i) > kk(i)

RR = R + K

U(i) = /  0, -kk(i) <= R(i) <= kk(i)
      \  1, otherwise

DDL(i) = /  1, dd(i) = 1
        \  0, otherwise

DDQ(i) = /  1, dd(i) = 2
        \  0, otherwise

Dl = diag(mm) * diag(U) * diag(DDL)
Dq = diag(mm) * diag(U) * diag(DDQ)

w = (Dl + Dq * diag(RR)) * RR

f_u(x, CP) = 1/2 * w' * H * w + Cw' * w
```

See also `opt_model`, `params_legacy_cost()` (page 222), `eval_legacy_cost()` (page 222).

`init_indexed_name(om, set_type, name, dim_list)`

`init_indexed_name()` (page 226) - Initializes the dimensions for an indexed named set.

```
OM.INIT_INDEXED_NAME(SET_TYPE, NAME, DIM_LIST)
```

Initializes the dimensions **for** an indexed named variable, constraint **or** cost **set**.

Variables, constraints **and** costs are referenced in OPT\_MODEL in terms of named sets. The specific **type** of named **set** being referenced is given by SET\_TYPE, with the following valid options:

```
SET_TYPE = 'var'   => variable set
SET_TYPE = 'lin'   => linear constraint set
SET_TYPE = 'nle'   => nonlinear equality constraint set
SET_TYPE = 'nli'   => nonlinear inequality constraint set
SET_TYPE = 'qdc'   => quadratic cost set
SET_TYPE = 'nlc'   => nonlinear cost set
SET_TYPE = 'cost'  => legacy cost set
```

Indexed Named Sets

A variable, constraint **or** cost **set** can be identified by a **single** NAME, such as 'Pmismatch', **or** by a name that is indexed by one **or** more indices, such as 'Pmismatch(3,4)'. For an indexed named **set**, before adding the indexed variable, constraint **or** cost sets themselves, the dimensions of the indexed **set** must be **set** by calling INIT\_INDEXED\_NAME, where DIM\_LIST is a **cell** array of the dimensions.

Examples:

```
%% linear constraints with indexed named set 'R(i,j)'
om.init_indexed_name('lin', 'R', {2, 3});
for i = 1:2
    for j = 1:3
        om.add_lin_constraint('R', {i, j}, A{i,j}, ...);
    end
end
```

See also `opt_model`, `add_var`, `add_lin_constraint`, `add_nln_constraint`, `add_quad_cost`, `add_nln_cost`, `add_legacy_cost()` (page 224).

## 5.2 Legacy Functions

### 5.2.1 Top-Level Simulation Functions

**runpf****runpf**(*casedata*, *mpopt*, *fname*, *solvedcase*)

runpf() - Runs a power flow.

[RESULTS, SUCCESS] = RUNPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)

Runs a **power** flow (full AC Newton's method by default), optionally returning a RESULTS **struct** and SUCCESS **flag**.

Inputs (all are optional):

CASEDATA : either a MATPOWER **case struct** or a string containing the name of the file with the **case** data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options **struct** to override default options can be used to specify the solution algorithm, output options termination tolerances, and more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results **struct**, with the following fields:  
 (all fields from the **input** MATPOWER **case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)  
 order - **info** used in external <-> internal data conversion  
 et - elapsed **time** in seconds  
 success - success **flag**, 1 = succeeded, 0 = failed

SUCCESS : the success **flag** can additionally be returned as a second output argument

Calling syntax options:

```
results = runpf;
results = runpf(casedata);
results = runpf(casedata, mpop);
results = runpf(casedata, mpop, fname);
results = runpf(casedata, mpop, fname, solvedcase);
[results, success] = runpf(...);
```

Alternatively, **for** compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, branch, success, et] = runpf(...);
```

If the pf.enforce\_q\_lims option is **set** to **true** (default is **false**) then, **if** any generator reactive **power** limit is violated after running the AC **power** flow, the corresponding bus is converted to a PQ bus, with Qg at the limit, and the **case** is re-run. The voltage magnitude at the bus will deviate from the specified value in order to satisfy the reactive **power** limit. If the reference bus is converted to PQ, the first remaining PV bus will be used as the slack bus **for** the next iteration. This may

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result in the **real power** output at this generator being slightly off from the specified values.

Examples:

```
results = runpf('case30');
results = runpf('case30', mpooption('pf.enforce_q_lims', 1));
```

See also `rundcpf()`.

## runcpf

**runcpf**(*basecasedata*, *targetcasedata*, *mpopt*, *fname*, *solvedcase*)

`runcpf()` - Runs a full AC continuation power flow

```
[RESULTS, SUCCESS] = RUNCPF(BASECASEDATA, TARGETCASEDATA, ...
                             MPOPT, FNAME, SOLVEDCASE)
```

Runs a **full AC continuation power** flow using a normalized tangent predictor **and** selected parameterization scheme, optionally returning a **RESULTS struct** **and** **SUCCESS flag**. Step **size** can be fixed **or** adaptive.

Inputs (all are optional):

**BASECASEDATA** : either a MATPOWER **case struct** **or** a string containing the name of the file with the **case** data defining the base loading **and** generation (default is `'case9'`)  
(see **CASEFORMAT** **and** **LOADCASE**)

**TARGETCASEDATA** : either a MATPOWER **case struct** **or** a string containing the name of the file with the **case** data defining the target loading **and** generation (default is `'case9target'`)

**MPOPT** : MATPOWER options **struct** to override default options can be used to specify the parameterization, output options, termination criteria, **and** more (see **MPOPTION**).

**FNAME** : name of a file to which the pretty-printed output will be appended

**SOLVEDCASE** : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with `'.mat'`)

Outputs (all are optional):

**RESULTS** : results **struct**, with the following fields:  
(all fields from the **input MATPOWER case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)

- order - **info** used in external <-> internal data conversion
- et - elapsed **time** in seconds
- success - success **flag**, 1 = succeeded, 0 = failed
- cpf - CPF output **struct** whose content depends on **any** user callback **functions**, where default contains fields:
  - done\_msg - string with message describing cause of continuation termination

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```

iterations - number of continuation steps performed
lam - (nsteps+1) row vector of lambda values from
      correction steps
lam_hat - (nsteps+1) row vector of lambda values from
          prediction steps
max_lam - maximum value of lambda in RESULTS.cpf.lam
steps - (nsteps+1) row vector of stepsizes taken at each
        continuation step
V - (nb x nsteps+1) complex bus voltages from
   correction steps
V_hat - (nb x nsteps+1) complex bus voltages from
        prediction steps
events - an array of structs of size nevents with the
         following fields:
         k - continuation step number at which event was located
         name - name of event
         idx - index(es) of critical elements in corresponding
              event function, e.g. index of generator reaching VAR
              limit
         msg - descriptive text detailing the event
SUCCESS : the success flag can additionally be returned as
         a second output argument

```

Calling syntax options:

```

results = runcpf;
results = runcpf(basecasedata, targetcasedata);
results = runcpf(basecasedata, targetcasedata, mpopt);
results = runcpf(basecasedata, targetcasedata, mpopt, fname);
results = runcpf(basecasedata, targetcasedata, mpopt, fname, solvedcase)
[results, success] = runcpf(...);

```

If the 'cpf.enforce\_q\_lims' option is set to true (default is false) then, if any generator reaches its reactive power limits during the AC continuation power flow,

- the corresponding bus is converted to a PQ bus, and the problem is modified to eliminate further reactive transfer on this bus
- the voltage magnitude at the bus will deviate from the specified setpoint to satisfy the reactive power limit,
- if the reference bus is converted to PQ, further real power transfer for the bus is also eliminated, and the first remaining PV bus is selected as the new slack, resulting in the transfers at both reference buses potentially deviating from the specified values
- if all reference and PV buses are converted to PQ, RUNCPF terminates with an infeasibility message.

If the 'cpf.enforce\_p\_lims' option is set to true (default is false) then, if any generator reaches its maximum active power limit during the AC continuation power flow,

- the problem is modified to eliminate further active transfer by this generator
- if the generator was at the reference bus, it is converted to PV and the first remaining PV bus is selected as the new slack.

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If the `'cpf.enforce_v_lims'` option is `set` to `true` (default is `false`) then the continuation power flow is `set` to terminate `if` any bus voltage magnitude exceeds its minimum `or` maximum limit.

If the `'cpf.enforce_flow_lims'` option is `set` to `true` (default is `false`) then the continuation power flow is `set` to terminate `if` any line MVA flow exceeds its `rateA` limit.

Possible CPF termination modes:

- when `cpf.stop_at == 'NOSE'`
  - Reached steady state loading limit
  - Nose point eliminated by limit induced bifurcation
- when `cpf.stop_at == 'FULL'`
  - Traced `full` continuation curve
- when `cpf.stop_at == <target_lam_val>`
  - Reached desired `lambda`
- when `cpf.enforce_p_lims == true`
  - All generators at PMAX
- when `cpf.enforce_q_lims == true`
  - No REF `or` PV buses remaining
- when `cpf.enforce_v_lims == true`
  - Any bus voltage magnitude limit is reached
- when `cpf.enforce_flow_lims == true`
  - Any branch MVA flow limit is reached
- other
  - Base `case` power flow did `not` converge
  - Base `and` target `case` have identical `load` `and` `generation`
  - Corrector did `not` converge
  - Could `not` locate `<event_name>` event
  - Too many rollback steps triggered by callbacks

Examples:

```
results = runcpf('case9', 'case9target');
results = runcpf('case9', 'case9target', ...
                mption('cpf.adapt_step', 1));
results = runcpf('case9', 'case9target', ...
                mption('cpf.enforce_q_lims', 1));
results = runcpf('case9', 'case9target', ...
                mption('cpf.stop_at', 'FULL'));
```

See also `mption()`, `runpf()`.

**runopf****runopf**(*casedata*, *mpopt*, *fname*, *solvedcase*)

runopf() - Runs an optimal power flow.

[RESULTS, SUCCESS] = RUNOPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)

Runs an optimal **power** flow (AC OPF by default), optionally returning a RESULTS **struct** and SUCCESS **flag**.

Inputs (all are optional):

CASEDATA : either a MATPOWER **case struct** or a string containing the name of the file with the **case** data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options **struct** to override default options can be used to specify the solution algorithm, output options termination tolerances, **and** more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results **struct**, with the following fields:  
 (all fields from the **input** MATPOWER **case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)  
 order - **info** used in external <-> internal data conversion  
 et - elapsed **time** in seconds  
 success - success **flag**, 1 = succeeded, 0 = failed  
 (additional OPF fields, see OPF **for** details)

SUCCESS : the success **flag** can additionally be returned as a second output argument

Calling syntax options:

```

results = runopf;
results = runopf(casedata);
results = runopf(casedata, mpopt);
results = runopf(casedata, mpopt, fname);
results = runopf(casedata, mpopt, fname, solvedcase);
[results, success] = runopf(...);

```

Alternatively, **for** compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, gencost, branch, f, success, et] = runopf(...);
```

Example:

```
results = runopf('case30');
```

See also rundcopf(), runuopf().

**runuopf****runuopf**(*casedata*, *mpopt*, *fname*, *solvedcase*)

runuopf() - Runs an optimal power flow with unit-decommitment heuristic.

[RESULTS, SUCCESS] = RUNUOPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)

Runs an optimal **power** flow (AC OPF by default) with a heuristic which allows it to shut down "**expensive**" generators, optionally returning a RESULTS **struct** and SUCCESS **flag**.

Inputs (all are optional):

CASEDATA : either a MATPOWER **case struct** or a string containing the name of the file with the **case** data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options **struct** to override default options can be used to specify the solution algorithm, output options termination tolerances, **and** more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results **struct**, with the following fields:  
 (all fields from the **input** MATPOWER **case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)  
 order - **info** used in external <-> internal data conversion  
 et - elapsed **time** in seconds  
 success - success **flag**, 1 = succeeded, 0 = failed  
 (additional OPF fields, see OPF **for** details)

SUCCESS : the success **flag** can additionally be returned as a second output argument

Calling syntax options:

```

results = runuopf;
results = runuopf(casedata);
results = runuopf(casedata, mpopt);
results = runuopf(casedata, mpopt, fname);
results = runuopf(casedata, mpopt, fname, solvedcase);
[results, success] = runuopf(...);

```

Alternatively, **for** compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, gencost, branch, f, success, et] = runuopf(...);
```

Example:

```
results = runuopf('case30');
```

See also runopf(), runduopf().

**rundcpf****rundcpf**(*casedata*, *mpopt*, *fname*, *solvedcase*)

rundcpf() - Runs a DC power flow.

```
[RESULTS, SUCCESS] = RUNDCPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)
```

Runs a DC power flow, optionally returning a RESULTS struct and SUCCESS flag.

Inputs (all are optional):

CASEDATA : either a MATPOWER case struct or a string containing the name of the file with the case data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options struct to override default options can be used to specify the solution algorithm, output options termination tolerances, and more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved case will be saved in MATPOWER case format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results struct, with the following fields:  
 (all fields from the input MATPOWER case, i.e. bus, branch, gen, etc., but with solved voltages, power flows, etc.)  
 order - info used in external <-> internal data conversion  
 et - elapsed time in seconds  
 success - success flag, 1 = succeeded, 0 = failed

SUCCESS : the success flag can additionally be returned as a second output argument

Calling syntax options:

```
results = rundcpf;
results = rundcpf(casedata);
results = rundcpf(casedata, mpopt);
results = rundcpf(casedata, mpopt, fname);
results = rundcpf(casedata, mpopt, fname, solvedcase);
[results, success] = rundcpf(...);
```

Alternatively, for compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, branch, success, et] = rundcpf(...);
```

Example:

```
results = rundcpf('case30');
```

See also runpf().

**rundcopf****rundcopf**(*casedata, mpopt, fname, solvedcase*)

rundcopf() - Runs a DC optimal power flow.

[RESULTS, SUCCESS] = RUNCOPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)

Runs a DC optimal **power** flow, optionally returning a RESULTS **struct** and SUCCESS **flag**.

Inputs (all are optional):

CASEDATA : either a MATPOWER **case struct** or a string containing the name of the file with the **case** data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options **struct** to override default options can be used to specify the solution algorithm, output options termination tolerances, and more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results **struct**, with the following fields:  
 (all fields from the **input** MATPOWER **case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)  
 order - **info** used in external <-> internal data conversion  
 et - elapsed **time** in seconds  
 success - success **flag**, 1 = succeeded, 0 = failed  
 (additional OPF fields, see OPF **for** details)

SUCCESS : the success **flag** can additionally be returned as a second output argument

Calling syntax options:

```
results = rundcopf;
results = rundcopf(casedata);
results = rundcopf(casedata, mpopt);
results = rundcopf(casedata, mpopt, fname);
results = rundcopf(casedata, mpopt, fname, solvedcase);
[results, success] = rundcopf(...);
```

Alternatively, **for** compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, gencost, branch, f, success, et] = rundcopf(...);
```

Example:

```
results = rundcopf('case30');
```

See also runopf(), runduopf().

**runduopf****runduopf**(*casedata, mpopt, fname, solvedcase*)

runduopf() - Runs a DC optimal power flow with unit-decommitment heuristic.

[RESULTS, SUCCESS] = RUNDUOPF(CASEDATA, MPOPT, FNAME, SOLVEDCASE)

Runs a DC optimal **power** flow with a heuristic which allows it to shut down "**expensive**" generators optionally returning a RESULTS **struct** and SUCCESS **flag**.

Inputs (all are optional):

CASEDATA : either a MATPOWER **case struct** or a string containing the name of the file with the **case** data (default is 'case9') (see CASEFORMAT and LOADCASE)

MPOPT : MATPOWER options **struct** to override default options can be used to specify the solution algorithm, output options termination tolerances, and more (see MPOPTION).

FNAME : name of a file to which the pretty-printed output will be appended

SOLVEDCASE : name of file to which the solved **case** will be saved in MATPOWER **case** format (M-file will be assumed unless the specified name ends with '.mat')

Outputs (all are optional):

RESULTS : results **struct**, with the following fields:  
 (all fields from the **input** MATPOWER **case**, i.e. bus, branch, gen, etc., but with solved voltages, **power** flows, etc.)  
 order - **info** used in external <-> internal data conversion  
 et - elapsed **time** in seconds  
 success - success **flag**, 1 = succeeded, 0 = failed  
 (additional OPF fields, see OPF **for** details)

SUCCESS : the success **flag** can additionally be returned as a second output argument

Calling syntax options:

```
results = runduopf;
results = runduopf(casedata);
results = runduopf(casedata, mpopt);
results = runduopf(casedata, mpopt, fname);
results = runduopf(casedata, mpopt, fname, solvedcase);
[results, success] = runduopf(...);
```

Alternatively, **for** compatibility with previous versions of MATPOWER, some of the results can be returned as individual output arguments:

```
[baseMVA, bus, gen, gencost, branch, f, success, et] = runduopf(...);
```

Example:

```
results = runduopf('case30');
```

See also rundcopf(), runuopf().

**runopf\_w\_res****runopf\_w\_res**(varargin)

*runopf\_w\_res*() (page 236) - Runs an optimal power flow with fixed zonal reserves.

```
RESULTS = RUNOPF_W_RES(CASEDATA, MPOPT, FNAME, SOLVEDCASE)
[RESULTS, SUCCESS] = RUNOPF_W_RES(CASEDATA, MPOPT, FNAME, SOLVEDCASE)
```

Runs an optimal **power** flow with the addition of reserve requirements specified as a **set** of fixed zonal reserves. See **RUNOPF** for a description of the **input** and output arguments, which are the same, with the exception that the **case** file or **struct** CASEDATA must define a **'reserves'** field, which is a **struct** with the following fields:

```
zones    nrz x ng, zone(i, j) = 1, if gen j belongs to zone i
          0, otherwise
req      nrz x 1, zonal reserve requirement in MW
cost     (ng or ngr) x 1, cost of reserves in $/MW
qty      (ng or ngr) x 1, max quantity of reserves in MW (optional)
```

where nrz is the number of reserve zones and ngr is the number of generators belonging to at least one reserve zone and ng is the total number of generators.

In addition to the normal OPF output, the RESULTS **struct** contains a new **'reserves'** field with the following fields, in addition to those provided in the **input**:

```
R        - ng x 1, reserves provided by each gen in MW
Rmin     - ng x 1, lower limit on reserves provided by each gen, (MW)
Rmax     - ng x 1, upper limit on reserves provided by each gen, (MW)
mu.l     - ng x 1, shadow price on reserve lower limit, ($/MW)
mu.u     - ng x 1, shadow price on reserve upper limit, ($/MW)
mu.Pmax  - ng x 1, shadow price on  $P_g + R \leq P_{max}$  constraint, ($/MW)
prc      - ng x 1, reserve price for each gen equal to maximum of the
          shadow prices on the zonal requirement constraint
          for each zone the generator belongs to
```

See T\_CASE30\_USERFCNS for an **example case** file with fixed reserves, and TOGGLE\_RESERVES for the implementation.

Calling syntax options:

```
results = runopf_w_res(casedata);
results = runopf_w_res(casedata, mpopt);
results = runopf_w_res(casedata, mpopt, fname);
results = runopf_w_res(casedata, mpopt, fname, solvedcase);
[results, success] = runopf_w_res(...);
```

Example:

```
results = runopf_w_res('t_case30_userfcns');
```

See also *runopf*(), *toggle\_reserves*() (page 307), *t\_case30\_userfcns*() (page 382).

## 5.2.2 Input/Output Functions

### caseformat

#### caseformat()

caseformat - Defines the MATPOWER case file format.

A MATPOWER **case** file is an M-file or MAT-file that defines or returns a **struct** named `mpc`, referred to as a "MATPOWER case struct". The fields of this **struct** are `baseMVA`, `bus`, `gen`, `branch`, and (optional) `gencost`. With the exception of `baseMVA`, a scalar, each data variable is a matrix, where a row corresponds to a **single** bus, branch, gen, etc. The format of the data is similar to the PTI format described in

<https://labs.ece.uw.edu/pstca/formats/pti.txt>

except where noted. An item marked with (+) indicates that it is included in this data but is **not** part of the PTI format. An item marked with (-) is one that is in the PTI format but is **not** included here. Those marked with (2) were added **for version 2** of the **case** file format. The **columns for** each data matrix are given below.

#### MATPOWER Case Version Information:

There are two versions of the MATPOWER **case** file format. The current **version** of MATPOWER uses **version 2** of the MATPOWER **case** format internally, and includes a `'version'` field with a value of `'2'` to make the **version** explicit. Earlier versions of MATPOWER used the **version 1 case** format, which defined the data matrices as individual variables, as opposed to fields of a **struct**. Case files in **version 1** format with OPF data also included an (unused) `'areas'` variable. While the **version 1** format has **now** been deprecated, it is still be handled automatically by `LOADCASE` and `SAVECASE` which are able to **load and save case** files in both **version 1 and version 2** formats.

See `IDX_BUS`, `IDX_BRCH`, `IDX_GEN`, `IDX_AREA` and `IDX_COST` regarding constants which can be used as named column indices **for** the data matrices. Also described in the first three are additional results **columns** that are added to the bus, branch and gen matrices by the **power flow and OPF solvers**.

The **case struct** also allows **for** additional fields to be included. The OPF is designed to recognize fields named `A`, `l`, `u`, `H`, `Cw`, `N`, `fparm`, `z0`, `z1` and `zu` as parameters used to directly extend the OPF formulation (see OPF **for** details). Additional standard optional fields include `bus_name`, `gentype` and `genfuel`. Other user-defined fields may also be included and will be automatically loaded by the `LOADCASE` **function** and, given an appropriate `'savecase'` callback **function** (see `ADD_USERFCN`), saved by the `SAVECASE` **function**.

#### Bus Data Format

- 1 bus number (positive integer)
- 2 bus type

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```

        PQ bus          = 1
        PV bus          = 2
        reference bus   = 3
        isolated bus    = 4
3  Pd, real power demand (MW)
4  Qd, reactive power demand (MVar)
5  Gs, shunt conductance (MW demanded at V = 1.0 p.u.)
6  Bs, shunt susceptance (MVar injected at V = 1.0 p.u.)
7  area number, (positive integer)
8  Vm, voltage magnitude (p.u.)
9  Va, voltage angle (degrees)
(-) (bus name)
10 baseKV, base voltage (kV)
11 zone, loss zone (positive integer)
(+) 12 maxVm, maximum voltage magnitude (p.u.)
(+) 13 minVm, minimum voltage magnitude (p.u.)

Generator Data Format
1  bus number
(-) (machine identifier, 0-9, A-Z)
2  Pg, real power output (MW)
3  Qg, reactive power output (MVar)
4  Qmax, maximum reactive power output (MVar)
5  Qmin, minimum reactive power output (MVar)
6  Vg, voltage magnitude setpoint (p.u.)
(-) (remote controlled bus index)
7  mBase, total MVA base of this machine, defaults to baseMVA
(-) (machine impedance, p.u. on mBase)
(-) (step up transformer impedance, p.u. on mBase)
(-) (step up transformer off nominal turns ratio)
8  status, > 0 - machine in service
      <= 0 - machine out of service
(-) (% of total VAR's to come from this gen in order to hold V at
      remote bus controlled by several generators)
9  Pmax, maximum real power output (MW)
10 Pmin, minimum real power output (MW)
(2) 11 Pc1, lower real power output of PQ capability curve (MW)
(2) 12 Pc2, upper real power output of PQ capability curve (MW)
(2) 13 Qc1min, minimum reactive power output at Pc1 (MVar)
(2) 14 Qc1max, maximum reactive power output at Pc1 (MVar)
(2) 15 Qc2min, minimum reactive power output at Pc2 (MVar)
(2) 16 Qc2max, maximum reactive power output at Pc2 (MVar)
(2) 17 ramp rate for load following/AGC (MW/min)
(2) 18 ramp rate for 10 minute reserves (MW)
(2) 19 ramp rate for 30 minute reserves (MW)
(2) 20 ramp rate for reactive power (2 sec timescale) (MVar/min)
(2) 21 APF, area participation factor

Branch Data Format
1  f, from bus number
2  t, to bus number
(-) (circuit identifier)

```

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```

3  r, resistance (p.u.)
4  x, reactance (p.u.)
5  b, total line charging susceptance (p.u.)
6  rateA, MVA rating A (long term rating), set to 0 for unlimited
7  rateB, MVA rating B (short term rating), set to 0 for unlimited
8  rateC, MVA rating C (emergency rating), set to 0 for unlimited
9  tap, transformer off nominal turns ratio, if non-zero
   (taps at "from" bus, impedance at "to" bus, i.e. if r = x = b = 0,
    then tap = Vf / Vt; tap = 0 used to indicate transmission
    line rather than transformer, i.e. mathematically equivalent to
    transformer with tap = 1)
10 shift, transformer phase shift angle (degrees), positive => delay
(-) (Gf, shunt conductance at from bus p.u.)
(-) (Bf, shunt susceptance at from bus p.u.)
(-) (Gt, shunt conductance at to bus p.u.)
(-) (Bt, shunt susceptance at to bus p.u.)
11 initial branch status, 1 - in service, 0 - out of service
(2) 12 minimum angle difference, angle(Vf) - angle(Vt) (degrees)
(2) 13 maximum angle difference, angle(Vf) - angle(Vt) (degrees)
   (The voltage angle difference is taken to be unbounded below
    if ANGMIN < -360 and unbounded above if ANGMAX > 360.
    If both parameters are zero, it is unconstrained.)

(+) Generator Cost Data Format
NOTE: If gen has ng rows, then the first ng rows of gencost contain
the cost for active power produced by the corresponding generators.
If gencost has 2*ng rows then rows ng+1 to 2*ng contain the reactive
power costs in the same format.
1  model, 1 - piecewise linear, 2 - polynomial
2  startup, startup cost in US dollars
3  shutdown, shutdown cost in US dollars
4  N (= n+1), number of data points to follow defining an n-segment
   piecewise linear cost function, or of cost coefficients defining
   an n-th order polynomial cost function
5  and following, parameters defining total cost function f(p),
   units of f and p are $/hr and MW (or MVar), respectively.
   (MODEL = 1) : p1, f1, p2, f2, ..., pN, fN
               where p1 < p2 < ... < pN and the cost f(p) is defined by
               the coordinates (p1,f1), (p2,f2), ..., (pN,fN) of the
               end/break-points of the piecewise linear cost function
   (MODEL = 2) : cn, ..., c1, c0
               N coefficients of an n-th order polynomial cost function,
               starting with highest order, where cost is
               f(p) = cn*p^n + ... + c1*p + c0

(+) Area Data Format (deprecated)
   (this data is not used by MATPOWER and is no longer necessary for
   version 2 case files with OPF data).
1  i, area number
2  price_ref_bus, reference bus for that area

```

See also `loadcase()`, `savecase()`, `idx_bus()` (page 340), `idx_brch()` (page 339), `idx_gen()` (page 345), `idx_area` `idx_cost()` (page 341).

**cdf2mpc****cdf2mpc**(cdf\_file\_name, mpc\_name, verbose)

cdf2mpc() - Converts an IEEE CDF data file into a MATPOWER case struct.

```

MPC = CDF2MPC(CDF_FILE_NAME)
MPC = CDF2MPC(CDF_FILE_NAME, VERBOSE)
MPC = CDF2MPC(CDF_FILE_NAME, MPC_NAME)
MPC = CDF2MPC(CDF_FILE_NAME, MPC_NAME, VERBOSE)
[MPC, WARNINGS] = CDF2MPC(CDF_FILE_NAME, ...)

```

Converts an IEEE Common Data Format (CDF) data file into a MATPOWER **case struct**.

## Input:

CDF\_FILE\_NAME : name of the IEEE CDF file to be converted  
MPC\_NAME : (optional) file name to use to save the resulting MATPOWER **case struct**  
VERBOSE : 1 (default) to **display progress info**, 0 **otherwise**

## Output(s):

MPC : resulting MATPOWER **case struct**  
WARNINGS : (optional) **cell array** of strings containing **warning messages** (included by default in comments of MPC\_NAME).

The IEEE CDF does **not** include some data need to **run** an optimal **power flow**. This script creates default values **for** some of this data as follows:

## Bus data:

Vmin = 0.94 p.u.  
Vmax = 1.06 p.u.

## Gen data:

Pmin = 0 MW  
Pmax = Pg + baseMVA

## Gen cost data:

## Quadratic costs with:

c2 = 10 / Pg, c1 = 20, c0 = 0, **if** Pg is non-zero, **and**  
c2 = 0.01, c1 = 40, c0 = 0, **if** Pg is zero

This should yield an OPF solution "**close**" to the existing solution (assuming it is a solved **case**) with lambdas near \$40/MWh. See '**help caseformat**' **for** details on the cost curve format.

CDF2MPC may modify some of the data which are "**infeasible**" **for** running optimal **power flow**. If so, **warning** information will be printed out on screen.

Note: Since our code can **not** handle transformers with variable tap, you may **not** expect to **get** exactly the same **power flow** solution using converted data. This is the **case** when we converted ieee300.cdf.

## loadcase

### loadcase(*casefile*)

loadcase() - Load .m or .mat case files or data struct in MATPOWER format.

```
[BASEMVA, BUS, GEN, BRANCH, AREAS, GENCOST] = LOADCASE(CASEFILE)
[BASEMVA, BUS, GEN, BRANCH, GENCOST] = LOADCASE(CASEFILE)
[BASEMVA, BUS, GEN, BRANCH] = LOADCASE(CASEFILE)
MPC = LOADCASE(CASEFILE)
```

Returns the individual data matrices or a **struct** containing them as fields.

Here CASEFILE is either (1) a **struct** containing the fields baseMVA, bus, gen, branch and, optionally, areas and/or gencost, or (2) a string containing the name of the file. If CASEFILE contains the extension '.mat' or '.m', then the explicit file is searched. If CASEFILE contains no extension, then LOADCASE looks for a MAT-file first, then for an M-file. If the file does not exist or doesn't define all required matrices, the routine aborts with an appropriate error message.

If the input data is from an M-file or MAT-file defining individual data matrices, or from a **struct** with out a 'version' field whose GEN matrix has fewer than 21 columns, then it is assumed to be a MATPOWER case file in version 1 format, and will be converted to version 2 format.

## mpoption

### mpoption(*varargin*)

mpoption() - Used to set and retrieve a MATPOWER options struct.

```
OPT = MPOPTION
```

Returns the default options **struct**.

```
OPT = MPOPTION(OVERRIDES)
```

Returns the default options **struct**, with some fields overridden by values from OVERRIDES, which can be a **struct** or the name of a **function** that returns a **struct**.

```
OPT = MPOPTION(NAME1, VALUE1, NAME2, VALUE2, ...)
```

Same as previous, except override options are specified by NAME, VALUE pairs. This can be used to **set any** part of the options **struct**. The names can be individual fields or multi-level field names with embedded periods. The values can be scalars or **structs**.

For backward compatibility, the NAMES and VALUES may correspond to old-style MATPOWER option names (elements in the old-style options vector) as well.

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OPT = MPOPTION(OPT0)  
 Converts an old-style options vector OPT0 into the corresponding options `struct`. If OPT0 is an options `struct` it does nothing.

OPT = MPOPTION(OPT0, OVERRIDES)  
 Applies overrides to an existing `set` of options, OPT0, which can be an old-style options vector or an options `struct`.

OPT = MPOPTION(OPT0, NAME1, VALUE1, NAME2, VALUE2, ...)  
 Same as above except it uses the old-style options vector OPT0 as a base instead of the old default options vector.

OPT\_VECTOR = MPOPTION(OPT, [])  
 Creates and returns an old-style options vector from an options `struct` OPT.

Note: The use of old-style MATPOWER options vectors and their names and values has been deprecated and will be removed in a future version of MATPOWER. Until then, all uppercase option names are not permitted for new top-level options.

Examples:

```
mpopt = mpooption('pf.alg', 'FDXB', 'pf.tol', 1e-4);
mpopt = mpooption(mpooption, 'opf.dc.solver', 'CPLEX', 'verbose', 2);
```

The currently defined options are as follows:

name	default	description [options]
Model options:		
model	'AC'	AC vs. DC power flow model
[ 'AC'	- use nonlinear AC model & corresponding algorithms/options	]
[ 'DC'	- use linear DC model & corresponding algorithms/options	]
Power Flow options:		
pf.alg	'NR'	AC power flow algorithm
[ 'NR'	- Newton's method (formulation depends on values of	]
[	pf.current_balance and pf.v_cartesian options)	]
[ 'NR-SP'	- Newton's method (power mismatch, polar)	]
[ 'NR-SC'	- Newton's method (power mismatch, cartesian)	]
[ 'NR-SH'	- Newton's method (power mismatch, hybrid)	]
[ 'NR-IP'	- Newton's method (current mismatch, polar)	]
[ 'NR-IC'	- Newton's method (current mismatch, cartesian)	]
[ 'NR-IH'	- Newton's method (current mismatch, hybrid)	]
[ 'FDXB'	- Fast-Decoupled (XB version)	]
[ 'FDBX'	- Fast-Decoupled (BX version)	]
[ 'GS'	- Gauss-Seidel	]
[ 'ZG'	- Implicit Z-bus Gauss	]
[ 'PQSUM'	- Power Summation method (radial networks only)	]
[ 'ISUM'	- Current Summation method (radial networks only)	]
[ 'YSUM'	- Admittance Summation method (radial networks only)	]

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```

pf.current_balance    0          type of nodal balance equation
  [ 0 - use complex power balance equations          ]
  [ 1 - use complex current balance equations        ]
pf.v_cartesian       0          voltage representation
  [ 0 - bus voltage variables represented in polar   ]
  [ 1 - bus voltage variables represented in cartesian ]
  [ 2 - hybrid, polar updates computed via modified cartesian Jacobian ]
pf.tol               1e-8      termination tolerance on per unit
                              P & Q mismatch
pf.nr.max_it         10        maximum number of iterations for
                              Newton's method
pf.nr.lin_solver     ''        linear solver passed to MPLINSOLVE to
                              solve Newton update step
  [ '' - default to '\' for small systems, 'LU3' for larger ones ]
  [ '\' - built-in backslash operator                ]
  [ 'LU' - explicit default LU decomposition and back substitution ]
  [ 'LU3' - 3 output arg form of LU, Gilbert-Peierls algorithm with ]
  [          approximate minimum degree (AMD) reordering            ]
  [ 'LU4' - 4 output arg form of LU, UMFPACK solver (same as 'LU') ]
  [ 'LU5' - 5 output arg form of LU, UMFPACK solver, w/row scaling ]
  [ (see MPLINSOLVE for complete list of all options)             ]
pf.fد.max_it        30        maximum number of iterations for
                              fast decoupled method
pf.gs.max_it         1000     maximum number of iterations for
                              Gauss-Seidel method
pf.zg.max_it         1000     maximum number of iterations for
                              Implicit Z-bus Gauss method
pf.radial.max_it     20        maximum number of iterations for
                              radial power flow methods
pf.radial.vcorr      0          perform voltage correction procedure
                              in distribution power flow
  [ 0 - do NOT perform voltage correction            ]
  [ 1 - perform voltage correction                    ]
pf.enforce_q_lims    0          enforce gen reactive power limits at
                              expense of |V|
  [ 0 - do NOT enforce limits                        ]
  [ 1 - enforce limits, simultaneous bus type conversion ]
  [ 2 - enforce limits, one-at-a-time bus type conversion ]

Continuation Power Flow options:
cpf.parameterization  3          choice of parameterization
  [ 1 - natural                                       ]
  [ 2 - arc length                                   ]
  [ 3 - pseudo arc length                             ]
cpf.stop_at          'NOSE'     determines stopping criterion
  [ 'NOSE' - stop when nose point is reached          ]
  [ 'FULL' - trace full nose curve                    ]
  [ <lam_stop> - stop upon reaching specified target lambda value ]
cpf.enforce_p_lims    0          enforce gen active power limits
  [ 0 - do NOT enforce limits                        ]
  [ 1 - enforce limits, simultaneous bus type conversion ]
cpf.enforce_q_lims    0          enforce gen reactive power limits at

```

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```

expense of |V|
[ 0 - do NOT enforce limits ]
[ 1 - enforce limits, simultaneous bus type conversion ]
cpf.enforce_v_lims 0 enforce bus voltage magnitude limits
[ 0 - do NOT enforce limits ]
[ 1 - enforce limits, termination on detection ]
cpf.enforce_flow_lims 0 enforce branch flow MVA limits
[ 0 - do NOT enforce limits ]
[ 1 - enforce limits, termination on detection ]
cpf.step 0.05 continuation power flow step size
cpf.adapt_step 0 toggle adaptive step size feature
[ 0 - adaptive step size disabled ]
[ 1 - adaptive step size enabled ]
cpf.step_min 1e-4 minimum allowed step size
cpf.step_max 0.2 maximum allowed step size
cpf.adapt_step_damping 0.7 damping factor for adaptive step
sizing
cpf.adapt_step_tol 1e-3 tolerance for adaptive step sizing
cpf.target_lam_tol 1e-5 tolerance for target lambda detection
cpf.nose_tol 1e-5 tolerance for nose point detection (pu)
cpf.p_lims_tol 0.01 tolerance for generator active
power limit enforcement (MW)
cpf.q_lims_tol 0.01 tolerance for generator reactive
power limit enforcement (MVAR)
cpf.v_lims_tol 1e-4 tolerance for bus voltage
magnitude enforcement (p.u)
cpf.flow_lims_tol 0.01 tolerance for line MVA flow
enforcement (MVA)
cpf.plot.level 0 control plotting of nose curve
[ 0 - do not plot nose curve ]
[ 1 - plot when completed ]
[ 2 - plot incrementally at each iteration ]
[ 3 - same as 2, with 'pause' at each iteration ]
cpf.plot.bus <empty> index of bus whose voltage is to be
plotted
cpf.user_callback <empty> string containing the name of a user
callback function, or struct with
function name, and optional priority
and/or args, or cell array of such
strings and/or structs, see
'help cpf_default_callback' for details

```

Optimal Power Flow options:

name	default	description [options]
opf.ac.solver	'DEFAULT'	AC optimal power flow solver
[ 'DEFAULT'	- choose default solver, i.e. 'MIPS'	]
[ 'MIPS'	- MIPS, MATPOWER Interior Point Solver, primal/dual	]
[ interior point method (pure MATLAB/Octave)		]
[ 'FMINCON'	- MATLAB Optimization Toolbox, FMINCON	]
[ 'IPOPT'	- IPOPT, requires MEX interface to IPOPT solver	]
[ available from:		]

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```

[          https://github.com/coin-or/Ipopt ]
[ 'KNITRO' - Artelys Knitro, requires Artelys Knitro solver, ]
[          available from:https://www.artelys.com/solvers/knitro/]
[ 'MINOPF' - MINOPF, MINOS-based solver, requires optional ]
[          MEX-based MINOPF package, available from: ]
[          http://www.pserc.cornell.edu/minopf/ ]
[ 'PDIPM'  - PDIPM, primal/dual interior point method, requires ]
[          optional MEX-based TSPOPF package, available from: ]
[          http://www.pserc.cornell.edu/tspopf/ ]
[ 'SDPOPF' - SDPOPF, solver based on semidefinite relaxation of ]
[          OPF problem, requires optional packages: ]
[          SDP_PF, available in extras/sdp_pf ]
[          YALMIP, available from: ]
[          https://yalmip.github.io ]
[          SDP solver such as SeDuMi, available from: ]
[          http://sedumi.ie.lehigh.edu/ ]
[ 'TRALM'  - TRALM, trust region based augmented Langrangian ]
[          method, requires TSPOPF (see 'PDIPM') ]
opf.dc.solver      'DEFAULT'  DC optimal power flow solver
[ 'DEFAULT' - choose solver based on availability in the following ]
[          order: 'GUROBI', 'CPLEX', 'MOSEK', 'OT', ]
[          'GLPK' (linear costs only), 'BPMPD', 'MIPS' ]
[ 'MIPS'    - MIPS, MATPOWER Interior Point Solver, primal/dual ]
[          interior point method (pure MATLAB/Octave) ]
[ 'BPMPD'   - BPMPD, requires optional MEX-based BPMPD_MEX package ]
[          available from: http://www.pserc.cornell.edu/bmpmd/ ]
[ 'CLP'     - CLP, requires interface to COIN-OP LP solver ]
[          available from:https://github.com/coin-or/Clp ]
[ 'CPLEX'   - CPLEX, requires CPLEX solver available from: ]
[          https://www.ibm.com/analytics/cplex-optimizer ]
[ 'GLPK'    - GLPK, requires interface to GLPK solver ]
[          available from: https://www.gnu.org/software/glpk/ ]
[          (GLPK does not work with quadratic cost functions) ]
[ 'GUROBI'  - GUROBI, requires Gurobi optimizer (v. 5+) ]
[          available from: https://www.gurobi.com/ ]
[ 'IPOPT'   - IPOPT, requires MEX interface to IPOPT solver ]
[          available from: ]
[          https://github.com/coin-or/Ipopt ]
[ 'MOSEK'   - MOSEK, requires MATLAB interface to MOSEK solver ]
[          available from: https://www.mosek.com/ ]
[ 'OSQP'    - OSQP, requires MATLAB interface to OSQP solver ]
[          available from: https://osqp.org/ ]
[ 'OT'      - MATLAB Optimization Toolbox, QUADPROG, LINPROG ]
opf.current_balance  0          type of nodal balance equation
[ 0 - use complex power balance equations ]
[ 1 - use complex current balance equations ]
opf.v_cartesian      0          voltage representation
[ 0 - bus voltage variables represented in polar coordinates ]
[ 1 - bus voltage variables represented in cartesian coordinates ]
opf.violation        5e-6       constraint violation tolerance
opf.use_vg            0          respect gen voltage setpt [ 0-1 ]
[ 0 - use specified bus Vmin & Vmax, and ignore gen Vg ]

```

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```

[ 1 - replace specified bus Vmin & Vmax by corresponding gen Vg ]
[ between 0 and 1 - use a weighted average of the 2 options ]
opf.flow_lim      'S'      quantity limited by branch flow
                        constraints
[ 'S' - apparent power flow (limit in MVA) ]
[ 'P' - active power flow, implemented using P (limit in MW) ]
[ '2' - active power flow, implemented using P^2 (limit in MW) ]
[ 'I' - current magnitude (limit in MVA at 1 p.u. voltage) ]
opf.ignore_angle_lim  0      angle diff limits for branches
[ 0 - include angle difference limits, if specified ]
[ 1 - ignore angle difference limits even if specified ]
opf.softlims.default  1      behavior of OPF soft limits for
                        which parameters are not explicitly
                        provided
[ 0 - do not include softlims if not explicitly specified ]
[ 1 - include softlims w/default values if not explicitly specified ]
opf.start          0      strategy for initializing OPF start pt
[ 0 - default, MATPOWER decides based on solver ]
[ (currently identical to 1) ]
[ 1 - ignore current state in MATPOWER case (only applies to ]
[ fmincon, Ipopt, Knitro and MIPS, which use an interior pt ]
[ estimate; others use current state as with opf.start = 2) ]
[ 2 - use current state in MATPOWER case ]
[ 3 - solve power flow and use resulting state ]
opf.return_raw_der  0      for AC OPF, return constraint and
                        derivative info in results.raw
                        (in fields g, dg, df, d2f) [ 0 or 1 ]

```

Output options:

name	default	description [options]
verbose	1	amount of progress info printed
[ 0 - print no progress info ]		
[ 1 - print a little progress info ]		
[ 2 - print a lot of progress info ]		
[ 3 - print all progress info ]		
out.all	-1	controls pretty-printing of results
[ -1 - individual flags control what prints ]		
[ 0 - do not print anything (overrides individual flags, ignored ]		
[ for files specified as FNAME arg to runpf(), runopf(), etc.) ]		
[ 1 - print everything (overrides individual flags) ]		
out.sys_sum	1	print system summary [ 0 or 1 ]
out.area_sum	0	print area summaries [ 0 or 1 ]
out.bus	1	print bus detail [ 0 or 1 ]
out.branch	1	print branch detail [ 0 or 1 ]
out.gen	0	print generator detail [ 0 or 1 ]
out.lim.all	-1	controls constraint info output
[ -1 - individual flags control what constraint info prints ]		
[ 0 - no constraint info (overrides individual flags) ]		
[ 1 - binding constraint info (overrides individual flags) ]		
[ 2 - all constraint info (overrides individual flags) ]		
out.lim.v	1	control voltage limit info

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```

[ 0 - do not print ]
[ 1 - print binding constraints only ]
[ 2 - print all constraints ]
[ (same options for OUT_LINE_LIM, OUT_PG_LIM, OUT_QG_LIM) ]
out.lim.line      1          control line flow limit info
out.lim.pg        1          control gen active power limit info
out.lim.qg        1          control gen reactive pwr limit info
out.force         0          print results even if success
                        flag = 0 [ 0 or 1 ]
out.suppress_detail -1      suppress all output but system summary
[ -1 - suppress details for large systems (> 500 buses) ]
[ 0 - do not suppress any output specified by other flags ]
[ 1 - suppress all output except system summary section ]
[ (overrides individual flags, but not out.all = 1) ]

```

Solver specific options:

name	default	description [options]
MIPS:		
mips.linsolver	''	linear system solver
[ '' or '\'	build-in backslash \ operator (e.g. x = A \ b)	]
[ 'PARDISO'	PARDISO solver (if available)	]
mips.feastol	0	feasibility (equality) tolerance (set to opf.violation by default)
mips.gradtol	1e-6	gradient tolerance
mips.comptol	1e-6	complementary condition (inequality) tolerance
mips.costtol	1e-6	optimality tolerance
mips.max_it	150	maximum number of iterations
mips.step_control	0	enable step-size cntrl [ 0 or 1 ]
mips.sc.red_it	20	maximum number of reductions per iteration with step control
mips.xi	0.99995	constant used in alpha updates*
mips.sigma	0.1	centering parameter*
mips.z0	1	used to initialize slack variables*
mips.alpha_min	1e-8	returns "Numerically Failed" if either alpha parameter becomes smaller than this value*
mips.rho_min	0.95	lower bound on rho_t*
mips.rho_max	1.05	upper bound on rho_t*
mips.mu_threshold	1e-5	KT multipliers smaller than this value for non-binding constraints are forced to zero
mips.max_stepsize	1e10	returns "Numerically Failed" if the 2-norm of the reduced Newton step exceeds this value*

\* See the corresponding Appendix in the manual for details.

CPLEX:

```

cplex.lpmethod    0          solution algorithm for LP problems
[ 0 - automatic: let CPLEX choose ]
[ 1 - primal simplex ]

```

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```

    [ 2 - dual simplex ]
    [ 3 - network simplex ]
    [ 4 - barrier ]
    [ 5 - sifting ]
    [ 6 - concurrent (dual, barrier, and primal) ]
cplex.qpmethod      0          solution algorithm for QP problems
    [ 0 - automatic: let CPLEX choose ]
    [ 1 - primal simplex optimizer ]
    [ 2 - dual simplex optimizer ]
    [ 3 - network optimizer ]
    [ 4 - barrier optimizer ]
cplex.opts          <empty>    see CPLEX_OPTIONS for details
cplex.opt_fname    <empty>    see CPLEX_OPTIONS for details
cplex.opt           0          see CPLEX_OPTIONS for details

FMINCON:
fmincon.alg        4          algorithm used by fmincon() for OPF
                        for Opt Toolbox 4 and later
    [ 1 - active-set (not suitable for large problems) ]
    [ 2 - interior-point, w/default 'bfgs' Hessian approx ]
    [ 3 - interior-point, w/ 'lbfgs' Hessian approx ]
    [ 4 - interior-point, w/exact user-supplied Hessian ]
    [ 5 - interior-point, w/Hessian via finite differences ]
    [ 6 - sqp (not suitable for large problems) ]
fmincon.tol_x      1e-4      termination tol on x
fmincon.tol_f      1e-4      termination tol on f
fmincon.max_it     0          maximum number of iterations
                        [ 0 => default ]

GUROBI:
gurobi.method      0          solution algorithm (Method)
    [ -1 - automatic, let Gurobi decide ]
    [ 0 - primal simplex ]
    [ 1 - dual simplex ]
    [ 2 - barrier ]
    [ 3 - concurrent (LP only) ]
    [ 4 - deterministic concurrent (LP only) ]
    [ 5 - deterministic concurrent simplex (LP only) ]
gurobi.timelimit   Inf       maximum time allowed (TimeLimit)
gurobi.threads     0          max number of threads (Threads)
gurobi.opts        <empty>    see GUROBI_OPTIONS for details
gurobi.opt_fname   <empty>    see GUROBI_OPTIONS for details
gurobi.opt         0          see GUROBI_OPTIONS for details

IPOPT:
ipopt.opts         <empty>    see IPOPT_OPTIONS for details
ipopt.opt_fname    <empty>    see IPOPT_OPTIONS for details
ipopt.opt          0          see IPOPT_OPTIONS for details

KNITRO:
knitro.tol_x       1e-4      termination tol on x
knitro.tol_f       1e-4      termination tol on f

```

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```

knitro.maxit          0          maximum number of iterations
                        [ 0 => default ]
knitro.opt_fname     <empty>    name of user-supplied native
                                Knitro options file that overrides
                                all other options
knitro.opt            0          if knitro.opt_fname is empty and
                                knitro.opt is a non-zero integer N
                                then knitro.opt_fname is auto-
                                generated as:
                                'knitro_user_options_N.txt'

LINPROG:
  linprog             <empty>    LINPROG options passed to
                                OPTIMOPTIONS or OPTIMSET.
                                see LINPROG in the Optimization
                                Toolbox for details

MINOPF:
  minopf.feastol      0 (1e-3)    primal feasibility tolerance
                                (set to opf.violation by default)
  minopf.rowtol       0 (1e-3)    row tolerance
  minopf.xtol         0 (1e-4)    x tolerance
  minopf.majdamp      0 (0.5)    major damping parameter
  minopf.mindamp      0 (2.0)    minor damping parameter
  minopf.penalty      0 (1.0)    penalty parameter
  minopf.major_it     0 (200)    major iterations
  minopf.minor_it     0 (2500)   minor iterations
  minopf.max_it       0 (2500)   iterations limit
  minopf.verbosity    -1        amount of progress info printed
                                [ -1 - controlled by 'verbose' option ]
                                [ 0 - print nothing ]
                                [ 1 - print only termination status message ]
                                [ 2 - print termination status and screen progress ]
                                [ 3 - print screen progress, report file (usually fort.9) ]
  minopf.core         0 (1200*nb + 2*(nb+ng)^2) memory allocation
  minopf.supbasic_lim 0 (2*nb + 2*ng) superbasics limit
  minopf.mult_price   0 (30)     multiple price

MOSEK:
  mosek.lp_alg        0          solution algorithm
                                (MSK_IPAR_OPTIMIZER)
                                for MOSEK 8.x ... (see MOSEK_SYMBCON for a "better way")
                                [ 0 - automatic: let MOSEK choose ]
                                [ 1 - dual simplex ]
                                [ 2 - automatic: let MOSEK choose ]
                                [ 3 - automatic simplex (MOSEK chooses which simplex method) ]
                                [ 4 - interior point ]
                                [ 6 - primal simplex ]
  mosek.max_it        0 (400)    interior point max iterations
                                (MSK_IPAR_INTPNT_MAX_ITERATIONS)
  mosek.gap_tol       0 (1e-8)   interior point relative gap tol
                                (MSK_DPAR_INTPNT_TOL_REL_GAP)

```

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mosek.max_time	0 (-1)	maximum time allowed (MSK_DPAR_OPTIMIZER_MAX_TIME)
mosek.num_threads	0 (1)	max number of threads (MSK_IPAR_INTPNT_NUM_THREADS)
mosek.opts	<empty>	see MOSEK_OPTIONS for details
mosek.opt_fname	<empty>	see MOSEK_OPTIONS for details
mosek.opt	0	see MOSEK_OPTIONS for details
OSQP:		
osqp.opts	<empty>	see OSQP_OPTIONS for details
QUADPROG:		
quadprog	<empty>	QUADPROG options passed to OPTIMOPTIONS or OPTIMSET. see QUADPROG in the Optimization Toolbox for details
TSPOPF:		
pdipm.feastol	0	feasibility (equality) tolerance (set to opf.violation by default)
pdipm.gradtol	1e-6	gradient tolerance
pdipm.comptol	1e-6	complementary condition (inequality) tolerance
pdipm.costtol	1e-6	optimality tolerance
pdipm.max_it	150	maximum number of iterations
pdipm.step_control	0	enable step-size cntrl [ 0 or 1 ]
pdipm.sc.red_it	20	maximum number of reductions per iteration with step control
pdipm.sc.smooth_ratio	0.04	piecewise linear curve smoothing ratio
tralm.feastol	0	feasibility tolerance (set to opf.violation by default)
tralm.primaltol	5e-4	primal variable tolerance
tralm.dualtol	5e-4	dual variable tolerance
tralm.costtol	1e-5	optimality tolerance
tralm.major_it	40	maximum number of major iterations
tralm.minor_it	40	maximum number of minor iterations
tralm.smooth_ratio	0.04	piecewise linear curve smoothing ratio
Experimental Options:		
exp.use_legacy_core	0	set to 1 to bypass MP-Core and force use of legacy core code for runpf(), runcpf(), runopf().
exp.sys_wide_zip_loads.pw	<empty>	1 x 3 vector of active load fraction to be modeled as constant power, constant current and constant impedance, respectively, where <empty> means use [1 0 0]
exp.sys_wide_zip_loads.qw	<empty>	same for reactive power, where <empty> means use same value as

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**for** 'pw'

## printf

**printf**(*baseMVA, bus, gen, branch, f, success, et, fd, mpopt*)

printf() - Prints power flow results.

```
PRINTPF(RESULTS, FD, MPOPT)
PRINTPF(BASEMVA, BUS, GEN, BRANCH, F, SUCCESS, ET, FD, MPOPT)
```

Prints power flow and optimal power flow results to FD (a file descriptor which defaults to STDOUT), with the details of what gets printed controlled by the optional MPOPT argument, which is a MATPOWER options struct (see MPOPTION for details).

The data can either be supplied in a single RESULTS struct, or in the individual arguments: BASEMVA, BUS, GEN, BRANCH, F, SUCCESS and ET, where F is the OPF objective function value, SUCCESS is true if the solution converged and false otherwise, and ET is the elapsed time for the computation in seconds. If F is given, it is assumed that the output is from an OPF run, otherwise it is assumed to be a simple power flow run.

Examples:

```
mpopt = mpoptions('out.gen', 1, 'out.bus', 0, 'out.branch', 0);
[fd, msg] = fopen(fname, 'at');
results = runopf(mpc);
printf(results);
printf(results, fd);
printf(results, fd, mpopt);
printf(baseMVA, bus, gen, branch, f, success, et);
printf(baseMVA, bus, gen, branch, f, success, et, fd);
printf(baseMVA, bus, gen, branch, f, success, et, fd, mpopt);
fclose(fd);
```

## psse2mpc

**psse2mpc**(*rawfile\_name, mpc\_name, verbose, rev*)

psse2mpc() - Converts a PSS/E RAW data file into a MATPOWER case struct.

```
MPC = PSSE2MPC(RAWFILE_NAME)
MPC = PSSE2MPC(RAWFILE_NAME, VERBOSE)
MPC = PSSE2MPC(RAWFILE_NAME, VERBOSE, REV)
MPC = PSSE2MPC(RAWFILE_NAME, MPC_NAME)
MPC = PSSE2MPC(RAWFILE_NAME, MPC_NAME, VERBOSE)
MPC = PSSE2MPC(RAWFILE_NAME, MPC_NAME, VERBOSE, REV)
[MPC, WARNINGS] = PSSE2MPC(RAWFILE_NAME, ...)
```

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Converts a PSS/E RAW data file into a MATPOWER **case struct**.

Input:

RAWFILE\_NAME : name of the PSS/E RAW file to be converted  
(opened directly with FILEREAD)  
MPC\_NAME : (optional) file name to use to save the resulting  
MATPOWER **case**  
VERBOSE : 1 (default) to **display** progress info, 0 **otherwise**  
REV : (optional) assume the **input** file is of this  
PSS/E revision number, attempts to determine  
REV from the file by default

Output(s):

MPC : resulting MATPOWER **case struct**  
WARNINGS : (optional) **cell** array of strings containing **warning**  
messages (included by default in comments of MPC\_NAME).

NOTE: The data sections to be read in the PSS/E raw file includes:  
identification data; bus data; branch data; fixed shunt data;  
generator data; transformer data; switched shunt data; **area** data  
**and** hvdc **line** data. Other data sections are currently ignored.

## save2psse

**save2psse**(*fname, mpc, rawver*)

save2psse() - Saves a MATPOWER case to PSS/E RAW format.

SAVE2PSSE(FNAME, MPC)

FNAME = SAVE2PSSE(FNAME, ...)

Saves a MATPOWER **case struct** MPC as a PSS/E RAW file. The FNAME parameter is a string containing the name of the file to be created **or** overwritten. If FNAME does **not** include a file extension, **'raw'** will be added. Optionally returns the, possibly updated, filename. Currently exports to RAW format Rev 33.

## savecase

**savecase**(*fname*, *varargin*)

savecase() - Saves a MATPOWER case file, given a filename and the data.

```

SAVECASE(FNAME, CASESTRUCT)
SAVECASE(FNAME, CASESTRUCT, VERSION)
SAVECASE(FNAME, BASEMVA, BUS, GEN, BRANCH)
SAVECASE(FNAME, BASEMVA, BUS, GEN, BRANCH, GENCOST)
SAVECASE(FNAME, BASEMVA, BUS, GEN, BRANCH, AREAS, GENCOST)
SAVECASE(FNAME, COMMENT, CASESTRUCT)
SAVECASE(FNAME, COMMENT, CASESTRUCT, VERSION)
SAVECASE(FNAME, COMMENT, BASEMVA, BUS, GEN, BRANCH)
SAVECASE(FNAME, COMMENT, BASEMVA, BUS, GEN, BRANCH, GENCOST)
SAVECASE(FNAME, COMMENT, BASEMVA, BUS, GEN, BRANCH, AREAS, GENCOST)

FNAME = SAVECASE(FNAME, ...)

```

Writes a MATPOWER **case** file, given a filename and data **struct** or list of data matrices. The FNAME parameter is the name of the file to be created or overwritten. If FNAME ends with **' .mat '** it saves the **case** as a MAT-file **otherwise** it saves it as an M-file. Optionally returns the filename, with extension added **if** necessary. The optional COMMENT argument is either string (**single line** comment) or a **cell** array of strings which are inserted as comments. When using a MATPOWER **case struct**, **if** the optional VERSION argument is **'1'** it will modify the data matrices to **version 1** format before saving.

## savechgtab

**savechgtab**(*fname*, *chgtab*, *warnings*)

savechgtab() - Save a change table to a file.

```

SAVECHGTAB(FNAME, CHGTAB)
SAVECHGTAB(FNAME, CHGTAB, WARNINGS)
FNAME = SAVECHGTAB(FNAME, ...)

```

Writes a CHGTAB, suitable **for** use with APPLY\_CHANGES to a file specified by FNAME. If FNAME ends with **' .mat '** it saves CHGTAB and WARNINGS to a MAT-file as the variables **'chgtab'** and **'warnings'**, respectively. Otherwise, it saves an M-file **function** that returns the CHGTAB, with the optional WARNINGS in comments.

Optionally returns the filename, with extension added **if** necessary.

Input:

```

FNAME : name of the file to be saved
CHGTAB : change table suitable for use with APPLY_CHANGES
WARNINGS : optional cell array of warning messages (to be
           included in comments), such as those returned by

```

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PSSECON2CHGTAB

Output(s):

FNAME : name of the file, with extension added **if** necessary

### 5.2.3 Data Conversion Functions

#### ext2int

**ext2int**(*bus, gen, branch, areas*)

ext2int() - Converts external to internal indexing.

This **function** has two forms, (1) the old form that operates on **and** returns individual matrices **and** (2) the new form that operates on **and** returns an entire MATPOWER **case struct**.

1. [I2E, BUS, GEN, BRANCH, AREAS] = EXT2INT(BUS, GEN, BRANCH, AREAS)  
[I2E, BUS, GEN, BRANCH] = EXT2INT(BUS, GEN, BRANCH)

If the first argument is a matrix, it simply converts from (possibly non-consecutive) external bus numbers to consecutive internal bus numbers which start at 1. Changes are made to BUS, GEN **and** BRANCH, which are returned along with a vector of indices I2E that can be passed to INT2EXT to perform the reverse conversion, where EXTERNAL\_BUS\_NUMBER = I2E(INTERNAL\_BUS\_NUMBER).

AREAS is completely ignored **and** is only included here **for** backward compatibility of the API.

Examples:

```
[i2e, bus, gen, branch, areas] = ext2int(bus, gen, branch, areas);
[i2e, bus, gen, branch] = ext2int(bus, gen, branch);
```

2. MPC = EXT2INT(MPC)  
MPC = EXT2INT(MPC, MPOPT)

If the **input** is a **single** MATPOWER **case struct**, followed optionally by a MATPOWER options **struct**, then **all** isolated buses, off-line generators **and** branches are removed along with **any** generators **or** branches connected to isolated buses. Then the buses are renumbered consecutively, beginning at 1. Any '**ext2int**' callback routines registered in the **case** are also invoked automatically. All of the related indexing information **and** the original data matrices are stored in an '**order**' field in the **struct** to be used by INT2EXT to perform the reverse conversions. If the **case** is already using internal numbering it is returned unchanged.

Examples:

```
mpc = ext2int(mpc);
```

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```
mpc = ext2int(mpc, mpopt);
```

The `'order'` field of MPC used to store the indexing information needed for subsequent internal to external conversion is structured as:

```
order
  state      'i' | 'e'
  ext | int
    bus
    branch
    gen
    gencost
    A
    N
  bus
    e2i
    i2e
    status
      on
      off
  gen
    e2i
    i2e
    status
      on
      off
  branch
    status
      on
      off
```

See also `int2ext()`, `e2i_field()` (page 256), `e2i_data()` (page 255).

## e2i\_data

`e2i_data(mpc, val, ordering, dim)`

`e2i_data()` (page 255) - Converts data from external to internal indexing.

```
VAL = E2I_DATA(MPC, VAL, ORDERING)
VAL = E2I_DATA(MPC, VAL, ORDERING, DIM)
```

When given a **case struct** that has already been converted to internal indexing, this **function** can be used to convert other data structures as well by passing in 2 or 3 extra parameters in addition to the **case struct**. If the value passed in the 2nd argument is a column vector or cell array, it will be converted according to the ORDERING specified by the 3rd argument (described below). If VAL is an n-dimensional matrix or cell array, then the optional 4th argument (DIM, default = 1) can be used to specify

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which dimension to reorder. The **return** value in this **case** is the value passed in, converted to internal indexing.

The 3rd argument, ORDERING, is used to indicate whether the data corresponds to bus-, gen- or branch-ordered data. It can be one of the following three strings: 'bus', 'gen' or 'branch'. For data structures with multiple blocks of data, ordered by bus, gen or branch, they can be converted with a **single** call by specifying ORDERING as a **cell** array of strings.

Any extra elements, rows, columns, etc. beyond those indicated in ORDERING, are **not** disturbed.

Examples:

```
A_int = e2i_data(mpc, A_ext, {'bus','bus','gen','gen'}, 2);
```

Converts an A matrix **for** user-supplied OPF constraints from external to internal ordering, where the **columns** of the A matrix correspond to bus voltage angles, then voltage magnitudes, then generator **real power** injections and finally generator reactive **power** injections.

```
gencost_int = e2i_data(mpc, gencost_ext, {'gen','gen'}, 1);
```

Converts a GENCOST matrix that has both **real and reactive power** costs (in **rows** 1--ng and ng+1--2\*ng, respectively).

See also *i2e\_data()* (page 258), *e2i\_field()* (page 256), *ext2int()*.

## e2i\_field

**e2i\_field**(mpc, field, ordering, dim)

*e2i\_field()* (page 256) - Converts fields of mpc from external to internal indexing.

This **function** performs several different tasks, depending on the arguments passed.

```
MPC = E2I_FIELD(MPC, FIELD, ORDERING)
MPC = E2I_FIELD(MPC, FIELD, ORDERING, DIM)
```

When given a **case struct** that has already been converted to internal indexing, this **function** can be used to convert other data structures as well by passing in 2 or 3 extra parameters in addition to the **case struct**.

The 2nd argument is a string or **cell** array of strings, specifying a field in the **case struct** whose value should be converted by a corresponding call to E2I\_DATA. The field can contain either a numeric or a **cell** array. The converted value is stored back in the specified field, the original value is saved **for** later use and the

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updated **case struct** is returned. If **FIELD** is a **cell** array of strings, they specify nested fields.

The 3rd and optional 4th arguments are simply passed along to the call to **E2I\_DATA**.

Examples:

```
mpc = e2i_field(mpc, {'reserves', 'cost'}, 'gen');
```

Reorders **rows** of **mpc.reserves.cost** to match internal generator ordering.

```
mpc = e2i_field(mpc, {'reserves', 'zones'}, 'gen', 2);
```

Reorders **columns** of **mpc.reserves.zones** to match internal generator ordering.

See also *i2e\_field()* (page 259), *e2i\_data()* (page 255), *ext2int()*.

## int2ext

**int2ext**(*i2e, bus, gen, branch, areas*)

**int2ext()** - Converts internal to external bus numbering.

This **function** has two forms, (1) the old form that operates on **and** returns individual matrices **and** (2) the new form that operates on **and** returns an entire MATPOWER **case struct**.

1. **[BUS, GEN, BRANCH, AREAS] = INT2EXT(I2E, BUS, GEN, BRANCH, AREAS)**  
**[BUS, GEN, BRANCH] = INT2EXT(I2E, BUS, GEN, BRANCH)**

Converts from the consecutive internal bus numbers back to the originals using the mapping provided by the **I2E** vector returned from **EXT2INT**, where **EXTERNAL\_BUS\_NUMBER = I2E(INTERNAL\_BUS\_NUMBER)**.

**AREAS** is completely ignored **and** is only included here **for** backward compatibility of the API.

Examples:

```
[bus, gen, branch, areas] = int2ext(i2e, bus, gen, branch, areas);
[bus, gen, branch] = int2ext(i2e, bus, gen, branch);
```

2. **MPC = INT2EXT(MPC)**  
**MPC = INT2EXT(MPC, MPOPT)**

If the **input** is a **single** MATPOWER **case struct**, followed optionally by a MATOWER options **struct**, then it restores **all** buses, generators **and** branches that were removed because of being isolated **or** off-line, **and** reverts to the original generator ordering **and** original bus numbering. This requires that the **'order'** field created by **EXT2INT** be in place.

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Examples:

```
mpc = int2ext(mpc);
mpc = int2ext(mpc, mpopt);
```

See also `ext2int()`, `i2e_field()` (page 259), `i2e_data()` (page 258).

## `i2e_data`

`i2e_data(mpc, val, oldval, ordering, dim)`

`i2e_data()` (page 258) - Converts data from internal to external indexing.

```
VAL = I2E_DATA(MPC, VAL, OLDVAL, ORDERING)
VAL = I2E_DATA(MPC, VAL, OLDVAL, ORDERING, DIM)
```

For a **case struct** using internal indexing, this **function** can be used to convert other data structures as well by passing in 3 or 4 extra parameters in addition to the **case struct**. If the value passed in the 2nd argument (VAL) is a column vector or cell array, it will be converted according to the ordering specified by the 4th argument (ORDERING, described below). If VAL is an n-dimensional matrix or cell array, then the optional 5th argument (DIM, default = 1) can be used to specify which dimension to reorder. The 3rd argument (OLDVAL) is used to initialize the **return** value before converting VAL to external indexing. In particular, any data corresponding to off-line gens or branches or isolated buses or any connected gens or branches will be taken from OLDVAL, with VAL supplying the rest of the returned data.

The ORDERING argument is used to indicate whether the data corresponds to bus-, gen- or branch-ordered data. It can be one of the following three strings: 'bus', 'gen' or 'branch'. For data structures with multiple blocks of data, ordered by bus, gen or branch, they can be converted with a **single** call by specifying ORDERING as a cell array of strings.

Any extra elements, rows, columns, etc. beyond those indicated in ORDERING, are **not** disturbed.

Examples:

```
A_ext = i2e_data(mpc, A_int, A_orig, {'bus','bus','gen','gen'}, 2);
```

Converts an A matrix for user-supplied OPF constraints from internal to external ordering, where the columns of the A matrix correspond to bus voltage angles, then voltage magnitudes, then generator real power injections and finally generator reactive power injections.

```
gencost_ext = i2e_data(mpc, gencost_int, gencost_orig, {'gen','gen'}, 1);
```

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Converts a GENCO<sub>ST</sub> matrix that has both **real** and **reactive power** costs (in **rows** `1--ng` and `ng+1--2*ng`, respectively).

See also `e2i_data()` (page 255), `i2e_field()` (page 259), `int2ext()`.

## `i2e_field`

`i2e_field(mpc, field, ordering, dim)`

`i2e_field()` (page 259) - Converts fields of `mpc` from internal to external bus numbering.

```
MPC = I2E_FIELD(MPC, FIELD, ORDERING)
MPC = I2E_FIELD(MPC, FIELD, ORDERING, DIM)
```

For a **case struct** using internal indexing, this **function** can be used to convert other data structures as well by passing in **2** or **3** extra parameters in addition to the **case struct**.

The **2nd** argument is a string or **cell** array of strings, specifying a field in the **case struct** whose value should be converted by a corresponding call to `I2E_DATA`. The field can contain either a numeric or a **cell** array. The corresponding `OLDVAL` is taken from where it was stored by `EXT2INT` in `MPC.ORDER.EXT` and the updated **case struct** is returned. If `FIELD` is a **cell** array of strings, they specify nested fields.

The **3rd** and optional **4th** arguments are simply passed along to the call to `I2E_DATA`.

Examples:

```
mpc = i2e_field(mpc, {'reserves', 'cost'}, 'gen');
```

Reorders **rows** of `mpc.reserves.cost` to match external generator ordering.

```
mpc = i2e_field(mpc, {'reserves', 'zones'}, 'gen', 2);
```

Reorders **columns** of `mpc.reserves.zones` to match external generator ordering.

See also `e2i_field()` (page 256), `i2e_data()` (page 258), `int2ext()`.

## get\_reorder

`get_reorder(A, idx, dim)`

`get_reorder()` (page 260) - Returns A with one of its dimensions indexed.

```
B = GET_REORDER(A, IDX, DIM)
```

Returns `A(:, ..., :, IDX, :, ..., :)`, where DIM determines in which dimension to place the IDX.

See also `set_reorder()` (page 260).

## set\_reorder

`set_reorder(A, B, idx, dim)`

`set_reorder()` (page 260) - Assigns B to A with one of the dimensions of A indexed.

```
A = SET_REORDER(A, B, IDX, DIM)
```

Returns A after doing `A(:, ..., :, IDX, :, ..., :) = B` where DIM determines in which dimension to place the IDX.

If **any** dimension of B is smaller than the corresponding dimension of A, the "extra" elements in A are untouched. If **any** dimension of B is larger than the corresponding dimension of A, then A is padded with **zeros** (if numeric) or empty matrices (if cell array) before performing the assignment.

See also `get_reorder()` (page 260).

## 5.2.4 Power Flow Functions

### calc\_v\_i\_sum

`calc_v_i_sum(Vslack, nb, nl, f, Zb, Ybf, Ybt, Yd, Sd, pv, Pg, Vg, mpopt)`

`calc_v_i_sum()` (page 260) - Solves the power flow using the current summation method.

```
[V, Qpv, Sf, St, Sslack, iter, success] = calc_v_i_sum(Vslack, nb, nl, f, Zb, Ybf, Ybt, Yd,
→ Sd, pv, Pg, Vg, tol, iter_max)
```

Solves **for** bus voltages, generator reactive **power**, branch active and reactive **power** flows and slack bus active and reactive **power**. The input data consist of slack bus voltage, vector "from bus" indices, branch impedance and shunt admittance, vector of bus shunt admittances and load demand, as well as vectors with indices of PV buses with their specified voltages and active powers. It is assumed that the branches are ordered using the principle of oriented ordering: indices of

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sending nodes are smaller than the indices of the receiving nodes. The branch `index` is equal to the `index` of their receiving node. Branch admittances are added in `Yd` and treated as constant admittance bus loads. The applied method is current summation taken from:

D. Shirmohammadi, H. W. Hong, A. Semlyen and G. X. Luo, "A compensation-based power flow method for weakly meshed distribution and transmission networks," IEEE Transactions on Power Systems, vol. 3, no. 2, pp. 753-762, May 1988. <https://doi.org/10.1109/59.192932> and G. X. Luo and A. Semlyen, "Efficient load flow for large weakly meshed networks," IEEE Transactions on Power Systems, vol. 5, no. 4, pp. 1309-1316, Nov 1990. <https://doi.org/10.1109/59.99382>

See also `radial_pf()` (page 269).

### `calc_v_pq_sum`

`calc_v_pq_sum(Vslack, nb, nl, f, Zb, Ybf, Ybt, Yd, Sd, pv, Pg, Vg, mpopt)`

`calc_v_pq_sum()` (page 261) - Solves the power flow using the power summation method.

```
[V, Qpv, Sf, St, Sslack, iter, success] = calc_v_pq_sum(Vslack, nb, nl, f, Zb, Ybf, Ybt, ,
↳ Yd, Sd, pv, Pg, Vg, tol, iter_max)
```

Solves **for** bus voltages, generator reactive power, branch active and reactive power flows and slack bus active and reactive power. The input data consist of slack bus voltage, vector "from bus" indices, branch impedance and shunt admittance, vector of bus shunt admittances and load demand, as well as vectors with indices of PV buses with their specified voltages and active powers. It is assumed that the branches are ordered using the principle of oriented ordering: indices of sending nodes are smaller than the indices of the receiving nodes. The branch `index` is equal to the `index` of their receiving node. Branch admittances are added in `Yd` and treated as constant admittance bus loads. The applied method is Voltage correction power flow (VCPF) taken from:

D. Rajicic, R. Ackovski and R. Taleski, "Voltage correction power flow," IEEE Transactions on Power Delivery, vol. 9, no. 2, pp. 1056-1062, Apr 1994. <https://doi.org/10.1109/61.296308>

See also `radial_pf()` (page 269).



**calc\_v\_y\_sum****calc\_v\_y\_sum**(Vslack, nb, nl, f, Zb, Ybf, Ybt, Yd, Sd, pv, Pg, Vg, mpopt)*calc\_v\_y\_sum*() (page 262) - Solves the power flow using the admittance summation method.

```
[V, Qpv, Sf, St, Sslack, iter, success] = calc_v_y_sum(Vslack, nb, nl, f, Zb, Ybf, Ybt, Yd,
↳ Sd, pv, Pg, Vg, tol, iter_max)
```

Solves **for** bus voltages, generator reactive **power**, branch active **and** reactive **power** flows **and** slack bus active **and** reactive **power**. The **input** data consist of slack bus voltage, vector "**from bus**" indices, branch impedance **and** shunt admittance, vector of bus shunt admittances **and** load demand, as well as vectors with indices of PV buses with their specified voltages **and** active powers. It is assumed that the branches are ordered using the principle of oriented ordering: indices of sending nodes are smaller than the indices of the receiving nodes. The branch **index** is equal to the **index** of their receiving node. Branch admittances are added in Yd **and** treated as constant admittance bus loads. The applied method is admittance summation taken from: Dragoslav Rajičić, Rubin Taleski, Two novel **methods for radial and** weakly meshed network analysis, Electric Power Systems Research, Volume 48, Issue 2, 15 December 1998, Pages 79-87  
[https://doi.org/10.1016/S0378-7796\(98\)00067-4](https://doi.org/10.1016/S0378-7796(98)00067-4)

See also *radial\_pf*() (page 269).**dcpf****dcpf**(B, Pbus, Va0, ref, pv, pq)*dcpf*() - Solves a DC power flow.

```
[VA, SUCCESS] = DCPF(B, PBUS, VA0, REF, PV, PQ) solves for the bus
voltage angles at all but the reference bus, given the full system
B matrix and the vector of bus real power injections, the initial
vector of bus voltage angles (in radians), and column vectors with
the lists of bus indices for the swing bus, PV buses, and PQ buses,
respectively. Returns a vector of bus voltage angles in radians.
```

See also *rundcpf*(), *runpf*() .

**fdpf****fdpf**(*Ybus, Sbus, V0, Bp, Bpp, ref, pv, pq, mpopt*)

fdpf() - Solves the power flow using a fast decoupled method.

```
[V, CONVERGED, I] = FDPF(YBUS, SBUS, V0, BP, BPP, REF, PV, PQ, MPOPT)
solves for bus voltages given the full system admittance matrix (for
all buses), the complex bus power injection vector (for all buses),
the initial vector of complex bus voltages, the FDPF matrices B prime
and B double prime, and column vectors with the lists of bus indices
for the swing bus, PV buses, and PQ buses, respectively. The bus voltage
vector contains the set point for generator (including ref bus)
buses, and the reference angle of the swing bus, as well as an initial
guess for remaining magnitudes and angles. MPOPT is a MATPOWER options
vector which can be used to set the termination tolerance, maximum
number of iterations, and output options (see MPOPTION for details).
Uses default options if this parameter is not given. Returns the
final complex voltages, a flag which indicates whether it converged
or not, and the number of iterations performed.
```

See also runpf().

**gausspf****gausspf**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

gausspf() - Solves the power flow using a Gauss-Seidel method.

```
[V, CONVERGED, I] = GAUSSPF(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)
solves for bus voltages given the full system admittance matrix (for
all buses), the complex bus power injection vector (for all buses),
the initial vector of complex bus voltages, and column vectors with
the lists of bus indices for the swing bus, PV buses, and PQ buses,
respectively. The bus voltage vector contains the set point for
generator (including ref bus) buses, and the reference angle of the
swing bus, as well as an initial guess for remaining magnitudes and
angles. MPOPT is a MATPOWER options struct which can be used to
set the termination tolerance, maximum number of iterations, and
output options (see MPOPTION for details). Uses default options
if this parameter is not given. Returns the final complex voltages,
a flag which indicates whether it converged or not, and the number
of iterations performed.
```

See also runpf().

## make\_vcorr

**make\_vcorr**(*DD, pv, nb, nl, f, Zb*)

*make\_vcorr*() (page 264) - Voltage Correction used in distribution power flow.

```
V_corr = make_vcorr(DD,pv,nb,nl,f,Zb)
```

Calculates voltage corrections with current generators placed at PV buses. Their currents are calculated with the voltage difference at PV buses **break** points and loop impedances. The slack bus voltage is **set** to zero. Details can be seen in D. Rajcic, R. Ackovski and R. Taleski, "Voltage correction power flow," IEEE Transactions on Power Delivery, vol. 9, no. 2, pp. 1056-1062, Apr 1994. <https://doi.org/10.1109/61.296308>

See also *radial\_pf*() (page 269).

## make\_zpv

**make\_zpv**(*pv, nb, nl, f, Zb, Yd*)

*make\_zpv*() (page 264) - Calculates loop impedances for all PV buses.

```
Zpv = make_zpv(pv,nb,nl,f,Zb,Yd)
```

Loop impedance of a PV bus is defined as impedance of the **path** between the bus and the slack bus. The mutual impedance between two PV buses is the impedance of the joint part of the two **path** going from each of the PV buses to the slack bus. The impedances are calculated as bus voltages in cases when at one of the PV buses we inject current of -1 A. All voltages are calculated with the backward-forward sweep method. The **input** variables are the vector of indicies with "from" buses **for** each branch, the vector of branch impedances and indicies of PV buses.

See also *calc\_v\_pq\_sum*() (page 261).

## newtonpf

**newtonpf**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

*newtonpf*() - Solves power flow using full Newton's method (power/polar).

```
[V, CONVERGED, I] = NEWTONPF(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)
```

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal **power balance** equations and **polar** coordinate representation of voltages, given the following inputs:

- YBUS - **full system** admittance matrix (**for all** buses)
- SBUS - handle to **function** that returns the **complex** bus **power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)

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**V0** - initial vector of **complex** bus voltages  
**REF** - bus **index** of reference bus (voltage ang reference & gen slack)  
**PV** - vector of bus indices **for** PV buses  
**PQ** - vector of bus indices **for** PQ buses  
**MPOPT** - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, and output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, and the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes and angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, and the number of iterations performed.

See also `runpf()`, `newtonpf_S_cart()` (page 267), `newtonpf_I_polar()` (page 266), `newtonpf_I_cart()` (page 265).

## newtonpf\_I\_cart

**newtonpf\_I\_cart**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

*newtonpf\_I\_cart()* (page 265) - Solves power flow using full Newton's method (current/cartesian).

[*V*, *CONVERGED*, *I*] = NEWTONPF\_I\_CART(*YBUS, SBUS, V0, REF, PV, PQ, MPOPT*)

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal current **balance** equations and cartesian coordinate representation of voltages, given the following inputs:

**YBUS** - **full system** admittance matrix (**for all** buses)  
**SBUS** - handle to **function** that returns the **complex** bus **power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)  
**V0** - initial vector of **complex** bus voltages  
**REF** - bus **index** of reference bus (voltage ang reference & gen slack)  
**PV** - vector of bus indices **for** PV buses  
**PQ** - vector of bus indices **for** PQ buses  
**MPOPT** - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, and output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, and the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes and angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, and the number of iterations performed.

See also `runpf()`, `newtonpf()`, `newtonpf_S_cart()` (page 267), `newtonpf_I_polar()` (page 266).

## newtonpf\_I\_hybrid

**newtonpf\_I\_hybrid**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

*newtonpf\_I\_hybrid*() (page 266) - Solves power flow using full Newton's method (current/hybrid).

```
[V, CONVERGED, I] = NEWTONPF_I_HYBRID(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)
```

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal current **balance** equations **and** a hybrid representation of voltages, where a **polar** update is computed using a cartesian Jacobian, given the following inputs:

- YBUS - **full system** admittance matrix (**for all** buses)
- SBUS - handle to **function** that returns the **complex bus power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)
- V0 - initial vector of **complex** bus voltages
- REF - bus **index** of reference bus (voltage ang reference & gen slack)
- PV - vector of bus indices **for** PV buses
- PQ - vector of bus indices **for** PQ buses
- MPOPT - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, **and** output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, **and** the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes **and** angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, **and** the number of iterations performed.

See also `runpf()`, `newtonpf()`, `newtonpf_S_cart()` (page 267), `newtonpf_I_polar()` (page 266).

## newtonpf\_I\_polar

**newtonpf\_I\_polar**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

*newtonpf\_I\_polar*() (page 266) - Solves power flow using full Newton's method (current/cartesian).

```
[V, CONVERGED, I] = NEWTONPF_I_POLAR(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)
```

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal current **balance** equations **and** **polar** coordinate representation of voltages, given the following inputs:

- YBUS - **full system** admittance matrix (**for all** buses)
- SBUS - handle to **function** that returns the **complex bus power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)
- V0 - initial vector of **complex** bus voltages

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REF - bus **index** of reference bus (voltage ang reference & gen slack)  
 PV - vector of bus indices **for** PV buses  
 PQ - vector of bus indices **for** PQ buses  
 MPOPT - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, and output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, and the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes and angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, and the number of iterations performed.

See also `runpf()`, `newtonpf()`, `newtonpf_S_cart()` (page 267), `newtonpf_I_cart()` (page 265).

## newtonpf\_S\_cart

`newtonpf_S_cart(Ybus, Sbus, V0, ref, pv, pq, mpopt)`

`newtonpf_S_cart()` (page 267) - Solves power flow using full Newton's method (power/cartesian).

`[V, CONVERGED, I] = NEWTONPF_S_CART(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)`

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal **power balance** equations and cartesian coordinate representation of voltages, given the following inputs:

YBUS - **full system** admittance matrix (**for all** buses)  
 SBUS - handle to **function** that returns the **complex bus power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)  
 V0 - initial vector of **complex** bus voltages  
 REF - bus **index** of reference bus (voltage ang reference & gen slack)  
 PV - vector of bus indices **for** PV buses  
 PQ - vector of bus indices **for** PQ buses  
 MPOPT - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, and output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, and the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes and angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, and the number of iterations performed.

See also `runpf()`, `newtonpf()`, `newtonpf_I_polar()` (page 266), `newtonpf_I_cart()` (page 265).

## newtonpf\_S\_hybrid

**newtonpf\_S\_hybrid**(*Ybus, Sbus, V0, ref, pv, pq, mpopt*)

*newtonpf\_S\_hybrid*() (page 268) - Solves power flow using full Newton's method (power/hybrid).

```
[V, CONVERGED, I] = NEWTONPF_S_HYBRID(YBUS, SBUS, V0, REF, PV, PQ, MPOPT)
```

Solves **for** bus voltages using a **full** Newton-Raphson method, using nodal **power balance** equations **and** a hybrid representation of voltages, where a **polar** update is computed using a cartesian Jacobian, given the following inputs:

- YBUS - **full system** admittance matrix (**for all** buses)
- SBUS - handle to **function** that returns the **complex** bus **power** injection vector (**for all** buses), given the bus voltage magnitude vector (**for all** buses)
- V0 - initial vector of **complex** bus voltages
- REF - bus **index** of reference bus (voltage ang reference & gen slack)
- PV - vector of bus indices **for** PV buses
- PQ - vector of bus indices **for** PQ buses
- MPOPT - (optional) MATPOWER option **struct**, used to **set** the termination tolerance, maximum number of iterations, **and** output options (see MPOPTION **for** details).

The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, **and** the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes **and** angles.

Returns the final **complex** voltages, a **flag** which indicates whether it converged **or not**, **and** the number of iterations performed.

See also `runpf()`, `newtonpf()`, `newtonpf_I_polar()` (page 266), `newtonpf_I_cart()` (page 265).

## order\_radial

**order\_radial**(*mpc*)

*order\_radial*() (page 268) - Performs oriented ordering to buses and branches.

```
mpc = order_radial(mpc)
```

orders the branches by the the principle of oriented ordering: indicies of sending nodes are smaller than the indicies of the receiving nodes. The branch **index** is equal to the **index** of their receiving node. The ordering is taken from:

D. Rajcic, R. Ackovski **and** R. Taleski, "Voltage correction power flow," IEEE Transactions on Power Delivery, vol. 9, no. 2, pp. 1056-1062, Apr 1994.

See also `radial_pf()` (page 269).

## pfsoln

**pfsoln**(baseMVA, bus0, gen0, branch0, Ybus, Yf, Yt, V, ref, pv, pq, mpopt)

pfsoln() - Updates bus, gen, branch data structures to match power flow soln.

```
[BUS, GEN, BRANCH] = PFSOLN(BASEMVA, BUS0, GEN0, BRANCH0, ...
                           YBUS, YF, YT, V, REF, PV, PQ, MPOPT)
```

## radial\_pf

**radial\_pf**(mpc, mpopt)

radial\_pf() (page 269) - Solves the power flow using a backward-forward sweep method.

```
[mpc, success, iterations] = radial_pf(mpc,mpopt)
```

**Inputs:**

mpc : MATPOWER **case struct** with internal bus numbering  
mpopt : MATPOWER options **struct** to override default options  
can be used to specify the solution algorithm, output options  
termination tolerances, **and** more.

**Outputs:**

mpc : results **struct** with **all** fields from the **input** MATPOWER **case**,  
with solved voltages, active **and** reactive **power** flows  
**and** generator active **and** reactive **power** output.  
success : success **flag**, 1 = succeeded, 0 = failed  
iterations : number of iterations

See also caseformat, loadcase(), mpoption().

## zgausspf

**zgausspf**(Ybus, Sbus, V0, ref, pv, pq, Bpp, mpopt)

zgausspf() - Solves the power flow using an Implicit Z-bus Gauss method.

```
[V, CONVERGED, I] = ZGAUSSPF(YBUS, SBUS, V0, REF, PV, PQ, BPP, MPOPT)
```

solves **for** bus voltages given the **full system** admittance matrix (**for** **all** buses), the **complex** bus **power** injection vector (**all** buses), the initial vector of **complex** bus voltages, column vectors with the lists of bus indices **for** the swing bus, PV buses, **and** PQ buses, respectively, **and** the fast-decoupled B **double-prime** matrix (**all** buses) **for** Q updates at PV buses. The bus voltage vector contains the **set** point **for** generator (including ref bus) buses, **and** the reference **angle** of the swing bus, as well as an initial guess **for** remaining magnitudes **and** angles. MPOPT is a MATPOWER options **struct** which can be used to **set** the termination tolerance, maximum number of iterations, **and** output options (see MPOPTION **for** details). Uses default options **if** this parameter is **not** given. Returns the final **complex** voltages,

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a **flag** which indicates whether it converged **or not**, **and** the number of iterations performed.

NOTE: This method does **not** scale well with the number of generators **and** seems to have serious problems with some systems with many PV buses.

See also `runpf()`.

## 5.2.5 Continuation Power Flow Functions

### `cpf_corrector`

`cpf_corrector(Ybus, Sbusb, V_hat, ref, pv, pq, lam_hat, Sbus, Vprv, lamprv, z, step, parameterization, mpopt)`  
`cpf_corrector()` (page 270) - Solves the corrector step of a continuation power flow.

```
[V, CONVERGED, I, LAM] = CPF_CORRECTOR(YBUS, SBUSB, V_HAT, REF, PV, PQ, ...
                                     LAM_HAT, SBUST, VPRV, LPRV, Z, ...
                                     STEP, PARAMETERIZATION, MPOPT)
```

Computes the corrector step of a continuation **power** flow using a **full** Newton method with selected parameterization scheme.

#### Inputs:

YBUS : **complex** bus admittance matrix  
 SBUSB : handle of **function** returning nb x 1 vector of **complex**  
         base **case** injections in p.u. **and** derivatives w.r.t. |V|  
 V\_HAT : predicted **complex** bus voltage vector  
 REF : vector of indices **for** REF buses  
 PV : vector of indices of PV buses  
 PQ : vector of indices of PQ buses  
 LAM\_HAT : predicted scalar lambda  
 SBUST : handle of **function** returning nb x 1 vector of **complex**  
         target **case** injections in p.u. **and** derivatives w.r.t. |V|  
 VPRV : **complex** bus voltage vector at previous solution  
 LAMPRV : scalar lambda value at previous solution  
 STEP : continuation step **length**  
 Z : normalized tangent prediction vector  
 STEP : continuation step **size**  
 PARAMETERIZATION : Value of `cpf.parameterization` option.  
 MPOPT : Options **struct**

#### Outputs:

V : **complex** bus voltage solution vector  
 CONVERGED : Newton iteration count  
 I : Newton iteration count  
 LAM : lambda continuation parameter

See also `runcpf()`.

## cpf\_current\_mpc

**cpf\_current\_mpc**(*mpc, mpct, Ybus, Yf, Yt, ref, pv, pq, V, lam, mpopt*)

*cpf\_current\_mpc*() (page 271) - Construct *mpc* for current continuation step.

```
MPC = CPF_CURRENT_MPC(MPC_BASE, MPC_TARGET, YBUS, YF, YT, REF, PV, PQ, V, LAM,
↳MPOPT)
```

Constructs the MATPOWER **case struct** for the current continuation step based on the MPC\_BASE and MPC\_TARGET cases and the value of LAM.

## cpf\_default\_callback

**cpf\_default\_callback**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*cpf\_default\_callback*() (page 271) - Default callback function for CPF.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =
CPF_DEFAULT_CALLBACK(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...
CB_DATA, CB_ARGS, RESULTS)
```

Default callback **function** used by RUNCPF that collects the results and optionally, plots the nose curve. Inputs and outputs are defined below, with the RESULTS argument being optional, used only for the final call when K is negative.

### Inputs:

- K - continuation step iteration count
- NX - next state (corresponding to proposed next step), **struct** with the following fields:
  - lam\_hat - value of LAMBDA from predictor
  - V\_hat - vector of **complex** bus voltages from predictor
  - lam - value of LAMBDA from corrector
  - V - vector of **complex** bus voltages from corrector
  - z - normalized tangent predictor
  - default\_step - default step **size**
  - default\_parm - default parameterization
  - this\_step - step **size** for this step only
  - this\_parm - parameterization for this step only
  - step - current step **size**
  - parm - current parameterization
  - events** - **struct** array, event **log**
  - cb - user state, for callbacks (replaces CB\_STATE), the user may add fields containing any information the callback **function** would like to pass from one invocation to the next, taking care **not** to step on fields being used by other callbacks, such as the 'default' field used by this default callback
  - ef - **cell** array of event **function** values
- CX - current state (corresponding to most recent successful step)

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(same structure as NX)

PX - previous state (corresponding to last successful step prior to CX)

DONE - **struct**, with **flag** to indicate CPF termination and reason, with fields:

- flag** - termination flag, 1 => terminate, 0 => **continue**
- msg** - string containing reason **for** termination

ROLLBACK - scalar **flag** to indicate that the current step should be rolled back and retried with a different step size, etc.

EVNTS - **struct** array listing any **events** detected **for** this step, see CPF\_DETECT\_EVENTS **for** details

CB\_DATA - **struct** containing potentially useful "static" data, with the following fields (all based on internal indexing):

- mpc\_base** - MATPOWER **case struct** of base state
- mpc\_target** - MATPOWER **case struct** of target state
- Sbusb** - handle of **function** returning nb x 1 vector of **complex** base **case** injections in p.u. and derivatives w.r.t. |V|
- Sbust** - handle of **function** returning nb x 1 vector of **complex** target **case** injections in p.u. and derivatives w.r.t. |V|
- Ybus** - bus admittance matrix
- Yf** - branch admittance matrix, "from" end of branches
- Yt** - branch admittance matrix, "to" end of branches
- pv** - vector of indices of PV buses
- pq** - vector of indices of PQ buses
- ref** - vector of indices of REF buses
- idx\_pmax** - vector of generator indices **for** generators fixed at their PMAX limits
- mpopt** - MATPOWER options **struct**

CB\_ARGS - arbitrary data structure containing callback arguments

RESULTS - initial value of output **struct** to be assigned to CPF field of results **struct** returned by RUNCPF

## Outputs:

(all are updated versions of the corresponding **input** arguments)

NX - user state ('cb' field) should be updated here **if** ROLLBACK is **false**

CX - may contain updated 'this\_step' or 'this\_parm' values to be used **if** ROLLBACK is **true**

DONE - callback may have requested termination and **set** the msg field

ROLLBACK - callback can request a rollback step, even **if** it was **not** indicated by an event **function**

EVNTS - msg field **for** a given event may be updated

CB\_DATA - this data should only be modified **if** the underlying problem has been changed (e.g. generator limit reached) and should always be followed by a step of zero length, i.e. **set** NX.this\_step to 0  
It is the job of any callback modifying CB\_DATA to ensure that **all** data in CB\_DATA is kept consistent.

RESULTS - updated **version** of RESULTS **input arg**

This **function** is called in three different contexts, distinguished by the value of K, as follows:

- (1) initial - called with K = 0, without RESULTS **input/output** args, after base **power** flow, before 1st CPF step.

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- (2) iterations - called with  $K > 0$ , without RESULTS input/output args, at each iteration, after predictor-corrector step
- (3) final - called with  $K < 0$ , with RESULTS input/output args, after exiting predictor-corrector loop, inputs identical to last iteration call, except K which is negated

**User Defined CPF Callback Functions:**

The user can define their own callback functions which take the same form and are called in the same contexts as CPF\_DEFAULT\_CALLBACK. These are specified via the MATPOWER option 'cpf.user\_callback'. This option can be a string containing the name of the callback function, or a struct with the following fields, where all but the first are optional:

- 'fcn' - string with name of callback function
- 'priority' - numerical value specifying callback priority (default = 20, see CPF\_REGISTER\_CALLBACK for details)
- 'args' - arbitrary value (any type) passed to the callback as CB\_ARGS each time it is invoked

Multiple user callbacks can be registered by assigning a cell array of such strings and/or structs to the 'cpf.user\_callback' option.

See also `runcpf()`, `cpf_register_callback()` (page 279).

**cpf\_detect\_events**

`cpf_detect_events(cpf_events, cef, pef, step, verbose)`

`cpf_detect_events()` (page 273) - Detect events from event function values.

```
[ROLLBACK, CRITICAL_EVENTS, CEF] = CPF_DETECT_EVENTS(CPF_EVENTS, CEF, PEF, STEP,
→VERBOSE)
```

**Inputs:**

- CPF\_EVENTS : struct containing info about registered CPF event fcns
- CEF : cell array of Current Event Function values
- PEF : cell array of Previous Event Function values
- STEP : current step size
- VERBOSE : 0 = no output, otherwise level of verbose output

**Outputs:**

- ROLLBACK : flag indicating whether any event has requested a rollback step
- CRITICAL\_EVENTS : struct array containing information about any detected events, with fields:
  - eidx : event index, in list of registered events
    - 0 if no event detected
  - name : name of event function, empty if none detected
  - zero : 1 if zero has been detected, 0 otherwise (interval detected or no event detected)
  - idx : index(es) of critical elements in event function
  - step\_scale : linearly interpolated estimate of scaling factor

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```

    for current step size required to reach event zero
log      : 1 log the event in the results, 0 don't log the event
          (set to 1 for zero events, 0 otherwise, can be
          modified by callbacks)
msg      : event message, set to something generic like
          'ZERO detected for TARGET_LAM event' or
          'INTERVAL detected for QLIM(3) event', but intended
          to be changed/updated by callbacks
CEF : cell array of Current Event Function values

```

### cpf\_flim\_event

**cpf\_flim\_event**(*cb\_data, cx*)

*cpf\_flim\_event*() (page 274) - Event function to detect branch flow limit (MVA) violations.

```
EF = CPF_FLIM_EVENT(CB_DATA, CX)
```

CPF event **function** to detect branch flow limit (MVA) violations,  
i.e.  $\max(S_f, S_t) \geq S_{rateA}$ .

Inputs:

```

CB_DATA : struct of data for callback functions
CX      : struct containing info about current point (continuation soln)

```

Outputs:

```
EF : event function value
```

### cpf\_flim\_event\_cb

**cpf\_flim\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*cpf\_flim\_event\_cb*() (page 274) - Callback to handle FLIM events.

```

[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =
CPF_NOSE_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...
                  CB_DATA, CB_ARGS, RESULTS)

```

Callback to handle FLIM (branch flow limit violation) **events**,  
triggered by event **function** CPF\_FLIM\_EVENT to indicate the point at which  
a branch flow limit is reached.

All branch flows are expected to be within limits **for** the base **case**,  
**otherwise** the continuation terminates.

This **function** sets the msg field of the event when the flow in **any** branch  
reaches its limit, raises the DONE.**flag** and sets the DONE.msg.

For details of the input and output arguments see also *cpf\_default\_callback*() (page 271).

## cpf\_nose\_event

**cpf\_nose\_event**(*cb\_data, cx*)

*cpf\_nose\_event*() (page 275) - Event function to detect the nose point.

```
EF = CPF_NOSE_EVENT(CB_DATA, CX)
```

CPF event **function** to detect the nose point of the continuation curve, based on the **sign** of the lambda component of the tangent vector.

Inputs:

CB\_DATA : **struct** of data **for** callback **functions**  
CX : **struct** containing **info** about current point (continuation soln)

Outputs:

EF : event **function** value

## cpf\_nose\_event\_cb

**cpf\_nose\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*cpf\_nose\_event\_cb*() (page 275) - Callback to handle NOSE events.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =  
CPF_NOSE_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...  
CB_DATA, CB_ARGS, RESULTS)
```

Callback to handle NOSE **events**, triggered by event **function** CPF\_NOSE\_EVENT to indicate the nose point of the continuation curve.

This **function** sets the msg field of the event when the nose point has been found, raises the DONE.**flag** and sets the DONE.msg.

For details of the input and output arguments see also *cpf\_default\_callback*() (page 271).

## cpf\_p

**cpf\_p**(*parameterization, step, z, V, lam, Vprv, lamprv, pv, pq*)

*cpf\_p*() (page 275) m - Computes the value of the CPF parameterization function.

```
P = CPF_P(PARAMETERIZATION, STEP, Z, V, LAM, VPRV, LAMPRV, PV, PQ)
```

Computes the value of the parameterization **function** at the current solution point.

Inputs:

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```

PARAMETERIZATION : Value of cpf.parameterization option
STEP : continuation step size
Z : normalized tangent prediction vector from previous step
V : complex bus voltage vector at current solution
LAM : scalar lambda value at current solution
VPRV : complex bus voltage vector at previous solution
LAMPRV : scalar lambda value at previous solution
PV : vector of indices of PV buses
PQ : vector of indices of PQ buses

```

## Outputs:

```

P : value of the parameterization function at the current point

```

See also [cpf\\_predictor\(\)](#) (page 277), [cpf\\_corrector\(\)](#) (page 270).

**cpf\_p\_jac**

**cpf\_p\_jac**(parameterization, z, V, lam, Vprv, lamprv, pv, pq)

[cpf\\_p\\_jac\(\)](#) (page 276) - Computes partial derivatives of CPF parameterization function.

```

[DP_DV, DP_DLAM ] = CPF_P_JAC(PARAMETERIZATION, Z, V, LAM, ...
                               VPRV, LAMPRV, PV, PQ)

```

Computes the partial derivatives of the continuation power flow parameterization function w.r.t. bus voltages and the continuation parameter lambda.

## Inputs:

```

PARAMETERIZATION : Value of cpf.parameterization option.
Z : normalized tangent prediction vector from previous step
V : complex bus voltage vector at current solution
LAM : scalar lambda value at current solution
VPRV : complex bus voltage vector at previous solution
LAMPRV : scalar lambda value at previous solution
PV : vector of indices of PV buses
PQ : vector of indices of PQ buses

```

## Outputs:

```

DP_DV : partial of parameterization function w.r.t. voltages
DP_DLAM : partial of parameterization function w.r.t. lambda

```

See also [cpf\\_predictor\(\)](#) (page 277), [cpf\\_corrector\(\)](#) (page 270).

## cpf\_plim\_event

**cpf\_plim\_event**(*cb\_data, cx*)

[cpf\\_plim\\_event\(\)](#) (page 277) - Event function to detect gen active power limit violations.

```
EF = CPF_PLIM_EVENT(CB_DATA, CX)
```

CPF event **function** to detect generator active **power** limit violations, i.e.  $P_g \geq P_{max}$ .

Inputs:

CB\_DATA : **struct** of data **for** callback **functions**  
CX : **struct** containing **info** about current point (continuation soln)

Outputs:

EF : event **function** value

## cpf\_plim\_event\_cb

**cpf\_plim\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

[cpf\\_plim\\_event\\_cb\(\)](#) (page 277) - Callback to handle PLIM events.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =  
CPF_PLIM_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...  
CB_DATA, CB_ARGS, RESULTS)
```

Callback to handle PLIM (generator active **power** limit violation) **events**, triggered by event **function** CPF\_PLIM\_EVENT to indicate the point at which an **upper** active **power** output limit is reached **for** a generator.

When an active **power** limit is encountered, this **function** **zeros** out subsequent transfers from that generator, chooses a new reference bus **if** necessary, **and** updates the CB\_DATA accordingly, setting the next step **size** to zero. The event msg is updated with the details of the changes. It also requests termination **if** all generators reach PMAX.

For details of the input and output arguments see also [cpf\\_default\\_callback\(\)](#) (page 271).

## cpf\_predictor

**cpf\_predictor**(*V, lam, z, step, pv, pq*)

[cpf\\_predictor\(\)](#) (page 277) - Performs the predictor step for the continuation power flow.

```
[V_HAT, LAM_HAT] = CPF_PREDICTOR(V, LAM, Z, STEP, PV, PQ)
```

Computes a prediction (approximation) to the next solution of the continuation **power** flow using a normalized tangent predictor.

(continues on next page)



(continued from previous page)

## Inputs:

V : complex bus voltage vector at current solution  
 LAM : scalar lambda value at current solution  
 Z : normalized tangent prediction vector from previous step  
 STEP : continuation step length  
 PV : vector of indices of PV buses  
 PQ : vector of indices of PQ buses

## Outputs:

V\_HAT : predicted complex bus voltage vector  
 LAM\_HAT : predicted lambda continuation parameter

**cpf\_qlim\_event****cpf\_qlim\_event**(*cb\_data, cx*)

*cpf\_qlim\_event*() (page 278) - Event function to detect gen reactive power limit violations.

```
EF = CPF_QLIM_EVENT(CB_DATA, CX)
```

CPF event **function** to detect generator reactive **power** limit violations, i.e.  $Q_g \leq Q_{min}$  or  $Q_g \geq Q_{max}$ .

## Inputs:

CB\_DATA : struct of data for callback functions  
 CX : struct containing info about current point (continuation soln)

## Outputs:

EF : event **function** value

**cpf\_qlim\_event\_cb****cpf\_qlim\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*cpf\_qlim\_event\_cb*() (page 278) - Callback to handle QLIM events.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =  
CPF_QLIM_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...  
CB_DATA, CB_ARGS, RESULTS)
```

Callback to handle QLIM (generator reactive **power** limit violation) **events**, triggered by event **function** CPF\_QLIM\_EVENT to indicate the point at which an **upper or lower** reactive **power** output limit is reached **for** a generator.

When a reactive **power** limit is encountered, this **function** **zeros** out subsequent transfers from that generator, changes its bus **type** to PQ, chooses a new reference bus **if** necessary, **and** updates the CB\_DATA accordingly, setting the next step **size** to zero. The event msg is updated

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with the details of the changes. It also requests termination **if** no more PV or REF buses remain.

For details of the input and output arguments see also `cpf_default_callback()` (page 271).

## cpf\_register\_callback

**cpf\_register\_callback**(*cpf\_callbacks, fcn, priority, args*)

`cpf_register_callback()` (page 279) - Register CPF callback functions.

```
CPF_CALLBACKS = CPF_REGISTER_CALLBACK(CPF_CALLBACKS, FCN, PRIORITY)
```

Registers a CPF callback **function** to be called by RUNCPF.

Inputs:

CPF\_CALLBACKS : **struct** containing **info** about registered CPF callback fcns

FCN : string containing name of callback **function**

PRIORITY : number that determines order of execution **for** multiple callback **functions**, where higher numbers **run** first, default priority is 20, where the standard callbacks are called with the following priority:

<code>cpf_flim_event_cb</code>	53
<code>cpf_vlim_event_cb</code>	52
<code>cpf_nose_event_cb</code>	51
<code>cpf_target_lam_event_cb</code>	50
<code>cpf_qlim_event_cb</code>	41
<code>cpf_plim_event_cb</code>	40
<code>cpf_default_callback</code>	0

ARGS : arguments to be passed to the callback each **time** it is invoked

Outputs:

CPF\_CALLBACKS : updated **struct** containing **info** about registered CPF callback fcns

User Defined CPF Callback Functions:

The user can define their own callback **functions** which take the same form **and** are called in the same contexts as CPF\_DEFAULT\_CALLBACK. These are specified via the MATPOWER option '`cpf.user_callback`'. This option can be a string containing the name of the callback **function**, or a **struct** with the following fields, where **all** but the first are optional:

- '`fcn`' - string with name of callback **function**
- '`priority`' - numerical value specifying callback priority (default = 20, see CPF\_REGISTER\_CALLBACK **for** details)
- '`args`' - arbitrary value (**any type**) passed to the callback as CB\_ARGS each **time** it is invoked

Multiple user callbacks can be registered by assigning a **cell** array of such strings **and/or** structs to the '`cpf.user_callback`' option.

See also `runcpf()`, `cpf_default_callback()` (page 271).

## cpf\_register\_event

**cpf\_register\_event**(*cpf\_events, name, fcn, tol, locate*)

*cpf\_register\_event*() (page 280) - Register event functions.

```
CPF_EVENTS = CPF_REGISTER_EVENT(CPF_EVENTS, NAME, FCN, TOL, LOCATE)
```

Registers a CPF event **function** to be called by RUNCPF.

Inputs:

CPF\_EVENTS : **struct** containing **info** about registered CPF event fcns  
NAME : string containing event name  
FCN : string containing name of event **function**, returning numerical scalar **or** vector value that changes **sign** at location of the event  
TOL : scalar **or** vector of same dimension as event **function return** value of tolerance **for** detecting the event, i.e.  $abs(val) \leq tol$   
LOCATE : **flag** indicating whether the event requests a rollback step to locate the event **function** zero

Outputs:

CPF\_EVENTS : updated **struct** containing **info** about registered CPF event fcns

## cpf\_tangent

**cpf\_tangent**(*V, lam, Ybus, Sbusb, Sbust, pv, pq, zprv, Vprv, lamprv, parameterization, direction*)

*cpf\_tangent*() (page 280) - Computes normalized tangent predictor for continuation power flow.

```
Z = CPF_TANGENT(V, LAM, YBUS, SBUSB, SBUST, PV, PQ, ...  
                ZPRV, VPRV, LAMPRV, PARAMETERIZATION, DIRECTION)
```

Computes a normalized tangent predictor **for** the continuation **power** flow.

Inputs:

V : **complex** bus voltage vector at current solution  
LAM : scalar lambda value at current solution  
YBUS : **complex** bus admittance matrix  
SBUSB : handle of **function** returning nb x 1 vector of **complex** base **case** injections in p.u. and derivatives w.r.t. |V|  
SBUST : handle of **function** returning nb x 1 vector of **complex** target **case** injections in p.u. and derivatives w.r.t. |V|  
PV : vector of indices of PV buses  
PQ : vector of indices of PQ buses  
ZPRV : normalized tangent prediction vector from previous step  
VPRV : **complex** bus voltage vector at previous solution  
LAMPRV : scalar lambda value at previous solution  
PARAMETERIZATION : value of cpf.parameterization option.  
DIRECTION: continuation direction (+1 **for** postive lambda increase, -1 **otherwise**)

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Outputs:  
 Z : the normalized tangent prediction vector

### cpf\_target\_lam\_event

**cpf\_target\_lam\_event**(*cb\_data, cx*)

*cpf\_target\_lam\_event*() (page 281) - Event function to detect a target lambda value.

```
EF = CPF_TARGET_LAM_EVENT(CB_DATA, CX)
```

CPF event **function** to detect the completion of the continuation curve or another target value of lambda.

Inputs:

CB\_DATA : **struct** of data **for** callback **functions**  
 CX : **struct** containing **info** about current point (continuation soln)

Outputs:

EF : event **function** value

### cpf\_target\_lam\_event\_cb

**cpf\_target\_lam\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*cpf\_target\_lam\_event\_cb*() (page 281) - Callback to handle TARGET\_LAM events.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =  

  CPF_TARGET_LAM_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...  

  CB_DATA, CB_ARGS, RESULTS)
```

Callback to handle TARGET\_LAM **events**, triggered by event **function** CPF\_TARGET\_LAM\_EVENT to indicate that a target lambda value has been reached or that the **full** continuation curve has been traced.

This **function** sets the msg field of the event when the target lambda has been found, raises the DONE.**flag** and sets the DONE.msg. If the current or predicted next step overshoot the target lambda, it adjusts the step **size** to be exactly **what** is needed to reach the target, **and** sets the parameterization **for** that step to be the natural parameterization.

For details of the input and output arguments see also *cpf\_default\_callback*() (page 271).

## cpf\_vlim\_event

**cpf\_vlim\_event**(*cb\_data, cx*)

[cpf\\_vlim\\_event\(\)](#) (page 282) - Event function to detect bus voltage limit violations.

```
EF = CPF_VLIM_EVENT(CB_DATA, CX)
```

CPF event **function** to detect bus voltage limits violations,  
i.e.  $V_m \leq V_{min}$  or  $V_m \geq V_{max}$ .

Inputs:

CB\_DATA : **struct** of data **for** callback **functions**  
CX : **struct** containing **info** about current point (continuation soln)

Outputs:

EF : event **function** value

## cpf\_vlim\_event\_cb

**cpf\_vlim\_event\_cb**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

[cpf\\_vlim\\_event\\_cb\(\)](#) (page 282) - Callback to handle VLIM events.

```
[NX, CX, DONE, ROLLBACK, EVNTS, CB_DATA, RESULTS] =  
CPF_VLIM_EVENT_CB(K, NX, CX, PX, DONE, ROLLBACK, EVNTS, ...  
CB_DATA, CB_ARGS, RESULTS)
```

Callback to handle VLIM (bus voltage magnitude limit violation) **events**,  
triggered by event **function** CPF\_VLIM\_EVENT to indicate the point at which  
an **upper or lower** voltage magnitude limit is reached **for** a bus.

All bus voltages are expected to be within limits **for** the base **case**,  
**otherwise** the continuation terminates.

This **function** sets the msg field of the event when the voltage magnitude  
at **any** bus reaches its **upper or lower** limit, raises the DONE.flag and sets  
the DONE.msg.

For details of the input and output arguments see also [cpf\\_default\\_callback\(\)](#) (page 271).

## 5.2.6 OPF and Wrapper Functions

**opf****opf**(varargin)

opf() - Solves an optimal power flow.

```
[RESULTS, SUCCESS] = OPF(MPC, MPOPT)
```

Returns either a RESULTS **struct** and an optional SUCCESS **flag**, or individual data matrices, the objective **function** value and a SUCCESS **flag**. In the latter **case**, there are additional optional **return** values. See Examples below **for** the possible calling syntax options.

## Examples:

Output argument options:

```
results = opf(...)
[results, success] = opf(...)
[bus, gen, branch, f, success] = opf(...)
[bus, gen, branch, f, success, info, et, g, jac, xr, pimul] = opf(...)
```

Input arguments options:

```
opf(mpc)
opf(mpc, mpopt)
opf(mpc, userfcn, mpopt)
opf(mpc, A, l, u)
opf(mpc, A, l, u, mpopt)
opf(mpc, A, l, u, mpopt, N, fparm, H, Cw)
opf(mpc, A, l, u, mpopt, N, fparm, H, Cw, z0, zl, zu)

opf(baseMVA, bus, gen, branch, areas, gencost)
opf(baseMVA, bus, gen, branch, areas, gencost, mpopt)
opf(baseMVA, bus, gen, branch, areas, gencost, userfcn, mpopt)
opf(baseMVA, bus, gen, branch, areas, gencost, A, l, u)
opf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, mpopt)
opf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
    mpopt, N, fparm, H, Cw)
opf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
    mpopt, N, fparm, H, Cw, z0, zl, zu)
```

The data **for** the problem can be specified in one of three ways:

- (1) a string (mpc) containing the file name of a MATPOWER **case** which defines the data matrices baseMVA, bus, gen, branch, and gencost (areas is **not** used at **all**, it is only included **for** backward compatibility of the API).
- (2) a **struct** (mpc) containing the data matrices as fields.
- (3) the individual data matrices themselves.

The optional user parameters **for** user constraints (A, l, u), user costs (N, fparm, H, Cw), user variable initializer (z0), and user variable limits (zl, zu) can also be specified as fields in a **case struct**, either passed in directly or defined in a **case** file referenced by name.

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When specified,  $A$ ,  $l$ ,  $u$  represent additional linear constraints on the optimization variables,  $l \leq A[x; z] \leq u$ . If the user specifies an  $A$  matrix that has more columns than the number of "x" (OPF) variables, then there are extra linearly constrained "z" variables. For an explanation of the formulation used and instructions for forming the  $A$  matrix, see the manual.

A generalized cost on all variables can be applied if input arguments  $N$ ,  $fparm$ ,  $H$  and  $Cw$  are specified. First, a linear transformation of the optimization variables is defined by means of  $r = N * [x; z]$ . Then, to each element of  $r$  a function is applied as encoded in the  $fparm$  matrix (see manual). If the resulting vector is named  $w$ , then  $H$  and  $Cw$  define a quadratic cost on  $w$ :  $(1/2)*w'*H*w + Cw * w$ .  $H$  and  $N$  should be sparse matrices and  $H$  should also be symmetric.

The optional `mpopt` vector specifies MATPOWER options. If the OPF algorithm is not explicitly set in the options MATPOWER will use the default solver, based on a primal-dual interior point method. For the AC OPF this is `opf.ac.solver = 'MIPS'`, unless the TSPOPF optional package is installed, in which case the default is `'PDIPM'`. For the DC OPF, the default is `opf.dc.solver = 'MIPS'`. See `MPOPTION` for more details on the available OPF solvers and other OPF options and their default values.

The solved case is returned either in a single results struct (described below) or in the individual data matrices, `bus`, `gen` and `branch`. Also returned are the final objective function value (`f`) and a flag which is true if the algorithm was successful in finding a solution (`success`). Additional optional return values are an algorithm specific return status (`info`), elapsed time in seconds (`et`), the constraint vector (`g`), the Jacobian matrix (`jac`), and the vector of variables (`xr`) as well as the constraint multipliers (`pimul`).

The single results struct is a MATPOWER case struct (`mpc`) with the usual `baseMVA`, `bus`, `branch`, `gen`, `gencost` fields, along with the following additional fields:

```
.order      see 'help ext2int' for details of this field
.et         elapsed time in seconds for solving OPF
.success    1 if solver converged successfully, 0 otherwise
.om         OPF model object, see 'help opf_model'
.x          final value of optimization variables (internal order)
.f          final objective function value
.mu         shadow prices on ...

.var
  .l        lower bounds on variables
  .u        upper bounds on variables

.nln
  .l        lower bounds on nonlinear constraints
  .u        upper bounds on nonlinear constraints

.lin
  .l        lower bounds on linear constraints
```

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```

    .u upper bounds on linear constraints
.raw   raw solver output in form returned by MINOS, and more
.xr    final value of optimization variables
.pimul constraint multipliers
.info  solver specific termination code
.output solver specific output information
    .alg algorithm code of solver used
.g     (optional) constraint values
.dg    (optional) constraint 1st derivatives
.df    (optional) obj fun 1st derivatives (not yet implemented)
.d2f   (optional) obj fun 2nd derivatives (not yet implemented)
.var
.val   optimization variable values, by named block
    .Va voltage angles
    .Vm voltage magnitudes (AC only)
    .Pg real power injections
    .Qg reactive power injections (AC only)
    .y constrained cost variable (only if have pwl costs)
    (other) any user defined variable blocks
.mu    variable bound shadow prices, by named block
    .l lower bound shadow prices
        .Va, Vm, Pg, Qg, y, (other)
    .u upper bound shadow prices
        .Va, Vm, Pg, Qg, y, (other)
.nle   (AC only)
    .lambda shadow prices on nonlinear equality constraints,
        by named block
        .Pmis real power mismatch equations
        .Qmis reactive power mismatch equations
        (other) use defined constraints
.nli   (AC only)
    .mu shadow prices on nonlinear inequality constraints,
        by named block
        .Sf flow limits at "from" end of branches
        .St flow limits at "to" end of branches
        (other) use defined constraints
.lin
    .mu shadow prices on linear constraints, by named block
    .l lower bounds
        .Pmis real power mismatch equations (DC only)
        .Pf flow limits at "from" end of branches (DC only)
        .Pt flow limits at "to" end of branches (DC only)
        .PQh upper portion of gen PQ-capability curve (AC only)
        .PQl lower portion of gen PQ-capability curve (AC only)
        .vl constant power factor constraint for loads (AC only)
        .ycon basin constraints for CCV for pwl costs
        (other) any user defined constraint blocks
    .u upper bounds
        .Pmis, Pf, Pt, PQh, PQl, vl, ycon, (other)
.cost  user defined cost values, by named block

```

See also `runopf()`, `dcopf()`, `uopf()`, `caseformat`.



## dcopf

### dcopf(*varargin*)

dcopf() - Solves a DC optimal power flow.

This is a simple wrapper function around opf() that sets the model option to 'DC' before calling opf(). See opf() for the details of input and output arguments.

See also rundcopf().

## fmincopf

### fmincopf(*varargin*)

fmincopf() - Solves an AC optimal power flow using FMINCON (Opt Tbx 2.x & later).

Uses algorithm 520. Please see opf() for the details of input and output arguments.

## uopf

### uopf(*varargin*)

uopf() - Solves combined unit decommitment / optimal power flow.

```
[RESULTS, SUCCESS] = UOPF(MPC, MPOPT)
```

Returns either a RESULTS struct and an optional SUCCESS flag, or individual data matrices, the objective function value and a SUCCESS flag. In the latter case, there are additional optional return values. See Examples below for the possible calling syntax options.

Examples:

Output argument options:

```
results = uopf(...)
```

```
[results, success] = uopf(...)
```

```
[bus, gen, branch, f, success] = uopf(...)
```

```
[bus, gen, branch, f, success, info, et, g, jac, xr, pimul] = uopf(...)
```

Input arguments options:

```
uopf(mpc)
```

```
uopf(mpc, mpopt)
```

```
uopf(mpc, userfcn, mpopt)
```

```
uopf(mpc, A, l, u)
```

```
uopf(mpc, A, l, u, mpopt)
```

```
uopf(mpc, A, l, u, mpopt, N, fparm, H, Cw)
```

```
uopf(mpc, A, l, u, mpopt, N, fparm, H, Cw, z0, z1, zu)
```

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```

uopf(baseMVA, bus, gen, branch, areas, gencost)
uopf(baseMVA, bus, gen, branch, areas, gencost, mpopt)
uopf(baseMVA, bus, gen, branch, areas, gencost, userfcn, mpopt)
uopf(baseMVA, bus, gen, branch, areas, gencost, A, l, u)
uopf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, mpopt)
uopf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
      mpopt, N, fparm, H, Cw)
uopf(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
      mpopt, N, fparm, H, Cw, z0, z1, zu)

```

See OPF [for](#) more information on [input](#) and [output](#) arguments.

Solves a combined unit decommitment and optimal power flow [for](#) a [single time](#) period. Uses an algorithm similar to dynamic programming. It proceeds through a sequence of stages, where stage N has N generators shut down, starting with N=0. In each stage, it forms a list of candidates (gens at their Pmin limits) and computes the cost with each one of them shut down. It selects the least cost [case](#) as the starting point [for](#) the next stage, continuing [until](#) there are no more candidates to be shut down or no more improvement can be gained by shutting something down. If MPOPT.verbose (see MPOPTION) is [true](#), it prints progress [info](#), [if](#) it is > 1 it prints the output of each individual opf.

See also opf(), runuopf().

## 5.2.7 Other OPF Functions

### dcopf\_solver

**dcopf\_solver**(om, mpopt)

*dcopf\_solver()* (page 287) - Solves a DC optimal power flow.

```
[RESULTS, SUCCESS, RAW] = DCOPF_SOLVER(OM, MPOPT)
```

Inputs are an OPF model object and a MATPOWER options struct.

Outputs are a RESULTS struct, SUCCESS flag and RAW output struct.

RESULTS is a MATPOWER case struct (mpc) with the usual baseMVA, bus branch, gen, gencost fields, along with the following additional fields:

```

.order      see 'help ext2int' for details of this field
.x          final value of optimization variables (internal order)
.f          final objective function value
.mu         shadow prices on ...
.var
  .l        lower bounds on variables
  .u        upper bounds on variables

```

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```

.lin
    .l lower bounds on linear constraints
    .u upper bounds on linear constraints

SUCCESS    1 if solver converged successfully, 0 otherwise

RAW        raw output in form returned by MINOS
.xr        final value of optimization variables
.pimul     constraint multipliers
.info      solver specific termination code
.output    solver specific output information

```

See also `opf()`, `opt_model.solve()`.

## nlpopf\_solver

### nlpopf\_solver(*om*, *mpopt*)

*nlpopf\_solver()* (page 288) - Solves AC optimal power flow using MP-Opt-Model.

```

[RESULTS, SUCCESS, RAW] = NLPPOF_SOLVER(OM, MPOPT)

Inputs are an OPF model object and a MATPOWER options struct.

Outputs are a RESULTS struct, SUCCESS flag and RAW output struct.

RESULTS is a MATPOWER case struct (mpc) with the usual baseMVA, bus
branch, gen, gencost fields, along with the following additional
fields:
.order      see 'help ext2int' for details of this field
.x          final value of optimization variables (internal order)
.f          final objective function value
.mu         shadow prices on ...
.var
    .l lower bounds on variables
    .u upper bounds on variables
.nln        (deprecated) 2*nb+2*nl - Pmis, Qmis, Sf, St
    .l lower bounds on nonlinear constraints
    .u upper bounds on nonlinear constraints
.nle        nonlinear equality constraints
.nli        nonlinear inequality constraints
.lin
    .l lower bounds on linear constraints
    .u upper bounds on linear constraints

SUCCESS    1 if solver converged successfully, 0 otherwise

RAW        raw output in form returned by MINOS
.xr        final value of optimization variables
.pimul     constraint multipliers

```

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```
.info solver specific termination code
.output solver specific output information
```

See also `opf()`, `mips()`.

## makeAang

**makeAang**(*baseMVA*, *branch*, *nb*, *mpopt*)

*makeAang()* (page 289) - Construct constraints for branch angle difference limits.

```
[AANG, LANG, UANG, IANG] = MAKEAANG(BASEMVA, BRANCH, NB, MPOPT)
```

Constructs the parameters **for** the following linear constraint limiting the voltage **angle** differences across branches, where  $V_a$  is the vector of bus voltage angles. NB is the number of buses.

$$LANG \leq AANG * Va \leq UANG$$

IANG is the vector of indices of branches with **angle** difference limits. The limits are given in the ANGMIN and ANGMAX **columns** of the branch matrix. Voltage **angle** differences are taken to be unbounded below **if** ANGMIN < -360 and unbounded above **if** ANGMAX > 360. If both ANGMIN and ANGMAX are zero, the **angle** difference is assumed to be unconstrained.

Example:

```
[Aang, lang, uang, iang] = makeAang(baseMVA, branch, nb, mpopt);
```

## makeApq

**makeApq**(*baseMVA*, *gen*)

*makeApq()* (page 289) - Construct linear constraints for generator capability curves.

```
[APQH, UBPQH, APQL, UBPQL, DATA] = MAKEAPQ(BASEMVA, GEN)
```

Constructs the parameters **for** the following linear constraints implementing trapezoidal generator capability curves, where  $P_g$  and  $Q_g$  are the **real** and **reactive** generator injections.

$$APQH * [P_g; Q_g] \leq UBPQH$$

$$APQL * [P_g; Q_g] \leq UBPQL$$

DATA contains additional information as shown below.

Example:

```
[Apqh, ubpqh, Apql, ubpql, data] = makeApq(baseMVA, gen);
```

```
data.h      [QC1MAX-QC2MAX, PC2-PC1]
```

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```

data.l      [QC2MIN-QC1MIN, PC1-PC2]
data.ipqh   indices of gens with general PQ cap curves (upper)
data.ipql   indices of gens with general PQ cap curves (lower)

```

## makeAvl

**makeAvl**(*baseMVA*, *gen*)*makeAvl*() (page 290) - Construct linear constraints for constant power factor var loads.

```

[AVL, LVL, UVL, IVL] = MAKEAVL(MPC)
[AVL, LVL, UVL, IVL] = MAKEAVL(BASEMVA, GEN) (deprecated)

```

Constructs parameters **for** the following linear constraint enforcing a constant **power factor** constraint **for** dispatchable loads.

$$LVL \leq AVL * [Pg; Qg] \leq UVL$$

IVL is the vector of indices of generators representing variable loads.

Example:

```

[Avl, lvl, uvl, ivl] = makeAvl(mpc);
[Avl, lvl, uvl, ivl] = makeAvl(baseMVA, gen); %% deprecated

```

## makeAy

**makeAy**(*baseMVA*, *ng*, *gencost*, *pgbas*, *qgbas*, *ybas*)*makeAy*() (page 290) - Make the A matrix and RHS for the CCV formulation.

```

[AY, BY] = MAKEAY(BASEMVA, NG, GENCOST, PGBAS, QGBAS, YBAS)

```

Constructs the parameters **for** linear "**basin constraints**" on Pg, Qg and Y used by the CCV cost formulation, expressed as

$$AY * X \leq BY$$

where X is the vector of optimization variables. The starting **index** within the X vector **for** the active, reactive sources and the Y variables should be provided in arguments PGBAS, QGBAS, YBAS. The number of generators is NG.

Assumptions: All generators are in-service. Filter **any** generators that are offline from the GENCOST matrix before calling MAKEAY. Efficiency depends on Qg variables being after Pg variables, and the Y variables must be the last variables within the vector X **for** the dimensions of the resulting AY to be conformable with X.

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Example:

```
[Ay, by] = makeAy(baseMVA, ng, gencost, pgbas, qgbas, ybas);
```

## margcost

**margcost**(*gencost*, *Pg*)

**margcost**() - Computes marginal cost for generators at given output level.

MARGINALCOST = MARGCOST(GENCOST, PG) computes marginal cost **for** generators given a matrix in gencost format **and** a column vector of generation levels. The **return** value has the same dimensions as PG. Each row of GENCOST is used to evaluate the cost at the points specified in the corresponding row of PG.

## opf\_args

**opf\_args**(*baseMVA*, *bus*, *gen*, *branch*, *areas*, *gencost*, *Au*, *lbu*, *ubu*, *mpopt*, *N*, *fparm*, *H*, *Cw*, *z0*, *zl*, *zu*)

**opf\_args**() (page 291) - Parses and initializes OPF input arguments.

```
[MPC, MPOPT] = OPF_ARGS( ... )
[BASEMVA, BUS, GEN, BRANCH, GENCOST, A, L, U, MPOPT, ...
 N, FPARAM, H, CW, Z0, ZL, ZU, USERFCN] = OPF_ARGS( ... )
```

Returns the **full set** of initialized OPF **input** arguments, filling in default values **for** missing arguments. See Examples below **for** the possible calling syntax options.

Examples:

Output argument options:

```
[mpc, mpopt] = opf_args( ... )
[baseMVA, bus, gen, branch, gencost, A, l, u, mpopt, ...
 N, fparm, H, Cw, z0, zl, zu, userfcn] = opf_args( ... )
```

Input arguments options:

```
opf_args(mpc)
opf_args(mpc, mpopt)
opf_args(mpc, userfcn, mpopt)
opf_args(mpc, A, l, u)
opf_args(mpc, A, l, u, mpopt)
opf_args(mpc, A, l, u, mpopt, N, fparm, H, Cw)
opf_args(mpc, A, l, u, mpopt, N, fparm, H, Cw, z0, zl, zu)

opf_args(baseMVA, bus, gen, branch, areas, gencost)
opf_args(baseMVA, bus, gen, branch, areas, gencost, mpopt)
opf_args(baseMVA, bus, gen, branch, areas, gencost, userfcn, mpopt)
opf_args(baseMVA, bus, gen, branch, areas, gencost, A, l, u)
```

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```

opf_args(baseMVA, bus, gen, branch, areas, gencost, A, l, u, mpop)
opf_args(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
        mpop, N, fparm, H, Cw)
opf_args(baseMVA, bus, gen, branch, areas, gencost, A, l, u, ...
        mpop, N, fparm, H, Cw, z0, zl, zu)

```

The data **for** the problem can be specified in one of three ways:

- (1) a string (*mpc*) containing the file name of a MATPOWER **case** which defines the data matrices *baseMVA*, *bus*, *gen*, *branch*, and *gencost* (*areas* is **not** used at **all**, it is only included **for** backward compatibility of the API).
- (2) a **struct** (*mpc*) containing the data matrices as fields.
- (3) the individual data matrices themselves.

The optional user parameters **for** user constraints (*A*, *l*, *u*), user costs (*N*, *fparm*, *H*, *Cw*), user variable initializer (*z0*), and user variable limits (*zl*, *zu*) can also be specified as fields in a **case struct**, either passed in directly or defined in a **case** file referenced by name.

When specified, *A*, *l*, *u* represent additional linear constraints on the optimization variables,  $l \leq A[x; z] \leq u$ . If the user specifies an *A* matrix that has more **columns** than the number of "x" (OPF) variables, then there are extra linearly constrained "z" variables. For an explanation of the formulation used and instructions **for** forming the *A* matrix, see the manual.

A generalized cost on **all** variables can be applied **if** input arguments *N*, *fparm*, *H* and *Cw* are specified. First, a linear transformation of the optimization variables is defined by means of  $r = N * [x; z]$ . Then, to each element of *r* a **function** is applied as encoded in the *fparm* matrix (see manual). If the resulting vector is named *w*, then *H* and *Cw* define a quadratic cost on *w*:  $(1/2)*w'*H*w + Cw * w$ . *H* and *N* should be **sparse** matrices and *H* should also be **symmetric**.

The optional *mpopt* vector specifies MATPOWER options. See **MPOPTION** **for** details and default values.

## opf\_setup

**opf\_setup**(*mpc*, *mpopt*)

*opf\_setup*() (page 292) - Constructs an OPF model object from a MATPOWER case struct.

```
OM = OPF_SETUP(MPC, MPOPT)
```

Assumes that *MPC* is a MATPOWER **case struct** with internal indexing, **all** equipment in-service, etc.

See also *opf*(), *ext2int*(), *opf\_execute*() (page 293).

## opf\_execute

### opf\_execute(*om*, *mpop*)

*opf\_execute()* (page 293) - Executes the OPF specified by an OPF model object.

```
[RESULTS, SUCCESS, RAW] = OPF_EXECUTE(OM, MPOPT)
```

RESULTS are returned with internal indexing, **all** equipment in-service, etc.

See also *opf()*, *opf\_setup()* (page 292).

## opf\_branch\_ang\_fcn

### opf\_branch\_ang\_fcn(*x*, *Aang*, *lang*, *uang*)

*opf\_branch\_ang\_fcn()* (page 293) - Evaluates branch angle difference constraints and gradients.

```
[VADIF, DVADIF] = OPF_BRANCH_ANG_FCN(X, AANG, LANG, UANG);
```

Computes the **lower and upper** constraints on branch **angle** differences **for** voltages in cartesian coordinates. Computes constraint vectors **and** their gradients. The constraints are of the form:

Aang \* Va >= lang

Aang \* Va <= uang

where Va is the voltage **angle**, a non-linear **function** of the Vr **and** Vi.

Inputs:

X : optimization vector

AANG : constraint matrix, see MAKEAANG

LANG : **lower** bound vector, see MAKEAANG

UANG : **upper** bound vector, see MAKEAANG

Outputs:

VADIF : constraint vector [ lang - Aang \* Va; Aang \* Va - uang ]

DVADIF : (optional) constraint gradients

Examples:

VaDif = opf\_branch\_ang\_fcn(x, Aang, lang, uang);

[VaDif, dVaDif] = opf\_branch\_ang\_fcn(x, Aang, lang, uang);

See also *opf\_branch\_ang\_hess()* (page 294).



## opf\_branch\_ang\_hess

`opf_branch_ang_hess(x, lambda, Aang, lang, uang)`

`opf_branch_ang_hess()` (page 294) - Evaluates Hessian of branch angle difference constraints.

```
D2VADIF = OPF_BRANCH_ANG_HESS(X, LAMBDA, AANG, LANG, UANG)
```

Hessian evaluation **function for** branch **angle** difference constraints **for** voltages in cartesian coordinates.

Inputs:

X : optimization vector  
LAMBDA : column vector of Lagrange multipliers on branch **angle** difference constraints, **lower**, then **upper**  
AANG : constraint matrix, see MAKEAANG  
LANG : **lower** bound vector, see MAKEAANG  
UANG : **upper** bound vector, see MAKEAANG

Outputs:

D2VADIF : Hessian of branch **angle** difference constraints.

Example:

```
d2VaDif = opf_branch_ang_hess(x, lambda, Aang, lang, uang);
```

See also `opf_branch_ang_fcn()` (page 293).

## opf\_branch\_flow\_fcn

`opf_branch_flow_fcn(x, mpc, Yf, Yt, il, mpopt)`

`opf_branch_flow_fcn()` (page 294) - Evaluates AC branch flow constraints and Jacobian.

```
[H, DH] = OPF_BRANCH_FLOW_FCN(X, OM, YF, YT, IL, MPOPT)
```

Branch flow constraints **for** AC optimal **power** flow.  
Computes constraint vectors **and** their gradients.

Inputs:

X : optimization vector  
MPC : MATPOWER **case struct**  
YF : admittance matrix **for "from" end** of constrained branches  
YT : admittance matrix **for "to" end** of constrained branches  
IL : vector of branch indices corresponding to branches with flow limits (**all** others are assumed to be unconstrained).  
YF **and** YT contain only the **rows** corresponding to IL.  
MPOPT : MATPOWER options **struct**

Outputs:

H : vector of inequality constraint values (flow limits) where the flow can be apparent **power**, **real power**, or current, depending on the value of `opf.flow_lim` in MPOPT (only **for** constrained lines), normally expressed as

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```

    (limit^2 - flow^2), except when opf.flow_lim == 'P',
    in which case it is simply (limit - flow).
    DH : (optional) inequality constraint gradients, column j is
          gradient of H(j)

Examples:
    h = opf_branch_flow_fcn(x, mpc, Yf, Yt, il, mpopt);
    [h, dh] = opf_branch_flow_fcn(x, mpc, Yf, Yt, il, mpopt);

```

See also [opf\\_branch\\_flow\\_hess\(\)](#) (page 295).

## opf\_branch\_flow\_hess

**opf\_branch\_flow\_hess**(*x, lambda, mpc, Yf, Yt, il, mpopt*)

[opf\\_branch\\_flow\\_hess\(\)](#) (page 295) - Evaluates Hessian of branch flow constraints.

```

D2H = OPF_BRANCH_FLOW_HESS(X, LAMBDA, OM, YF, YT, IL, MPOPT)

```

Hessian evaluation **function for** AC branch flow constraints.

Inputs:

- X : optimization vector
- LAMBDA : column vector of Kuhn-Tucker multipliers on constrained branch flows
- MPC : MATPOWER **case struct**
- YF : admittance matrix **for "from" end** of constrained branches
- YT : admittance matrix **for "to" end** of constrained branches
- IL : vector of branch indices corresponding to branches with flow limits (**all** others are assumed to be unconstrained). YF and YT contain only the **rows** corresponding to IL.
- MPOPT : MATPOWER options **struct**

Outputs:

- D2H : Hessian of AC branch flow constraints.

Example:

```

d2H = opf_branch_flow_hess(x, lambda, mpc, Yf, Yt, il, mpopt);

```

See also [opf\\_branch\\_flow\\_fcn\(\)](#) (page 294).

**opf\_current\_balance\_fcn****opf\_current\_balance\_fcn**(*x, mpc, Ybus, mpopt*)*opf\_current\_balance\_fcn()* (page 296) - Evaluates AC current balance constraints and their gradients.

```
[G, DG] = OPF_CURRENT_BALANCE_FCN(X, OM, YBUS, MPOPT)
```

Computes the **real** or imaginary current **balance** equality constraints **for** AC optimal **power** flow. Computes constraint vectors **and** their gradients.

Inputs:

X : optimization vector  
MPC : MATPOWER **case struct**  
YBUS : bus admittance matrix  
MPOPT : MATPOWER options **struct**

Outputs:

G : vector of equality constraint values (**real**/imaginary current balances)  
DG : (optional) equality constraint gradients

Examples:

```
g = opf_current_balance_fcn(x, mpc, Ybus, mpopt);
[g, dg] = opf_current_balance_fcn(x, mpc, Ybus, mpopt);
```

See also *opf\_power\_balance\_hess()* (page 298).**opf\_current\_balance\_hess****opf\_current\_balance\_hess**(*x, lambda, mpc, Ybus, mpopt*)*opf\_current\_balance\_hess()* (page 296) - Evaluates Hessian of current balance constraints.

```
D2G = OPF_CURRENT_BALANCE_HESS(X, LAMBDA, OM, YBUS, MPOPT)
```

Hessian evaluation **function for** AC **real and** imaginary current **balance** constraints.

Inputs:

X : optimization vector  
LAMBDA : column vector of Lagrange multipliers on **real and** imaginary current **balance** constraints  
MPC : MATPOWER **case struct**  
YBUS : bus admittance matrix  
MPOPT : MATPOWER options **struct**

Outputs:

D2G : Hessian of current **balance** constraints.

Example:

```
d2G = opf_current_balance_hess(x, lambda, mpc, Ybus, mpopt);
```

See also *opf\_current\_balance\_fcn()* (page 296).

## opf\_gen\_cost\_fcn

**opf\_gen\_cost\_fcn**(*x*, *baseMVA*, *gencost*, *ig*)

*opf\_gen\_cost\_fcn*() (page 297) - Evaluates polynomial generator costs and derivatives.

```
[F, DF, D2F] = OPF_GEN_COST_FCN(X, BASEMVA, COST)
```

Evaluates the polynomial generator costs and derivatives.

Inputs:

X : single-element cell array with vector of (active or reactive) dispatches (in per unit)  
BASEMVA : system per unit base  
GENCOST : standard gencost matrix corresponding to dispatch (active or reactive) provided in X  
IG : vector of generator indices of interest  
MPOPT : MATPOWER options struct

Outputs:

F : sum of generator polynomial costs  
DF : (optional) gradient (column vector) of polynomial costs  
D2F : (optional) Hessian of polynomial costs

Examples:

```
f = opf_gen_cost_fcn(x, baseMVA, gencost, ig);  
[f, df] = opf_gen_cost_fcn(x, baseMVA, gencost, ig);  
[f, df, d2f] = opf_gen_cost_fcn(x, baseMVA, gencost, ig);
```

## opf\_legacy\_user\_cost\_fcn

**opf\_legacy\_user\_cost\_fcn**(*x*, *cp*)

*opf\_legacy\_user\_cost\_fcn*() (page 297) - Evaluates legacy user costs and derivatives.

```
[F, DF, D2F] = OPF_LEGACY_USER_COST_FCN(X, CP)
```

Evaluates the legacy user-defined costs and derivatives.

Inputs:

X : cell array with vectors of optimization variables  
CP : legacy user-defined cost parameter struct such as returned by OPT\_MODEL.GET\_COST\_PARAMS

Outputs:

F : sum of generator polynomial costs  
DF : (optional) gradient (column vector) of polynomial costs  
D2F : (optional) Hessian of polynomial costs

Examples:

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```
f = opf_legacy_user_cost_fcn(x, cp);
[f, df] = opf_legacy_user_cost_fcn(x, cp);
[f, df, d2f] = opf_legacy_user_cost_fcn(x, cp);
```

## opf\_power\_balance\_fcn

**opf\_power\_balance\_fcn**(*x, mpc, Ybus, mpopt*)

[opf\\_power\\_balance\\_fcn\(\)](#) (page 298) - Evaluates AC power balance constraints and their gradients.

```
[G, DG] = OPF_POWER_BALANCE_FCN(X, OM, YBUS, MPOPT)
```

Computes the active or reactive power balance equality constraints for AC optimal power flow. Computes constraint vectors and their gradients.

Inputs:

X : optimization vector  
MPC : MATPOWER case struct  
YBUS : bus admittance matrix  
MPOPT : MATPOWER options struct

Outputs:

G : vector of equality constraint values (active/reactive power balances)  
DG : (optional) equality constraint gradients

Examples:

```
g = opf_power_balance_fcn(x, mpc, Ybus, mpopt);
[g, dg] = opf_power_balance_fcn(x, mpc, Ybus, mpopt);
```

See also [opf\\_power\\_balance\\_hess\(\)](#) (page 298).

## opf\_power\_balance\_hess

**opf\_power\_balance\_hess**(*x, lambda, mpc, Ybus, mpopt*)

[opf\\_power\\_balance\\_hess\(\)](#) (page 298) - Evaluates Hessian of power balance constraints.

```
D2G = OPF_POWER_BALANCE_HESS(X, LAMBDA, OM, YBUS, MPOPT)
```

Hessian evaluation function for AC active and reactive power balance constraints.

Inputs:

X : optimization vector  
LAMBDA : column vector of Lagrange multipliers on active and reactive power balance constraints  
MPC : MATPOWER case struct  
YBUS : bus admittance matrix  
MPOPT : MATPOWER options struct

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**Outputs:**D2G : Hessian of **power balance** constraints.**Example:**

```
d2G = opf_power_balance_hess(x, lambda, mpc, Ybus, mpopt);
```

See also *opf\_power\_balance\_fcn()* (page 298).**opf\_veq\_fcn****opf\_veq\_fcn**(*x, mpc, idx, mpopt*)*opf\_veq\_fcn()* (page 299) - Evaluates voltage magnitude equality constraint and gradients.

```
[Veq, dVeq] = OPF_VEQ_FCN(X, MPC, IDX, MPOPT)
```

Computes the voltage magnitudes using **real and** imaginary part of **complex** voltage **for** AC optimal **power** flow. Computes constraint vectors **and** their gradients.

**Inputs:**

X : optimization vector

MPC : MATPOWER **case struct**IDX : **index** of buses whose voltage magnitudes should be fixedMPOPT : MATPOWER options **struct****Outputs:**

VEQ : vector of voltage magnitudes

DVEQ : (optional) magnitude gradients

**Examples:**

```
Veq = opf_veq_fcn(x, mpc, mpopt);
```

```
[Veq, dVeq] = opf_veq_fcn(x, mpc, idx, mpopt);
```

See also *opf\_veq\_hess()* (page 299).**opf\_veq\_hess****opf\_veq\_hess**(*x, lambda, mpc, idx, mpopt*)*opf\_veq\_hess()* (page 299) - Evaluates Hessian of voltage magnitude equality constraint.

```
D2VEQ = OPF_VEQ_HESS(X, LAMBDA, MPC, IDX, MPOPT)
```

Hessian evaluation **function for** voltage magnitudes.

**Inputs:**

X : optimization vector

LAMBDA : column vector of Lagrange multipliers on active **and** reactive

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```

    power balance constraints
MPC : MATPOWER case struct
IDX : index of buses whose voltage magnitudes should be fixed
MPOPT : MATPOWER options struct

Outputs:
  D2VEQ : Hessian of voltage magnitudes.

Example:
  d2Veq = opf_veq_hess(x, lambda, mpc, idx, mpopt);

```

See also [opf\\_veq\\_fcn\(\)](#) (page 299).

### opf\_vlim\_fcn

**opf\_vlim\_fcn**(*x*, *mpc*, *idx*, *mpopt*)

[opf\\_vlim\\_fcn\(\)](#) (page 300) - Evaluates voltage magnitudes and their gradients.

```

[Vlims, dVlims] = OPF_VLIM_FCN(X, MPC, IDX, MPOPT)

```

Computes the voltage magnitudes using real and imaginary part of complex voltage for AC optimal power flow. Computes constraint vectors and their gradients.

Inputs:

```

  X : optimization vector
  MPC : MATPOWER case struct
  IDX : index of buses whose voltage magnitudes should be fixed
  MPOPT : MATPOWER options struct

```

Outputs:

```

  VLIMS : vector of voltage magnitudes
  DVLIMS : (optional) magnitude gradients

```

Examples:

```

  Vlims = opf_vlim_fcn(x, mpc, mpopt);
  [Vlims, dVlims] = opf_vlim_fcn(x, mpc, idx, mpopt);

```

See also [opf\\_vlim\\_hess\(\)](#) (page 301).

## opf\_vlim\_hess

**opf\_vlim\_hess**(*x, lambda, mpc, idx, mpopt*)

*opf\_vlim\_hess*() (page 301) - Evaluates Hessian of voltage magnitudes.

```
D2VLIMS = OPF_VLIM_HESS(X, LAMBDA, MPC, IDX, MPOPT)
```

Hessian evaluation **function for** voltage magnitudes.

Inputs:

X : optimization vector  
LAMBDA : column vector of Lagrange multipliers on active **and** reactive  
power balance constraints  
MPC : MATPOWER **case struct**  
IDX : **index** of buses whose voltage magnitudes should be fixed  
MPOPT : MATPOWER options **struct**

Outputs:

D2VLIMS : Hessian of voltage magnitudes.

Example:

```
d2Vlims = opf_vlim_hess(x, lambda, mpc, idx, mpopt);
```

See also *opf\_vlim\_fcn*() (page 300).

## opf\_vref\_fcn

**opf\_vref\_fcn**(*x, mpc, refs, mpopt*)

*opf\_vref\_fcn*() (page 301) - Evaluates voltage angle reference and their gradients.

```
[Vref, dVref] = OPF_VREF_FCN(X, MPC, REF, MPOPT)
```

Computes the voltage **angle** reference using **real and** imaginary part of **complex** voltage **for**  
AC optimal **power** flow. Computes constraint vectors **and** their gradients.

Inputs:

X : optimization vector  
MPC : MATPOWER **case struct**  
REFS : reference vector  
MPOPT : MATPOWER options **struct**

Outputs:

VREF : vector of voltage **angle** reference  
DVREF : (optional) **angle** reference gradients

Examples:

```
Vref = opf_vref_fcn(x, mpc, refs, mpopt);  
[Vref, dVref] = opf_vref_fcn(x, mpc, refs, mpopt);
```

See also *opf\_vref\_hess*() (page 302).



## opf\_vref\_hess

**opf\_vref\_hess**(*x, lam, mpc, refs, mpopt*)

*opf\_vref\_hess*() (page 302) - Evaluates Hessian of voltage angle reference.

```
D2VREF = OPF_VREF_HESS(X, LAMBDA, MPC, REFS, MPOPT)
```

Hessian evaluation **function for** voltage **angle** reference.

Inputs:

X : optimization vector  
LAMBDA : column vector of Lagrange multipliers on active **and** reactive  
power balance constraints  
MPC : MATPOWER **case struct**  
REFS : reference vector  
MPOPT : MATPOWER options **struct**

Outputs:

D2VREF : Hessian of voltage **angle** reference.

Example:

```
d2Vref = opf_vref_hess(x, lambda, mpc, refs, mpopt);
```

See also *opf\_vref\_fcn*() (page 301).

## totcost

**totcost**(*gencost, Pg*)

*totcost*() - Computes total cost for generators at given output level.

```
TOTALCOST = TOTCOST(GENCOST, PG) computes total cost for generators given  
a matrix in gencost format and a column vector or matrix of generation  
levels. The return value has the same dimensions as PG. Each row  
of GENCOST is used to evaluate the cost at the points specified in the  
corresponding row of PG.
```

## update\_mupq

**update\_mupq**(*baseMVA, gen, mu\_PQh, mu\_PQl, data*)

*update\_mupq*() (page 302) - Updates values of generator limit shadow prices.

```
GEN = UPDATE_MUPQ(BASEMVA, GEN, MU_PQH, MU_PQL, DATA)
```

Updates the values of MU\_PMIN, MU\_PMAX, MU\_QMIN, MU\_QMAX based  
on **any** shadow prices on the sloped portions of the generator

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capability curve constraints.

MU\_PQH - shadow prices on **upper** sloped portion of capability curves  
 MU\_PQL - shadow prices on **lower** sloped portion of capability curves  
 DATA - **"data"** struct returned by MAKEAPQ

See also *makeApq()* (page 289).

## 5.2.8 OPF User Callback Functions

### add\_userfcn

**add\_userfcn**(*mpc, stage, fcn, args, allow\_multiple*)

*add\_userfcn()* (page 303) - Appends a userfcn to the list to be called for a case.

```
MPC = ADD_USERFCN(MPC, STAGE, FCN)
MPC = ADD_USERFCN(MPC, STAGE, FCN, ARGS)
MPC = ADD_USERFCN(MPC, STAGE, FCN, ARGS, ALLOW_MULTIPLE)
```

A userfcn is a callback **function** that can be called automatically by MATPOWER at one of various stages in a simulation.

MPC : the **case struct**  
 STAGE : the name of the stage at which this **function** should be called: ext2int, formulation, int2ext, printpf, savecase  
 FCN : the name of the userfcn  
 ARGS : (optional) the value to be passed as an argument to the userfcn (typically a **struct**)  
 ALLOW\_MULTIPLE : (optional) **if** TRUE, allows the same **function** to be added more than once.

Currently there are 5 different callback stages defined. Each stage has a name, **and** by convention, the name of a user-defined callback **function** ends with the name of the stage. The following is a description of each stage, when it is called **and** the **input and** output arguments which vary depending on the stage. The reserves **example** (see RUNOPF\_W\_RES) is used to illustrate how these callback userfcns might be used.

#### 1. ext2int

Called from EXT2INT immediately after the **case** is converted from external to internal indexing. Inputs are a MATPOWER **case struct** (MPC), freshly converted to internal indexing **and any** (optional) ARGS value supplied via ADD\_USERFCN. Output is the (presumably updated) MPC. This is typically used to reorder **any input** arguments that may be needed in internal ordering by the formulation stage.

E.g. `mpc = userfcn_reserves_ext2int(mpc, mpopt, args)`

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## 2. formulation

Called from OPF after the OPF Model (OM) object has been initialized with the standard OPF formulation, but before calling the solver. Inputs are the OM object and any (optional) ARGS supplied via ADD\_USERFCN. Output is the OM object. This is the ideal place to add any additional vars, constraints or costs to the OPF formulation.

E.g. `om = userfcn_reserves_formulation(om, mpopt, args)`

## 3. int2ext

Called from INT2EXT immediately before the resulting case is converted from internal back to external indexing. Inputs are the RESULTS struct and any (optional) ARGS supplied via ADD\_USERFCN. Output is the RESULTS struct. This is typically used to convert any results to external indexing and populate any corresponding fields in the RESULTS struct.

E.g. `results = userfcn_reserves_int2ext(results, mpopt, args)`

## 4. printf

Called from PRINTPF after the pretty-printing of the standard OPF output. Inputs are the RESULTS struct, the file descriptor to write to, a MATPOWER options struct, and any (optional) ARGS supplied via ADD\_USERFCN. Output is the RESULTS struct. This is typically used for any additional pretty-printing of results.

E.g. `results = userfcn_reserves_printf(results, fd, mpopt, args)`

## 5. savecase

Called from SAVECASE when saving a case struct to an M-file after printing all of the other data to the file. Inputs are the case struct, the file descriptor to write to, the variable prefix (typically 'mpc.') and any (optional) ARGS supplied via ADD\_USERFCN. Output is the case struct. This is typically used to write any non-standard case struct fields to the case file.

E.g. `mpc = userfcn_reserves_printf(mpc, fd, prefix, args)`

See also `run_userfcn()` (page 305), `remove_userfcn()` (page 305), `toggle_reserves()` (page 307), `toggle_iflims()` (page 306), `toggle_dcline()` (page 305), `toggle_softlims()` (page 308), `runopf_w_res()` (page 236).

## remove\_userfcn

**remove\_userfcn**(*mpc, stage, fcn*)

*remove\_userfcn()* (page 305) - Removes a userfcn from the list to be called for a case.

```
MPC = REMOVE_USERFCN(MPC, STAGE, FCN)
```

A userfcn is a callback **function** that can be called automatically by MATPOWER at one of various stages in a simulation. This **function** removes the last instance of the userfcn **for** the given STAGE with the **function** handle specified by FCN.

See also *add\_userfcn()* (page 303), *run\_userfcn()* (page 305), *toggle\_reserves()* (page 307), *toggle\_iflims()* (page 306), *runopf\_w\_res()* (page 236).

## run\_userfcn

**run\_userfcn**(*userfcn, stage, varargin*)

*run\_userfcn()* (page 305) - Runs the userfcn callbacks for a given stage.

```
RV = RUN_USERFCN(USERFCN, STAGE, VARARGIN)
```

USERFCN : the 'userfcn' field of mpc, populated by ADD\_USERFCN  
STAGE : the name of the callback stage being executed  
(additional arguments) some stages require additional arguments.

Example:

```
mpc = om.get_mpc();  
om = run_userfcn(mpc.userfcn, 'formulation', om);
```

See also *add\_userfcn()* (page 303), *remove\_userfcn()* (page 305), *toggle\_reserves()* (page 307), *toggle\_iflims()* (page 306), *runopf\_w\_res()* (page 236).

## toggle\_dcline

**toggle\_dcline**(*mpc, on\_off*)

*toggle\_dcline()* (page 305) - Enable, disable or check status of DC line modeling.

```
MPC = TOGGLE_DCLINE(MPC, 'on')  
MPC = TOGGLE_DCLINE(MPC, 'off')  
T_F = TOGGLE_DCLINE(MPC, 'status')
```

Enables, disables **or** checks the status of a **set** of OPF userfcn callbacks to implement DC lines as a pair of linked generators. While it uses the OPF extension mechanism, this implementation works **for** simple **power** flow as well as OPF problems.

These callbacks expect to **find** a 'dcline' field in the **input** MPC, where MPC.dcline is an ndc x 17 matrix with **columns** as defined

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in `IDX_DCLINE`, where `ndc` is the number of DC lines.

The `'int2ext'` callback also packages up flow results and stores them in appropriate `columns` of `MPC.dcline`.

NOTE: Because of the way this extension modifies the number of `rows` in the `gen` and `gencost` matrices, caution must be taken when using it with other extensions that `deal` with generators.

Examples:

```
mpc = loadcase('t_case9_dcline');
mpc = toggle_dcline(mpc, 'on');
results1 = runpf(mpc);
results2 = runopf(mpc);
```

See also `idx_dcline()` (page 344), `add_userfcn()` (page 303), `remove_userfcn()` (page 305), `run_userfcn()` (page 305).

## toggle\_iflims

`toggle_iflims(mpc, on_off)`

`toggle_iflims()` (page 306) - Enable, disable or check status of set of interface flow limits.

```
MPC = TOGGLE_IFLIMS(MPC, 'on')
MPC = TOGGLE_IFLIMS(MPC, 'off')
T_F = TOGGLE_IFLIMS(MPC, 'status')
```

Enables, disables or checks the status of a `set` of OPF `userfcn` callbacks to implement interface flow limits based on a DC flow model.

These callbacks expect to find an `'if'` field in the `input` MPC, where `MPC.if` is a `struct` with the following fields:

```
map      n x 2, defines each interface in terms of a set of
          branch indices and directions. Interface I is defined
          by the set of rows whose 1st col is equal to I. The
          2nd column is a branch index multiplied by 1 or -1
          respectively for lines whose orientation is the same
          as or opposite to that of the interface.
lims     nif x 3, defines the DC model flow limits in MW
          for specified interfaces. The first column is the index
          of the interface, the 2nd and 3rd columns specify
          the lower and upper limits on the (DC model) flow
          across the interface, respectively. Normally, the lower
          limit is negative, indicating a flow in the opposite
          direction.
```

The `'int2ext'` callback also packages up results and stores them in the following output fields of `results.if`:

```
P        - nif x 1, actual flow across each interface in MW
```

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```
mu.l    - nif x 1, shadow price on lower flow limit, ($/MW)
mu.u    - nif x 1, shadow price on upper flow limit, ($/MW)
```

See also [add\\_userfcn\(\)](#) (page 303), [remove\\_userfcn\(\)](#) (page 305), [run\\_userfcn\(\)](#) (page 305), [t\\_case30\\_userfcns\(\)](#) (page 382).

## toggle\_reserves

**toggle\_reserves**(*mpc, on\_off*)

[toggle\\_reserves\(\)](#) (page 307) - Enable, disable or check status of fixed reserve requirements.

```
MPC = TOGGLE_RESERVES(MPC, 'on')
MPC = TOGGLE_RESERVES(MPC, 'off')
T_F = TOGGLE_RESERVES(MPC, 'status')
```

Enables, disables or checks the status of a set of OPF userfcn callbacks to implement co-optimization of reserves with fixed zonal reserve requirements.

These callbacks expect to find a 'reserves' field in the input MPC, where MPC.reserves is a struct with the following fields:

```
zones    nrz x ng, zone(i, j) = 1, if gen j belongs to zone i
          0, otherwise
req      nrz x 1, zonal reserve requirement in MW
cost     (ng or ngr) x 1, cost of reserves in $/MW
qty      (ng or ngr) x 1, max quantity of reserves in MW (optional)
```

where nrz is the number of reserve zones and ngr is the number of generators belonging to at least one reserve zone and ng is the total number of generators.

The 'int2ext' callback also packages up results and stores them in the following output fields of results.reserves:

```
R        - ng x 1, reserves provided by each gen in MW
Rmin     - ng x 1, lower limit on reserves provided by each gen, (MW)
Rmax     - ng x 1, upper limit on reserves provided by each gen, (MW)
mu.l     - ng x 1, shadow price on reserve lower limit, ($/MW)
mu.u     - ng x 1, shadow price on reserve upper limit, ($/MW)
mu.Pmax  - ng x 1, shadow price on Pg + R <= Pmax constraint, ($/MW)
prc      - ng x 1, reserve price for each gen equal to maximum of the
          shadow prices on the zonal requirement constraint
          for each zone the generator belongs to
```

See also [runopf\\_w\\_res\(\)](#) (page 236), [add\\_userfcn\(\)](#) (page 303), [remove\\_userfcn\(\)](#) (page 305), [run\\_userfcn\(\)](#) (page 305), [t\\_case30\\_userfcns\(\)](#) (page 382).

**toggle\_softlims****toggle\_softlims**(*mpc, on\_off*)*toggle\_softlims*() (page 308) - Relax DC optimal power flow branch limits.

```

MPC = TOGGLE_SOFTLIMS(MPC, 'on')
MPC = TOGGLE_SOFTLIMS(MPC, 'off')
T_F = TOGGLE_SOFTLIMS(MPC, 'status')

```

Enables, disables or checks the status of a **set** of OPF userfcn callbacks to implement relaxed inequality constraints **for** an OPF model.

These callbacks expect to **find** a 'softlims' field in the **input** MPC, where MPC.softlims is a **struct** with fields corresponding to the possible limits, namely:

VMIN, VMAX, RATE\_A, PMIN, PMAX, QMIN, QMAX, ANGMAX, ANGMIN

Each of these is itself a **struct** with the following fields, **all** of which are optional:

```

idx      index of affected buses, branches, or generators. These are
         row indices into the respective matrices. The default is to
         include all online elements for which the constraint in
         question is not unbounded, except for generators, which also
         exclude those used to model dispatchable loads
         (i.e. those for which isload(gen) is true).
busnum   for bus constraints, such as VMIN and VMAX, the affected
         buses can be specified by a vector of external bus numbers
         in the 'busnum' field instead of bus row indices in the 'idx'
         field. If both are present, 'idx' overrides 'busnum'.
cost     linear marginal cost of exceeding the original limit
         The defaults are set as:
         base_cost x 100 $/pu      for VMAX and VMIN
         base_cost $/MW           for RATE_A, PMAX, and PMIN
         base_cost $/MVar        for QMAX, QMIN
         base_cost $/deg         for ANGMAX, ANGMIN
         where base_cost is the maximum of $1000 and twice the
         maximum generator cost of all online generators.
hl_mod   type of modification to hard limit, hl:
         'none'      : do *not* add soft limit, no change to original
                       hard limit
         'remove'    : add soft limit, relax hard limit by removing
                       it completely
         'replace'   : add soft limit, relax hard limit by replacing
                       original with value specified in hl_val
         'scale'     : add soft limit, relax hard limit by scaling
                       original by value specified in hl_val
         'shift'     : add soft limit, relax hard limit by shifting
                       original by value specified in hl_val
hl_val   value used to modify hard limit according to hl_mod. Ignored
         for 'none' and 'remove', required for 'replace', and optional,
         with the following defaults, for 'scale' and 'shift':
         'scale'    : 2 for positive upper limits or negative lower
                       limits, 0.5 otherwise
         'shift'    : 0.25 for VMAX and VMIN, 10 otherwise

```

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For limits that are left unspecified in the structure, the default behavior is determined by the value of the `mpopt.opf.softlims.default` option. If `mpopt.opf.softlims.default = 0`, then the unspecified softlims are ignored (`hl_mod = 'none'`, i.e. original hard limits left in place). If `mpopt.opf.softlims.default = 1` (default), then the unspecified softlims are enabled with default values, which specify to `'remove'` the hard limit, except in the **case** of `VMIN` and `PMIN`, whose defaults are **set** as follows:

```
.VMIN
  .hl_mod = 'replace'
  .hl_val = 0
.PMIN
  .hl_mod = 'replace'
  .hl_val = 0   for normal generators (PMIN > 0)
  .hl_val = -Inf for for generators with PMIN < 0 AND PMAX > 0
```

With `mpopt.opf.softlims.default = 0`, it is still possible to enable a softlim with default values by setting that specification to an empty `struct`. E.g. `mpc.softlims.VMAX = struct()` would enable a default softlim on `VMAX`.

The `'int2ext'` callback also packages up results and stores them in the following output fields of `results.softlims.(lim)`, where `lim` is one of the above mentioned limits:

```
overload - amount of overload, i.e. violation of hard-limit.
ovl_cost  - total cost of overload in $/hr
```

The shadow prices on the soft limit constraints are also returned in the relevant **columns** of the respective matrices (`MU_SF`, `MU_ST` for `RATE_A`, `MU_VMAX` for `VMAX`, etc.)

Note: These shadow prices are equal to the corresponding hard limit shadow prices when the soft limits are **not** violated. When violated, the shadow price on a soft limit constraint is equal to the user-specified soft limit violation cost + the shadow price on **any** binding remaining hard limit.

See also `add_userfcn()` (page 303), `remove_userfcn()` (page 305), `run_userfcn()` (page 305), `t_opf_softlims()` (page 379).



## 5.2.9 Power Flow Derivative Functions

### dlbr\_dV

**dIbr\_dV**(branch, Yf, Yt, V, vcart)

*dIbr\_dV*() (page 310) - Computes partial derivatives of branch currents w.r.t. voltage.

The derivatives can be take with respect to **polar** or cartesian coordinates of voltage, depending on the 5th argument.

```
[DIF_DVA, DIF_DVM, DIT_DVA, DIT_DVM, IF, IT] = DIBR_DV(BRANCH, YF, YT, V)
[DIF_DVA, DIF_DVM, DIT_DVA, DIT_DVM, IF, IT] = DIBR_DV(BRANCH, YF, YT, V, 0)
```

Returns four matrices containing partial derivatives of the **complex** branch currents at "from" and "to" ends of each branch w.r.t voltage magnitude and voltage **angle**, respectively (**for all buses**).

```
[DIF_DVR, DIF_DVI, DIT_DVR, DIT_DVI, IF, IT] = DIBR_DV(BRANCH, YF, YT, V, 1)
```

Returns four matrices containing partial derivatives of the **complex** branch currents at "from" and "to" ends of each branch w.r.t **real and imaginary parts** of voltage, respectively (**for all buses**).

If YF is a **sparse** matrix, the partial derivative matrices will be as well. Optionally returns vectors containing the currents themselves. The following explains the expressions used to form the matrices:

$$If = Yf * V;$$

Polar coordinates:

Partials of V, Vf & If w.r.t. voltage angles

$$dV/dVa = j * \text{diag}(V)$$

$$dVf/dVa = \text{sparse}(1:nl, f, j * V(f)) = j * \text{sparse}(1:nl, f, V(f))$$

$$dIf/dVa = Yf * dV/dVa = Yf * j * \text{diag}(V)$$

Partials of V, Vf & If w.r.t. voltage magnitudes

$$dV/dVm = \text{diag}(V./\text{abs}(V))$$

$$dVf/dVm = \text{sparse}(1:nl, f, V(f)./abs(V(f)))$$

$$dIf/dVm = Yf * dV/dVm = Yf * \text{diag}(V./abs(V))$$

Cartesian coordinates:

Partials of V, Vf & If w.r.t. **real part** of **complex** voltage

$$dV/dVr = \text{diag}(\text{ones}(n,1))$$

$$dVf/dVr = Cf$$

$$dIf/dVr = Yf$$

where Cf is the connection matrix **for line** & from buses

Partials of V, Vf & If w.r.t. **imaginary part** of **complex** voltage

$$dV/dVi = j * \text{diag}(\text{ones}(n,1))$$

$$dVf/dVi = j * Cf$$

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```
dIf/dVi = j * Yf
```

Derivations for "to" bus are similar.

Example:

```
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[dIf_dVa, dIf_dVm, dIt_dVa, dIt_dVm, If, It] = ...
    dIbr_dV(branch, Yf, Yt, V);
[dIf_dVr, dIf_dVi, dIt_dVr, dIt_dVi, If, It] = ...
    dIbr_dV(branch, Yf, Yt, V, 1);
```

For more details on the derivations behind the derivative code used in MATPOWER information, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: 10.5281/zenodo.3237866
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: 10.5281/zenodo.3237909

## dSbr\_dV

**dSbr\_dV**(branch, Yf, Yt, V, vcart)

*dSbr\_dV*( ) (page 311) - Computes partial derivatives of branch power flows w.r.t. voltage.

The derivatives can be taken with respect to polar or cartesian coordinates of voltage, depending on the 5th argument.

```
[DSF_DVA, DSF_DVM, DST_DVA, DST_DVM, SF, ST] = DSBR_DV(BRANCH, YF, YT, V)
[DSF_DVA, DSF_DVM, DST_DVA, DST_DVM, SF, ST] = DSBR_DV(BRANCH, YF, YT, V, 0)
```

Returns four matrices containing partial derivatives of the complex branch power flows at "from" and "to" ends of each branch w.r.t voltage magnitude and voltage angle, respectively (for all buses).

```
[DSF_DVR, DSF_DVI, DST_DVR, DST_DVI, SF, ST] = DSBR_DV(BRANCH, YF, YT, V, 1)
```

Returns four matrices containing partial derivatives of the complex branch power flows at "from" and "to" ends of each branch w.r.t real and imaginary parts of voltage, respectively (for all buses).

If YF is a sparse matrix, the partial derivative matrices will be as well. Optionally returns vectors containing the power flows themselves. The following explains the expressions used to form the matrices:

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```
If = Yf * V;
Sf = diag(Vf) * conj(If) = diag(conj(If)) * Vf
```

Polar coordinates:

Partials of V, Vf & If w.r.t. voltage angles

```
dV/dVa = j * diag(V)
dVf/dVa = sparse(1:nl, f, j * V(f)) = j * sparse(1:nl, f, V(f))
dIf/dVa = Yf * dV/dVa = Yf * j * diag(V)
```

Partials of V, Vf & If w.r.t. voltage magnitudes

```
dV/dVm = diag(V./abs(V))
dVf/dVm = sparse(1:nl, f, V(f)./abs(V(f)))
dIf/dVm = Yf * dV/dVm = Yf * diag(V./abs(V))
```

Partials of Sf w.r.t. voltage angles

```
dSf/dVa = diag(Vf) * conj(dIf/dVa)
          + diag(conj(If)) * dVf/dVa
= diag(Vf) * conj(Yf * j * diag(V))
          + conj(diag(If)) * j * sparse(1:nl, f, V(f))
= -j * diag(Vf) * conj(Yf * diag(V))
          + j * conj(diag(If)) * sparse(1:nl, f, V(f))
= j * (conj(diag(If)) * sparse(1:nl, f, V(f))
        - diag(Vf) * conj(Yf * diag(V)))
```

Partials of Sf w.r.t. voltage magnitudes

```
dSf/dVm = diag(Vf) * conj(dIf/dVm)
          + diag(conj(If)) * dVf/dVm
= diag(Vf) * conj(Yf * diag(V./abs(V)))
          + conj(diag(If)) * sparse(1:nl, f, V(f)./abs(V(f)))
```

Cartesian coordinates:

Partials of V, Vf & If w.r.t. real part of complex voltage

```
dV/dVr = diag(ones(n,1))
dVf/dVr = Cf
dIf/dVr = Yf
```

where Cf is the connection matrix for line & from buses

Partials of V, Vf & If w.r.t. imaginary part of complex voltage

```
dV/dVi = j * diag(ones(n,1))
dVf/dVi = j * Cf
dIf/dVi = j * Yf
```

Partials of Sf w.r.t. real part of complex voltage

```
dSf/dVr = conj(diag(If)) * Cf + diag(Vf) * conj(Yf)
```

Partials of Sf w.r.t. imaginary part of complex voltage

```
dSf/dVi = j * (conj(diag(If)) * Cf - diag(Vf) * conj(Yf))
```

Derivations for "to" bus are similar.

Examples:

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```
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[dSf_dVa, dSf_dVm, dSt_dVa, dSt_dVm, Sf, St] = ...
    dSbr_dV(branch, Yf, Yt, V);
[dSf_dVr, dSf_dVi, dSt_dVr, dSt_dVi, Sf, St] = ...
    dSbr_dV(branch, Yf, Yt, V, 1);
```

For more details on the derivations behind the derivative code used in MATPOWER, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## dAbr\_dV

**dAbr\_dV**(dFf\_dV1, dFf\_dV2, dFt\_dV1, dFt\_dV2, Ff, Ft)

*dAbr\_dV*( ) (page 313) - Partial derivatives of squared flow magnitudes w.r.t voltage.

```
[DAF_DV1, DAF_DV2, DAT_DV1, DAT_DV2] = ...
    DABR_DV(DFF_DV1, DFF_DV2, DFT_DV1, DFT_DV2, FF, FT)
```

returns four matrices containing partial derivatives of the square of the branch flow magnitudes at "from" & "to" ends of each branch w.r.t voltage components (either **angle** and **magnitude**, respectively, **if polar**, or **real** and **imaginary**, respectively, **if cartesian**) **for all buses**, given the flows and flow sensitivities. Flows could be **complex current** or **complex or real power**. Notation below is based on **complex power**. The following explains the expressions used to form the matrices:

Let  $A_f$  refer to the square of the apparent **power** at the "from" **end** of each branch,

$$\begin{aligned} A_f &= \text{abs}(S_f).^2 \\ &= S_f .* \text{conj}(S_f) \\ &= P_f.^2 + Q_f.^2 \end{aligned}$$

then ...

Partial w.r.t **real power**,  
 $dA_f/dP_f = 2 * \text{diag}(P_f)$

Partial w.r.t **reactive power**,  
 $dA_f/dQ_f = 2 * \text{diag}(Q_f)$

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```

Partial w.r.t V1 & V2 (e.g. Va and Vm, or Vr and Vi)
dAf/dV1 = dAf/dPf * dPf/dV1 + dAf/dQf * dQf/dV1
dAf/dV2 = dAf/dPf * dPf/dV2 + dAf/dQf * dQf/dV2

```

Derivations for "to" bus are similar.

Examples:

```

%% squared current magnitude
[dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft] = ...
    dIbr_dV(branch(il,:), Yf, Yt, V);
[dAf_dV1, dAf_dV2, dAt_dV1, dAt_dV2] = ...
    dAbr_dV(dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft);

%% squared apparent power flow
[dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft] = ...
    dSbr_dV(branch(il,:), Yf, Yt, V);
[dAf_dV1, dAf_dV2, dAt_dV1, dAt_dV2] = ...
    dAbr_dV(dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft);

%% squared real power flow
[dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft] = ...
    dSbr_dV(branch(il,:), Yf, Yt, V);
dFf_dV1 = real(dFf_dV1);
dFf_dV2 = real(dFf_dV2);
dFt_dV1 = real(dFt_dV1);
dFt_dV2 = real(dFt_dV2);
[dAf_dV1, dAf_dV2, dAt_dV1, dAt_dV2] = ...
    dAbr_dV(dFf_dV1, dFf_dV2, dFt_dV1, dFt_dV2, Ff, Ft);

```

See also *dIbr\_dV()* (page 310), *dSbr\_dV()* (page 311).

For more details on the derivations behind the derivative code used in MATPOWER information, see:

```

[TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and
their Derivatives using Complex Matrix Notation", MATPOWER
Technical Note 2, February 2010. [Online]. Available:
https://matpower.org/docs/TN2-OPF-Derivatives.pdf
doi: 10.5281/zenodo.3237866

```

## dImis\_dV

**dImis\_dV**(Sbus, Ybus, V, vcart)

*dImis\_dV()* (page 314) - Computes partial derivatives of current balance w.r.t. voltage.

The derivatives can be take with respect to polar or cartesian coordinates of voltage, depending on the 3rd argument.

```

[DIMIS_DVM, DIMIS_DVA] = DIMIS_DV(SBUS, YBUS, V)
[DIMIS_DVM, DIMIS_DVA] = DIMIS_DV(SBUS, YBUS, V, 0)

```

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Returns two matrices containing partial derivatives of the **complex** bus current **balance** w.r.t voltage magnitude **and** voltage **angle**, respectively (**for all** buses).

```
[DIMIS_DVR, DIMIS_DVI] = DIMIS_DV(SBUS, YBUS, V, 1)
```

Returns two matrices containing partial derivatives of the **complex** bus current **balance** w.r.t the **real and** imaginary parts of voltage, respectively (**for all** buses).

If YBUS is a **sparse** matrix, the **return** values will be also. The following explains the expressions used to form the matrices:

$$I_{mis} = I_{bus} + I_{dg} = Y_{bus} * V - \text{conj}(S_{bus}./V)$$

Polar coordinates:

Partials of V & I<sub>bus</sub> w.r.t. voltage angles

$$dV/dVa = j * \text{diag}(V)$$

$$dI/dVa = Y_{bus} * dV/dVa = Y_{bus} * j * \text{diag}(V)$$

Partials of V & I<sub>bus</sub> w.r.t. voltage magnitudes

$$dV/dVm = \text{diag}(V./\text{abs}(V))$$

$$dI/dVm = Y_{bus} * dV/dVm = Y_{bus} * \text{diag}(V./\text{abs}(V))$$

Partials of I<sub>mis</sub> w.r.t. voltage angles

$$dI_{mis}/dVa = j * (Y_{bus} * \text{diag}(V) - \text{diag}(\text{conj}(S_{bus}./V)))$$

Partials of I<sub>mis</sub> w.r.t. voltage magnitudes

$$dI_{mis}/dVm = Y_{bus} * \text{diag}(V./\text{abs}(V)) + \text{diag}(\text{conj}(S_{bus}./(V * \text{abs}(V))))$$

Cartesian coordinates:

Partials of V & I<sub>bus</sub> w.r.t. **real** part of **complex** voltage

$$dV/dVr = \text{diag}(\text{ones}(n,1))$$

$$dI/dVr = Y_{bus} * dV/dVr = Y_{bus}$$

Partials of V & I<sub>bus</sub> w.r.t. **imaginary** part of **complex** voltage

$$dV/dVi = j * \text{diag}(\text{ones}(n,1))$$

$$dI/dVi = Y_{bus} * dV/dVi = Y_{bus} * j$$

Partials of I<sub>mis</sub> w.r.t. **real** part of **complex** voltage

$$dI_{mis}/dVr = Y_{bus} + \text{conj}(\text{diag}(S_{bus}./V.^2))$$

Partials of S w.r.t. **imaginary** part of **complex** voltage

$$dI_{mis}/dVi = j * (Y_{bus} - \text{diag}(\text{conj}(S_{bus}./V.^2)))$$

Examples:

```
Sbus = makeSbus(baseMVA, bus, gen);
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[dImis_dVm, dImis_dVa] = dImis_dV(Sbus, Ybus, V);
[dImis_dVr, dImis_dVi] = dImis_dV(Sbus, Ybus, V, 1);
```

For more details on the derivations behind the derivative code used in MATPOWER information, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN3] B. Sereeter and R. D. Zimmerman, "Addendum to AC Power Flows and their Derivatives using Complex Matrix Notation: Nodal Current Balance," MATPOWER Technical Note 3, April 2018. [Online]. Available: <https://matpower.org/docs/TN3-More-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237900](https://doi.org/10.5281/zenodo.3237900)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## dSbus\_dV

**dSbus\_dV**(Ybus, V, vcart)

*dSbus\_dV*( ) (page 316) - Computes partial derivatives of power injection w.r.t. voltage.

The derivatives can be taken with respect to **polar or** cartesian coordinates of voltage, depending on the 3rd argument.

```
[DSBUS_DVA, DSBUS_DVM] = DSBUS_DV(YBUS, V)
[DSBUS_DVA, DSBUS_DVM] = DSBUS_DV(YBUS, V, 0)
```

Returns two matrices containing partial derivatives of the **complex** bus power injections w.r.t voltage **angle and** voltage magnitude, respectively (**for all** buses).

```
[DSBUS_DVR, DSBUS_DVI] = DSBUS_DV(YBUS, V, 1)
```

Returns two matrices containing partial derivatives of the **complex** bus power injections w.r.t the **real and** imaginary parts of voltage, respectively (**for all** buses).

If YBUS is a **sparse** matrix, the **return** values will be also. The following explains the expressions used to form the matrices:

$$S = \text{diag}(V) * \text{conj}(I_{\text{bus}}) = \text{diag}(\text{conj}(I_{\text{bus}})) * V$$

Polar coordinates:

```
Partials of V & Ibus w.r.t. voltage magnitudes
dV/dVm = diag(V./abs(V))
dI/dVm = Ybus * dV/dVm = Ybus * diag(V./abs(V))
```

```
Partials of V & Ibus w.r.t. voltage angles
dV/dVa = j * diag(V)
```

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```

dI/dVa = Ybus * dV/dVa = Ybus * j * diag(V)

Partials of S w.r.t. voltage magnitudes
dS/dVm = diag(V) * conj(dI/dVm) + diag(conj(Ibus)) * dV/dVm
        = diag(V) * conj(Ybus * diag(V./abs(V)))
          + conj(diag(Ibus)) * diag(V./abs(V))

Partials of S w.r.t. voltage angles
dS/dVa = diag(V) * conj(dI/dVa) + diag(conj(Ibus)) * dV/dVa
        = diag(V) * conj(Ybus * j * diag(V))
          + conj(diag(Ibus)) * j * diag(V)
        = -j * diag(V) * conj(Ybus * diag(V))
          + conj(diag(Ibus)) * j * diag(V)
        = j * diag(V) * conj(diag(Ibus) - Ybus * diag(V))

Cartesian coordinates:
Partials of V & Ibus w.r.t. real part of complex voltage
dV/dVr = diag(ones(n,1))
dI/dVr = Ybus * dV/dVr = Ybus

Partials of V & Ibus w.r.t. imaginary part of complex voltage
dV/dVi = j * diag(ones(n,1))
dI/dVi = Ybus * dV/dVi = Ybus * j

Partials of S w.r.t. real part of complex voltage
dS/dVr = diag(V) * conj(dI/dVr) + diag(conj(Ibus)) * dV/dVr
        = diag(V) * conj(Ybus) + conj(diag(Ibus))

Partials of S w.r.t. imaginary part of complex voltage
dS/dVi = diag(V) * conj(dI/dVi) + diag(conj(Ibus)) * dV/dVi
        = j * (conj(diag(Ibus)) - diag(V) conj(Ybus))

Examples:
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[dSbus_dVa, dSbus_dVm] = dSbus_dV(Ybus, V);
[dSbus_dVr, dSbus_dVi] = dSbus_dV(Ybus, V, 1);

```

For more details on the derivations behind the derivative code used in MATPOWER information, see:

```

[TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and
their Derivatives using Complex Matrix Notation", MATPOWER
Technical Note 2, February 2010. [Online]. Available:
https://matpower.org/docs/TN2-OPF-Derivatives.pdf
doi: 10.5281/zenodo.3237866

[TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their
Derivatives using Complex Matrix Notation and Cartesian
Coordinate Voltages," MATPOWER Technical Note 4, April 2018.
[Online]. Available: https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.
->.pdf
doi: 10.5281/zenodo.3237909

```



**d2Ibr\_dV2****d2Ibr\_dV2**(*Ybr, V, mu, vcart*)*d2Ibr\_dV2*( ) (page 318) - Computes 2nd derivatives of complex branch current w.r.t. voltage.

The derivatives can be take with respect to **polar** or cartesian coordinates of voltage, depending on the **4th** argument.

```
[HAA, HAV, HVA, HVV] = D2IBR_DV2(YBR, V, MU)
[HAA, HAV, HVA, HVV] = D2IBR_DV2(YBR, V, MU, 0)
```

Returns **4** matrices containing the partial derivatives w.r.t. voltage **angle** and magnitude of the product of a vector MU with the **1st** partial derivatives of the **complex** branch currents.

```
[HRR, HRI, HIR, HII] = D2IBR_DV2(YBR, V, MU, 1)
```

Returns **4** matrices (**all zeros**) containing the partial derivatives w.r.t. **real** and imaginary part of **complex** voltage of the product of a vector MU with the **1st** partial derivatives of the **complex** branch currents.

Takes **sparse** branch admittance matrix YBR, voltage vector V and **nl x 1** vector of multipliers MU. Output matrices are **sparse**.

Examples:

```
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
Ybr = Yf;
[Haa, Hav, Hva, Hvv] = d2Ibr_dV2(Ybr, V, mu);
```

Here the output matrices correspond to:

```
Haa = d/dVa (dIbr_dVa.' * mu)
Hav = d/dVm (dIbr_dVa.' * mu)
Hva = d/dVa (dIbr_dVm.' * mu)
Hvv = d/dVm (dIbr_dVm.' * mu)
```

```
[Hrr, Hri, Hir, Hii] = d2Ibr_dV2(Ybr, V, mu, 1);
```

Here the output matrices correspond to:

```
Hrr = d/dVr (dIbr_dVr.' * mu)
Hri = d/dVi (dIbr_dVr.' * mu)
Hir = d/dVr (dIbr_dVi.' * mu)
Hii = d/dVi (dIbr_dVi.' * mu)
```

For more details on the derivations behind the derivative code used in MATPOWER information, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf> doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018.

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[Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## d2Sbr\_dV2

**d2Sbr\_dV2**(*Cbr, Ybr, V, mu, vcart*)

*d2Sbr\_dV2*( ) (page 319) - Computes 2nd derivatives of complex brch power flow w.r.t. voltage.

The derivatives can be take with respect to **polar or cartesian** coordinates of voltage, depending on the **5th** argument.

```
[HAA, HAV, HVA, HVV] = D2SBR_DV2(CBR, YBR, V, MU)
[HAA, HAV, HVA, HVV] = D2SBR_DV2(CBR, YBR, V, MU, 0)
```

Returns **4** matrices containing the partial derivatives w.r.t. voltage **angle and** magnitude of the product of a vector **MU** with the **1st** partial derivatives of the **complex branch power** flows.

```
[HRR, HRI, HIR, HII] = d2Sbr_dV2(CBR, YBR, V, MU, 1)
```

Returns **4** matrices containing the partial derivatives w.r.t. **real and** imaginary part of **complex** voltage of the product of a vector **MU** with the **1st** partial derivatives of the **complex branch power** flows.

Takes **sparse** connection matrix **CBR**, **sparse** branch admittance matrix **YBR**, voltage vector **V** and **nl x 1** vector of multipliers **MU**. Output matrices are **sparse**.

Examples:

```
f = branch(:, F_BUS);
Cf = sparse(1:nl, f, ones(nl, 1), nl, nb);
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
Cbr = Cf;
Ybr = Yf;
[Haa, Hav, Hva, Hvv] = d2Sbr_dV2(Cbr, Ybr, V, mu);
```

Here the output matrices correspond to:

```
Haa = d/dVa (dSbr_dVa.' * mu)
Hav = d/dVm (dSbr_dVa.' * mu)
Hva = d/dVa (dSbr_dVm.' * mu)
Hvv = d/dVm (dSbr_dVm.' * mu)
```

```
[Hrr, Hri, Hir, Hii] = d2Sbr_dV2(Cbr, Ybr, V, mu, 1);
```

Here the output matrices correspond to:

```
Hrr = d/dVr (dSbr_dVr.' * mu)
Hri = d/dVi (dSbr_dVr.' * mu)
Hir = d/dVr (dSbr_dVi.' * mu)
Hii = d/dVi (dSbr_dVi.' * mu)
```

For more details on the derivations behind the derivative code used in MATPOWER information, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## d2Abr\_dV2

**d2Abr\_dV2**(d2F\_dV2, dF\_dV1, dF\_dV2, F, V, mu)

*d2Abr\_dV2*( ) (page 320) - Computes 2nd derivatives of |branch flow|^2 w.r.t. V.

The derivatives can be take with respect to **polar** or cartesian coordinates of voltage, depending on the first 3 arguments. Flows could be **complex** current or **complex** or **real** power. Notation below is based on **complex** power.

```
[H11, H12, H21, H22] = D2ABR_DV2(D2F_DV2, DF_DV1, DF_DV2, F, V, MU)
```

Returns 4 matrices containing the partial derivatives w.r.t. voltage components (**angle**, **magnitude** or **real**, **imaginary**) of the product of a vector MU with the 1st partial derivatives of the square of the magnitude of branch flows.

Takes as inputs a handle to a **function** that evaluates the 2nd derivatives of the flows (with args V and mu only), **sparse** first derivative matrices of flow, flow vector, voltage vector V and nl x 1 vector of multipliers MU. Output matrices are **sparse**.

Example:

```
f = branch(:, F_BUS);
Cf = sparse(1:nl, f, ones(nl, 1), nl, nb);
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[dSf_dV1, dSf_dV2, dSt_dV1, dSt_dV2, Sf, St] = ...
    dSbr_dV(branch, Yf, Yt, V);
dF_dV1 = dSf_dV1;
dF_dV2 = dSf_dV2;
F = Sf;
d2F_dV2 = @(V, mu)d2Sbr_dV2(Cf, Yf, V, mu, 0);
[H11, H12, H21, H22] = ...
    d2Abr_dV2(d2F_dV2, dF_dV1, dF_dV2, F, V, mu);
```

Here the output matrices correspond to:

```
H11 = d/dV1 (dAF_dV1.' * mu)
H12 = d/dV2 (dAF_dV1.' * mu)
```

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```
H21 = d/dV1 (dAF_dV2.' * mu)
H22 = d/dV2 (dAF_dV2.' * mu)
```

See also *dAbr\_dV()* (page 313), *dIbr\_dV()* (page 310), *dSbr\_dV()* (page 311).

For more details on the derivations behind the derivative code used in MATPOWER information, see:

[TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)

## d2Imis\_dV2

**d2Imis\_dV2**(*Sbus, Ybus, V, lam, vcart*)

*d2Imis\_dV2()* (page 321) - Computes 2nd derivatives of current balance w.r.t. voltage.

The derivatives can be take with respect to **polar** or cartesian coordinates of voltage, depending on the 5th argument.

```
[GAA, GAV, GVA, GVV] = D2IMIS_DV2(SBUS, YBUS, V, LAM)
[GAA, GAV, GVA, GVV] = D2IMIS_DV2(SBUS, YBUS, V, LAM, 0)
```

Returns 4 matrices containing the partial derivatives w.r.t. voltage **angle** and magnitude of the product of a vector LAM with the 1st partial derivatives of the **complex** bus current **balance**.

```
[GRR, GIR, GRI, GII] = D2IMIS_DV2(SBUS, YBUS, V, LAM, 1)
```

Returns 4 matrices containing the partial derivatives w.r.t. **real** and imaginary parts of voltage of the product of a vector LAM with the 1st partial derivatives of the **complex** bus current **balance**.

Takes bus **complex power** injection (gen-load) vector, **sparse** bus admittance matrix YBUS, voltage vector V and nb x 1 vector of multipliers LAM. Output matrices are **sparse**.

Examples:

```
Sbus = makeSbus(baseMVA, bus, gen);
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[Gaa, Gav, Gva, Gvv] = d2Imis_dV2(Sbus, Ybus, V, lam);
```

Here the output matrices correspond to:

```
Gaa = d/dVa (dImis_dVa.' * lam)
Gav = d/dVm (dImis_dVa.' * lam)
Gva = d/dVa (dImis_dVm.' * lam)
Gvv = d/dVm (dImis_dVm.' * lam)
```

```
[Grr, Gri, Gir, Gii] = d2Imis_dV2(Sbus, Ybus, V, lam, 1);
```

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Here the output matrices correspond to:

```
Grr = d/dVr (dImis_dVr.' * lam)
Gri = d/dVi (dImis_dVr.' * lam)
Gir = d/dVr (dImis_dVi.' * lam)
Gii = d/dVi (dImis_dVi.' * lam)
```

For more details on the derivations behind the derivative code used in MATPOWER, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN3] B. Sereeter and R. D. Zimmerman, "Addendum to AC Power Flows and their Derivatives using Complex Matrix Notation: Nodal Current Balance," MATPOWER Technical Note 3, April 2018. [Online]. Available: <https://matpower.org/docs/TN3-More-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237900](https://doi.org/10.5281/zenodo.3237900)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## d2Imis\_dVdSg

**d2Imis\_dVdSg**(*Cg, V, lam, vcart*)

*d2Imis\_dVdSg*(*C*) (page 322) - Computes 2nd derivatives of current balance w.r.t. *V* and *Sg*.

The derivatives can be take with respect to polar or cartesian coordinates of voltage, depending on the 4th argument.

```
GSV = D2IMIS_DVDSG(CG, V, LAM)
GSV = D2IMIS_DVDSG(CG, V, LAM, 0)
```

Returns a matrix containing the partial derivatives w.r.t. voltage angle and magnitude of the product of a vector *LAM* with the 1st partial derivatives of the real and reactive power generation.

```
GSV = D2IMIS_DVDSG(CG, V, LAM, 1)
```

Returns a matrix containing the partial derivatives w.r.t. real and imaginary parts of voltage of the product of a vector *LAM* with the 1st partial derivatives of the real and reactive power generation.

Takes the generator connection matrix, complex voltage vector *V* and *nb* x 1 vector of multipliers *LAM*. Output matrices are sparse.

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**Examples:**

```
Cg = sparse(gen(:, GEN_BUS), 1:ng, -, nb, ng);
Gsv = d2Imis_dVdSg(Cg, V, lam);
```

Here the output matrix corresponds to:

```
Gsv = [ Gpa Gpv;
        Gqa Gqv ];
Gpa = d/dVa (dImis_dPg.' * lam)
Gpv = d/dVm (dImis_dPg.' * lam)
Gqa = d/dVa (dImis_dQg.' * lam)
Gqv = d/dVm (dImis_dQg.' * lam)
```

```
[Grr, Gri, Gir, Gii] = d2Imis_dVdSg(Cg, V, lam, 1);
```

Here the output matrices correspond to:

```
Gsv = [ Gpr Gpi;
        Gqr Gqi ];
Gpr = d/dVr (dImis_dPg.' * lam)
Gpi = d/dVi (dImis_dPg.' * lam)
Gqr = d/dVr (dImis_dQg.' * lam)
Gqi = d/dVi (dImis_dQg.' * lam)
```

For more details on the derivations behind the derivative code used in MATPOWER, see:

- [TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237866](https://doi.org/10.5281/zenodo.3237866)
- [TN3] B. Sereeter and R. D. Zimmerman, "Addendum to AC Power Flows and their Derivatives using Complex Matrix Notation: Nodal Current Balance," MATPOWER Technical Note 3, April 2018. [Online]. Available: <https://matpower.org/docs/TN3-More-OPF-Derivatives.pdf>  
doi: [10.5281/zenodo.3237900](https://doi.org/10.5281/zenodo.3237900)
- [TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian.pdf>  
doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

**d2Sbus\_dV2****d2Sbus\_dV2**(Ybus, V, lam, vcart)*d2Sbus\_dV2*( ) (page 324) - Computes 2nd derivatives of power injection w.r.t. voltage.

The derivatives can be take with respect to **polar** or cartesian coordinates of voltage, depending on the 4th argument.

```
[GAA, GAV, GVA, GVV] = D2SBUS_DV2(YBUS, V, LAM)
[GAA, GAV, GVA, GVV] = D2SBUS_DV2(YBUS, V, LAM, 0)
```

Returns 4 matrices containing the partial derivatives w.r.t. voltage **angle** and magnitude of the product of a vector LAM with the 1st partial derivatives of the **complex** bus **power** injections.

```
[GRR, GIR, GRI, GII] = D2SBUS_DV2(YBUS, V, LAM, 1)
```

Returns 4 matrices containing the partial derivatives w.r.t. **real** and imaginary parts of voltage of the product of a vector LAM with the 1st partial derivatives of the **complex** bus **power** injections.

Takes **sparse** bus admittance matrix YBUS, voltage vector V and nb x 1 vector of multipliers LAM. Output matrices are **sparse**.

Examples:

```
[Ybus, Yf, Yt] = makeYbus(baseMVA, bus, branch);
[Gaa, Gav, Gva, Gvv] = d2Sbus_dV2(Ybus, V, lam);
```

Here the output matrices correspond to:

```
Gaa = d/dVa (dSbus_dVa.' * lam)
Gav = d/dVm (dSbus_dVa.' * lam)
Gva = d/dVa (dSbus_dVm.' * lam)
Gvv = d/dVm (dSbus_dVm.' * lam)
```

```
[Grr, Gri, Gir, Gii] = d2Sbus_dV2(Ybus, V, lam, 1);
```

Here the output matrices correspond to:

```
Grr = d/dVr (dSbus_dVr.' * lam)
Gri = d/dVi (dSbus_dVr.' * lam)
Gir = d/dVr (dSbus_dVi.' * lam)
Gii = d/dVi (dSbus_dVi.' * lam)
```

For more details on the derivations behind the derivative code used in MATPOWER, see:

[TN2] R. D. Zimmerman, "AC Power Flows, Generalized OPF Costs and their Derivatives using Complex Matrix Notation", MATPOWER Technical Note 2, February 2010. [Online]. Available: <https://matpower.org/docs/TN2-OPF-Derivatives.pdf>  
doi: 10.5281/zenodo.3237866

[TN4] B. Sereeter and R. D. Zimmerman, "AC Power Flows and their Derivatives using Complex Matrix Notation and Cartesian Coordinate Voltages," MATPOWER Technical Note 4, April 2018. [Online]. Available: <https://matpower.org/docs/TN4-OPF-Derivatives-Cartesian>.

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[→pdf](#)doi: [10.5281/zenodo.3237909](https://doi.org/10.5281/zenodo.3237909)

## 5.2.10 LP, QP, MILP & MIQP Solver Functions

### miqps\_matpower

**miqps\_matpower**(varargin)*miqps\_matpower*() (page 325) - Deprecated, please use *miqps\_master*() instead.

### qps\_matpower

**qps\_matpower**(varargin)*qps\_matpower*() (page 325) - Deprecated, please use *qps\_master*() instead.

## 5.2.11 Matrix Building Functions

### makeB

**makeB**(baseMVA, bus, branch, alg)*makeB*() (page 325) - Builds the FDPF matrices, B prime and B double prime.

```
[BP, BPP] = MAKEB(MPC, ALG)
[BP, BPP] = MAKEB(BASEMVA, BUS, BRANCH, ALG)
```

Returns the two matrices B prime and B double prime used in the fast decoupled power flow. Does appropriate conversions to p.u. ALG is either 'FDXB' or 'FDBX', the corresponding value of MPOPT.pf.alg option specifying the power flow algorithm. Bus numbers must be consecutive beginning at 1 (i.e. internal ordering).

Note: For backward compatibility, ALG can also take on a value of 2 or 3, corresponding to values of the old PF\_ALG option. This usage is deprecated and will be removed in a future version.

Example:

```
[Bp, Bpp] = makeB(baseMVA, bus, branch, 'FDXB');
```

See also *fdpf*().



## makeBdc

**makeBdc**(baseMVA, bus, branch)

*makeBdc*() (page 326) - Builds the B matrices and phase shift injections for DC power flow.

```
[BBUS, BF, PBUSINJ, PFINJ] = MAKEBDC(MPC)
[BBUS, BF, PBUSINJ, PFINJ] = MAKEBDC(BASEMVA, BUS, BRANCH)
```

Returns the B matrices and phase shift injection vectors needed for a DC power flow. The bus real power injections are related to bus voltage angles by

$$P = \text{BBUS} * Va + \text{PBUSINJ}$$

The real power flows at the from end the lines are related to the bus voltage angles by

$$Pf = \text{BF} * Va + \text{PFINJ}$$

Does appropriate conversions to p.u.

Bus numbers must be consecutive beginning at 1 (i.e. internal ordering).

Example:

```
[Bbus, Bf, Pbusinj, Pfinj] = makeBdc(baseMVA, bus, branch);
```

See also *dcpf*().

## makeJac

**makeJac**(baseMVA, bus, branch, gen, fullJac)

*makeJac*() (page 326) - Forms the power flow Jacobian.

```
J = MAKEJAC(MPC)
J = MAKEJAC(MPC, FULLJAC)
J = MAKEJAC(BASEMVA, BUS, BRANCH, GEN)
J = MAKEJAC(BASEMVA, BUS, BRANCH, GEN, FULLJAC)
[J, YBUS, YF, YT] = MAKEJAC(MPC)
```

Returns the power flow Jacobian and, optionally, the system admittance matrices. Inputs can be a MATPOWER case struct or individual BASEMVA, BUS, BRANCH and GEN values. Bus numbers must be consecutive beginning at 1 (i.e. internal ordering). If the FULLJAC argument is present and true, it returns the full Jacobian (sensitivities of all bus injections w.r.t all voltage angles/magnitudes) as opposed to the reduced version used in the Newton power flow updates. The units for all quantities are in per unit with radians for voltage angles.

Note: This function builds the Jacobian from scratch, rebuilding the YBUS matrix in the process. You probably don't want to use this in performance critical code.

See also *makeYbus*() (page 329), *ext2int*().

## makeLODF

**makeLODF**(*branch*, *PTDF*, *mask\_bridge*)

*makeLODF*() (page 327) - Builds the line outage distribution factor matrix.

```

LODF = MAKELODF(BRANCH, PTDF)
LODF = MAKELODF(MPC, PTDF)
LODF = MAKELODF(MPC, PTDF, MASK_BRIDGE)

```

Returns the DC model **line** outage distribution **factor** matrix corresponding to a given PTDF matrix. The LODF matrix is *nbr* x *nbr*, where *nbr* is the number of branches. If the optional MASK\_BRIDGE argument is **true**, **columns** corresponding to bridge branches (those whose removal result in islanding) are replaced with **NaN**.

Example:

```

H = makePTDF(mpc);
LODF = makeLODF(branch, H);
LODF = makeLODF(mpc, H);

% mask bridge branches in LODF
makeLODF(mpc, H, 1);

```

See also *makePTDF*() (page 327), *find\_bridges*() (page 335).

## makePTDF

**makePTDF**(*baseMVA*, *bus*, *branch*, *slack*, *bus\_idx*)

*makeLODF*() (page 327) - Builds the DC PTDF matrix for a given choice of slack.

```

H = MAKEPTDF(MPC)
H = MAKEPTDF(MPC, SLACK)
H = MAKEPTDF(MPC, SLACK, TXFR)
H = MAKEPTDF(MPC, SLACK, BUS_IDX)
H = MAKEPTDF(BASEMVA, BUS, BRANCH)
H = MAKEPTDF(BASEMVA, BUS, BRANCH, SLACK)
H = MAKEPTDF(BASEMVA, BUS, BRANCH, SLACK, TXFR)
H = MAKEPTDF(BASEMVA, BUS, BRANCH, SLACK, BUS_IDX)

```

Returns the DC PTDF matrix **for** a given choice of slack. The matrix is *nbr* x *nb*, where *nbr* is the number of branches **and** *nb* is the number of buses. The SLACK can be a scalar (**single** slack bus) **or** an *nb* x **1** column vector of weights specifying the proportion of the slack taken up at each bus. If the SLACK is **not** specified the reference bus is used by default. Bus numbers must be consecutive beginning at **1** (i.e. internal ordering).

For convenience, SLACK can also be an *nb* x *nb* matrix, where each column specifies how the slack should be handled **for** injections at that bus. This option only applies when computing the **full** PTDF matrix (i.e. when TXFR **and** BUS\_IDX are **not** provided.)

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If TXFR is supplied it must be a matrix (or vector) with nb rows whose columns each sum to zero, where each column defines a specific (slack independent) transfer. E.g. if k-th transfer is from bus i to bus j, TXFR(i, k) = 1 and TXFR(j, k) = -1. In this case H has the same number of columns as TXFR.

If BUS\_IDX is supplied, it contains a column vector of bus indices. The columns of H correspond to these indices, but they are computed individually rather than computing the full PTDF matrix and selecting the desired columns.

Examples:

```
H = makePTDF(mpc);
H = makePTDF(baseMVA, bus, branch, 1);
slack = rand(size(bus, 1), 1);
H = makePTDF(mpc, slack);

% for transfer from bus i to bus j
txfr = zeros(nb, 1); txfr(i) = 1; txfr(j) = -1;
H = makePTDF(mpc, slack, txfr);

% for buses i and j only
H = makePTDF(mpc, slack, [i;j]);
```

See also `makeLODF()` (page 327).

## makeSbus

`makeSbus(baseMVA, bus, gen, mpopt, Vm, Sg)`

`makeSbus()` (page 328) - Builds the vector of complex bus power injections.

```
SBUS = MAKESBUS(BASEMVA, BUS, GEN)
SBUS = MAKESBUS(BASEMVA, BUS, GEN, MPOPT, VM)
SBUS = MAKESBUS(BASEMVA, BUS, GEN, MPOPT, VM, SG)
```

returns the vector of complex bus power injections, that is, generation minus load. Power is expressed in per unit. If the MPOPT and VM arguments are present it evaluates any ZIP loads based on the provided voltage magnitude vector. If VM is empty, it assumes nominal voltage. If SG is provided, it is a complex  $n_g \times 1$  vector of generator power injections in p.u., and overrides the PG and QG columns in GEN, using GEN only for connectivity information.

```
[SBUS, DSBUS_DVM] = MAKESBUS(BASEMVA, BUS, GEN, MPOPT, VM)
```

With two output arguments, it computes the partial derivative of the bus injections with respect to voltage magnitude, leaving the first return value SBUS empty. If VM is empty, it assumes no voltage dependence and returns a sparse zero matrix.

See also `makeYbus()` (page 329).

## makeSdzip

**makeSdzip**(*baseMVA*, *bus*, *mpopt*)

*makeSdzip*() (page 329) - Builds vectors of nominal complex bus power demands for ZIP loads.

SD = MAKESDZIP(BASEMVA, BUS, MPOPT) returns a **struct** with three fields, each an nb x 1 vectors. The fields 'z', 'i' and 'p' correspond to the nominal p.u. **complex power** (at 1 p.u. voltage magnitude) of the constant impedance, constant current, and constant **power** portions, respectively of the ZIP load model.

Example:

```
Sd = makeSdzip(baseMVA, bus, mpopt);
```

## makeYbus

**makeYbus**(*baseMVA*, *bus*, *branch*)

*makeYbus*() (page 329) - Builds the bus admittance matrix and branch admittance matrices.

```
[YBUS, YF, YT] = MAKEYBUS(MPC)
[YBUS, YF, YT] = MAKEYBUS(BASEMVA, BUS, BRANCH)
```

Returns the **full** bus admittance matrix (i.e. **for all** buses) and the matrices YF and YT which, when multiplied by a **complex** voltage vector, yield the vector currents injected into each **line** from the "from" and "to" buses respectively of each **line**. Does appropriate conversions to p.u. Inputs can be a MATPOWER **case struct** or individual BASEMVA, BUS and BRANCH values. Bus numbers must be consecutive beginning at 1 (i.e. internal ordering).

See also *makeJac*() (page 326), *makeSbus*() (page 328), *ext2int*() .

## 5.2.12 Utility Functions

### apply\_changes

**apply\_changes**(*label*, *mpc*, *chgtab*)

*apply\_changes*() (page 329) - Applies a set of changes to a MATPOWER case

```
mpc_modified = apply_changes(label, mpc_original, chgtab)
```

Applies the **set** of changes identified by LABEL to the **case** in MPC, where the change sets are specified in CHGTAB.

LABEL is an integer which identifies the **set** of changes of interest

MPC is a MATPOWER **case struct** with at least fields bus, gen and branch

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## calc\_branch\_angle

### calc\_branch\_angle(*mpc*)

*calc\_branch\_angle()* (page 331) - Calculate branch angle differences across active branches

```
DELTA = CALC_BRANCH_ANGLE(MPC)
```

Calculates the **angle** difference (in degrees) across **all** active branches in the MATPOWER **case**. Angles are calculated as the difference between the FROM bus **and** the TO bus.

Input:

MPC - MATPOWER **case struct** (can have external bus numbering)

Output:

DELTA - n1 x 1 vector of branch **angle** differences  $A_f - A_t$ , where  $A_f$  **and**  $A_t$  are vectors of voltage angles at "from" **and** "to" ends of each **line** respectively. DELTA is 0 **for** out-of-service branches.

See also *toggle\_softlims()* (page 308).

## case\_info

### case\_info(*mpc*, *fd*)

*case\_info()* (page 331) - Prints information about islands in a network.

```
CASE_INFO(MPC)
CASE_INFO(MPC, FD)
[GROUPS, ISOLATED] = CASE_INFO(...)
```

Prints out detailed information about a MATPOWER **case**. Optionally prints to an open file, whose file identifier, as returned by FOPEN, is specified in the optional second parameter FD. Optional **return** arguments include GROUPS **and** ISOLATED buses, as returned by FIND\_ISLANDS.

## compare\_case

### compare\_case(*mpc1*, *mpc2*)

*compare\_case()* (page 331) - Compares the bus, gen, branch matrices of 2 MATPOWER cases.

```
COMPARE_CASE(MPC1, MPC2)
```

Compares the bus, branch **and** gen matrices of two MATPOWER cases **and** prints a summary of the differences. For each column of the matrix it prints the maximum of **any** non-zero differences.

**define\_constants****define\_constants()**

define\_constants - Defines useful constants for indexing data, etc.

This is simply a convenience script that defines the constants listed below, consisting primarily of named indices **for** the **columns** of the data matrices: bus, branch, gen **and** gencost. This includes **input columns** defined in caseformat as well as **columns** that are added in the **power** flow **and** OPF output. It also defines constants **for** the change tables used by apply\_changes().

bus:

PQ, PV, REF, NONE, BUS\_I, BUS\_TYPE, PD, QD, GS, BS, BUS\_AREA, VM, VA, BASE\_KV, ZONE, VMAX, VMIN, LAM\_P, LAM\_Q, MU\_VMAX, MU\_VMIN

branch:

F\_BUS, T\_BUS, BR\_R, BR\_X, BR\_B, RATE\_A, RATE\_B, RATE\_C, TAP, SHIFT, BR\_STATUS, PF, QF, PT, QT, MU\_SF, MU\_ST, ANGMIN, ANGMAX, MU\_ANGMIN, MU\_ANGMAX

gen:

GEN\_BUS, PG, QG, QMAX, QMIN, VG, MBASE, GEN\_STATUS, PMAX, PMIN, MU\_PMAX, MU\_PMIN, MU\_QMAX, MU\_QMIN, PC1, PC2, QC1MIN, QC1MAX, QC2MIN, QC2MAX, RAMP\_AGC, RAMP\_10, RAMP\_30, RAMP\_Q, APF

gencost:

PW\_LINEAR, POLYNOMIAL, MODEL, STARTUP, SHUTDOWN, NCOST, COST

change tables:

CT\_LABEL, CT\_PROB, CT\_TABLE, CT\_TBUS, CT\_TGEN, CT\_TBRCH, CT\_TAREABUS, CT\_TAREAGEN, CT\_TAREABRCH, CT\_ROW, CT\_COL, CT\_CHGTYPE, CT\_REP, CT\_REL, CT\_ADD, CT\_NEWVAL, CT\_TLOAD, CT\_TAREALOAD, CT\_LOAD\_ALL\_PQ, CT\_LOAD\_FIX\_PQ, CT\_LOAD\_DIS\_PQ, CT\_LOAD\_ALL\_P, CT\_LOAD\_FIX\_P, CT\_LOAD\_DIS\_P, CT\_TGENCOST, CT\_TAREAGENCOST, CT\_MODCOST\_F, CT\_MODCOST\_X

See CASEFORMAT, IDX\_BUS, IDX\_BRCH, IDX\_GEN, IDX\_COST **and** IDX\_CT **for** details on the meaning of these constants. Internally DEFINE\_CONSTANTS calls IDX\_BUS, IDX\_BRCH, IDX\_GEN, IDX\_COST **and** IDX\_CT. In performance sensitive code, such as internal MATPOWER **functions** that are called frequently, it is preferred to call these **functions** directly rather than using the DEFINE\_CONSTANTS script, which is less efficient.

This script is included **for** convenience **for** interactive use **or** **for** high-level code where maximum performance is **not** a concern.

**extract\_islands****extract\_islands**(*mpc, varargin*)*extract\_islands*() (page 333) - Extracts each island in a network with islands.

```

MPC_ARRAY = EXTRACT_ISLANDS(MPC)
MPC_ARRAY = EXTRACT_ISLANDS(MPC, GROUPS)
MPC_K = EXTRACT_ISLANDS(MPC, K)
MPC_K = EXTRACT_ISLANDS(MPC, GROUPS, K)
MPC_K = EXTRACT_ISLANDS(MPC, K, CUSTOM)
MPC_K = EXTRACT_ISLANDS(MPC, GROUPS, K, CUSTOM)

```

Returns a **cell** array of MATPOWER **case** structs **for** each island in the **input case struct**. If the optional second argument is a **cell** array GROUPS it is assumed to be a **cell** array of vectors of bus indices **for** each island (as returned by FIND\_ISLANDS). Providing the GROUPS avoids the need **for** another traversal of the network connectivity **and** can save a significant amount of **time** on very large systems. If an additional argument K is included, it indicates which island(s) to **return** and the **return** value is a **single case struct**, rather than a **cell** array. If K is a scalar **or** vector, it specifies the **index**(indices) of the island(s) to include in the resulting **case** file. K can also be the string **'all'** which will include **all** islands. This is the same as simply eliminating **all** isolated buses.

A final optional argument CUSTOM is a **struct** that can be used to indicate custom fields of MPC from which to extract data corresponding to buses generators, branches **or** DC lines. It has the following structure:

```
CUSTOM.<ORDERING>{DIM} = FIELDS
```

<ORDERING> is either **'bus'**, **'gen'**, **'branch'** **or** **'dcline'** and indicates that dimension DIM of FIELDS has dimensions corresponding to this <ORDERING> **and** should have the appropriate dimension extracted as well. FIELDS is a **cell** array, where each element is either a **single** string (field name of MPC) **or** a **cell** array of strings (nested fields of MPC).

Examples:

Extract each island into it's own **case struct**:

```
mpc_list = extract_islands(mpc);
```

Extract the 2nd (that is, 2nd largest) island:

```
mpc2 = extract_islands(mpc, 2);
```

Extract the first **and** 3rd islands without a re-traversals of the network:

```
groups = find_islands(mpc);
mpc1 = extract_islands(mpc, groups, 1);
mpc3 = extract_islands(mpc, groups, 3);
```

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Extract the 2nd island, including custom fields, where `mpc.bus_label{b}` contains a label for bus `b`, and `mpc.gen_name{g}`, `mpc.emissions.rate(g, :)`, and `mpc.genloc(:, g)` contain, respectively, the generator's name, emission rates and location coordinates:

```
custom.bus{1} = {'bus_label'};
custom.gen{1} = {'gen_name', {'emissions', 'rate'}};
custom.gen{2} = {'genloc'};
mpc = extract_islands(mpc, 1, custom);
```

Note: Fields `bus_name`, `gentype` and `genfuel` are handled automatically and do not need to be included in `custom`.

See also `find_islands()` (page 335), `case_info()` (page 331), `connected_components()` (page 355).

## feval\_w\_path

**feval\_w\_path**(*fpath*, *fname*, *varargin*)

`feval_w_path()` (page 334) - Calls a function located by the specified path.

```
FEVAL_W_PATH(FPATH, F, x1, ..., xn)
[y1, ..., yn] = FEVAL_W_PATH(FPATH, F, x1, ..., xn)
```

Identical to the built-in `FEVAL`, except that the **function** `F` need not be in the MATLAB/Octave **path** if it is defined in a file in the **path** specified by `FPATH`. Assumes that the current working directory is always first in the MATLAB/Octave **path**.

Inputs:

`FPATH` - string containing the **path** to the **function** to be called, can be absolute or relative to current working directory  
`F` - string containing the name of the **function** to be called  
`x1, ..., xn` - variable number of **input** arguments to be passed to `F`

Output:

`y1, ..., yn` - variable number arguments returned by `F` (depending on the caller)

Note that **any** sub-**functions** located in the directory specified by `FPATH` will also be available to be called by the `F` **function**.

Examples:

```
% Assume '/opt/testfunctions' is NOT in the MATLAB/Octave path, but
% /opt/testfunctions/mytestfcn.m defines the function mytestfcn()
% which takes 2 input arguments and outputs 1 return argument.
y = feval_w_path('/opt/testfunctions', 'mytestfcn', x1, x2);
```

## find\_bridges

### find\_bridges(*mpc*)

*find\_bridges()* (page 335) - Finds bridges in a network.

```
[ISLANDS, BRIDGES, NONBRIDGES] = FIND_BRIDGES(MPC)
```

Returns the islands, bridges **and** non-bridges in a network. Bridges are filtered out using Tarjan's algorithm. A BRIDGE is a branch whose removal breaks the island to multiple parts. The **return** value BRIDGES is a **cell** array of vectors of the bus indices **for** each island.

## find\_islands

### find\_islands(*mpc*)

*find\_islands()* (page 335) - Finds islands in a network.

```
GROUPS = FIND_ISLANDS(MPC)
[GROUPS, ISOLATED] = FIND_ISLANDS(MPC)
```

Returns the islands in a network. The **return** value GROUPS is a **cell** array of vectors of the bus indices **for** each island. The second **and** optional **return** value ISOLATED is a vector of indices of isolated buses that have no connecting branches.

See also *extract\_islands()* (page 333), *connected\_components()* (page 355).

## genfuels

### genfuels()

genfuels() - Return list of standard values for generator fuel types.

```
GF = GENFUELS()
```

Returns a **cell** array of strings containing the following standard generator fuel types **for** use in the optional MPC.GENFUEL field of the MATPOWER **case struct**. This is to be considered an unordered list, where the position of a particular fuel **type** in the list is **not** defined **and** is therefore subject to change.

biomass	- Biomass
coal	- Coal
dfo	- Distillate Fuel Oil (Diesel, F01, F02, F04)
geothermal	- Geothermal
hydro	- Hydro
hydrops	- Hydro Pumped Storage
jetfuel	- Jet Fuel
lng	- Liquefied Natural Gas

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ng	- Natural Gas
nuclear	- Nuclear
oil	- Unspecified Oil
refuse	- Refuse, Municipal Solid Waste
rfo	- Residual Fuel Oil (F05, F06)
solar	- Solar
syncgen	- Synchronous Condensor
wasteheat	- Waste Heat
wind	- Wind
wood	- Wood or Wood Waste
other	- Other
unknown	- Unknown
dl	- Dispatchable Load
ess	- Energy Storage System

Example:

```

if ~ismember(mpc.genfuel{k}, genfuels())
    error('unknown fuel type');
end

```

See also `gentypes()`, `savecase()`.

## gentypes

### gentypes()

`gentypes()` - Return list of standard values for generator unit types.

GT = GENTYPES()

Returns a `cell` array of strings containing the following standard two character generator unit types `for` use in the optional `MPC.GENTYPE` field of the MATPOWER `case struct`. This is to be considered an unordered list, where the position of a particular fuel `type` in the list is `not` defined `and` is therefore subject to change.

From Form EIA-860 Instructions, Table 2. Prime Mover Codes `and` Descriptions  
[https://www.eia.gov/survey/form/eia\\_860/instructions.pdf](https://www.eia.gov/survey/form/eia_860/instructions.pdf)

BA	- Energy Storage, Battery
CE	- Energy Storage, Compressed Air
CP	- Energy Storage, Concentrated Solar Power
FW	- Energy Storage, Flywheel
PS	- Hydraulic Turbine, Reversible (pumped storage)
ES	- Energy Storage, Other
ST	- Steam Turbine, including nuclear, geothermal <code>and</code> solar steam (does <code>not</code> include combined cycle)
GT	- Combustion (Gas) Turbine (includes <code>jet</code> engine design)
IC	- Internal Combustion Engine (diesel, piston, reciprocating)
CA	- Combined Cycle Steam Part
CT	- Combined Cycle Combustion Turbine Part ( <code>type</code> of coal <code>or</code> solid must be reported as energy <code>source</code> )

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	<b>for</b> integrated coal gasification)
CS	- Combined Cycle Single Shaft (combustion turbine <b>and</b> steam turbine share a <b>single</b> generator)
CC	- Combined Cycle Total Unit (use only <b>for</b> plants/generators that are in planning stage, <b>for</b> which specific generator details cannot be provided)
HA	- Hydrokinetic, Axial Flow Turbine
HB	- Hydrokinetic, Wave Buoy
HK	- Hydrokinetic, Other
HY	- Hydroelectric Turbine (includes turbines associated with delivery of water by pipeline)
BT	- Turbines Used in a Binary Cycle (including those used <b>for</b> geothermal applications)
PV	- Photovoltaic
WT	- Wind Turbine, Onshore
WS	- Wind Turbine, Offshore
FC	- Fuel Cell
OT	- Other
Additional codes (some from PowerWorld)	
UN	- Unknown
JE	- Jet Engine
NB	- ST - Boiling Water Nuclear Reactor
NG	- ST - Graphite Nuclear Reactor
NH	- ST - High Temperature Gas Nuclear Reactor
NP	- ST - Pressurized Water Nuclear Reactor
IT	- Internal Combustion Turbo Charged
SC	- Synchronous Condenser
DC	- represents DC ties
MP	- Motor/Pump
W1	- Wind Turbine, Type 1
W2	- Wind Turbine, Type 2
W3	- Wind Turbine, Type 3
W4	- Wind Turbine, Type 4
SV	- Static Var Compensator
DL	- Dispatchable Load
Example:	
	<b>if</b> <code>~ismember(mpc.gentype{k}, gentypes())</code>
	<code>error('unknown generator unit type');</code>
	<b>end</b>

See also `genfuels()`, `savecase()`.

**get\_losses****get\_losses**(*baseMVA, bus, branch*)*get\_losses()* (page 338) - Returns series losses (and reactive injections) per branch.

```

LOSS = GET_LOSSES(RESULTS)
LOSS = GET_LOSSES(BASEMVA, BUS, BRANCH)

[LOSS, CHG] = GET_LOSSES(RESULTS)
[LOSS, FCHG, TCHG] = GET_LOSSES(RESULTS)
[LOSS, FCHG, TCHG, DLOSS_DV] = GET_LOSSES(RESULTS)
[LOSS, FCHG, TCHG, DLOSS_DV, DCHG_DVM] = GET_LOSSES(RESULTS)

```

Computes branch series losses, **and** optionally reactive injections from **line** charging, as **functions** of bus voltages **and** branch parameters, using the following formulae:

$$\begin{aligned} \text{loss} &= \text{abs}(V_f / \tau - V_t)^2 / (R_s - j X_s) \\ \text{fchg} &= \text{abs}(V_f / \tau)^2 * B_c / 2 \\ \text{tchg} &= \text{abs}(V_t)^2 * B_c / 2 \end{aligned}$$

Optionally, computes the partial derivatives of the **line** losses with respect to voltage angles **and** magnitudes.

**Input:**

RESULTS - a MATPOWER **case struct** with bus voltages corresponding to a valid **power** flow solution.  
(Can optionally be specified as individual fields BASEMVA, BUS, **and** BRANCH.)

**Output(s):**

LOSS - **complex** NL x 1 vector of losses (in MW), where NL is the number of branches in the **system**, representing only the losses in the series impedance element of the PI model **for** each branch.

CHG - NL x 1 vector of total reactive injection **for** each **line** (in MVAR), representing the **line** charging injections of both of the shunt elements of PI model **for** each branch.

FCHG - Same as CHG, but **for** the element at the "from" **end** of the branch only.

TCHG - Same as CHG, but **for** the element at the "to" **end** of the branch.

DLOSS\_DV - Struct with partial derivatives of LOSS with respect to bus voltages, with fields:

- .a - Partial with respect to bus voltage angles.
- .m - Partial with respect to bus voltage magnitudes.

DCHG\_DVM - Struct with partial derivatives of FCHG **and** TCHG with respect to bus voltage magnitudes, with fields:

- .f - Partial of FCHG with respect to bus voltage magnitudes.
- .t - Partial of TCHG with respect to bus voltage magnitudes.

**Example:**

```

results = runpf(myCase);
[loss, chg] = get_losses(results);
total_system_real_losses = sum(real(loss));

```

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```
total_system_reac_losses = sum(imag(loss)) - sum(chg);

[loss, fchg, tchg, dloss_dV] = get_losses(results);
```

## hasPQcap

### hasPQcap(*gen, hilo*)

*hasPQcap()* (page 339) - Checks for P-Q capability curve constraints.

TORF = HASPQCAP(GEN, HILO) returns a column vector of 1's and 0's. The 1's correspond to rows of the GEN matrix which correspond to generators which have defined a capability curve (with sloped upper and/or lower bound on Q) and require that additional linear constraints be added to the OPF.

The GEN matrix in version 2 of the MATPOWER case format includes columns for specifying a P-Q capability curve for a generator defined as the intersection of two half-planes and the box constraints on P and Q. The two half planes are defined respectively as the area below the line connecting (Pc1, Qc1max) and (Pc2, Qc2max) and the area above the line connecting (Pc1, Qc1min) and (Pc2, Qc2min).

If the optional 2nd argument is 'U' this function returns true only for rows corresponding to generators that require the upper constraint on Q. If it is 'L', only for those requiring the lower constraint. If the 2nd argument is not specified or has any other value it returns true for rows corresponding to gens that require either or both of the constraints.

It is smart enough to return true only if the corresponding linear constraint is not redundant w.r.t the box constraints.

## idx\_brch

### idx\_brch()

*idx\_brch()* (page 339) - Defines constants for named column indices to branch matrix.

Example:

```
[F_BUS, T_BUS, BR_R, BR_X, BR_B, RATE_A, RATE_B, RATE_C, ...
TAP, SHIFT, BR_STATUS, PF, QF, PT, QT, MU_SF, MU_ST, ...
ANGMIN, ANGMAX, MU_ANGMIN, MU_ANGMAX] = idx_brch;
```

Some examples of usage, after defining the constants using the line above, are:

```
branch(4, BR_STATUS) = 0;           % take branch 4 out of service
Ploss = branch(:, PF) + branch(:, PT); % compute real power loss vector
```

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The `index`, name and meaning of each column of the branch matrix is given below:

columns 1-11 must be included in `input` matrix (in `case` file)

1	F_BUS	f, from bus number
2	T_BUS	t, to bus number
3	BR_R	r, resistance (p.u.)
4	BR_X	x, reactance (p.u.)
5	BR_B	b, total line charging susceptance (p.u.)
6	RATE_A	rateA, MVA rating A (long term rating)
7	RATE_B	rateB, MVA rating B (short term rating)
8	RATE_C	rateC, MVA rating C (emergency rating)
9	TAP	ratio, transformer off nominal turns ratio
10	SHIFT	angle, transformer phase shift angle (degrees)
11	BR_STATUS	initial branch status, 1 - in service, 0 - out of service
12	ANGMIN	minimum angle difference, $\text{angle}(V_f) - \text{angle}(V_t)$ (degrees)
13	ANGMAX	maximum angle difference, $\text{angle}(V_f) - \text{angle}(V_t)$ (degrees) (The voltage angle difference is taken to be unbounded below if $\text{ANGMIN} < -360$ and unbounded above if $\text{ANGMAX} > 360$ . If both parameters are zero, it is unconstrained.)

columns 14-17 are added to matrix after power flow or OPF solution  
they are typically not present in the `input` matrix

14	PF	real power injected into "from" end of branch (MW)
15	QF	reactive power injected into "from" end of branch (MVar)
16	PT	real power injected into "to" end of branch (MW)
17	QT	reactive power injected into "to" end of branch (MVar)

columns 18-21 are added to matrix after OPF solution

they are typically not present in the `input` matrix

		(assume OPF objective function has units, u)
18	MU_SF	Kuhn-Tucker multiplier on MVA limit at "from" bus (u/MVA)
19	MU_ST	Kuhn-Tucker multiplier on MVA limit at "to" bus (u/MVA)
20	MU_ANGMIN	Kuhn-Tucker multiplier lower angle difference limit (u/degree)
21	MU_ANGMAX	Kuhn-Tucker multiplier upper angle difference limit (u/degree)

See also `define_constants`.

## idx\_bus

### idx\_bus()

`idx_bus()` (page 340) - Defines constants for named column indices to bus matrix.

Example:

```
[PQ, PV, REF, NONE, BUS_I, BUS_TYPE, PD, QD, GS, BS, BUS_AREA, VM, ...
VA, BASE_KV, ZONE, VMAX, VMIN, LAM_P, LAM_Q, MU_VMAX, MU_VMIN] = idx_bus;
```

Some examples of usage, after defining the constants using the line above, are:

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```
Pd = bus(4, PD);      % get the real power demand at bus 4
bus(:, VMIN) = 0.95; % set the min voltage magnitude to 0.95 at all buses
```

The **index**, **name** and **meaning** of each column of the bus matrix is given below:

**columns 1-13** must be included in **input** matrix (in **case** file)

1	BUS_I	bus number (positive integer)
2	BUS_TYPE	bus type (1 = PQ, 2 = PV, 3 = ref, 4 = isolated)
3	PD	Pd, real power demand (MW)
4	QD	Qd, reactive power demand (MVAR)
5	GS	Gs, shunt conductance (MW demanded at V = 1.0 p.u.)
6	BS	Bs, shunt susceptance (MVar injected at V = 1.0 p.u.)
7	BUS_AREA	area number, (positive integer)
8	VM	Vm, voltage magnitude (p.u.)
9	VA	Va, voltage angle (degrees)
10	BASE_KV	baseKV, base voltage (kV)
11	ZONE	zone, loss zone (positive integer)
12	VMAX	maxVm, maximum voltage magnitude (p.u.)
13	VMIN	minVm, minimum voltage magnitude (p.u.)

**columns 14-17** are added to matrix after OPF solution

they are typically **not** present in the **input** matrix

		(assume OPF objective <b>function</b> has units, u)
14	LAM_P	Lagrange multiplier on real power mismatch (u/MW)
15	LAM_Q	Lagrange multiplier on reactive power mismatch (u/MVAR)
16	MU_VMAX	Kuhn-Tucker multiplier on upper voltage limit (u/p.u.)
17	MU_VMIN	Kuhn-Tucker multiplier on lower voltage limit (u/p.u.)

additional constants, used to assign/compare values in the BUS\_TYPE column

1	PQ	PQ bus
2	PV	PV bus
3	REF	reference bus
4	NONE	isolated bus

See also `define_constants`.

## idx\_cost

### idx\_cost()

`idx_cost()` (page 341) - Defines constants for named column indices to `gencost` matrix.

Example:

```
[PW_LINEAR, POLYNOMIAL, MODEL, STARTUP, SHUTDOWN, NCOST, COST] = idx_cost;
```

Some examples of **usage**, after defining the constants using the **line** above, are:

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```

start = gencost(4, STARTUP);           % get startup cost of generator 4
gencost(2, [MODEL, NCOST:COST+1]) = [ POLYNOMIAL 2 30 0 ];
% set the cost of generator 2 to a linear function COST = 30 * Pg

```

The **index**, **name** and **meaning** of each column of the gencost matrix is given below:

#### columns 1-5

1	MODEL	cost model, 1 = piecewise linear, 2 = polynomial
2	STARTUP	startup cost in US dollars
3	SHUTDOWN	shutdown cost in US dollars
4	NCOST	number $N = n+1$ of data points to follow defining an $n$ -segment piecewise linear cost <b>function</b> , or of cost coefficients defining an $n$ -th order polynomial cost <b>function</b>
5	COST	parameters defining total cost <b>function</b> $f(p)$ begin in this column (MODEL = 1) : $p_1, f_1, p_2, f_2, \dots, p_N, f_N$ where $p_1 < p_2 < \dots < p_N$ and the cost $f(p)$ is defined by the coordinates $(p_1, f_1), (p_2, f_2), \dots, (p_N, f_N)$ of the <b>end/break</b> -points of the piecewise linear cost fcn (MODEL = 2) : $c_n, \dots, c_1, c_0$ $N$ coefficients of an $n$ -th order polynomial cost <b>function</b> , starting with highest order, where cost is $f(p) = c_n * p^n + \dots + c_1 * p + c_0$

additional constants, used to assign/compare values in the MODEL column

1	PW_LINEAR	piecewise linear generator cost model
2	POLYNOMIAL	polynomial generator cost model

See also define\_constants.

## idx\_ct

### idx\_ct()

*idx\_ct()* (page 342) - Defines constants for named column indices to changes table

```

[CT_LABEL, CT_PROB, CT_TABLE, CT_TBUS, CT_TGEN, CT_TBRCH, CT_TAREABUS, ...
CT_TAREAGEN, CT_TAREABRCH, CT_ROW, CT_COL, CT_CHGTYPE, CT_REP, ...
CT_REL, CT_ADD, CT_NEWVAL, CT_TLOAD, CT_TAREALOAD, CT_LOAD_ALL_PQ, ...
CT_LOAD_FIX_PQ, CT_LOAD_DIS_PQ, CT_LOAD_ALL_P, CT_LOAD_FIX_P, ...
CT_LOAD_DIS_P, CT_TGENCOST, CT_TAREAGENCOST, CT_MODCOST_F, ...
CT_MODCOST_X] = idx_ct;

```

CT\_LABEL: column of changes **table** where the change **set** label is stored

CT\_PROB: column of changes **table** where the probability of the change **set** is stored

CT\_TABLE: column of the changes **table** where the **type** of **system** data **table** to be modified is stored;

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```

type CT_TBUS indicates bus table
type CT_TGEN indicates gen table
type CT_TBRCH indicates branch table
type CT_TLOAD indicates a load modification (bus and/or gen tables)
type CT_TAREABUS indicates area-wide change in bus table
type CT_TAREAGEN indicates area-wide change in generator table
type CT_TAREABRCH indicates area-wide change in branch table
type CT_TAREALOAD indicates area-wide change in load
                    (bus and/or gen tables)

```

CT\_ROW: column of changes table where the row number in the data table to be modified is stored. A value of "0" in this column has the special meaning "apply to all rows". For an area-wide type of change, the area number is stored here instead.

CT\_COL: column of changes table where the number of the column in the data table to be modified is stored  
 For CT\_TLOAD and CT\_TAREALOAD, the value entered in this column is one of the following codes (or its negative), rather than a column index:

```

type CT_LOAD_ALL_PQ modify all loads, real & reactive
type CT_LOAD_FIX_PQ modify only fixed loads, real & reactive
type CT_LOAD_DIS_PQ modify only dispatchable loads, real & reactive
type CT_LOAD_ALL_P modify all loads, real only
type CT_LOAD_FIX_P modify only fixed loads, real only
type CT_LOAD_DIS_P modify only dispatchable loads, real only

```

If the negative of one of these codes is used, then any affected dispatchable loads will have their costs scaled as well.  
 For CT\_TGENCOST and CT\_TAREAGENCOST, in addition to an actual column index, this value can also take one of the following codes to indicate a scaling (CT\_REL change type) or shifting (CT\_ADD change type) of the specified cost functions:

```

type CT_MODCOST_F scales or shifts the cost function vertically
type CT_MODCOST_X scales or shifts the cost function horizontally

```

See MODCOST.

CT\_CHGTYPE: column of changes table where the type of change to be made is stored:

```

type CT_REP replaces old value by value in CT_NEWVAL column
type CT_REL multiplies old value by factor in CT_NEWVAL column
type CT_ADD adds value in CT_NEWVAL column to old value

```

See also `apply_changes()` (page 329), `modcost()`.

**idx\_dcline****idx\_dcline()**

*idx\_dcline()* (page 344) - Defines constants for named column indices to dcline matrix.

Example:

```
c = idx_dcline;
```

Some examples of **usage**, after defining the constants using the **line** above, are:

```
mpc.dcline(4, c.BR_STATUS) = 0;           % take dcline 4 out of service
```

The **index**, name and meaning of each column of the dcline matrix is given below:

**columns 1-17** must be included in **input** matrix (in **case** file)

1	F_BUS	f, "from" bus number
2	T_BUS	t, "to" bus number
3	BR_STATUS	initial dcline status, 1 - in service, 0 - out of service
4	PF	MW flow at "from" bus ("from" -> "to")
5	PT	MW flow at "to" bus ("from" -> "to")
6	QF	MVAr injection at "from" bus ("from" -> "to")
7	QT	MVAr injection at "to" bus ("from" -> "to")
8	VF	voltage setpoint at "from" bus (p.u.)
9	VT	voltage setpoint at "to" bus (p.u.)
10	PMIN	lower limit on PF (MW flow at "from" end)
11	PMAX	upper limit on PF (MW flow at "from" end)
12	QMINF	lower limit on MVAr injection at "from" bus
13	QMAXF	upper limit on MVAr injection at "from" bus
14	QMINT	lower limit on MVAr injection at "to" bus
15	QMAXT	upper limit on MVAr injection at "to" bus
16	LOSS0	constant term of linear loss <b>function</b> (MW)
17	LOSS1	linear term of linear loss <b>function</b> (MW/MW) (loss = LOSS0 + LOSS1 * PF)

**columns 18-23** are added to matrix after OPF solution

they are typically **not** present in the **input** matrix

(assume OPF objective **function** has units, u)

18	MU_PMIN	Kuhn-Tucker multiplier on lower flow lim at "from" bus (u/MW)
19	MU_PMAX	Kuhn-Tucker multiplier on upper flow lim at "from" bus (u/MW)
20	MU_QMINF	Kuhn-Tucker multiplier on lower VAr lim at "from" bus (u/MVAr)
21	MU_QMAXF	Kuhn-Tucker multiplier on upper VAr lim at "from" bus (u/MVAr)
22	MU_QMINT	Kuhn-Tucker multiplier on lower VAr lim at "to" bus (u/MVAr)
23	MU_QMAXT	Kuhn-Tucker multiplier on upper VAr lim at "to" bus (u/MVAr)

See also *toggle\_dcline()* (page 305).

## idx\_gen

### idx\_gen()

`idx_gen()` (page 345) - Defines constants for named column indices to gen matrix.

Example:

```
[GEN_BUS, PG, QG, QMAX, QMIN, VG, MBASE, GEN_STATUS, PMAX, PMIN, ...
MU_PMAX, MU_PMIN, MU_QMAX, MU_QMIN, PC1, PC2, QC1MIN, QC1MAX, ...
QC2MIN, QC2MAX, RAMP_AGC, RAMP_10, RAMP_30, RAMP_Q, APF] = idx_gen;
```

Some examples of `usage`, after defining the constants using the `line` above, are:

```
Pg = gen(4, PG); % get the real power output of generator 4
gen(:, PMIN) = 0; % set to zero the minimum real power limit of all gens
```

The `index`, name and meaning of each column of the gen matrix is given below:

columns 1-21 must be included in input matrix (in `case` file)

1	GEN_BUS	bus number
2	PG	Pg, real power output (MW)
3	QG	Qg, reactive power output (MVar)
4	QMAX	Qmax, maximum reactive power output (MVar)
5	QMIN	Qmin, minimum reactive power output (MVar)
6	VG	Vg, voltage magnitude setpoint (p.u.)
7	MBASE	mBase, total MVA base of machine, defaults to baseMVA
8	GEN_STATUS	status, > 0 - in service, <= 0 - out of service
9	PMAX	Pmax, maximum real power output (MW)
10	PMIN	Pmin, minimum real power output (MW)
11	PC1	Pc1, lower real power output of PQ capability curve (MW)
12	PC2	Pc2, upper real power output of PQ capability curve (MW)
13	QC1MIN	Qc1min, minimum reactive power output at Pc1 (MVar)
14	QC1MAX	Qc1max, maximum reactive power output at Pc1 (MVar)
15	QC2MIN	Qc2min, minimum reactive power output at Pc2 (MVar)
16	QC2MAX	Qc2max, maximum reactive power output at Pc2 (MVar)
17	RAMP_AGC	ramp rate for load following/AGC (MW/min)
18	RAMP_10	ramp rate for 10 minute reserves (MW)
19	RAMP_30	ramp rate for 30 minute reserves (MW)
20	RAMP_Q	ramp rate for reactive power (2 sec timescale) (MVar/min)
21	APF	area participation factor

columns 22-25 are added to matrix after OPF solution

they are typically not present in the input matrix

		(assume OPF objective function has units, u)
22	MU_PMAX	Kuhn-Tucker multiplier on upper Pg limit (u/MW)
23	MU_PMIN	Kuhn-Tucker multiplier on lower Pg limit (u/MW)
24	MU_QMAX	Kuhn-Tucker multiplier on upper Qg limit (u/MVar)
25	MU_QMIN	Kuhn-Tucker multiplier on lower Qg limit (u/MVar)

See also `define_constants`.

## isload

### isload(*gen*)

isload() - Checks for dispatchable loads.

TORF = ISLOAD(GEN) returns a column vector of 1's and 0's. The 1's correspond to rows of the GEN matrix which represent dispatchable loads. The current test is  $P_{min} < 0$  AND  $P_{max} == 0$ . This may need to be revised to allow sensible specification of both elastic demand and pumped storage units.

## load2disp

### load2disp(*mpc0*, *fname*, *idx*, *voll*)

load2disp() - Converts fixed loads to dispatchable.

```
MPC = LOAD2DISP(MPC0);  
MPC = LOAD2DISP(MPC0, FNAME);  
MPC = LOAD2DISP(MPC0, FNAME, IDX);  
MPC = LOAD2DISP(MPC0, FNAME, IDX, VOLL);
```

Takes a MATPOWER case file or struct and converts fixed loads to dispatchable loads and returns the resulting case struct. Inputs are as follows:

MPC0 - File name or struct with initial MATPOWER case.

FNAME (optional) - Name to use to save resulting MATPOWER case. If empty, the case will not be saved to a file.

IDX (optional) - Vector of bus indices of loads to be converted. If empty or not supplied, it will convert all loads with positive real power demand.

VOLL (optional) - Scalar or vector specifying the value of lost load to use as the value for the dispatchable loads. If it is a scalar it is used for all loads, if a vector, the dimension must match that of IDX. Default is \$5000 per MWh.

## loadshed

### loadshed(*gen, ild*)

loadshed() - Returns a vector of curtailments of dispatchable loads.

```
SHED = LOADSHED(GEN)
SHED = LOADSHED(GEN, ILD)
```

Returns a column vector of MW curtailments of dispatchable loads.

Inputs:

GEN - MATPOWER generator matrix  
ILD - (optional) NLD x 1 vector of generator indices corresponding to the dispatchable loads of interest, default is **all** dispatchable loads as determined by the ISLOAD() **function**.

Output:

SHED - NLD x 1 vector of the MW curtailment **for** each dispatchable **load** of interest

Example:

```
total_load_shed = max(loadshed(mpc.gen));
```

## modcost

### modcost(*gencost, alpha, modtype*)

modcost() - Modifies generator costs by shifting or scaling (F or X).

```
NEWGENCOST = MODCOST(GENCOST, ALPHA)
NEWGENCOST = MODCOST(GENCOST, ALPHA, MODTYPE)
```

For each generator cost  $F(X)$  (**for real or reactive power**) in GENCOST, this **function** modifies the cost by scaling or shifting the **function** by ALPHA, depending on the value of MODTYPE, **and** returns the modified GENCOST. Rows of GENCOST can be a mix of polynomial **or** piecewise linear costs. ALPHA can be a scalar, applied to each row of GENCOST, **or** an NG x 1 vector, where each element is applied to the corresponding row of GENCOST.

MODTYPE takes one of the 4 possible values (let  $F_{\alpha}(X)$  denote the modified **function**):

```
'SCALE_F' (default) :  $F_{\alpha}(X) == F(X) * ALPHA$ 
'SCALE_X'           :  $F_{\alpha}(X * ALPHA) == F(X)$ 
'SHIFT_F'           :  $F_{\alpha}(X) == F(X) + ALPHA$ 
'SHIFT_X'           :  $F_{\alpha}(X + ALPHA) == F(X)$ 
```

## mpver

**mpver**(*varargin*)

mpver() - Prints or returns installed MATPOWER version info.

```
mpver
v = mpver
v = mpver('all')
```

When called with an output argument and no input argument, `mpver()` returns the current MATPOWER version numbers. With an input argument (e.g. 'all') it returns a struct with the fields Name, Version, Release, and Date (*all char arrays*). Calling `mpver()` without assigning the return value prints the version and release date of the current installation of MATPOWER, MATLAB (or MATLAB), the Optimization Toolbox, MP-Test, MIPS, MP-Opt-Model, MOST, and any optional MATPOWER packages.

## poly2pwl

**poly2pwl**(*polycost, Pmin, Pmax, npts*)

poly2pwl() - Converts polynomial cost variable to piecewise linear.

```
PWLCOST = POLY2PWL(POLYCOST, PMIN, PMAX, NPTS) converts the polynomial
cost variable POLYCOST into a piece-wise linear cost by evaluating at
NPTS evenly spaced points between PMIN and PMAX. If the range does not
include 0, then it is evaluated at 0 and NPTS-1 evenly spaced points
between PMIN and PMAX.
```

## polycost

**polycost**(*gencost, Pg, der*)

polycost() - Evaluates polynomial generator cost & derivatives.

```
F = POLYCOST(GENCOST, PG) returns the vector of costs evaluated at PG

DF = POLYCOST(GENCOST, PG, 1) returns the vector of first derivatives
of costs evaluated at PG

D2F = POLYCOST(GENCOST, PG, 2) returns the vector of second derivatives
of costs evaluated at PG

GENCOST must contain only polynomial costs
PG is in MW, not p.u. (works for QG too)

This is a more efficient implementation that what can be done with
MATLAB's built-in POLYVAL and POLYDER functions.
```

## pqcost

**pqcost**(*gencost, ng, on*)

pqcost() - Splits the gencost variable into two pieces if costs are given for Qg.

[PCOST, QCOST] = PQCOST(GENCOST, NG, ON) checks whether GENCOST has cost information **for** reactive **power** generation (**rows** ng+1 to 2\*ng). If so, it returns the first NG **rows** in PCOST **and** the last NG **rows** in QCOST. Otherwise, leaves QCOST empty. Also does some **error** checking. If ON is specified (list of indices of generators which are on **line**) it only returns the **rows** corresponding to these generators.

## scale\_load

**scale\_load**(*dmd, bus, gen, load\_zone, opt, gencost*)

*scale\_load*() (page 349) - Scales fixed and/or dispatchable loads.

```
MPC = SCALE_LOAD(LOAD, MPC);
MPC = SCALE_LOAD(LOAD, MPC, LOAD_ZONE)
MPC = SCALE_LOAD(LOAD, MPC, LOAD_ZONE, OPT)
BUS = SCALE_LOAD(LOAD, BUS);
[BUS, GEN] = SCALE_LOAD(LOAD, BUS, GEN, LOAD_ZONE, OPT)
[BUS, GEN, GENCOST] = ...
    SCALE_LOAD(LOAD, BUS, GEN, LOAD_ZONE, OPT, GENCOST)
```

Scales active (**and** optionally reactive) loads in each zone by a zone-specific ratio, i.e.  $R(k)$  **for** zone  $k$ . Inputs are ...

**LOAD** - Each element specifies the amount of scaling **for** the corresponding load zone, either as a direct scale **factor** **or** as a target quantity. If there are  $nz$  load zones this vector has  $nz$  elements.

**MPC** - standard MATPOWER **case struct** **or case** file name

**BUS** - standard BUS matrix with  $nb$  **rows**, where the fixed active **and** reactive loads available **for** scaling are specified in **columns** PD **and** QD

**GEN** - (optional) standard GEN matrix with  $ng$  **rows**, where the dispatchable loads available **for** scaling are specified by **columns** PG, QG, PMIN, QMIN **and** QMAX (in **rows** **for** which ISLOAD(GEN) returns **true**). If GEN is empty, it assumes there are no dispatchable loads.

**LOAD\_ZONE** - (optional)  $nb$  element vector where the value of each element is either zero **or** the **index** of the load zone to which the corresponding bus belongs. If  $LOAD\_ZONE(b) = k$  then the loads at bus  $b$  will be scaled according to the value of  $LOAD(k)$ . If  $LOAD\_ZONE(b) = 0$ , the loads at bus  $b$

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will **not** be modified. If `LOAD_ZONE` is empty, the default is determined by the dimensions of the `LOAD` vector. If `LOAD` is a scalar, a **single system-wide** zone including **all** buses is used, i.e. `LOAD_ZONE = ONES(nb, 1)`. If `LOAD` is a vector, the default `LOAD_ZONE` is defined as the areas specified in the `BUS` matrix, i.e. `LOAD_ZONE = BUS(:, BUS_AREA)`, and `LOAD` should have `dimension = MAX(BUS(:, BUS_AREA))`.

`OPT` - (optional) **struct** with three possible fields, `'scale'`, `'pq'` and `'which'` that determine the behavior as follows:

`OPT.scale` (default is `'FACTOR'`)

`'FACTOR'` : `LOAD` consists of direct scale factors, where  
 $LOAD(k) = \text{scale factor } R(k) \text{ for zone } k$   
`'QUANTITY'` : `LOAD` consists of target quantities, where  
 $LOAD(k) = \text{desired total active load in MW for zone } k \text{ after scaling by an appropriate } R(k)$

`OPT.pq` (default is `'PQ'`)

`'PQ'` : scale both active and reactive loads  
`'P'` : scale only active loads

`OPT.which` (default is `'BOTH'` if `GEN` is provided, else `'FIXED'`)

`'FIXED'` : scale only fixed loads  
`'DISPATCHABLE'` : scale only dispatchable loads  
`'BOTH'` : scale both fixed and dispatchable loads

`OPT.cost` : (default = `-1`) flag to include cost in scaling or not

`-1` : include cost if `gencost` is available  
`0` : do not include cost  
`1` : include cost (error if `gencost` not available)

`GENCOST` - (optional) standard `GENCOST` matrix with `ng` (or `2*ng`) rows, where the dispatchable load rows are determined by the `GEN` matrix. If included, the quantity axis of the marginal "cost" or benefit function of any dispatchable loads will be scaled with the size of the load itself (using `MODCOST` twice, once with `MODTYPE` equal to `SCALE_F` and once with `SCALE_X`).

Examples:

Scale all real and reactive fixed loads up by 10%.

```
bus = scale_load(1.1, bus);
```

Scale all active loads (fixed and dispatchable) at the first 10 buses so their total equals 100 MW, and at next 10 buses so their total equals 50 MW.

```
load_zone = zeros(nb, 1);
load_zone(1:10) = 1;
load_zone(11:20) = 2;
opt = struct('pq', 'P', 'scale', 'QUANTITY');
```

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```
dmd = [100; 50];
[bus, gen] = scale_load(dmd, bus, gen, load_zone, opt);
```

See also `total_load()` (page 351).

## total\_load

`total_load(bus, gen, load_zone, opt, mpopt)`

`total_load()` (page 351) - Returns vector of total load in each load zone.

```
PD = TOTAL_LOAD(MPC)
PD = TOTAL_LOAD(MPC, LOAD_ZONE)
PD = TOTAL_LOAD(MPC, LOAD_ZONE, OPT)
PD = TOTAL_LOAD(MPC, LOAD_ZONE, OPT, MPOPT)
PD = TOTAL_LOAD(BUS)
PD = TOTAL_LOAD(BUS, GEN)
PD = TOTAL_LOAD(BUS, GEN, LOAD_ZONE)
PD = TOTAL_LOAD(BUS, GEN, LOAD_ZONE, OPT)
PD = TOTAL_LOAD(BUS, GEN, LOAD_ZONE, OPT, MPOPT)
[PD, QD] = TOTAL_LOAD(...) returns both active and reactive power
demand for each zone.
```

MPC - standard MATPOWER case struct

BUS - standard BUS matrix with nb rows, where the fixed active and reactive loads are specified in columns PD and QD

GEN - (optional) standard GEN matrix with ng rows, where the dispatchable loads are specified by columns PG, QG, PMIN, QMIN and QMAX (in rows for which ISLOAD(GEN) returns true). If GEN is empty, it assumes there are no dispatchable loads.

LOAD\_ZONE - (optional) nb element vector where the value of each element is either zero or the index of the load zone to which the corresponding bus belongs. If LOAD\_ZONE(b) = k then the loads at bus b will added to the values of PD(k) and QD(k). If LOAD\_ZONE is empty, the default is defined as the areas specified in the BUS matrix, i.e. LOAD\_ZONE = BUS(:, BUS\_AREA) and load will have dimension = MAX(BUS(:, BUS\_AREA)). LOAD\_ZONE can also take the following string values:

- 'all' - use a single zone for the entire system (return scalar)
- 'area' - use LOAD\_ZONE = BUS(:, BUS\_AREA), same as default
- 'bus' - use a different zone for each bus (i.e. to compute final values of bus-wise loads, including voltage dependent fixed loads and or dispatchable loads)

OPT - (optional) option struct, with the following fields:

- 'type' - string specifying types of loads to include, default is 'BOTH' if GEN is provided, otherwise 'FIXED'
- 'FIXED' : sum only fixed loads

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```

'DISPATCHABLE' : sum only dispatchable loads
'BOTH'          : sum both fixed and dispatchable loads
'nominal' - 1 : use nominal load for dispatchable loads
            0 : (default) use actual realized load for
              dispatchable loads

```

For backward compatibility with MATPOWER 4.x, OPT can also take the form of a string, with the same options as OPT.type above. In this case, again for backward compatibility, it is the "nominal" load that is computed for dispatchable loads, not the actual realized load. Using a string for OPT is deprecated and will be removed in a future version.

MPOPT - (optional) MATPOWER options struct, which may specify a voltage dependent (ZIP) load model for fixed loads

Examples:

Return the total active load for each area as defined in BUS\_AREA.

```
Pd = total_load(bus);
```

Return total active and reactive load, fixed and dispatchable, for entire system.

```
[Pd, Qd] = total_load(bus, gen, 'all');
```

Return the total of the nominal dispatchable loads at buses 10-20.

```
load_zone = zeros(nb, 1);
load_zone(10:20) = 1;
opt = struct('type', 'DISPATCHABLE', 'nominal', 1);
Pd = total_load(mpc, load_zone, opt)
```

See also `scale_load()` (page 349).

## 5.2.13 Private Feature Detection Functions

### have\_feature\_e4st

#### have\_feature\_e4st()

`have_feature_e4st()` (page 352) - Detect availability/version info for E4ST.

Private feature detection function implementing 'e4st' tag for `have_feature()` to detect availability/version of E4ST, the Engineering, Economic, and Environmental Electricity Simulation Tool (<https://e4st.com>).

See also `have_feature()`.

## have\_feature\_minopf

### have\_feature\_minopf()

*have\_feature\_minopf()* (page 353) - Detect availability/version info for MINOPF.

Private feature detection function implementing 'minopf' tag for `have_feature()` to detect availability/version of MINOPF, a MINOS-based optimal power flow (OPF) solver.

See also `have_feature()`, `minopf`.

## have\_feature\_most

### have\_feature\_most()

*have\_feature\_most()* (page 353) - Detect availability/version info for MOST.

Private feature detection function implementing ':func: `most`' tag for `have_feature()` to detect availability/version of MOST (MATPOWER Optimal Scheduling Tool).

See also `have_feature()`, `most()`.

## have\_feature\_mp\_core

### have\_feature\_mp\_core()

*have\_feature\_mp\_core()* (page 353) - Detect availability of MP-Core.

Private feature detection function implementing 'mp\_core' tag for `have_feature()` to detect availability/version of MP-Core.

See also `have_feature()`.

## have\_feature\_pdipmopf

### have\_feature\_pdipmopf()

*have\_feature\_pdipmopf()* (page 353) - Detect availability/version info for PDIPMOPF.

Private feature detection function implementing 'pdipmopf' tag for `have_feature()` to detect availability/version of PDIPMOPF, a primal-dual interior point method optimal power flow (OPF) solver included in TSPOPF. (<https://www.pserc.cornell.edu/tspopf>)

See also `have_feature()`, `pdipmopf`.

## have\_feature\_regex\_split

### have\_feature\_regex\_split()

*have\_feature\_regex\_split()* (page 354) - Detect availability/version info for REGEXP 'split'.

Private feature detection function implementing 'regex\_split' tag for `have_feature()` to detect support for the 'split' argument to REGEXP.

See also `have_feature()`, `regex`.

## have\_feature\_scpdipmopf

### have\_feature\_scpdipmopf()

*have\_feature\_scpdipmopf()* (page 354) - Detect availability/version info for SCPDIPMOPF.

Private feature detection function implementing 'scpdipmopf' tag for `have_feature()` to detect availability/version of SCPDIPMOPF, step-controlled primal-dual interior point method optimal power flow (OPF) solver included in TSPOPF. (<https://www.pserc.cornell.edu/tspopf>)

See also `have_feature()`, `scpdipmopf`.

## have\_feature\_sdp\_pf

### have\_feature\_sdp\_pf()

*have\_feature\_sdp\_pf()* (page 354) - Detect availability/version info for SDP\_PF.

Private feature detection function implementing 'sdp\_pf' tag for `have_feature()` to detect availability/version of SDP\_PF, a MATPOWER extension for applications of semi-definite programming relaxations of power flow equations ([https://github.com/MATPOWER/mx-sdp\\_pf/](https://github.com/MATPOWER/mx-sdp_pf/)).

See also `have_feature()`.

## have\_feature\_smartmarket

### have\_feature\_smartmarket()

*have\_feature\_smartmarket()* (page 354) - Detect availability/version info for SMARTMARKET.

Private feature detection function implementing 'smartmarket' tag for `have_feature()` to detect availability/version of RUNMARKET and related files for running an energy auction, found under smartmarket in MATPOWER Extras. (<https://github.com/MATPOWER/matpower-extras/>).

See also `have_feature()`, `runmarket`.

## have\_feature\_syngrid

### have\_feature\_syngrid()

*have\_feature\_syngrid()* (page 355) - Detect availability/version info for SynGrid.

Private feature detection function implementing 'syngrid' tag for `have_feature()` to detect availability/version of SynGrid, Synthetic Grid Creation for MATPOWER (<https://github.com/MATPOWER/mx-syngrid>).

See also `have_feature()`, `syngrid`.

## have\_feature\_table

### have\_feature\_table()

*have\_feature\_table()* (page 355) - Detect availability/version info for table.

Private feature detection function implementing 'table' tag for `have_feature()` to detect availability/version of TABLE, included in MATLAB R2013b and as of this writing in Mar 2024, available for Octave as Tablicious: <https://github.com/apjanke/octave-tablicious>

See also `have_feature()`, `table`.

## have\_feature\_tralmopf

### have\_feature\_tralmopf()

*have\_feature\_tralmopf()* (page 355) - Detect availability/version info for TRALMOPF

Private feature detection function implementing 'tralmopf' tag for `have_feature()` to detect availability/version of TRALMOPF, trust region based augmented Langrangian optimal power flow (OPF) solver included in TSPOPF. (<https://www.pserc.cornell.edu/tspopf>)

See also `have_feature()`, `tralmopf`.

## 5.2.14 Other Functions

### connected\_components

#### `connected_components(C, groups, unvisited)`

*connected\_components()* (page 355) - Returns the connected components of a graph.

```
[GROUPS, ISOLATED] = CONNECTED_COMPONENTS(C)
```

Returns the connected components of a directed graph, specified by a node-branch incidence matrix `C`, where `C(I, J) = -1` if node `J` is connected to the beginning of branch `I`, `1` if it is connected to the end of branch `I`, and zero otherwise. The return value `GROUPS` is a cell array of vectors of the node indices for each component. The second return value `ISOLATED` is a vector of indices of isolated nodes that have no connecting branches.

## `moption_info_clp`

`moption_info_clp(selector)`

`moption_info_clp()` (page 356) - Returns MATPOWER option info for CLP.

```
DEFAULT_OPTS = MPOPTION_INFO_CLP('D')
VALID_OPTS   = MPOPTION_INFO_CLP('V')
EXCEPTIONS   = MPOPTION_INFO_CLP('E')
```

Returns a structure **for** CLP options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## `moption_info_cplex`

`moption_info_cplex(selector)`

`moption_info_cplex()` (page 356) - Returns MATPOWER option info for CPLEX.

```
DEFAULT_OPTS = MPOPTION_INFO_CPLEX('D')
VALID_OPTS   = MPOPTION_INFO_CPLEX('V')
EXCEPTIONS   = MPOPTION_INFO_CPLEX('E')
```

Returns a structure **for** CPLEX options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## mpoption\_info\_fmincon

### mpoption\_info\_fmincon(*selector*)

*mpoption\_info\_fmincon()* (page 357) - Returns MATPOWER option info for FMINCON.

```

DEFAULT_OPTS = MPOPTION_INFO_FMINCON('D')
VALID_OPTS   = MPOPTION_INFO_FMINCON('V')
EXCEPTIONS   = MPOPTION_INFO_FMINCON('E')

```

Returns a structure **for** FMINCON options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also mption().

## mpoption\_info\_glpk

### mpoption\_info\_glpk(*selector*)

*mpoption\_info\_glpk()* (page 357) - Returns MATPOWER option info for GLPK.

```

DEFAULT_OPTS = MPOPTION_INFO_GLPK('D')
VALID_OPTS   = MPOPTION_INFO_GLPK('V')
EXCEPTIONS   = MPOPTION_INFO_GLPK('E')

```

Returns a structure **for** GLPK options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also mption().



## `moption_info_gurobi`

`moption_info_gurobi(selector)`

`moption_info_gurobi()` (page 358) - Returns MATPOWER option info for Gurobi.

```
DEFAULT_OPTS = MPOPTION_INFO_GUROBI('D')
VALID_OPTS   = MPOPTION_INFO_GUROBI('V')
EXCEPTIONS   = MPOPTION_INFO_GUROBI('E')
```

Returns a structure **for** Gurobi options **for** MATPOWER containing ...  
(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## `moption_info_intlinprog`

`moption_info_intlinprog(selector)`

`moption_info_intlinprog()` (page 358) - Returns MATPOWER option info for INTLINPROG.

```
DEFAULT_OPTS = MPOPTION_INFO_INTLINPROG('D')
VALID_OPTS   = MPOPTION_INFO_INTLINPROG('V')
EXCEPTIONS   = MPOPTION_INFO_INTLINPROG('E')
```

Returns a structure **for** INTLINPROG options **for** MATPOWER containing ...  
(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## `moption_info_ipopt`

`moption_info_ipopt(selector)`

`moption_info_ipopt()` (page 359) - Returns MATPOWER option info for IPOPT.

```

DEFAULT_OPTS = MPOPTION_INFO_IPOPT('D')
VALID_OPTS   = MPOPTION_INFO_IPOPT('V')
EXCEPTIONS   = MPOPTION_INFO_IPOPT('E')

```

Returns a structure **for** IPOPT options **for** MATPOWER containing ...

(1) default options,  
 (2) valid options, **or**  
 (3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
 ... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## `moption_info_knitro`

`moption_info_knitro(selector)`

`moption_info_knitro()` (page 359) - Returns MATPOWER option info for Artelys Knitro.

```

DEFAULT_OPTS = MPOPTION_INFO_KNITRO('D')
VALID_OPTS   = MPOPTION_INFO_KNITRO('V')
EXCEPTIONS   = MPOPTION_INFO_KNITRO('E')

```

Returns a structure **for** Knitro options **for** MATPOWER containing ...

(1) default options,  
 (2) valid options, **or**  
 (3) NESTED\_STRUCT\_COPY exceptions **for** setting options  
 ... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## mpoption\_info\_linprog

**mpoption\_info\_linprog**(*selector*)

*mpoption\_info\_linprog*() (page 360) - Returns MATPOWER option info for LINPROG.

```

DEFAULT_OPTS = MPOPTION_INFO_LINPROG('D')
VALID_OPTS   = MPOPTION_INFO_LINPROG('V')
EXCEPTIONS   = MPOPTION_INFO_LINPROG('E')

```

Returns a structure **for** LINPROG options **for** MATPOWER containing ...

- (1) default options,
  - (2) valid options, **or**
  - (3) NESTED\_STRUCT\_COPY exceptions **for** setting options
- ... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also mption().

## mpoption\_info\_mips

**mpoption\_info\_mips**(*selector*)

*mpoption\_info\_mips*() (page 360) - Returns MATPOWER option info for MIPS (optional fields).

```

DEFAULT_OPTS = MPOPTION_INFO_MIPS('D')
VALID_OPTS   = MPOPTION_INFO_MIPS('V')
EXCEPTIONS   = MPOPTION_INFO_MIPS('E')

```

Returns a structure **for** MIPS options **for** MATPOWER containing ...

- (1) default options,
  - (2) valid options, **or**
  - (3) NESTED\_STRUCT\_COPY exceptions **for** setting options
- ... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also mption().

## `moption_info_mosek`

`moption_info_mosek(selector)`

`moption_info_mosek()` (page 361) - Returns MATPOWER option info for MOSEK.

```

DEFAULT_OPTS = MPOPTION_INFO_MOSEK('D')
VALID_OPTS   = MPOPTION_INFO_MOSEK('V')
EXCEPTIONS   = MPOPTION_INFO_MOSEK('E')

```

Returns a structure **for** MOSEK options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCTURE\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## `moption_info_osqp`

`moption_info_osqp(selector)`

`moption_info_osqp()` (page 361) - Returns MATPOWER option info for OSQP.

```

DEFAULT_OPTS = MPOPTION_INFO_OSQP('D')
VALID_OPTS   = MPOPTION_INFO_OSQP('V')
EXCEPTIONS   = MPOPTION_INFO_OSQP('E')

```

Returns a structure **for** OSQP options **for** MATPOWER containing ...

(1) default options,  
(2) valid options, **or**  
(3) NESTED\_STRUCTURE\_COPY exceptions **for** setting options  
... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `moption()`.

## mpoption\_info\_quadprog

**mpoption\_info\_quadprog**(*selector*)

*mpoption\_info\_quadprog*() (page 362) - Returns MATPOWER option info for QUADPROG.

```
DEFAULT_OPTS = MPOPTION_INFO_QUADPROG('D')
VALID_OPTS   = MPOPTION_INFO_QUADPROG('V')
EXCEPTIONS   = MPOPTION_INFO_QUADPROG('E')
```

Returns a structure **for** QUADPROG options **for** MATPOWER containing ...

- (1) default options,
  - (2) valid options, **or**
  - (3) NESTED\_STRUCT\_COPY exceptions **for** setting options
- ... depending on the value of the **input** argument.

This **function** is used by MPOPTION to **set** default options, check validity of option names **or** modify option setting/copying behavior **for** this subset of optional MATPOWER options.

See also `mpoption()`.

## mpoption\_old

**mpoption\_old**(*varargin*)

*mpoption\_old*() (page 362) - Used to set and retrieve old-style MATPOWER options vector.

```
OPT = MPOPTION_OLD
returns the default options vector
```

```
OPT = MPOPTION_OLD(NAME1, VALUE1, NAME2, VALUE2, ...)
returns the default options vector with new values for up to 7
options, NAME# is the name of an option, and VALUE# is the new
value.
```

```
OPT = MPOPTION_OLD(OPT, NAME1, VALUE1, NAME2, VALUE2, ...)
same as above except it uses the options vector OPT as a base
instead of the default options vector.
```

Examples:

```
opt = mption_old('PF_ALG', 2, 'PF_TOL', 1e-4);
opt = mption_old(opt, 'OPF_ALG', 565, 'VERBOSE', 2);
```

The currently defined options are as follows:

idx - NAME, default	description [options]
-----	
<b>power</b> flow options	
1 - PF_ALG, 1	AC <b>power</b> flow algorithm
[ 1 - Newton's method	]
[ 2 - Fast-Decoupled (XB <b>version</b> )	]
[ 3 - Fast-Decoupled (BX <b>version</b> )	]

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```

    [ 4 - Gauss-Seidel ]
2 - PF_TOL, 1e-8      termination tolerance on per unit
                      P & Q mismatch
3 - PF_MAX_IT, 10    maximum number of iterations for
                      Newton's method
4 - PF_MAX_IT_FD, 30 maximum number of iterations for
                      fast decoupled method
5 - PF_MAX_IT_GS, 1000 maximum number of iterations for
                      Gauss-Seidel method
6 - ENFORCE_Q_LIMS, 0 enforce gen reactive power limits
                      at expense of |V|
    [ 0 - do NOT enforce limits ]
    [ 1 - enforce limits, simultaneous bus type conversion ]
    [ 2 - enforce limits, one-at-a-time bus type conversion ]
10 - PF_DC, 0        DC modeling for power flow & OPF
    [ 0 - use AC formulation & corresponding algorithm options ]
    [ 1 - use DC formulation, ignore AC algorithm options ]
OPF options
11 - OPF_ALG, 0      solver to use for AC OPF
    [ 0 - choose default solver based on availability in the ]
    [ following order, 540, 560 ]
    [ 500 - MINOPF, MINOS-based solver, requires optional ]
    [ MEX-based MINOPF package, available from: ]
    [ http://www.pserc.cornell.edu/minopf/ ]
    [ 520 - fmincon, MATLAB Optimization Toolbox >= 2.x ]
    [ 540 - PDIPM, primal/dual interior point method, requires ]
    [ optional MEX-based TSPOPF package, available from: ]
    [ http://www.pserc.cornell.edu/tspopf/ ]
    [ 545 - SC-PDIPM, step-controlled variant of PDIPM, requires ]
    [ TSPOPF (see 540) ]
    [ 550 - TRALM, trust region based augmented Lagrangian ]
    [ method, requires TSPOPF (see 540) ]
    [ 560 - MIPS, MATPOWER Interior Point Solver ]
    [ primal/dual interior point method (pure MATLAB) ]
    [ 565 - MIPS-sc, step-controlled variant of MIPS ]
    [ primal/dual interior point method (pure MATLAB) ]
    [ 580 - IPOPT, requires MEX interface to IPOPT solver ]
    [ available from: https://projects.coin-or.org/Ipopt/ ]
    [ 600 - Artelys Knitro, requires Knitro solver, available from: ]
    [ https://www.artelys.com/solvers/knitro/ ]
16 - OPF_VIOLATION, 5e-6 constraint violation tolerance
17 - CONSTR_TOL_X, 1e-4 termination tol on x for fmincon/Knitro
18 - CONSTR_TOL_F, 1e-4 termination tol on f for fmincon/Knitro
19 - CONSTR_MAX_IT, 0  max number of iterations for fmincon
    [ 0 => default ]
24 - OPF_FLOW_LIM, 0  qty to limit for branch flow constraints
    [ 0 - apparent power flow (limit in MVA) ]
    [ 1 - active power flow (limit in MW) ]
    [ 2 - current magnitude (limit in MVA at 1 p.u. voltage) ]
25 - OPF_IGNORE_ANG_LIM, 0 ignore angle difference limits for branches
    even if specified [ 0 or 1 ]
26 - OPF_ALG_DC, 0    solver to use for DC OPF

```

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```

[ 0 - choose default solver based on availability in the ]
[ following order: 500, 600, 700, 100, 300, 200 ]
[ 100 - BPMPD, requires optional MEX-based BPMPD_MEX package ]
[ available from: http://www.pserc.cornell.edu/bpmpd/ ]
[ 200 - MIPS, MATLAB Interior Point Solver ]
[ primal/dual interior point method (pure MATLAB) ]
[ 250 - MIPS-sc, step-controlled variant of MIPS ]
[ 300 - MATLAB Optimization Toolbox, QUADPROG, LINPROG ]
[ 400 - IPOPT, requires MEX interface to IPOPT solver ]
[ available from: https://projects.coin-or.org/Ipopt/ ]
[ 500 - CPLEX, requires MATLAB interface to CPLEX solver ]
[ 600 - MOSEK, requires MATLAB interface to MOSEK solver ]
[ available from: https://www.mosek.com/ ]
[ 700 - GUROBI, requires Gurobi optimizer (v. 5+) ]
[ available from: https://www.gurobi.com ]
output options
31 - VERBOSE, 1 amount of progress info printed
[ 0 - print no progress info ]
[ 1 - print a little progress info ]
[ 2 - print a lot of progress info ]
[ 3 - print all progress info ]
32 - OUT_ALL, -1 controls pretty-printing of results
[ -1 - individual flags control what prints ]
[ 0 - do not print anything ]
[ (overrides individual flags) ]
[ 1 - print everything ]
[ (overrides individual flags) ]
33 - OUT_SYS_SUM, 1 print system summary [ 0 or 1 ]
34 - OUT_AREA_SUM, 0 print area summaries [ 0 or 1 ]
35 - OUT_BUS, 1 print bus detail [ 0 or 1 ]
36 - OUT_BRANCH, 1 print branch detail [ 0 or 1 ]
37 - OUT_GEN, 0 print generator detail [ 0 or 1 ]
(OUT_BUS also includes gen info)
38 - OUT_ALL_LIM, -1 controls what constraint info is printed
[ -1 - individual flags control what constraint info prints ]
[ 0 - no constraint info (overrides individual flags) ]
[ 1 - binding constraint info (overrides individual flags) ]
[ 2 - all constraint info (overrides individual flags) ]
39 - OUT_V_LIM, 1 control output of voltage limit info
[ 0 - do not print ]
[ 1 - print binding constraints only ]
[ 2 - print all constraints ]
[ (same options for OUT_LINE_LIM, OUT_PG_LIM, OUT_QG_LIM) ]
40 - OUT_LINE_LIM, 1 control output of line flow limit info
41 - OUT_PG_LIM, 1 control output of gen P limit info
42 - OUT_QG_LIM, 1 control output of gen Q limit info
44 - OUT_FORCE, 0 print results even if success = 0
[ 0 or 1 ]
52 - RETURN_RAW_DER, 0 return constraint and derivative info
in results.raw (in fields g, dg, df, d2f)
FMINCON options
55 - FMC_ALG, 4 algorithm used by fmincon for OPF

```

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		<b>for</b> Optimization Toolbox 4 and later	
[	1 - active- <b>set</b>		]
[	2 - interior-point, w/default 'bfgs' Hessian approx		]
[	3 - interior-point, w/ 'lbfgs' Hessian approx		]
[	4 - interior-point, w/exact user-supplied Hessian		]
[	5 - interior-point, w/Hessian via <b>finite</b> differences		]
Artelys Knitro options			
58 -	KNITRO_OPT, 0	a non-zero integer N indicates that <b>all</b> Knitro options should be handled by a Knitro options file named 'knitro_user_options_N.txt'	
IPOPT options			
60 -	IPOPT_OPT, 0	See IPOPT_OPTIONS <b>for</b> details.	
MINOPF options			
61 -	MNS_FEASTOL, 0 (1e-3)	primal feasibility tolerance, <b>set</b> to value of OPF_VIOLATION by default	
62 -	MNS_ROWTOL, 0 (1e-3)	row tolerance <b>set</b> to value of OPF_VIOLATION by default	
63 -	MNS_XTOL, 0 (1e-3)	x tolerance <b>set</b> to value of CONSTR_TOL_X by default	
64 -	MNS_MAJDAMP, 0 (0.5)	major damping parameter	
65 -	MNS_MINDAMP, 0 (2.0)	minor damping parameter	
66 -	MNS_PENALTY_PARM, 0 (1.0)	penalty parameter	
67 -	MNS_MAJOR_IT, 0 (200)	major iterations	
68 -	MNS_MINOR_IT, 0 (2500)	minor iterations	
69 -	MNS_MAX_IT, 0 (2500)	iterations limit	
70 -	MNS_VERBOSITY, -1		
[	-1 - controlled by VERBOSE option		]
[	0 - <b>print</b> nothing		]
[	1 - <b>print</b> only termination status message		]
[	2 - <b>print</b> termination status <b>and</b> screen progress		]
[	3 - <b>print</b> screen progress, report file (usually fort.9)		]
71 -	MNS_CORE, 0 (1200 * nb + 2 * (nb + ng)^2)	memory allocation	
72 -	MNS_SUPBASIC_LIM, 0 (2*nb + 2*ng)	superbasics limit	
73 -	MNS_MULT_PRICE, 0 (30)	multiple price	
MIPS (including MIPS-sc), PDIPM, SC-PDIPM, <b>and</b> TRALM options			
81 -	PDIPM_FEASTOL, 0	feasibility (equality) tolerance <b>for</b> MIPS, PDIPM <b>and</b> SC-PDIPM, <b>set</b> to value of OPF_VIOLATION by default	
82 -	PDIPM_GRADTOL, 1e-6	<b>gradient</b> tolerance <b>for</b> MIPS, PDIPM <b>and</b> SC-PDIPM	
83 -	PDIPM_COMPTOL, 1e-6	complementary condition (inequality) tolerance <b>for</b> MIPS, PDIPM <b>and</b> SC-PDIPM	
84 -	PDIPM_COSTTOL, 1e-6	optimality tolerance <b>for</b> MIPS, PDIPM <b>and</b> SC-PDIPM	
85 -	PDIPM_MAX_IT, 150	maximum number of iterations <b>for</b> MIPS, PDIPM <b>and</b> SC-PDIPM	
86 -	SCPDIPM_RED_IT, 20	maximum number of MIPS-sc <b>or</b> SC-PDIPM	

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		reductions per iteration	
87	- TRALM_FEASTOL, 0	feasibility tolerance <b>for</b> TRALM	
		<b>set</b> to value of OPF_VIOLATION by default	
88	- TRALM_PRIMETOL, 5e-4	primal variable tolerance <b>for</b> TRALM	
89	- TRALM_DUALTOL, 5e-4	dual variable tolerance <b>for</b> TRALM	
90	- TRALM_COSTTOL, 1e-5	optimality tolerance <b>for</b> TRALM	
91	- TRALM_MAJOR_IT, 40	maximum number of major iterations	
92	- TRALM_MINOR_IT, 100	maximum number of minor iterations	
93	- SMOOTHING_RATIO, 0.04	piecewise linear curve smoothing ratio	
		used in SC-PDIPM <b>and</b> TRALM	
CPLEX options			
95	- CPLEX_LPMETHOD, 0	solution algorithm <b>for</b> continuous LPs	
	[ 0 - automatic: let CPLEX choose		]
	[ 1 - primal simplex		]
	[ 2 - dual simplex		]
	[ 3 - network simplex		]
	[ 4 - barrier		]
	[ 5 - sifting		]
	[ 6 - concurrent (dual, barrier, <b>and</b> primal)		]
96	- CPLEX_QPMETHOD, 0	solution algorithm <b>for</b> continuous QPs	
	[ 0 - automatic: let CPLEX choose		]
	[ 1 - primal simplex optimizer		]
	[ 2 - dual simplex optimizer		]
	[ 3 - network optimizer		]
	[ 4 - barrier optimizer		]
97	- CPLEX_OPT, 0	See CPLEX_OPTIONS <b>for</b> details	
MOSEK options			
111	- MOSEK_LP_ALG, 0	solution algorithm <b>for</b> continuous LPs	
		(MSK_IPAR_OPTIMIZER)	
	[ 0 - automatic: let MOSEK choose		]
	[ 1 - interior point		]
	[ 4 - primal simplex		]
	[ 5 - dual simplex		]
	[ 6 - primal dual simplex		]
	[ 7 - automatic simplex (MOSEK chooses which simplex method)		]
	[ 10 - concurrent		]
112	- MOSEK_MAX_IT, 0 (400)	interior point <b>max</b> iterations	
		(MSK_IPAR_INTPNT_MAX_ITERATIONS)	
113	- MOSEK_GAP_TOL, 0 (1e-8)	interior point relative gap tolerance	
		(MSK_DPAR_INTPNT_TOL_REL_GAP)	
114	- MOSEK_MAX_TIME, 0 (-1)	maximum <b>time</b> allowed <b>for</b> solver	
		(MSK_DPAR_OPTIMIZER_MAX_TIME)	
115	- MOSEK_NUM_THREADS, 0 (1)	maximum number of threads to use	
		(MSK_IPAR_INTPNT_NUM_THREADS)	
116	- MOSEK_OPT, 0	See MOSEK_OPTIONS <b>for</b> details	
Gurobi options			
121	- GRB_METHOD, -1	solution algorithm (Method)	
	[ -1 - automatic, let Gurobi decide		]
	[ 0 - primal simplex		]

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```

[ 1 - dual simplex ]
[ 2 - barrier ]
[ 3 - concurrent (LP only) ]
[ 4 - deterministic concurrent (LP only) ]
122 - GRB_TIMELIMIT, Inf maximum time allowed for solver (TimeLimit)
123 - GRB_THREADS, 0 (auto) maximum number of threads to use (Threads)
124 - GRB_OPT, 0 See GUROBI_OPTIONS for details

```

## psse\_convert

**psse\_convert**(warns, data, verbose)

*psse\_convert*() (page 367) - Converts data read from PSS/E RAW file to MATPOWER case.

```

[MPC, WARNINGS] = PSSE_CONVERT(WARNINGS, DATA)
[MPC, WARNINGS] = PSSE_CONVERT(WARNINGS, DATA, VERBOSE)

```

Converts data read from a **version** RAW data file into a MATPOWER **case struct**.

Input:

```

WARNINGS : cell array of strings containing accumulated
           warning messages
DATA      : struct read by PSSE_READ (see PSSE_READ for details).
VERBOSE   : 1 to display progress info, 0 (default) otherwise

```

Output:

```

MPC : a MATPOWER case struct created from the PSS/E data
WARNINGS : cell array of strings containing updated accumulated
           warning messages

```

See also *psse\_read*() (page 372).

## psse\_convert\_hvdc

**psse\_convert\_hvdc**(dc, bus)

*psse\_convert\_hvdc*() (page 367) - Convert HVDC data from PSS/E RAW to MATPOWER.

```

DCLINE = PSSE_CONVERT_HVDC(DC, BUS)

```

Convert **all** two terminal HVDC **line** data read from a PSS/E RAW data file into MATPOWER format. Returns a dcline matrix **for** inclusion in a MATPOWER **case struct**.

Inputs:

```

DC : matrix of raw two terminal HVDC line data returned by
    PSSE_READ in data.twodc.num
BUS : MATPOWER bus matrix

```

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**Output:**

DCLINE : a MATPOWER dcline matrix suitable **for** inclusion in a MATPOWER **case struct**.

See also `psse_convert()` (page 367).

**psse\_convert\_xfmr**

**psse\_convert\_xfmr**(*warns, trans2, trans3, verbose, baseMVA, bus, bus\_name*)

`psse_convert_xfmr()` (page 368) - Convert transformer data from PSS/E RAW to MATPOWER.

```
[XFMR, BUS, WARNINGS] = PSSE_CONVERT_XFMR(WARNINGS, TRANS2, TRANS3, ...
                                         VERBOSE, BASEMVA, BUS)
[XFMR, BUS, WARNINGS, BUS_NAME] = PSSE_CONVERT_XFMR(WARNINGS, TRANS2, ...
                                                    TRANS3, VERBOSE, BASEMVA, BUS, BUS_NAME)
```

Convert **all** transformer data read from a PSS/E RAW data file into MATPOWER format. Returns a branch matrix corresponding to the transformers **and** an updated bus matrix, with additional buses added **for** the star points of three winding transformers.

**Inputs:**

WARNINGS : **cell** array of strings containing accumulated **warning** messages  
 TRANS2 : matrix of raw two winding transformer data returned by PSSE\_READ in data.trans2.num  
 TRANS3 : matrix of raw three winding transformer data returned by PSSE\_READ in data.trans3.num  
 VERBOSE : **1** to **display** progress **info**, **0** (default) **otherwise**  
 BASEMVA : **system** MVA base  
 BUS : MATPOWER bus matrix  
 BUS\_NAME: (optional) **cell** array of bus names

**Outputs:**

XFMR : MATPOWER branch matrix of transformer data  
 BUS : updated MATPOWER bus matrix, with additional buses added **for** star points of three winding transformers  
 WARNINGS : **cell** array of strings containing updated accumulated **warning** messages  
 BUS\_NAME: (optional) updated **cell** array of bus names

See also `psse_convert()` (page 367).

**psse\_parse****psse\_parse**(records, sections, verbose, rev)*psse\_parse()* (page 369) - Parses the data from a PSS/E RAW data file.

```

DATA = PSSE_PARSE(RECORDS, SECTIONS)
DATA = PSSE_PARSE(RECORDS, SECTIONS, VERBOSE)
DATA = PSSE_PARSE(RECORDS, SECTIONS, VERBOSE, REV)
[DATA, WARNINGS] = PSSE_PARSE(RECORDS, SECTIONS, ...)

```

Parses the data from a PSS/E RAW data file (as read by PSSE\_READ) into a **struct**.

## Inputs:

```

RECORDS : cell array of strings, corresponding to the lines
          in the RAW file
SECTIONS : struct array with indices marking the beginning
          and end of each section, and the name of the
          section, fields are:
    first : index into RECORDS of first line of section
    last  : index into RECORDS of last line of section
    name  : name of the section, as extracted from the
          END OF ... DATA comments
VERBOSE  : 1 (default) to display progress info, 0 otherwise
REV      : (optional) assume the input file is of this
          PSS/E revision number, attempts to determine
          REV from the file by default

```

## Output(s):

```

DATA : a struct with the following fields, each with two
       sub-fields, 'num' and 'txt' containing the numeric and
       text data read from the file for the corresponding section
    id
    bus
    load
    gen
    shunt
    branch
    trans2
    trans3
    area
    twodc
    swshunt
WARNINGS : cell array of strings containing accumulated
          warning messages

```

See also *psse2mpc()*, *psse\_read()* (page 372), *psse\_parse\_section()* (page 370), *psse\_parse\_line()* (page 370).

## psse\_parse\_line

**psse\_parse\_line**(*str, t*)

*psse\_parse\_line*() (page 370) - Reads and parses a single line from a PSS/E RAW data file.

```
[DATA, COMMENT] = PSSE_PARSE_LINE(FID)
[DATA, COMMENT] = PSSE_PARSE_LINE(FID, TEMPLATE)
[DATA, COMMENT] = PSSE_PARSE_LINE(STR)
[DATA, COMMENT] = PSSE_PARSE_LINE(STR, TEMPLATE)
```

Parses a **single line** from a PSS/E RAW data file, either directly read from the file, **or** passed as a string.

**Inputs:**

FID : (optional) file id of file from which to read the **line**

STR : string containing the **line** to be parsed

TEMPLATE : (optional) string of characters indicating how to interpret the **type** of the corresponding column, options are as follows:

- d, f **or** g : integer floating point number to be converted via SSCANF with **%d, %f or %g, respectively.**
- D, F **or** G : integer floating point number, possibly enclosed in **single or double** quotes, to be converted via SSCANF with **%d, %f or %g, respectively.**
- c **or** s : character **or** string, possibly enclosed in **single or double** quotes, which are stripped from the string

Note: Data **columns** in STR that have no valid corresponding entry in TEMPLATE (beyond **end** of TEMPLATE, **or** a character other than those listed, e.g. **.'**) are returned as a string with no conversion. TEMPLATE entries **for** which there is no corresponding column are returned as **NaN or** empty string, depending on the **type**.

**Outputs:**

DATA : a **cell** array whose elements contain the contents of the corresponding column in the data, converted according to the TEMPLATE.

COMMENT : (optional) possible comment at the **end** of the **line**

## psse\_parse\_section

**psse\_parse\_section**(*warns, records, sections, s, verbose, label, template*)

*psse\_parse\_section*() (page 370) - Parses the data from a section of a PSS/E RAW data file.

```
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, SECTIONS, SIDX, ...
                                       VERBOSE, LABEL, TEMPLATE)
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, SECTIONS, SIDX, ...
                                       VERBOSE, LABEL)
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, SECTIONS, SIDX, ...
                                       VERBOSE)
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, SECTIONS, SIDX)
```

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```
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, VERBOSE, LABEL, ...
                                     TEMPLATE)
```

```
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, VERBOSE, LABEL)
```

```
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS, VERBOSE)
```

```
[DATA, WARNINGS] = PSSE_PARSE_SECTION(WARNINGS, RECORDS)
```

**Inputs:**

WARNINGS : cell array of strings containing accumulated warning messages

RECORDS : a cell array of strings returned by PSSE\_READ

SECTIONS : a struct array returned by PSSE\_READ

SIDX : (optional) index if the section to be read if included, the RECORD indices are taken from SECTIONS(SIDX), otherwise use all RECORDS

VERBOSE : 1 to display progress info, 0 (default) otherwise

LABEL : (optional) name for the section, to be compared with the section name typically found in the END OF <LABEL> DATA comment at the end of each section

TEMPLATE : (optional) string of characters indicating how to interpret the type of the corresponding column, options are as follows:

d, f or g : integer floating point number to be converted via SSCANF with %d, %f or %g, respectively.

D, F or G : integer floating point number, possibly enclosed in single or double quotes, to be converted via SSCANF with %d, %f or %g, respectively.

c or s : character or string, possibly enclosed in single or double quotes, which are stripped from the string

Note: Data columns in RECORDS that have no valid corresponding entry in TEMPLATE (beyond end of TEMPLATE, or a character other than those listed, e.g. '.') are returned in DATA.txt with no conversion. TEMPLATE entries for which there is no corresponding column in RECORDS are returned as NaN and empty, respectively, in DATA.num and DATA.txt.

**Output:**

DATA : a struct with two fields:

num : matrix containing the numeric data for the section, for columns with no numeric data, num contain NaNs.

txt : a cell array containing the non-numeric (char/string) data for the section, for columns with numeric data, txt entries are empty

WARNINGS : cell array of strings containing updated accumulated warning messages

See also psse2mpc(), psse\_parse() (page 369).

## psse\_read

**psse\_read**(rawfile\_name, verbose)

*psse\_read()* (page 372) - Reads the data from a PSS/E RAW data file.

```
[RECORDS, SECTIONS] = PSSE_READ(RAWFILE_NAME)
```

```
[RECORDS, SECTIONS] = PSSE_READ(RAWFILE_NAME, VERBOSE)
```

Reads the data from a PSS/E RAW data file into a `cell` array of strings, corresponding to the lines/records in the file. It detects the beginning **and** ending indices of each section as well as **any** Q **record** used to indicate the **end** of the data.

Input:

RAWFILE\_NAME : name of the PSS/E RAW file to be read  
(opened directly with FILEREAD)

VERBOSE : 1 to **display** progress **info**, 0 (default) **otherwise**

Output:

RECORDS : a `cell` array of strings, one **for** each **line** in the file (new **line** characters **not** included)

SECTIONS : a `struct` array with the following fields

first : **index** into RECORDS of first **line** of the section

last : **index** into RECORDS of last **line** of the section

name : name of the section (**if** available) extracted

from the 'END OF <NAME> DATA, BEGIN ... DATA'

comment typically found in the terminator **line**

See also psse2mpc().

## 5.3 Legacy Tests

### 5.3.1 Legacy MATPOWER Tests

#### t\_apply\_changes

**t\_apply\_changes**(quiet)

*t\_apply\_changes()* (page 372) - Tests for *apply\_changes()* (page 329).

### **t\_auction\_minopf**

#### **t\_auction\_minopf**(*quiet*)

*t\_auction\_minopf*() (page 373) - Tests for code in auction.m, using MINOPF solver.

### **t\_auction\_mips**

#### **t\_auction\_mips**(*quiet*)

*t\_auction\_mips*() (page 373) - Tests for code in auction.m, using MIPS solver.

### **t\_auction\_tspopf\_pdipm**

#### **t\_auction\_tspopf\_pdipm**(*quiet*)

*t\_auction\_tspopf\_pdipm*() (page 373) - Tests for code in auction.m, using PDIPMOPF solver.

### **t\_chgtab**

#### **t\_chgtab**()

*t\_chgtab*() (page 373) - Returns a change table for testing *apply\_changes*() (page 329).

### **t\_cpf**

#### **t\_cpf**(*quiet*)

*t\_cpf*() (page 373) - Tests for legacy continuation power flow.

### **t\_dcline**

#### **t\_dcline**(*quiet*)

*t\_dcline*() (page 373) - Tests for DC line extension in *toggle\_dcline*() (page 305).

### **t\_ext2int2ext**

#### **t\_ext2int2ext**(*quiet*)

*t\_ext2int2ext*() (page 373) - Tests *ext2int*(), *int2ext*(), and related functions.

Includes tests for *get\_reorder*() (page 260), *set\_reorder*() (page 260), *e2i\_data*() (page 255), *i2e\_data*() (page 258), *e2i\_field*() (page 256), *i2e\_field*() (page 259), *ext2int*(), and *int2ext*() .



### **t\_feval\_w\_path**

**t\_feval\_w\_path**(*quiet*)

*t\_feval\_w\_path*() (page 374) - Tests for *feval\_w\_path*() (page 334).

### **t\_get\_losses**

**t\_get\_losses**(*quiet*)

*t\_get\_losses*() (page 374) - Tests for *get\_losses*() (page 338).

### **t\_hasPQcap**

**t\_hasPQcap**(*quiet*)

*t\_hasPQcap*() (page 374) - Tests for *hasPQcap*() (page 339).

### **t\_hessian**

**t\_hessian**(*quiet*)

*t\_hessian*() (page 374) - Numerical tests of 2nd derivative code.

### **t\_islands**

**t\_islands**(*quiet*)

*t\_islands*() (page 374) - Tests for *find\_islands*() (page 335), *extract\_islands*() (page 333), *connected\_components*() (page 355) and *case\_info*() (page 331).

### **t\_jacobian**

**t\_jacobian**(*quiet*)

*t\_jacobian*() (page 374) - Numerical tests of partial derivative code.

**t\_load2disp****t\_load2disp**(*quiet*)

[t\\_load2disp\(\)](#) (page 375) - Tests for `load2disp()`.

**t\_loadcase****t\_loadcase**(*quiet*)

[t\\_loadcase\(\)](#) (page 375) - Test that `loadcase()` works with a struct as well as case file.

**t\_makeLODF****t\_makeLODF**(*quiet*)

[t\\_makeLODF\(\)](#) (page 375) - Tests for `makeLODF()` (page 327).

**t\_makePTDF****t\_makePTDF**(*quiet*)

[t\\_makePTDF\(\)](#) (page 375) - Tests for `makePTDF()` (page 327).

**t\_margcost****t\_margcost**(*quiet*)

[t\\_margcost\(\)](#) (page 375) - Tests for `margcost()`.

**t\_miqps\_matpower****t\_miqps\_matpower**(*quiet*)

[t\\_miqps\\_matpower\(\)](#) (page 375) - Tests of MIQP solvers via (deprecated) `miqps_matpower()` (page 325).

**t\_modcost****t\_modcost**(*quiet*)

[t\\_modcost\(\)](#) (page 375) - Tests for code in `modcost()`.

### **t\_moption**

**t\_moption**(*quiet*)

*t\_moption*() (page 376) - Tests for moption().

### **t\_moption\_ov**

**t\_moption\_ov**()

*t\_moption\_ov*() (page 376) - Example of option overrides from file.

### **t\_off2case**

**t\_off2case**(*quiet*)

*t\_off2case*() (page 376) - Tests for off2case.

### **t\_opf\_dc\_bpmpd**

**t\_opf\_dc\_bpmpd**(*quiet*)

*t\_opf\_dc\_bpmpd*() (page 376) - Tests for legacy DC optimal power flow using BPMPD\_MEX solver.

### **t\_opf\_dc\_clp**

**t\_opf\_dc\_clp**(*quiet*)

*t\_opf\_dc\_clp*() (page 376) - Tests for legacy DC optimal power flow using CLP solver.

### **t\_opf\_dc\_cplex**

**t\_opf\_dc\_cplex**(*quiet*)

*t\_opf\_dc\_cplex*() (page 376) - Tests for legacy DC optimal power flow using CPLEX solver.

### **t\_opf\_dc\_default**

**t\_opf\_dc\_default**(*quiet*)

*t\_opf\_dc\_default*() (page 376) - Tests for legacy DC optimal power flow using DEFAULT solver.

**t\_opf\_dc\_glpk****t\_opf\_dc\_glpk**(*quiet*)*t\_opf\_dc\_glpk*() (page 377) - Tests for legacy DC optimal power flow using GLPK solver.**t\_opf\_dc\_gurobi****t\_opf\_dc\_gurobi**(*quiet*)*t\_opf\_dc\_gurobi*() (page 377) - Tests for legacy DC optimal power flow using Gurobi solver.**t\_opf\_dc\_ipopt****t\_opf\_dc\_ipopt**(*quiet*)*t\_opf\_dc\_ipopt*() (page 377) - Tests for legacy DC optimal power flow using MIPS solver.**t\_opf\_dc\_mips****t\_opf\_dc\_mips**(*quiet*)*t\_opf\_dc\_mips*() (page 377) - Tests for legacy DC optimal power flow using MIPS solver.**t\_opf\_dc\_mips\_sc****t\_opf\_dc\_mips\_sc**(*quiet*)*t\_opf\_dc\_mips\_sc*() (page 377) - Tests for legacy DC optimal power flow using MIPS-sc solver.**t\_opf\_dc\_mosek****t\_opf\_dc\_mosek**(*quiet*)*t\_opf\_dc\_mosek*() (page 377) - Tests for legacy DC optimal power flow using MOSEK solver.**t\_opf\_dc\_osqp****t\_opf\_dc\_osqp**(*quiet*)*t\_opf\_dc\_osqp*() (page 377) - Tests for legacy DC optimal power flow using OSQP solver.

### **t\_opf\_dc\_ot**

**t\_opf\_dc\_ot**(*quiet*)

*t\_opf\_dc\_ot*() (page 378) - Tests for legacy DC optimal power flow using Opt Tbx solvers.

### **t\_opf\_default**

**t\_opf\_default**(*quiet*)

*t\_opf\_default*() (page 378) - Tests for legacy AC optimal power flow using default solver.

### **t\_opf\_fmincon**

**t\_opf\_fmincon**(*quiet*)

*t\_opf\_fmincon*() (page 378) - Tests for legacy FMINCON-based optimal power flow.

### **t\_opf\_ipopt**

**t\_opf\_ipopt**(*quiet*)

*t\_opf\_ipopt*() (page 378) - Tests for legacy IPOPT-based AC optimal power flow.

### **t\_opf\_knitro**

**t\_opf\_knitro**(*quiet*)

*t\_opf\_knitro*() (page 378) - Tests for legacy Artelys Knitro-based optimal power flow.

### **t\_opf\_minopf**

**t\_opf\_minopf**(*quiet*)

*t\_opf\_minopf*() (page 378) - Tests for legacy MINOS-based optimal power flow.

### **t\_opf\_mips**

**t\_opf\_mips**(*quiet*)

*t\_opf\_mips*() (page 378) - Tests for legacy MIPS-based AC optimal power flow.

### **t\_opf\_model**

#### **t\_opf\_model**(*quiet*)

*t\_opf\_model*() (page 379) - Tests for *opf\_model* (page 220).

### **t\_opf\_softlims**

#### **t\_opf\_softlims**(*quiet*)

*t\_opf\_softlims*() (page 379) - Tests for userfcn callbacks (softlims) w/OPF.

Includes high-level tests of soft limits implementations.

### **t\_opf\_tspopf\_pdipm**

#### **t\_opf\_tspopf\_pdipm**(*quiet*)

*t\_opf\_tspopf\_pdipm*() (page 379) - Tests for legacy PDIPM-based optimal power flow.

### **t\_opf\_tspopf\_scpdipm**

#### **t\_opf\_tspopf\_scpdipm**(*quiet*)

*t\_opf\_tspopf\_scpdipm*() (page 379) - Tests for legacy SCPDIPM-based optimal power flow.

### **t\_opf\_tspopf\_tralm**

#### **t\_opf\_tspopf\_tralm**(*quiet*)

*t\_opf\_tspopf\_tralm*() (page 379) - Tests for legacy TRALM-based optimal power flow.

### **t\_opf\_userfcns**

#### **t\_opf\_userfcns**(*quiet*)

*t\_opf\_userfcns*() (page 379) - Tests for userfcn callbacks (reserves/iflms) w/OPF.

Includes high-level tests of reserves and iflms implementations.

## **t\_pf\_ac**

### **t\_pf\_ac**(*quiet*)

*t\_pf\_ac*() (page 380) - Tests for legacy AC power flow solvers.

## **t\_pf\_dc**

### **t\_pf\_dc**(*quiet*)

*t\_pf\_dc*() (page 380) - Tests for legacy DC power flow solver.

## **t\_pf\_radial**

### **t\_pf\_radial**(*quiet*)

*t\_pf\_radial*() (page 380) - Tests for legacy distribution power flow solvers.

## **t\_printpf**

### **t\_printpf**(*quiet*)

*t\_printpf*() (page 380) - Tests for `printpf`() .

## **t\_psse**

### **t\_psse**(*quiet*)

*t\_psse*() (page 380) - Tests for `psse2mpc`() and related functions.

## **t\_qps\_matpower**

### **t\_qps\_matpower**(*quiet*)

*t\_qps\_matpower*() (page 380) - Tests of QP solvers via (deprecated) `qps_matpower`() (page 325).

## **t\_runmarket**

### **t\_runmarket**(*quiet*)

*t\_runmarket*() (page 380) - Tests for `runmkt`, `smartmkt` and `auction`.

**t\_runopf\_w\_res****t\_runopf\_w\_res**(*quiet*)

*t\_runopf\_w\_res*() (page 381) - Tests *runopf\_w\_res*() (page 236) and the associated callbacks.

**t\_scale\_load****t\_scale\_load**(*quiet*)

*t\_scale\_load*() (page 381) - Tests for *scale\_load*() (page 349).

**t\_total\_load****t\_total\_load**(*quiet*)

*t\_total\_load*() (page 381) - Tests for *total\_load*() (page 351).

**t\_totcost****t\_totcost**(*quiet*)

*t\_totcost*() (page 381) - Tests for *totcost*() .

**t\_vdep\_load****t\_vdep\_load**(*quiet*)

*t\_vdep\_load*() (page 381) - Test voltage dependent ZIP load model for legacy PF, CPF, OPF.

### 5.3.2 Legacy MATPOWER Test Data

**opf\_nle\_fcn1****opf\_nle\_fcn1**(*x*)

*opf\_nle\_fcn1*() (page 381) - Example user-defined nonlinear OPF constraint function.



## **opf\_nle\_hess1**

**opf\_nle\_hess1**(*x*, *lambda*)

*opf\_nle\_hess1*() (page 382) - Example user-defined nonlinear OPF constraint Hessian.

## **t\_auction\_case**

**t\_auction\_case**()

*t\_auction\_case*() (page 382) - Power flow data for testing auction code.

Please see caseformat for details on the case file format.

## **t\_case30\_userfcns**

**t\_case30\_userfcns**()

*t\_case30\_userfcns*() (page 382) - Power flow data for 30 bus, 6 gen case w/reserves & iflims.

Please see caseformat for details on the case file format.

Same as case30.m, but with fixed reserve and interface flow limit data. The reserve data is defined in the fields of mpc.reserves and the interface flow limit data in mpc.if at the bottom of the file.

## **t\_case9\_dcline**

**t\_case9\_dcline**()

*t\_case9\_dcline*() (page 382) - Same as *t\_case9\_opfv2*() (page 383) with addition of DC line data.

Please see caseformat for details on the case file format.

See also *toggle\_dcline*() (page 305), *idx\_dcline*() (page 344).

## **t\_case9\_opf**

**t\_case9\_opf**()

*t\_case9\_opf*() (page 382) - Power flow data for 9 bus, 3 generator case, with OPF data.

Please see caseformat for details on the case file format.

**t\_case9\_opfv2****t\_case9\_opfv2()**

*t\_case9\_opfv2()* (page 383) - Power flow data for 9 bus, 3 generator case, with OPF data.

Please see caseformat for details on the case file format.

**t\_case9\_pf****t\_case9\_pf()**

*t\_case9\_pf()* (page 383) - Power flow data for 9 bus, 3 generator case, no OPF data.

Please see caseformat for details on the case file format.

**t\_case9\_pfv2****t\_case9\_pfv2()**

*t\_case9\_pfv2()* (page 383) - Power flow data for 9 bus, 3 generator case, no OPF data.

Please see caseformat for details on the case file format.

**t\_case9\_save2psse****t\_case9\_save2psse()**

*t\_case9\_save2psse()* (page 383) - Power flow data to test save2psse().

Please see caseformat for details on the case file format.

**t\_case\_ext****t\_case\_ext()**

*t\_case\_ext()* (page 383) - Case data in external format used to test ext2int() and int2ext().

**t\_case\_int****t\_case\_int()**

*t\_case\_int()* (page 383) - Case data in internal format used to test ext2int() and int2ext().

**t\_cpf\_cb1**

**t\_cpf\_cb1**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*t\_cpf\_cb1()* (page 384) - User callback function 1 for continuation power flow testing.

**t\_cpf\_cb2**

**t\_cpf\_cb2**(*k, nx, cx, px, done, rollback, evnts, cb\_data, cb\_args, results*)

*t\_cpf\_cb2()* (page 384) - User callback function 2 for continuation power flow testing.

## Previous Versions

Reference documentation for previous versions of MATPOWER can be found in the corresponding Function Reference.

- [MATPOWER 4.0 Function Reference](#)
- [MATPOWER 4.1 Function Reference](#)
- [MATPOWER 5.0 Function Reference](#)
- [MATPOWER 5.1 Function Reference](#)
- [MATPOWER 6.0 Function Reference](#)
- [MATPOWER 7.0 Function Reference](#)
- [MATPOWER 7.1 Function Reference](#)

## A

- add\_aux\_data() (*mp.math\_model* method), 124
- add\_constraints() (*mp.math\_model* method), 125
- add\_constraints() (*mp.mm\_element* method), 145
- add\_constraints() (*mp.mme\_branch\_opf\_ac* method), 148
- add\_constraints() (*mp.mme\_branch\_opf\_acc* method), 149
- add\_constraints() (*mp.mme\_branch\_opf\_acp* method), 149
- add\_constraints() (*mp.mme\_branch\_opf\_dc* method), 150
- add\_constraints() (*mp.mme\_bus\_opf\_acc* method), 151
- add\_constraints() (*mp.mme\_buslink\_opf\_acc* method), 202
- add\_constraints() (*mp.mme\_buslink\_opf\_acp* method), 202
- add\_constraints() (*mp.mme\_buslink\_pf\_ac* method), 199
- add\_constraints() (*mp.mme\_buslink\_pf\_acc* method), 200
- add\_constraints() (*mp.mme\_buslink\_pf\_acp* method), 200
- add\_constraints() (*mp.mme\_gen\_opf\_ac* method), 154
- add\_constraints() (*mp.mme\_gen\_opf\_ac\_oval* method), 212
- add\_constraints() (*mp.mme\_gen\_opf\_dc* method), 154
- add\_constraints() (*mp.mme\_legacy\_dcline\_opf* method), 211
- add\_constraints() (*mp.mme\_reserve\_gen* method), 178
- add\_constraints() (*mp.mme\_reserve\_zone* method), 179
- add\_costs() (*mp.math\_model* method), 125
- add\_costs() (*mp.math\_model\_pf* method), 127
- add\_costs() (*mp.mm\_element* method), 146
- add\_costs() (*mp.mme\_gen\_opf* method), 153
- add\_costs() (*mp.mme\_gen\_opf\_ac* method), 154
- add\_costs() (*mp.mme\_legacy\_dcline\_opf* method), 211
- add\_costs() (*mp.mme\_reserve\_gen* method), 178
- add\_elements() (*mp.mapped\_array* method), 169
- add\_legacy\_cost() (*mp.mm\_shared\_opf\_legacy* method), 143
- add\_legacy\_cost() (*opf\_model* method), 224
- add\_legacy\_user\_constraints() (*mp.mm\_shared\_opf\_legacy* method), 143
- add\_legacy\_user\_constraints\_ac() (*mp.mm\_shared\_opf\_legacy* method), 143
- add\_legacy\_user\_costs() (*mp.mm\_shared\_opf\_legacy* method), 143
- add\_legacy\_user\_vars() (*mp.mm\_shared\_opf\_legacy* method), 143
- add\_named\_set() (*mp.math\_model\_opf\_acci\_legacy* method), 134
- add\_named\_set() (*mp.math\_model\_opf\_accs\_legacy* method), 135
- add\_named\_set() (*mp.math\_model\_opf\_acpi\_legacy* method), 136
- add\_named\_set() (*mp.math\_model\_opf\_acps\_legacy* method), 137
- add\_named\_set() (*mp.math\_model\_opf\_dc\_legacy* method), 139
- add\_named\_set() (*opf\_model* method), 224
- add\_names() (*mp.mapped\_array* method), 169
- add\_node() (*mp.net\_model* method), 96
- add\_node\_balance\_constraints() (*mp.math\_model* method), 125
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acci* method), 131
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_accs* method), 131
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acpi* method), 132
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acps* method), 132
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acci* method), 134
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_accs* method), 135
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acpi* method), 136
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_acps* method), 137
- add\_node\_balance\_constraints() (*mp.math\_model\_opf\_dc* method), 138
- add\_node\_balance\_constraints() (*mp.math\_model\_pf\_acci* method), 128
- add\_node\_balance\_constraints() (*mp.math\_model\_pf\_accs* method), 128
- add\_node\_balance\_constraints() (*mp.math\_model\_pf\_acpi* method), 129
- add\_node\_balance\_constraints() (*mp.math\_model\_pf\_acps* method), 129
- add\_node\_balance\_constraints() (*mp.math\_model\_pf\_dc* method), 130
- add\_nodes() (*mp.net\_model* method), 93
- add\_nodes() (*mp.mm\_element* method), 111
- add\_port() (*mp.net\_model* method), 96
- add\_state() (*mp.net\_model* method), 96
- add\_states() (*mp.net\_model* method), 94
- add\_states() (*mp.mm\_element* method), 111
- add\_system\_constraints() (*mp.math\_model* method), 125
- add\_system\_constraints() (*mp.math\_model\_opf\_acci\_legacy* method), 134
- add\_system\_constraints() (*mp.math\_model\_opf\_accs\_legacy* method), 135
- add\_system\_constraints() (*mp.math\_model\_opf\_acpi\_legacy* method), 137
- add\_system\_constraints() (*mp.math\_model\_opf\_acps\_legacy* method), 138
- add\_system\_constraints() (*mp.math\_model\_opf\_dc\_legacy* method), 139
- add\_system\_costs() (*mp.math\_model* method), 126
- add\_system\_costs() (*mp.math\_model\_opf\_acci\_legacy* method),

- 134  
 add\_system\_costs() (*mp.math\_model\_opf\_accs\_legacy* method), 135  
 add\_system\_costs() (*mp.math\_model\_opf\_acpi\_legacy* method), 137  
 add\_system\_costs() (*mp.math\_model\_opf\_acps\_legacy* method), 138  
 add\_system\_costs() (*mp.math\_model\_opf\_dc\_legacy* method), 139  
 add\_system\_vars() (*mp.math\_model* method), 124  
 add\_system\_vars() (*mp.math\_model\_opf* method), 133  
 add\_system\_vars() (*mp.math\_model\_pf* method), 127  
 add\_system\_vars\_pf() (*mp.mm\_shared\_pfcpf\_acci* method), 141  
 add\_system\_vars\_pf() (*mp.mm\_shared\_pfcpf\_accs* method), 141  
 add\_system\_vars\_pf() (*mp.mm\_shared\_pfcpf\_acpi* method), 142  
 add\_system\_vars\_pf() (*mp.mm\_shared\_pfcpf\_acps* method), 142  
 add\_system\_vars\_pf() (*mp.mm\_shared\_pfcpf\_dc* method), 142  
 add\_system\_varset\_pf() (*mp.mm\_shared\_pfcpf\_ac* method), 139  
 add\_userfcn() (*built-in* function), 303  
 add\_var() (*mp.net\_model* method), 97  
 add\_vars() (*mp.math\_model* method), 124  
 add\_vars() (*mp.math\_model\_opf\_acci\_legacy* method), 134  
 add\_vars() (*mp.math\_model\_opf\_accs\_legacy* method), 135  
 add\_vars() (*mp.math\_model\_opf\_acpi\_legacy* method), 137  
 add\_vars() (*mp.math\_model\_opf\_acps\_legacy* method), 138  
 add\_vars() (*mp.math\_model\_opf\_dc\_legacy* method), 139  
 add\_vars() (*mp.mm\_element* method), 145  
 add\_vars() (*mp.nme\_buslink\_pf\_ac* method), 199  
 add\_vars() (*mp.nme\_gen\_opf* method), 153  
 add\_vars() (*mp.nme\_legacy\_dcline\_opf* method), 211  
 add\_vars() (*mp.nme\_reserve\_gen* method), 178  
 add\_vvars() (*mp.net\_model* method), 95  
 add\_vvars() (*mp.nm\_element* method), 111  
 add\_vvars() (*mp.nme\_bus3p\_acp* method), 194  
 add\_vvars() (*mp.nme\_bus3p\_acp* method), 194  
 add\_vvars() (*mp.nme\_bus\_acc* method), 117  
 add\_vvars() (*mp.nme\_bus\_acp* method), 117  
 add\_vvars() (*mp.nme\_bus\_dc* method), 118  
 add\_zvars() (*mp.net\_model* method), 95  
 add\_zvars() (*mp.nm\_element* method), 112  
 add\_zvars() (*mp.nme\_buslink* method), 197  
 add\_zvars() (*mp.nme\_gen3p* method), 195  
 add\_zvars() (*mp.nme\_gen\_ac* method), 118  
 add\_zvars() (*mp.nme\_gen\_dc* method), 119  
 add\_zvars() (*mp.nme\_legacy\_dcline\_ac* method), 208  
 add\_zvars() (*mp.nme\_legacy\_dcline\_dc* method), 209  
 ang\_diff\_fcn() (*mp.nme\_branch\_acc* method), 116  
 ang\_diff\_hess() (*mp.nme\_branch\_acc* method), 116  
 ang\_diff\_params() (*mp.nme\_branch\_opf* method), 148  
 ang\_diff\_prices() (*mp.nme\_branch\_opf* method), 148  
 ang\_diff\_prices() (*mp.nme\_branch\_opf\_acc* method), 149  
 apply\_changes() (*built-in* function), 329  
 apply\_vm\_setpoint() (*mp.dme\_gen* method), 53  
 apply\_vm\_setpoint() (*mp.dme\_gen3p* method), 186  
 apply\_vm\_setpoints() (*mp.dme\_legacy\_dcline* method), 206  
 aux\_data (*mp.math\_model* attribute), 123  
 aux\_data\_va\_vm() (*mp.form\_ac* method), 83  
 aux\_data\_va\_vm() (*mp.form\_acc* method), 85  
 aux\_data\_va\_vm() (*mp.form\_acp* method), 89
- ## B
- B (*mp.form\_dc* attribute), 90  
 b\_fr (*mp.dme\_branch* attribute), 47  
 b\_to (*mp.dme\_branch* attribute), 48  
 base\_kva (*mp.data\_model* attribute), 29  
 base\_mva (*mp.data\_model* attribute), 29  
 bs (*mp.dme\_shunt* attribute), 57  
 build() (*mp.data\_model* method), 30  
 build() (*mp.dm\_converter* method), 60  
 build() (*mp.math\_model* method), 123  
 build() (*mp.math\_model\_opf\_acci\_legacy* method), 134  
 build() (*mp.math\_model\_opf\_accs\_legacy* method), 135  
 build() (*mp.math\_model\_opf\_acpi\_legacy* method), 137  
 build() (*mp.math\_model\_opf\_acps\_legacy* method), 138  
 build() (*mp.math\_model\_opf\_dc\_legacy* method), 139  
 build() (*mp.net\_model* method), 93  
 build\_aux\_data() (*mp.math\_model\_opf* method), 133  
 build\_aux\_data() (*mp.mm\_shared\_pfcpf* method), 139  
 build\_aux\_data() (*mp.mm\_shared\_pfcpf\_acci* method), 141  
 build\_aux\_data() (*mp.mm\_shared\_pfcpf\_acpi* method), 142  
 build\_aux\_data() (*mp.mm\_shared\_pfcpf\_acps* method), 142  
 build\_aux\_data() (*mp.mm\_shared\_pfcpf\_dc* method), 142  
 build\_aux\_data\_i() (*mp.mm\_shared\_pfcpf\_ac\_i* method), 140  
 build\_base\_aux\_data() (*mp.math\_model* method), 124  
 build\_cost\_params() (*mp.dme\_gen\_opf* method), 54  
 build\_cost\_params() (*mp.dme\_legacy\_dcline\_opf* method), 207  
 build\_cost\_params() (*mp.nme\_gen\_opf\_ac* method), 154  
 build\_cost\_params() (*mp.nme\_gen\_opf\_dc* method), 154  
 build\_cost\_params() (*mp.nme\_legacy\_dcline\_opf* method), 211  
 build\_legacy() (*mp.mm\_shared\_opf\_legacy* method), 143  
 build\_params() (*mp.data\_model* method), 31  
 build\_params() (*mp.dm\_element* method), 42  
 build\_params() (*mp.dme\_branch* method), 48  
 build\_params() (*mp.dme\_bus* method), 51  
 build\_params() (*mp.dme\_bus3p* method), 184  
 build\_params() (*mp.dme\_buslink* method), 192  
 build\_params() (*mp.dme\_gen* method), 53  
 build\_params() (*mp.dme\_gen3p* method), 186  
 build\_params() (*mp.dme\_legacy\_dcline* method), 206  
 build\_params() (*mp.dme\_line3p* method), 189  
 build\_params() (*mp.dme\_load* method), 56  
 build\_params() (*mp.dme\_load3p* method), 187  
 build\_params() (*mp.dme\_reserve\_gen* method), 177  
 build\_params() (*mp.dme\_reserve\_zone* method), 178  
 build\_params() (*mp.dme\_shunt* method), 58  
 build\_params() (*mp.dme\_xfmr3p* method), 191  
 build\_params() (*mp.net\_model* method), 94  
 build\_params() (*mp.net\_model\_ac* method), 102  
 build\_params() (*mp.net\_model\_dc* method), 108  
 build\_params() (*mp.nm\_element* method), 112  
 build\_params() (*mp.nme\_branch\_ac* method), 115  
 build\_params() (*mp.nme\_branch\_dc* method), 116  
 build\_params() (*mp.nme\_buslink* method), 197  
 build\_params() (*mp.nme\_gen3p* method), 195  
 build\_params() (*mp.nme\_gen\_ac* method), 118  
 build\_params() (*mp.nme\_gen\_dc* method), 119  
 build\_params() (*mp.nme\_legacy\_dcline\_ac* method), 208  
 build\_params() (*mp.nme\_legacy\_dcline\_dc* method), 209  
 build\_params() (*mp.nme\_line3p* method), 196  
 build\_params() (*mp.nme\_load3p* method), 195  
 build\_params() (*mp.nme\_load\_ac* method), 120  
 build\_params() (*mp.nme\_load\_dc* method), 120  
 build\_params() (*mp.nme\_shunt\_ac* method), 121  
 build\_params() (*mp.nme\_shunt\_dc* method), 122  
 build\_params() (*mp.nme\_xfmr3p* method), 196  
 bus (*mp.dmce\_load3p\_mpc2* attribute), 182  
 bus (*mp.dmce\_load\_mpc2* attribute), 71  
 bus (*mp.dmce\_shunt\_mpc2* attribute), 72  
 bus (*mp.dme\_buslink* attribute), 191  
 bus (*mp.dme\_gen* attribute), 52  
 bus (*mp.dme\_gen3p* attribute), 185  
 bus (*mp.dme\_load* attribute), 55  
 bus (*mp.dme\_load3p* attribute), 187  
 bus (*mp.dme\_shunt* attribute), 57  
 bus3p (*mp.dme\_buslink* attribute), 191  
 bus\_name\_export() (*mp.dmce\_bus\_mpc2* method), 70

bus\_name\_import() (*mp.dmce\_bus\_mpc2* method), 70  
 bus\_on (*mp.dme\_gen* attribute), 52  
 bus\_on (*mp.dme\_gen3p* attribute), 185  
 bus\_status\_import() (*mp.dmce\_bus3p\_mpc2* method), 181  
 bus\_status\_import() (*mp.dmce\_bus\_mpc2* method), 70  
 bustypes() (*built-in function*), 330

## C

C (*mp.nm\_element* attribute), 109  
 calc\_branch\_angle() (*built-in function*), 331  
 calc\_v\_i\_sum() (*built-in function*), 260  
 calc\_v\_pq\_sum() (*built-in function*), 261  
 calc\_v\_y\_sum() (*built-in function*), 262  
 callback\_vlim() (*mp.math\_model\_cpf\_acp* method), 131  
 case\_info() (*built-in function*), 331  
 caseformat() (*built-in function*), 237  
 cdf2mpc() (*built-in function*), 240  
 compare\_case() (*built-in function*), 331  
 connected\_components() (*built-in function*), 355  
 convert\_x\_m2n() (*mp.math\_model\_opf\_acc* method), 133  
 convert\_x\_m2n() (*mp.math\_model\_opf\_acp* method), 136  
 convert\_x\_m2n() (*mp.math\_model\_opf\_dc* method), 138  
 convert\_x\_m2n() (*mp.mm\_shared\_pfcpf\_acc* method), 140  
 convert\_x\_m2n() (*mp.mm\_shared\_pfcpf\_acp* method), 141  
 convert\_x\_m2n() (*mp.mm\_shared\_pfcpf\_dc* method), 143  
 copy() (*mp.data\_model* method), 30  
 copy() (*mp.dm\_converter* method), 60  
 copy() (*mp.dm\_element* method), 41  
 copy() (*mp.mapped\_array* method), 168  
 cost (*mp.mme\_gen\_opf* attribute), 153  
 cost (*mp.mme\_legacy\_dcline\_opf* attribute), 210  
 cost (*opf\_model* attribute), 221  
 cost\_table (*class in mp*), 162  
 cost\_table() (*mp.cost\_table* method), 163  
 cost\_table2gencost() (*mp.dmce\_gen\_mpc2* static method), 71  
 cost\_table\_utils (*class in mp*), 165  
 count() (*mp.data\_model* method), 30  
 count() (*mp.dm\_element* method), 41  
 count() (*mp.dme\_load* method), 56  
 count() (*mp.dme\_shunt* method), 58  
 count() (*mp.nm\_element* method), 111  
 cpf\_corrector() (*built-in function*), 270  
 cpf\_current\_mpc() (*built-in function*), 271  
 cpf\_default\_callback() (*built-in function*), 271  
 cpf\_detect\_events() (*built-in function*), 273  
 cpf\_flim\_event() (*built-in function*), 274  
 cpf\_flim\_event\_cb() (*built-in function*), 274  
 cpf\_nose\_event() (*built-in function*), 275  
 cpf\_nose\_event\_cb() (*built-in function*), 275  
 cpf\_p() (*built-in function*), 275  
 cpf\_p\_jac() (*built-in function*), 276  
 cpf\_plim\_event() (*built-in function*), 277  
 cpf\_plim\_event\_cb() (*built-in function*), 277  
 cpf\_predictor() (*built-in function*), 277  
 cpf\_qlim\_event() (*built-in function*), 278  
 cpf\_qlim\_event\_cb() (*built-in function*), 278  
 cpf\_register\_callback() (*built-in function*), 279  
 cpf\_register\_event() (*built-in function*), 280  
 cpf\_tangent() (*built-in function*), 280  
 cpf\_target\_lam\_event() (*built-in function*), 281  
 cpf\_target\_lam\_event\_cb() (*built-in function*), 281  
 cpf\_vlim\_event() (*built-in function*), 282  
 cpf\_vlim\_event\_cb() (*built-in function*), 282  
 create\_line\_construction\_table() (*mp.dmce\_line3p\_mpc2* method), 182  
 create\_line\_construction\_table() (*mp.dme\_line3p* method), 189

ctol (*mp.dme\_shared\_opf* attribute), 59  
 cxn\_idx\_prop() (*mp.dm\_element* method), 39  
 cxn\_idx\_prop() (*mp.dme\_branch* method), 48  
 cxn\_idx\_prop() (*mp.dme\_buslink* method), 192  
 cxn\_idx\_prop() (*mp.dme\_gen* method), 53  
 cxn\_idx\_prop() (*mp.dme\_gen3p* method), 186  
 cxn\_idx\_prop() (*mp.dme\_legacy\_dcline* method), 206  
 cxn\_idx\_prop() (*mp.dme\_line3p* method), 189  
 cxn\_idx\_prop() (*mp.dme\_load* method), 56  
 cxn\_idx\_prop() (*mp.dme\_load3p* method), 187  
 cxn\_idx\_prop() (*mp.dme\_shunt* method), 58  
 cxn\_idx\_prop() (*mp.dme\_xfmr3p* method), 190  
 cxn\_type() (*mp.dm\_element* method), 39  
 cxn\_type() (*mp.dme\_branch* method), 48  
 cxn\_type() (*mp.dme\_buslink* method), 192  
 cxn\_type() (*mp.dme\_gen* method), 53  
 cxn\_type() (*mp.dme\_gen3p* method), 186  
 cxn\_type() (*mp.dme\_legacy\_dcline* method), 206  
 cxn\_type() (*mp.dme\_line3p* method), 189  
 cxn\_type() (*mp.dme\_load* method), 56  
 cxn\_type() (*mp.dme\_load3p* method), 187  
 cxn\_type() (*mp.dme\_shunt* method), 58  
 cxn\_type() (*mp.dme\_xfmr3p* method), 190  
 cxn\_type\_prop() (*mp.dm\_element* method), 40

## D

D (*mp.nm\_element* attribute), 110  
 d2Abr\_dV2() (*built-in function*), 320  
 d2Ibr\_dV2() (*built-in function*), 318  
 d2Imis\_dV2() (*built-in function*), 321  
 d2Imis\_dVdSg() (*built-in function*), 322  
 d2Sbr\_dV2() (*built-in function*), 319  
 d2Sbus\_dV2() (*built-in function*), 324  
 dAbr\_dV() (*built-in function*), 313  
 data\_exists() (*mp.dmc\_element* method), 65  
 data\_field() (*mp.dmc\_element* method), 64  
 data\_field() (*mp.dmce\_branch\_mpc2* method), 70  
 data\_field() (*mp.dmce\_bus3p\_mpc2* method), 181  
 data\_field() (*mp.dmce\_bus\_mpc2* method), 70  
 data\_field() (*mp.dmce\_buslink\_mpc2* method), 183  
 data\_field() (*mp.dmce\_gen3p\_mpc2* method), 181  
 data\_field() (*mp.dmce\_gen\_mpc2* method), 71  
 data\_field() (*mp.dmce\_legacy\_dcline\_mpc2* method), 204  
 data\_field() (*mp.dmce\_line3p\_mpc2* method), 182  
 data\_field() (*mp.dmce\_load3p\_mpc2* method), 182  
 data\_field() (*mp.dmce\_load\_mpc2* method), 71  
 data\_field() (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
 data\_field() (*mp.dmce\_reserve\_zone\_mpc2* method), 176  
 data\_field() (*mp.dmce\_shunt\_mpc2* method), 72  
 data\_field() (*mp.dmce\_xfmr3p\_mpc2* method), 183  
 data\_model (*class in mp*), 28  
 data\_model() (*mp.data\_model* method), 29  
 data\_model\_build() (*mp.task* method), 15  
 data\_model\_build() (*mp.task\_cpf* method), 22  
 data\_model\_build\_post() (*mp.task* method), 15  
 data\_model\_build\_post() (*mp.task\_opf* method), 23  
 data\_model\_build\_post() (*mp.task\_opf\_legacy* method), 27  
 data\_model\_build\_pre() (*mp.task* method), 15  
 data\_model\_class() (*mp.extension* method), 172  
 data\_model\_class() (*mp.task* method), 14  
 data\_model\_class\_default() (*mp.task* method), 14  
 data\_model\_class\_default() (*mp.task\_cpf* method), 22  
 data\_model\_class\_default() (*mp.task\_opf* method), 23  
 data\_model\_cpf (*class in mp*), 35  
 data\_model\_cpf() (*mp.data\_model\_cpf* method), 35  
 data\_model\_create() (*mp.task* method), 14  
 data\_model\_element() (*mp.dmc\_element* method), 64



- data\_model\_element() (*mp.mm\_element* method), 145  
 data\_model\_element() (*mp.nm\_element* method), 110  
 data\_model\_opf (class in *mp*), 35  
 data\_model\_opf() (*mp.data\_model\_opf* method), 35  
 data\_model\_update() (*mp.math\_model* method), 127  
 data\_model\_update() (*mp.mm\_element* method), 146  
 data\_model\_update\_off() (*mp.mm\_element* method), 146  
 data\_model\_update\_on() (*mp.mm\_element* method), 146  
 data\_model\_update\_on() (*mp.mme\_branch\_opf\_ac* method), 148  
 data\_model\_update\_on() (*mp.mme\_branch\_opf\_dc* method), 150  
 data\_model\_update\_on() (*mp.mme\_branch\_pf\_ac* method), 147  
 data\_model\_update\_on() (*mp.mme\_branch\_pf\_dc* method), 148  
 data\_model\_update\_on() (*mp.mme\_bus3p* method), 197  
 data\_model\_update\_on() (*mp.mme\_bus\_opf\_acc* method), 151  
 data\_model\_update\_on() (*mp.mme\_bus\_opf\_acp* method), 152  
 data\_model\_update\_on() (*mp.mme\_bus\_opf\_dc* method), 152  
 data\_model\_update\_on() (*mp.mme\_bus\_pf\_ac* method), 150  
 data\_model\_update\_on() (*mp.mme\_bus\_pf\_dc* method), 150  
 data\_model\_update\_on() (*mp.mme\_gen3p* method), 198  
 data\_model\_update\_on() (*mp.mme\_gen\_opf\_ac* method), 154  
 data\_model\_update\_on() (*mp.mme\_gen\_opf\_dc* method), 154  
 data\_model\_update\_on() (*mp.mme\_gen\_pf\_ac* method), 152  
 data\_model\_update\_on() (*mp.mme\_gen\_pf\_dc* method), 153  
 data\_model\_update\_on() (*mp.mme\_legacy\_dcline\_opf\_ac* method), 211  
 data\_model\_update\_on() (*mp.mme\_legacy\_dcline\_opf\_dc* method), 211  
 data\_model\_update\_on() (*mp.mme\_legacy\_dcline\_pf\_ac* method), 210  
 data\_model\_update\_on() (*mp.mme\_legacy\_dcline\_pf\_dc* method), 210  
 data\_model\_update\_on() (*mp.mme\_line3p* method), 198  
 data\_model\_update\_on() (*mp.mme\_load\_cpf* method), 156  
 data\_model\_update\_on() (*mp.mme\_load\_pf\_ac* method), 155  
 data\_model\_update\_on() (*mp.mme\_load\_pf\_dc* method), 155  
 data\_model\_update\_on() (*mp.mme\_reserve\_gen* method), 178  
 data\_model\_update\_on() (*mp.mme\_reserve\_zone* method), 179  
 data\_model\_update\_on() (*mp.mme\_shunt\_cpf* method), 157  
 data\_model\_update\_on() (*mp.mme\_shunt\_pf\_ac* method), 156  
 data\_model\_update\_on() (*mp.mme\_shunt\_pf\_dc* method), 157  
 data\_model\_update\_on() (*mp.mme\_xfmr3p* method), 199  
 data\_subs() (*mp.dmc\_element* method), 65  
 data\_subs() (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
 data\_subs() (*mp.dmce\_reserve\_zone\_mpc2* method), 176  
 dc (*mp.task\_opf* attribute), 23  
 dc (*mp.task\_pf* attribute), 20  
 dcline\_cost\_export() (*mp.dmce\_legacy\_dcline\_mpc2* method), 204  
 dcline\_cost\_import() (*mp.dmce\_legacy\_dcline\_mpc2* method), 204  
 dcopyf() (built-in function), 286  
 dcopyf\_solver() (built-in function), 287  
 dcopyf() (built-in function), 262  
 def\_set\_types() (*mp.math\_model\_opf\_acci\_legacy* method), 134  
 def\_set\_types() (*mp.math\_model\_opf\_accs\_legacy* method), 135  
 def\_set\_types() (*mp.math\_model\_opf\_acpi\_legacy* method), 137  
 def\_set\_types() (*mp.math\_model\_opf\_acps\_legacy* method), 137  
 def\_set\_types() (*mp.math\_model\_opf\_dc\_legacy* method), 139  
 def\_set\_types() (*mp.net\_model* method), 95  
 def\_set\_types() (*mp.net\_model\_ac* method), 102  
 def\_set\_types() (*mp.net\_model\_acc* method), 105  
 def\_set\_types() (*mp.net\_model\_acp* method), 106  
 def\_set\_types() (*mp.net\_model\_dc* method), 108  
 def\_set\_types() (*opf\_model* method), 222  
 def\_set\_types\_legacy() (*mp.mm\_shared\_opf\_legacy* method), 143  
 default\_export\_data\_nrows() (*mp.dmc\_element* method), 69  
 default\_export\_data\_table() (*mp.dmc\_element* method), 69  
 default\_export\_data\_table() (*mp.dmce\_branch\_mpc2* method), 70  
 default\_export\_data\_table() (*mp.dmce\_bus\_mpc2* method), 70  
 default\_export\_data\_table() (*mp.dmce\_gen\_mpc2* method), 71  
 default\_export\_data\_table() (*mp.dmce\_legacy\_dcline\_mpc2* method), 204  
 define\_constants() (built-in function), 332  
 delete\_elements() (*mp.mapped\_array* method), 169  
 dIbr\_dV() (built-in function), 310  
 diff\_poly\_fcn() (*mp.cost\_table* static method), 165  
 dImis\_dV() (built-in function), 314  
 disp\_load\_constant\_pf\_constraint() (*mp.mme\_gen\_opf\_ac* method), 154  
 display() (*mp.data\_model* method), 31  
 display() (*mp.dm\_converter* method), 61  
 display() (*mp.dm\_element* method), 43  
 display() (*mp.mapped\_array* method), 170  
 display() (*mp.math\_model* method), 124  
 display() (*mp.net\_model* method), 95  
 display() (*mp.nm\_element* method), 115  
 display() (*mp\_table* method), 160  
 display() (*opf\_model* method), 222  
 dm (*mp.task* attribute), 10  
 dm\_converter (class in *mp*), 60  
 dm\_converter\_build() (*mp.task* method), 13  
 dm\_converter\_class() (*mp.extension* method), 172  
 dm\_converter\_class() (*mp.task* method), 13  
 dm\_converter\_class() (*mp.task\_cpf* method), 22  
 dm\_converter\_class\_mpc2\_default() (*mp.task* method), 13  
 dm\_converter\_class\_mpc2\_default() (*mp.task\_opf\_legacy* method), 27  
 dm\_converter\_create() (*mp.task* method), 13  
 dm\_converter\_element() (*mp.dm\_element* method), 41  
 dm\_converter\_mpc2 (class in *mp*), 62  
 dm\_converter\_mpc2() (*mp.dm\_converter\_mpc2* method), 62  
 dm\_converter\_mpc2\_legacy (class in *mp*), 63  
 dm\_element (class in *mp*), 36  
 dm\_element\_classes() (*mp.extension* method), 173  
 dm\_element\_classes() (*mp.xt\_3p* method), 180  
 dm\_element\_classes() (*mp.xt\_legacy\_dcline* method), 203  
 dm\_element\_classes() (*mp.xt\_reserves* method), 174  
 dmc (*mp.task* attribute), 10  
 dmc\_element (class in *mp*), 63  
 dmc\_element\_classes() (*mp.extension* method), 173  
 dmc\_element\_classes() (*mp.xt\_3p* method), 180  
 dmc\_element\_classes() (*mp.xt\_legacy\_dcline* method), 203  
 dmc\_element\_classes() (*mp.xt\_reserves* method), 174  
 dmce\_branch\_mpc2 (class in *mp*), 70  
 dmce\_bus3p\_mpc2 (class in *mp*), 181  
 dmce\_bus\_mpc2 (class in *mp*), 70  
 dmce\_buslink\_mpc2 (class in *mp*), 183  
 dmce\_gen3p\_mpc2 (class in *mp*), 181  
 dmce\_gen\_mpc2 (class in *mp*), 70  
 dmce\_legacy\_dcline\_mpc2 (class in *mp*), 204  
 dmce\_line3p\_mpc2 (class in *mp*), 182  
 dmce\_load3p\_mpc2 (class in *mp*), 182  
 dmce\_load\_mpc2 (class in *mp*), 71  
 dmce\_reserve\_gen\_mpc2 (class in *mp*), 175  
 dmce\_reserve\_zone\_mpc2 (class in *mp*), 176  
 dmce\_shunt\_mpc2 (class in *mp*), 72  
 dmce\_xfmr3p\_mpc2 (class in *mp*), 183  
 dme\_branch (class in *mp*), 47  
 dme\_branch\_opf (class in *mp*), 49  
 dme\_bus (class in *mp*), 50  
 dme\_bus3p (class in *mp*), 183  
 dme\_bus3p\_opf (class in *mp*), 192  
 dme\_bus\_opf (class in *mp*), 51  
 dme\_buslink (class in *mp*), 191



dme\_buslink\_opf (class in mp), 193  
 dme\_gen (class in mp), 52  
 dme\_gen3p (class in mp), 185  
 dme\_gen3p\_opf (class in mp), 192  
 dme\_gen\_opf (class in mp), 54  
 dme\_legacy\_dcline (class in mp), 205  
 dme\_legacy\_dcline\_opf (class in mp), 207  
 dme\_line3p (class in mp), 188  
 dme\_line3p\_opf (class in mp), 193  
 dme\_load (class in mp), 55  
 dme\_load3p (class in mp), 186  
 dme\_load3p\_opf (class in mp), 193  
 dme\_load\_cpf (class in mp), 56  
 dme\_load\_opf (class in mp), 56  
 dme\_reserve\_gen (class in mp), 176  
 dme\_reserve\_zone (class in mp), 177  
 dme\_shared\_opf (class in mp), 59  
 dme\_shunt (class in mp), 57  
 dme\_shunt\_cpf (class in mp), 57  
 dme\_shunt\_opf (class in mp), 58  
 dme\_xfmr3p (class in mp), 190  
 dme\_xfmr3p\_opf (class in mp), 193  
 dSbr\_dV() (built-in function), 311  
 dSbus\_dV() (built-in function), 316

## E

e2i\_data() (built-in function), 255  
 e2i\_field() (built-in function), 256  
 element\_classes (mp.element\_container attribute), 166  
 element\_container (class in mp), 166  
 elements (mp.element\_container attribute), 166  
 end() (mp\_table method), 159  
 enforce\_q\_lims() (mp.task\_pf method), 20  
 ensure\_ref\_node() (mp.net\_model method), 100  
 et (mp.task attribute), 10  
 eval\_legacy\_cost() (mp.mm\_shared\_opf\_legacy method), 143  
 eval\_legacy\_cost() (opf\_model method), 222  
 eval\_poly\_fcn() (mp.cost\_table static method), 164  
 event\_vlim() (mp.math\_model\_cpf\_acp method), 131  
 expand\_z\_warmstart() (mp.math\_model\_cpf\_acps method), 132  
 export() (mp.dmc\_element method), 68  
 export\_col() (mp.dmc\_element method), 69  
 export\_table\_values() (mp.dmc\_element method), 68  
 export\_vars() (mp.dm\_element method), 40  
 export\_vars() (mp.dme\_branch method), 48  
 export\_vars() (mp.dme\_branch\_opf method), 49  
 export\_vars() (mp.dme\_bus method), 50  
 export\_vars() (mp.dme\_bus\_opf method), 51  
 export\_vars() (mp.dme\_gen method), 53  
 export\_vars() (mp.dme\_gen\_opf method), 54  
 export\_vars() (mp.dme\_legacy\_dcline method), 206  
 export\_vars() (mp.dme\_legacy\_dcline\_opf method), 207  
 export\_vars() (mp.dme\_load\_cpf method), 56  
 export\_vars() (mp.dme\_reserve\_gen method), 177  
 export\_vars() (mp.dme\_reserve\_zone method), 178  
 export\_vars() (mp.dme\_shunt\_cpf method), 57  
 export\_vars\_offline\_val() (mp.dm\_element method), 41  
 export\_vars\_offline\_val() (mp.dme\_branch method), 48  
 export\_vars\_offline\_val() (mp.dme\_branch\_opf method), 49  
 export\_vars\_offline\_val() (mp.dme\_bus method), 50  
 export\_vars\_offline\_val() (mp.dme\_bus\_opf method), 51  
 export\_vars\_offline\_val() (mp.dme\_gen method), 53  
 export\_vars\_offline\_val() (mp.dme\_gen\_opf method), 54  
 export\_vars\_offline\_val() (mp.dme\_legacy\_dcline method), 206  
 export\_vars\_offline\_val() (mp.dme\_legacy\_dcline\_opf method), 207

export\_vars\_offline\_val() (mp.dme\_reserve\_gen method), 177  
 export\_vars\_offline\_val() (mp.dme\_reserve\_zone method), 178  
 ext2int() (built-in function), 254  
 extension (class in mp), 171  
 extract\_islands() (built-in function), 333  
 extract\_named\_args() (mp\_table static method), 160

## F

fbus (mp.dme\_branch attribute), 47  
 fbus (mp.dme\_legacy\_dcline attribute), 205  
 fbus (mp.dme\_line3p attribute), 188  
 fbus (mp.dme\_xfmr3p attribute), 190  
 fbus\_on (mp.dme\_legacy\_dcline attribute), 205  
 fd\_jac\_approx() (mp.math\_model\_pf\_acps method), 129  
 fdpf() (built-in function), 263  
 fdpf\_B\_matrix\_models() (mp.math\_model\_pf\_acps method), 129  
 feval\_w\_path() (built-in function), 334  
 find\_bridges() (built-in function), 335  
 find\_form\_class() (mp.form method), 74  
 find\_islands() (built-in function), 335  
 fixed\_q\_idx (mp.task\_pf attribute), 20  
 fixed\_q\_qty (mp.task\_pf attribute), 20  
 fmincopf() (built-in function), 286  
 form (class in mp), 72  
 form\_ac (class in mp), 74  
 form\_acc (class in mp), 83  
 form\_acp (class in mp), 87  
 form\_dc (class in mp), 89  
 form\_name() (mp.form method), 73  
 form\_name() (mp.form\_acc method), 84  
 form\_name() (mp.form\_acp method), 87  
 form\_name() (mp.form\_dc method), 90  
 form\_name() (mp.math\_model method), 123  
 form\_name() (mp.math\_model\_cpf\_acci method), 131  
 form\_name() (mp.math\_model\_cpf\_accs method), 131  
 form\_name() (mp.math\_model\_cpf\_acps method), 132  
 form\_name() (mp.math\_model\_cpf\_acps method), 132  
 form\_name() (mp.math\_model\_opf\_acci method), 134  
 form\_name() (mp.math\_model\_opf\_accs method), 135  
 form\_name() (mp.math\_model\_opf\_acpi method), 136  
 form\_name() (mp.math\_model\_opf\_acps method), 137  
 form\_name() (mp.math\_model\_opf\_dc method), 138  
 form\_name() (mp.math\_model\_pf\_acci method), 128  
 form\_name() (mp.math\_model\_pf\_accs method), 128  
 form\_name() (mp.math\_model\_pf\_acpi method), 129  
 form\_name() (mp.math\_model\_pf\_acps method), 129  
 form\_name() (mp.math\_model\_pf\_dc method), 130  
 form\_tag() (mp.form method), 73  
 form\_tag() (mp.form\_acc method), 84  
 form\_tag() (mp.form\_acp method), 88  
 form\_tag() (mp.form\_dc method), 90  
 form\_tag() (mp.math\_model method), 123  
 form\_tag() (mp.math\_model\_cpf\_acci method), 130  
 form\_tag() (mp.math\_model\_cpf\_accs method), 131  
 form\_tag() (mp.math\_model\_cpf\_acpi method), 132  
 form\_tag() (mp.math\_model\_cpf\_acps method), 132  
 form\_tag() (mp.math\_model\_opf\_acci method), 134  
 form\_tag() (mp.math\_model\_opf\_accs method), 135  
 form\_tag() (mp.math\_model\_opf\_acpi method), 136  
 form\_tag() (mp.math\_model\_opf\_acps method), 137  
 form\_tag() (mp.math\_model\_opf\_dc method), 138  
 form\_tag() (mp.math\_model\_pf\_acci method), 128  
 form\_tag() (mp.math\_model\_pf\_accs method), 128  
 form\_tag() (mp.math\_model\_pf\_acpi method), 129  
 form\_tag() (mp.math\_model\_pf\_acps method), 129  
 form\_tag() (mp.math\_model\_pf\_dc method), 130  
 format\_tag() (mp.dm\_converter method), 60

`format_tag()` (*mp.dm\_converter\_mpc2* method), 62  
`freq` (*mp.dme\_line3p* attribute), 188

## G

`g_fr` (*mp.dme\_branch* attribute), 47  
`g_to` (*mp.dme\_branch* attribute), 47  
`gausspf()` (*built-in function*), 263  
`gen` (*mp.dme\_reserve\_gen* attribute), 176  
`gen_cost_export()` (*mp.dmce\_gen\_mpc2* method), 71  
`gen_cost_import()` (*mp.dmce\_gen\_mpc2* method), 71  
`gencost2cost_table()` (*mp.dmce\_gen\_mpc2* static method), 71  
`genfuels()` (*built-in function*), 335  
`gentypes()` (*built-in function*), 336  
`get_export_size()` (*mp.dmc\_element* method), 66  
`get_export_size()` (*mp.dmce\_load\_mpc2* method), 71  
`get_export_size()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`get_export_size()` (*mp.dmce\_shunt\_mpc2* method), 72  
`get_export_spec()` (*mp.dmc\_element* method), 65  
`get_import_size()` (*mp.dmc\_element* method), 66  
`get_import_size()` (*mp.dmce\_load\_mpc2* method), 71  
`get_import_size()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`get_import_size()` (*mp.dmce\_shunt\_mpc2* method), 72  
`get_import_spec()` (*mp.dmc\_element* method), 65  
`get_input_table_values()` (*mp.dmc\_element* method), 67  
`get_losses()` (*built-in function*), 338  
`get_mpc()` (*mp.mm\_shared\_opf\_legacy* method), 143  
`get_mpc()` (*opf\_model* method), 222  
`get_node_idx()` (*mp.net\_model* method), 99  
`get_nv_()` (*mp.nm\_element* method), 112  
`get_params()` (*mp.form* method), 74  
`get_port_idx()` (*mp.net\_model* method), 99  
`get_reorder()` (*built-in function*), 260  
`get_state_idx()` (*mp.net\_model* method), 99  
`get_table()` (*mp.table\_subclass* method), 162  
`get_va()` (*mp.net\_model\_ac* method), 104  
`gs` (*mp.dme\_shunt* attribute), 57  
`gs_x_update()` (*mp.math\_model\_pf\_acps* method), 129

## H

`has_name()` (*mp.mapped\_array* method), 169  
`has_pq_cap()` (*mp.mme\_gen\_opf\_ac* method), 154  
`hasPQcap()` (*built-in function*), 339  
`have_cost()` (*mp.dme\_gen* method), 53  
`have_cost()` (*mp.dme\_gen\_opf* method), 54  
`have_cost()` (*mp.dme\_legacy\_dcline* method), 206  
`have_cost()` (*mp.dme\_legacy\_dcline\_opf* method), 207  
`have_feature_e4st()` (*built-in function*), 352  
`have_feature_minopf()` (*built-in function*), 353  
`have_feature_most()` (*built-in function*), 353  
`have_feature_mp_core()` (*built-in function*), 353  
`have_feature_pdipmopf()` (*built-in function*), 353  
`have_feature_regex_split()` (*built-in function*), 354  
`have_feature_scddipmopf()` (*built-in function*), 354  
`have_feature_sdp_pf()` (*built-in function*), 354  
`have_feature_smartmarket()` (*built-in function*), 354  
`have_feature_syngrid()` (*built-in function*), 355  
`have_feature_table()` (*built-in function*), 355  
`have_feature_tralmopf()` (*built-in function*), 355  
`horzcat()` (*mp.table* method), 160

## I

`i` (*mp.form\_ac* attribute), 76  
`i2e_data()` (*built-in function*), 258  
`i2e_field()` (*built-in function*), 259  
`i2on` (*mp.dm\_element* attribute), 38  
`i_dm` (*mp.task* attribute), 10

`i_mmm` (*mp.task* attribute), 10  
`i_nm` (*mp.task* attribute), 10  
`ID()` (*mp.dm\_element* method), 42  
`ID2i` (*mp.dm\_element* attribute), 38  
`idx_brch()` (*built-in function*), 339  
`idx_bus()` (*built-in function*), 340  
`idx_cost()` (*built-in function*), 341  
`idx_ct()` (*built-in function*), 342  
`idx_dcline()` (*built-in function*), 344  
`idx_gen()` (*built-in function*), 345  
`import()` (*mp.dm\_converter* method), 60  
`import()` (*mp.dm\_converter\_mpc2* method), 62  
`import()` (*mp.dmc\_element* method), 66  
`import()` (*mp.dmce\_line3p\_mpc2* method), 182  
`import()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`import_col()` (*mp.dmc\_element* method), 67  
`import_cost()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`import_qty()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`import_ramp()` (*mp.dmce\_reserve\_gen\_mpc2* method), 175  
`import_req()` (*mp.dmce\_reserve\_zone\_mpc2* method), 176  
`import_table_values()` (*mp.dmc\_element* method), 67  
`import_zones()` (*mp.dmce\_reserve\_zone\_mpc2* method), 176  
`incidence_matrix()` (*mp.nm\_element* method), 113  
`init_export()` (*mp.dm\_converter* method), 61  
`init_export()` (*mp.dm\_converter\_mpc2* method), 62  
`init_export_data()` (*mp.dmc\_element* method), 68  
`init_export_data()` (*mp.dmce\_bus\_mpc2* method), 70  
`init_indexed_name()` (*opf\_model* method), 226  
`init_set_types()` (*mp.math\_model\_opf\_acci\_legacy* method), 134  
`init_set_types()` (*mp.math\_model\_opf\_accs\_legacy* method), 135  
`init_set_types()` (*mp.math\_model\_opf\_acpi\_legacy* method), 137  
`init_set_types()` (*mp.math\_model\_opf\_acps\_legacy* method), 138  
`init_set_types()` (*mp.math\_model\_opf\_dc\_legacy* method), 139  
`init_set_types()` (*mp.net\_model* method), 95  
`init_set_types()` (*opf\_model* method), 222  
`init_set_types_legacy()` (*mp.mm\_shared\_opf\_legacy* method), 143  
`init_status()` (*mp.dm\_element* method), 42  
`init_status()` (*mp.dme\_bus* method), 50  
`init_status()` (*mp.dme\_bus3p* method), 184  
`initial_voltage_angle()` (*mp.net\_model\_acc* method), 106  
`initial_voltage_angle()` (*mp.net\_model\_acp* method), 107  
`initialize()` (*mp.data\_model* method), 30  
`initialize()` (*mp.dm\_element* method), 41  
`initialize()` (*mp.dme\_branch* method), 48  
`initialize()` (*mp.dme\_buslink* method), 192  
`initialize()` (*mp.dme\_gen* method), 53  
`initialize()` (*mp.dme\_gen3p* method), 186  
`initialize()` (*mp.dme\_legacy\_dcline* method), 206  
`initialize()` (*mp.dme\_line3p* method), 189  
`initialize()` (*mp.dme\_load3p* method), 187  
`initialize()` (*mp.dme\_xfmr3p* method), 191  
`inln` (*mp.form\_ac* attribute), 76  
`inln_hess` (*mp.form\_ac* attribute), 76  
`install_matpower()` (*built-in function*), 2  
`int2ext()` (*built-in function*), 257  
`interior_va()` (*mp.math\_model\_opf* method), 133  
`interior_va()` (*mp.math\_model\_opf\_acc* method), 133  
`interior_vm()` (*mp.mme\_bus\_opf\_ac* method), 151  
`interior_x0()` (*mp.math\_model\_opf* method), 133  
`interior_x0()` (*mp.mme\_bus3p\_opf\_acc* method), 200  
`interior_x0()` (*mp.mme\_bus3p\_opf\_acp* method), 200  
`interior_x0()` (*mp.mme\_bus\_opf\_acc* method), 151  
`interior_x0()` (*mp.mme\_bus\_opf\_acp* method), 152  
`interior_x0()` (*mp.mme\_bus\_opf\_dc* method), 152  
`interior_x0()` (*mp.mme\_buslink\_opf* method), 202  
`interior_x0()` (*mp.mme\_gen3p\_opf* method), 201  
`interior_x0()` (*mp.mme\_gen\_opf* method), 153

interior\_x0() (*mp.mme\_legacy\_dcline\_opf method*), 211  
interior\_x0() (*mp.mme\_line3p\_opf method*), 201  
interior\_x0() (*mp.mme\_xfmr3p\_opf method*), 201  
is\_valid() (*mp.NODE\_TYPE static method*), 170  
isempty() (*mp\_table method*), 158  
isload() (*built-in function*), 346  
isload() (*mp.dme\_gen method*), 53  
istable() (*mp\_table method*), 158  
iterations (*mp.task\_pf attribute*), 20

## K

K (*mp.form\_dc attribute*), 90

## L

L (*mp.form\_ac attribute*), 76  
label() (*mp.dm\_element method*), 39  
label() (*mp.dme\_branch method*), 48  
label() (*mp.dme\_bus method*), 50  
label() (*mp.dme\_bus3p method*), 184  
label() (*mp.dme\_buslink method*), 192  
label() (*mp.dme\_gen method*), 53  
label() (*mp.dme\_gen3p method*), 186  
label() (*mp.dme\_legacy\_dcline method*), 206  
label() (*mp.dme\_line3p method*), 189  
label() (*mp.dme\_load method*), 55  
label() (*mp.dme\_load3p method*), 187  
label() (*mp.dme\_reserve\_gen method*), 177  
label() (*mp.dme\_reserve\_zone method*), 178  
label() (*mp.dme\_shunt method*), 58  
label() (*mp.dme\_xfmr3p method*), 190  
labels() (*mp.dm\_element method*), 39  
labels() (*mp.dme\_branch method*), 48  
labels() (*mp.dme\_bus method*), 50  
labels() (*mp.dme\_bus3p method*), 184  
labels() (*mp.dme\_buslink method*), 192  
labels() (*mp.dme\_gen method*), 53  
labels() (*mp.dme\_gen3p method*), 186  
labels() (*mp.dme\_legacy\_dcline method*), 206  
labels() (*mp.dme\_line3p method*), 189  
labels() (*mp.dme\_load method*), 56  
labels() (*mp.dme\_load3p method*), 187  
labels() (*mp.dme\_reserve\_gen method*), 177  
labels() (*mp.dme\_reserve\_zone method*), 178  
labels() (*mp.dme\_shunt method*), 58  
labels() (*mp.dme\_xfmr3p method*), 190  
lc (*mp.dme\_line3p attribute*), 188  
lc\_tab (*mp.dme\_line3p attribute*), 189  
lc\_table\_var\_names() (*mp.dme\_line3p method*), 189  
legacy\_post\_run() (*mp.task\_cpf\_legacy method*), 25  
legacy\_post\_run() (*mp.task\_opf\_legacy method*), 27  
legacy\_post\_run() (*mp.task\_pf\_legacy method*), 24  
legacy\_user\_mod\_inputs() (*mp.dm\_converter\_mpc2\_legacy method*), 63  
legacy\_user\_nln\_constraints() (*mp.dm\_converter\_mpc2\_legacy method*), 63  
legacy\_user\_var\_names() (*mp.math\_model\_opf\_acci\_legacy method*), 134  
legacy\_user\_var\_names() (*mp.math\_model\_opf\_accs\_legacy method*), 135  
legacy\_user\_var\_names() (*mp.math\_model\_opf\_acpi\_legacy method*), 137  
legacy\_user\_var\_names() (*mp.math\_model\_opf\_acps\_legacy method*), 138  
legacy\_user\_var\_names() (*mp.math\_model\_opf\_dc\_legacy method*), 139  
len (*mp.dme\_line3p attribute*), 189  
length() (*mp.mapped\_array method*), 168

load2disp() (*built-in function*), 346  
loadcase() (*built-in function*), 241  
loadshed() (*built-in function*), 347  
loss0 (*mp.dme\_legacy\_dcline attribute*), 205  
loss1 (*mp.dme\_legacy\_dcline attribute*), 205

## M

M (*mp.form\_ac attribute*), 76  
main\_table\_var\_names() (*mp.dm\_element method*), 40  
main\_table\_var\_names() (*mp.dme\_branch method*), 48  
main\_table\_var\_names() (*mp.dme\_branch\_opf method*), 49  
main\_table\_var\_names() (*mp.dme\_bus method*), 50  
main\_table\_var\_names() (*mp.dme\_bus3p method*), 184  
main\_table\_var\_names() (*mp.dme\_bus\_opf method*), 51  
main\_table\_var\_names() (*mp.dme\_buslink method*), 192  
main\_table\_var\_names() (*mp.dme\_gen method*), 53  
main\_table\_var\_names() (*mp.dme\_gen3p method*), 186  
main\_table\_var\_names() (*mp.dme\_gen\_opf method*), 54  
main\_table\_var\_names() (*mp.dme\_legacy\_dcline method*), 206  
main\_table\_var\_names() (*mp.dme\_legacy\_dcline\_opf method*), 207  
main\_table\_var\_names() (*mp.dme\_line3p method*), 189  
main\_table\_var\_names() (*mp.dme\_load method*), 56  
main\_table\_var\_names() (*mp.dme\_load3p method*), 187  
main\_table\_var\_names() (*mp.dme\_reserve\_gen method*), 177  
main\_table\_var\_names() (*mp.dme\_reserve\_zone method*), 178  
main\_table\_var\_names() (*mp.dme\_shunt method*), 58  
main\_table\_var\_names() (*mp.dme\_xfmr3p method*), 190  
make\_vcorr() (*built-in function*), 264  
make\_zpv() (*built-in function*), 264  
makeAang() (*built-in function*), 289  
makeAppq() (*built-in function*), 289  
makeAvl() (*built-in function*), 290  
makeAy() (*built-in function*), 290  
makeB() (*built-in function*), 325  
makeBdc() (*built-in function*), 326  
makeJac() (*built-in function*), 326  
makeLODF() (*built-in function*), 327  
makePTDF() (*built-in function*), 327  
makeSbus() (*built-in function*), 328  
makeSdzip() (*built-in function*), 329  
makeYbus() (*built-in function*), 329  
mapped\_array (*class in mp*), 167  
mapped\_array() (*mp.mapped\_array method*), 168  
margcost() (*built-in function*), 291  
math\_model (*class in mp*), 122  
math\_model\_build() (*mp.task method*), 18  
math\_model\_class() (*mp.extension method*), 173  
math\_model\_class() (*mp.task method*), 17  
math\_model\_class\_default() (*mp.task method*), 18  
math\_model\_class\_default() (*mp.task\_cpf method*), 22  
math\_model\_class\_default() (*mp.task\_opf method*), 23  
math\_model\_class\_default() (*mp.task\_opf\_legacy method*), 27  
math\_model\_class\_default() (*mp.task\_pf method*), 21  
math\_model\_cpf\_acc (*class in mp*), 130  
math\_model\_cpf\_acc() (*mp.math\_model\_cpf\_acc method*), 130  
math\_model\_cpf\_acci (*class in mp*), 130  
math\_model\_cpf\_accs (*class in mp*), 131  
math\_model\_cpf\_acp (*class in mp*), 131  
math\_model\_cpf\_acp() (*mp.math\_model\_cpf\_acp method*), 131  
math\_model\_cpf\_acpi (*class in mp*), 132  
math\_model\_cpf\_acps (*class in mp*), 132  
math\_model\_create() (*mp.task method*), 18  
math\_model\_element() (*mp.nm\_element method*), 111  
math\_model\_opf (*class in mp*), 132  
math\_model\_opf\_ac (*class in mp*), 133  
math\_model\_opf\_acc (*class in mp*), 133  
math\_model\_opf\_acc() (*mp.math\_model\_opf\_acc method*), 133

- `math_model_opf_acci` (class in mp), 134  
`math_model_opf_acci_legacy` (class in mp), 134  
`math_model_opf_acci_legacy()` (mp.math\_model\_opf\_acci\_legacy method), 134  
`math_model_opf_accs` (class in mp), 135  
`math_model_opf_accs_legacy` (class in mp), 135  
`math_model_opf_accs_legacy()` (mp.math\_model\_opf\_accs\_legacy method), 135  
`math_model_opf_acp` (class in mp), 136  
`math_model_opf_acp()` (mp.math\_model\_opf\_acp method), 136  
`math_model_opf_acpi` (class in mp), 136  
`math_model_opf_acpi_legacy` (class in mp), 136  
`math_model_opf_acpi_legacy()` (mp.math\_model\_opf\_acpi\_legacy method), 136  
`math_model_opf_acps` (class in mp), 137  
`math_model_opf_acps_legacy` (class in mp), 137  
`math_model_opf_acps_legacy()` (mp.math\_model\_opf\_acps\_legacy method), 137  
`math_model_opf_dc` (class in mp), 138  
`math_model_opf_dc()` (mp.math\_model\_opf\_dc method), 138  
`math_model_opf_dc_legacy` (class in mp), 138  
`math_model_opf_dc_legacy()` (mp.math\_model\_opf\_dc\_legacy method), 138  
`math_model_opt()` (mp.task method), 19  
`math_model_opt()` (mp.task\_cpf method), 22  
`math_model_pf` (class in mp), 127  
`math_model_pf_ac` (class in mp), 128  
`math_model_pf_ac()` (mp.math\_model\_pf\_ac method), 128  
`math_model_pf_acci` (class in mp), 128  
`math_model_pf_accs` (class in mp), 128  
`math_model_pf_acpi` (class in mp), 129  
`math_model_pf_acps` (class in mp), 129  
`math_model_pf_dc` (class in mp), 130  
`math_model_pf_dc()` (mp.math\_model\_pf\_dc method), 130  
`max_pwl_cost()` (mp.cost\_table method), 164  
`max_pwl_cost()` (mp.cost\_table\_utils static method), 166  
`max_pwl_gencost()` (mp.dme\_gen\_opf method), 54  
`message` (mp.task attribute), 10  
`miqps_matpower()` (built-in function), 325  
`mm` (mp.task attribute), 10  
`mm_element` (class in mp), 144  
`mm_element_classes()` (mp.extension method), 173  
`mm_element_classes()` (mp.xt\_3p method), 181  
`mm_element_classes()` (mp.xt\_legacy\_dcline method), 204  
`mm_element_classes()` (mp.xt\_oval\_cap\_curve method), 212  
`mm_element_classes()` (mp.xt\_reserves method), 175  
`mm_opt` (mp.task attribute), 10  
`mm_shared_opf_legacy` (class in mp), 143  
`mm_shared_pfcopf` (class in mp), 139  
`mm_shared_pfcopf_ac` (class in mp), 139  
`mm_shared_pfcopf_ac_i` (class in mp), 140  
`mm_shared_pfcopf_acc` (class in mp), 140  
`mm_shared_pfcopf_acci` (class in mp), 141  
`mm_shared_pfcopf_accs` (class in mp), 141  
`mm_shared_pfcopf_acp` (class in mp), 141  
`mm_shared_pfcopf_acpi` (class in mp), 142  
`mm_shared_pfcopf_acps` (class in mp), 142  
`mm_shared_pfcopf_dc` (class in mp), 142  
`mme_branch` (class in mp), 147  
`mme_branch_opf` (class in mp), 148  
`mme_branch_opf_ac` (class in mp), 148  
`mme_branch_opf_acc` (class in mp), 149  
`mme_branch_opf_acp` (class in mp), 149  
`mme_branch_opf_dc` (class in mp), 149  
`mme_branch_pf_ac` (class in mp), 147  
`mme_branch_pf_dc` (class in mp), 148  
`mme_bus` (class in mp), 150  
`mme_bus3p` (class in mp), 197  
`mme_bus3p_opf_acc` (class in mp), 200  
`mme_bus3p_opf_acp` (class in mp), 200  
`mme_bus_opf_ac` (class in mp), 151  
`mme_bus_opf_acc` (class in mp), 151  
`mme_bus_opf_acp` (class in mp), 151  
`mme_bus_opf_dc` (class in mp), 152  
`mme_bus_pf_ac` (class in mp), 150  
`mme_bus_pf_dc` (class in mp), 150  
`mme_buslink` (class in mp), 199  
`mme_buslink_opf` (class in mp), 202  
`mme_buslink_opf_acc` (class in mp), 202  
`mme_buslink_opf_acp` (class in mp), 202  
`mme_buslink_pf_ac` (class in mp), 199  
`mme_buslink_pf_acc` (class in mp), 199  
`mme_buslink_pf_acp` (class in mp), 200  
`mme_gen` (class in mp), 152  
`mme_gen3p` (class in mp), 198  
`mme_gen3p_opf` (class in mp), 201  
`mme_gen_opf` (class in mp), 153  
`mme_gen_opf_ac` (class in mp), 154  
`mme_gen_opf_ac_oval` (class in mp), 212  
`mme_gen_opf_dc` (class in mp), 154  
`mme_gen_pf_ac` (class in mp), 152  
`mme_gen_pf_dc` (class in mp), 153  
`mme_legacy_dcline` (class in mp), 209  
`mme_legacy_dcline_opf` (class in mp), 210  
`mme_legacy_dcline_opf_ac` (class in mp), 211  
`mme_legacy_dcline_opf_dc` (class in mp), 211  
`mme_legacy_dcline_pf_ac` (class in mp), 210  
`mme_legacy_dcline_pf_dc` (class in mp), 210  
`mme_line3p` (class in mp), 198  
`mme_line3p_opf` (class in mp), 201  
`mme_load` (class in mp), 155  
`mme_load_cpf` (class in mp), 156  
`mme_load_pf_ac` (class in mp), 155  
`mme_load_pf_dc` (class in mp), 155  
`mme_reserve_gen` (class in mp), 178  
`mme_reserve_zone` (class in mp), 179  
`mme_shunt` (class in mp), 156  
`mme_shunt_cpf` (class in mp), 157  
`mme_shunt_pf_ac` (class in mp), 156  
`mme_shunt_pf_dc` (class in mp), 157  
`mme_xfmr3p` (class in mp), 198  
`mme_xfmr3p_opf` (class in mp), 201  
`modcost()` (built-in function), 347  
`model_params()` (mp.form method), 73  
`model_params()` (mp.form\_ac method), 77  
`model_params()` (mp.form\_dc method), 90  
`model_vvars()` (mp.form method), 73  
`model_vvars()` (mp.form\_acc method), 84  
`model_vvars()` (mp.form\_acp method), 88  
`model_vvars()` (mp.form\_dc method), 90  
`model_zvars()` (mp.form method), 73  
`model_zvars()` (mp.form\_ac method), 77  
`model_zvars()` (mp.form\_dc method), 91  
`modify_element_classes()` (mp.element\_container method), 166  
`mp_foo_table` (built-in class), 217  
`mp_table` (built-in class), 157  
`mp_table()` (mp\_table method), 158  
`mp_table_class()` (built-in function), 7  
`mp_table_subclass` (built-in class), 161  
`mpc` (opf\_model attribute), 221  
`mpoption()` (built-in function), 241  
`mpoption_info_clp()` (built-in function), 356  
`mpoption_info_cplex()` (built-in function), 356  
`mpoption_info_fmincon()` (built-in function), 357  
`mpoption_info_glpk()` (built-in function), 357  
`mpoption_info_gurobi()` (built-in function), 358



mpoption\_info\_intlinprog() (built-in function), 358  
 mption\_info\_ipopt() (built-in function), 359  
 mption\_info\_knitro() (built-in function), 359  
 mption\_info\_linprog() (built-in function), 360  
 mption\_info\_mips() (built-in function), 360  
 mption\_info\_mosek() (built-in function), 361  
 mption\_info\_osqp() (built-in function), 361  
 mption\_info\_quadprog() (built-in function), 362  
 mption\_old() (built-in function), 362  
 mpver() (built-in function), 348

## N

n (mp.dm\_element attribute), 38  
 N (mp.form\_ac attribute), 76  
 name (mp.task attribute), 10  
 name (mp.task\_pf attribute), 20  
 name() (mp.dm\_element method), 38  
 name() (mp.dmc\_element method), 64  
 name() (mp.dmce\_branch\_mpc2 method), 70  
 name() (mp.dmce\_bus3p\_mpc2 method), 181  
 name() (mp.dmce\_bus\_mpc2 method), 70  
 name() (mp.dmce\_buslink\_mpc2 method), 183  
 name() (mp.dmce\_gen3p\_mpc2 method), 181  
 name() (mp.dmce\_gen\_mpc2 method), 71  
 name() (mp.dmce\_legacy\_dcline\_mpc2 method), 204  
 name() (mp.dmce\_line3p\_mpc2 method), 182  
 name() (mp.dmce\_load3p\_mpc2 method), 182  
 name() (mp.dmce\_load\_mpc2 method), 71  
 name() (mp.dmce\_reserve\_gen\_mpc2 method), 175  
 name() (mp.dmce\_reserve\_zone\_mpc2 method), 176  
 name() (mp.dmce\_shunt\_mpc2 method), 72  
 name() (mp.dmce\_xfmr3p\_mpc2 method), 183  
 name() (mp.dme\_branch method), 48  
 name() (mp.dme\_bus method), 50  
 name() (mp.dme\_bus3p method), 184  
 name() (mp.dme\_buslink method), 192  
 name() (mp.dme\_gen method), 53  
 name() (mp.dme\_gen3p method), 186  
 name() (mp.dme\_legacy\_dcline method), 206  
 name() (mp.dme\_line3p method), 189  
 name() (mp.dme\_load method), 55  
 name() (mp.dme\_load3p method), 187  
 name() (mp.dme\_reserve\_gen method), 177  
 name() (mp.dme\_reserve\_zone method), 178  
 name() (mp.dme\_shunt method), 58  
 name() (mp.dme\_xfmr3p method), 190  
 name() (mp.mm\_element method), 145  
 name() (mp.mme\_branch method), 147  
 name() (mp.mme\_bus method), 150  
 name() (mp.mme\_bus3p method), 197  
 name() (mp.mme\_buslink method), 199  
 name() (mp.mme\_gen method), 152  
 name() (mp.mme\_gen3p method), 198  
 name() (mp.mme\_legacy\_dcline method), 209  
 name() (mp.mme\_line3p method), 198  
 name() (mp.mme\_load method), 155  
 name() (mp.mme\_reserve\_gen method), 178  
 name() (mp.mme\_reserve\_zone method), 179  
 name() (mp.mme\_shunt method), 156  
 name() (mp.mme\_xfmr3p method), 198  
 name() (mp.net\_model method), 93  
 name() (mp.nm\_element method), 110  
 name() (mp.nme\_branch method), 115  
 name() (mp.nme\_bus method), 117  
 name() (mp.nme\_bus3p method), 193  
 name() (mp.nme\_buslink method), 197  
 name() (mp.nme\_gen method), 118  
 name() (mp.nme\_gen3p method), 195  
 name() (mp.nme\_legacy\_dcline method), 208  
 name() (mp.nme\_line3p method), 196  
 name() (mp.nme\_load method), 119  
 name() (mp.nme\_load3p method), 195  
 name() (mp.nme\_shunt method), 121  
 name() (mp.nme\_xfmr3p method), 196  
 name2idx() (mp.mapped\_array method), 169  
 net\_model (class in mp), 91  
 net\_model\_ac (class in mp), 101  
 net\_model\_acc (class in mp), 105  
 net\_model\_acc() (mp.net\_model\_acc method), 105  
 net\_model\_acp (class in mp), 106  
 net\_model\_acp() (mp.net\_model\_acp method), 106  
 net\_model\_dc (class in mp), 107  
 net\_model\_dc() (mp.net\_model\_dc method), 107  
 network\_model\_build() (mp.task method), 16  
 network\_model\_build() (mp.task\_cpf method), 22  
 network\_model\_build\_post() (mp.task method), 17  
 network\_model\_build\_post() (mp.task\_pf method), 20  
 network\_model\_build\_pre() (mp.task method), 16  
 network\_model\_class() (mp.extension method), 172  
 network\_model\_class() (mp.task method), 15  
 network\_model\_class\_default() (mp.task method), 16  
 network\_model\_class\_default() (mp.task\_opf method), 23  
 network\_model\_class\_default() (mp.task\_pf method), 20  
 network\_model\_create() (mp.task method), 16  
 network\_model\_element() (mp.mm\_element method), 145  
 network\_model\_update() (mp.task method), 17  
 network\_model\_update() (mp.task\_cpf method), 22  
 network\_model\_x\_soln() (mp.math\_model method), 127  
 network\_model\_x\_soln() (mp.task method), 17  
 network\_model\_x\_soln() (mp.task\_cpf method), 22  
 network\_model\_x\_soln() (mp.task\_pf method), 20  
 newtonpf() (built-in function), 264  
 newtonpf\_I\_cart() (built-in function), 265  
 newtonpf\_I\_hybrid() (built-in function), 266  
 newtonpf\_I\_polar() (built-in function), 266  
 newtonpf\_S\_cart() (built-in function), 267  
 newtonpf\_S\_hybrid() (built-in function), 268  
 next\_dm() (mp.task method), 11  
 next\_dm() (mp.task\_pf method), 20  
 next\_nm() (mp.task method), 11  
 next\_nm() (mp.task\_cpf method), 22  
 next\_nm() (mp.task method), 11  
 nk (mp.nm\_element attribute), 109  
 nlpopf\_solver() (built-in function), 288  
 nm (mp.task attribute), 10  
 nm\_element (class in mp), 108  
 nm\_element\_classes() (mp.extension method), 173  
 nm\_element\_classes() (mp.xt\_3p method), 180  
 nm\_element\_classes() (mp.xt\_legacy\_dcline method), 203  
 nme\_branch (class in mp), 115  
 nme\_branch\_ac (class in mp), 115  
 nme\_branch\_acc (class in mp), 116  
 nme\_branch\_acp (class in mp), 116  
 nme\_branch\_dc (class in mp), 116  
 nme\_bus (class in mp), 117  
 nme\_bus3p (class in mp), 193  
 nme\_bus3p\_acc (class in mp), 194  
 nme\_bus3p\_acp (class in mp), 194  
 nme\_bus\_acc (class in mp), 117  
 nme\_bus\_acp (class in mp), 117  
 nme\_bus\_dc (class in mp), 118  
 nme\_buslink (class in mp), 196  
 nme\_buslink\_acc (class in mp), 197  
 nme\_buslink\_acp (class in mp), 197  
 nme\_gen (class in mp), 118

*nme\_gen3p* (class in *mp*), 194  
*nme\_gen3p\_acc* (class in *mp*), 195  
*nme\_gen3p\_acp* (class in *mp*), 195  
*nme\_gen\_ac* (class in *mp*), 118  
*nme\_gen\_acc* (class in *mp*), 119  
*nme\_gen\_acp* (class in *mp*), 119  
*nme\_gen\_dc* (class in *mp*), 119  
*nme\_legacy\_dcline* (class in *mp*), 208  
*nme\_legacy\_dcline\_ac* (class in *mp*), 208  
*nme\_legacy\_dcline\_acc* (class in *mp*), 209  
*nme\_legacy\_dcline\_acp* (class in *mp*), 209  
*nme\_legacy\_dcline\_dc* (class in *mp*), 209  
*nme\_line3p* (class in *mp*), 196  
*nme\_load* (class in *mp*), 119  
*nme\_load3p* (class in *mp*), 195  
*nme\_load\_ac* (class in *mp*), 120  
*nme\_load\_acc* (class in *mp*), 120  
*nme\_load\_acp* (class in *mp*), 120  
*nme\_load\_dc* (class in *mp*), 120  
*nme\_shunt* (class in *mp*), 121  
*nme\_shunt\_ac* (class in *mp*), 121  
*nme\_shunt\_acc* (class in *mp*), 121  
*nme\_shunt\_acp* (class in *mp*), 121  
*nme\_shunt\_dc* (class in *mp*), 122  
*nme\_xfmr3p* (class in *mp*), 196  
*nn*() (*mp.nm\_element* method), 110  
*nn*() (*mp.nme\_bus* method), 117  
*nn*() (*mp.nme\_bus3p* method), 194  
*nodal\_complex\_current\_balance*() (*mp.net\_model\_ac* method), 103  
*nodal\_complex\_current\_balance\_hess*() (*mp.net\_model\_ac* method), 104  
*nodal\_complex\_power\_balance*() (*mp.net\_model\_ac* method), 103  
*nodal\_complex\_power\_balance\_hess*() (*mp.net\_model\_ac* method), 104  
*nodal\_current\_balance\_fcn*() (*mp.math\_model\_opf\_ac* method), 133  
*nodal\_current\_balance\_hess*() (*mp.math\_model\_opf\_ac* method), 133  
*nodal\_power\_balance\_fcn*() (*mp.math\_model\_opf\_ac* method), 133  
*nodal\_power\_balance\_hess*() (*mp.math\_model\_opf\_ac* method), 133  
*node* (*mp.net\_model* attribute), 93  
*node\_balance\_equations*() (*mp.mm\_shared\_pfcpf\_acci* method), 141  
*node\_balance\_equations*() (*mp.mm\_shared\_pfcpf\_accs* method), 141  
*node\_balance\_equations*() (*mp.mm\_shared\_pfcpf\_acpi* method), 142  
*node\_balance\_equations*() (*mp.mm\_shared\_pfcpf\_acps* method), 142  
*node\_indices*() (*mp.nm\_element* method), 113  
*node\_power\_balance\_prices*() (*mp.math\_model\_opf\_acci* method), 134  
*node\_power\_balance\_prices*() (*mp.math\_model\_opf\_accs* method), 135  
*node\_power\_balance\_prices*() (*mp.math\_model\_opf\_acpi* method), 136  
*node\_power\_balance\_prices*() (*mp.math\_model\_opf\_acps* method), 137  
*NODE\_TYPE* (class in *mp*), 170  
*node\_types*() (*mp.net\_model* method), 99  
*node\_types*() (*mp.nm\_element* method), 114  
*node\_types*() (*mp.nme\_bus* method), 117  
*node\_types*() (*mp.nme\_bus3p* method), 194  
*NONE* (*mp.NODE\_TYPE* attribute), 170  
*np*() (*mp.net\_model* method), 93

*np*() (*mp.nm\_element* method), 110  
*np*() (*mp.nme\_branch* method), 115  
*np*() (*mp.nme\_buslink* method), 197  
*np*() (*mp.nme\_gen* method), 118  
*np*() (*mp.nme\_gen3p* method), 195  
*np*() (*mp.nme\_legacy\_dcline* method), 208  
*np*() (*mp.nme\_line3p* method), 196  
*np*() (*mp.nme\_load* method), 119  
*np*() (*mp.nme\_load3p* method), 195  
*np*() (*mp.nme\_shunt* method), 121  
*np*() (*mp.nme\_xfmr3p* method), 196  
*nr* (*mp.dm\_element* attribute), 38  
*nv* (*mp.net\_model* attribute), 93  
*nz*() (*mp.net\_model* method), 93  
*nz*() (*mp.nm\_element* method), 110  
*nz*() (*mp.nme\_buslink* method), 197  
*nz*() (*mp.nme\_gen* method), 118  
*nz*() (*mp.nme\_gen3p* method), 195  
*nz*() (*mp.nme\_legacy\_dcline* method), 208

## O

*off* (*mp.dm\_element* attribute), 38  
*on* (*mp.dm\_element* attribute), 38  
*online*() (*mp.data\_model* method), 31  
*opf*() (built-in function), 283  
*opf\_args*() (built-in function), 291  
*opf\_branch\_ang\_fcn*() (built-in function), 293  
*opf\_branch\_ang\_hess*() (built-in function), 294  
*opf\_branch\_flow\_fcn*() (built-in function), 294  
*opf\_branch\_flow\_hess*() (built-in function), 295  
*opf\_current\_balance\_fcn*() (built-in function), 296  
*opf\_current\_balance\_hess*() (built-in function), 296  
*opf\_execute*() (built-in function), 293  
*opf\_gen\_cost\_fcn*() (built-in function), 297  
*opf\_legacy\_user\_cost\_fcn*() (built-in function), 297  
*opf\_model* (built-in class), 220  
*opf\_model*() (*opf\_model* method), 221  
*opf\_nle\_fcn1*() (built-in function), 381  
*opf\_nle\_hess1*() (built-in function), 382  
*opf\_power\_balance\_fcn*() (built-in function), 298  
*opf\_power\_balance\_hess*() (built-in function), 298  
*opf\_setup*() (built-in function), 292  
*opf\_veq\_fcn*() (built-in function), 299  
*opf\_veq\_hess*() (built-in function), 299  
*opf\_vlim\_fcn*() (built-in function), 300  
*opf\_vlim\_hess*() (built-in function), 301  
*opf\_vref\_fcn*() (built-in function), 301  
*opf\_vref\_hess*() (built-in function), 302  
*order\_radial*() (built-in function), 268  
*oval\_pq\_capability\_fcn*() (*mp.nme\_gen\_opf\_ac\_oval* method), 212  
*oval\_pq\_capability\_hess*() (*mp.nme\_gen\_opf\_ac\_oval* method), 213

## P

*p* (*mp.form\_dc* attribute), 90  
*p\_fr\_lb* (*mp.dme\_legacy\_dcline* attribute), 206  
*p\_fr\_start* (*mp.dme\_legacy\_dcline* attribute), 205  
*p\_fr\_ub* (*mp.dme\_legacy\_dcline* attribute), 206  
*p\_to\_start* (*mp.dme\_legacy\_dcline* attribute), 205  
*param\_ncols* (*mp.form\_ac* attribute), 76  
*param\_ncols* (*mp.form\_dc* attribute), 90  
*parameterized*() (*mp.dme\_load\_cpf* method), 56  
*parameterized*() (*mp.dme\_shunt\_cpf* method), 57  
*params\_legacy\_cost*() (*mp.mm\_shared\_opf\_legacy* method), 144  
*params\_legacy\_cost*() (*opf\_model* method), 222  
*params\_var*() (*mp.net\_model* method), 98

- pd (*mp.dme\_load* attribute), 55  
 pd1 (*mp.dme\_load3p* attribute), 187  
 pd2 (*mp.dme\_load3p* attribute), 187  
 pd3 (*mp.dme\_load3p* attribute), 187  
 pd\_i (*mp.dme\_load* attribute), 55  
 pd\_z (*mp.dme\_load* attribute), 55  
 pf1 (*mp.dme\_load3p* attribute), 187  
 pf2 (*mp.dme\_load3p* attribute), 187  
 pf3 (*mp.dme\_load3p* attribute), 187  
 pf\_va\_fcn() (*mp.mme\_buslink\_pf\_acc* method), 200  
 pf\_vm\_fcn() (*mp.mme\_buslink\_pf\_acc* method), 200  
 pfsoln() (built-in function), 269  
 pg1\_start (*mp.dme\_buslink* attribute), 191  
 pg1\_start (*mp.dme\_gen3p* attribute), 185  
 pg2\_start (*mp.dme\_buslink* attribute), 191  
 pg2\_start (*mp.dme\_gen3p* attribute), 185  
 pg3\_start (*mp.dme\_buslink* attribute), 191  
 pg3\_start (*mp.dme\_gen3p* attribute), 185  
 pg\_lb (*mp.dme\_gen* attribute), 53  
 pg\_start (*mp.dme\_gen* attribute), 52  
 pg\_ub (*mp.dme\_gen* attribute), 53  
 poly2pwl() (built-in function), 348  
 poly\_cost\_fcn() (*mp.cost\_table* static method), 164  
 poly\_params() (*mp.cost\_table* method), 163  
 poly\_params() (*mp.cost\_table\_utils* static method), 165  
 polycost() (built-in function), 348  
 port (*mp.net\_model* attribute), 93  
 port\_active\_power2\_lim\_fcn() (*mp.form\_ac* method), 80  
 port\_active\_power2\_lim\_hess() (*mp.form\_ac* method), 82  
 port\_active\_power\_lim\_fcn() (*mp.form\_ac* method), 80  
 port\_active\_power\_lim\_hess() (*mp.form\_ac* method), 82  
 port\_apparent\_power\_lim\_fcn() (*mp.form\_ac* method), 80  
 port\_apparent\_power\_lim\_hess() (*mp.form\_ac* method), 81  
 port\_current\_lim\_fcn() (*mp.form\_ac* method), 81  
 port\_current\_lim\_hess() (*mp.form\_ac* method), 82  
 port\_inj\_current() (*mp.form\_ac* method), 77  
 port\_inj\_current\_hess() (*mp.form\_ac* method), 78  
 port\_inj\_current\_hess\_v() (*mp.form\_ac* method), 79  
 port\_inj\_current\_hess\_v() (*mp.form\_acc* method), 84  
 port\_inj\_current\_hess\_v() (*mp.form\_acp* method), 88  
 port\_inj\_current\_hess\_vz() (*mp.form\_ac* method), 79  
 port\_inj\_current\_hess\_vz() (*mp.form\_acc* method), 84  
 port\_inj\_current\_hess\_vz() (*mp.form\_acp* method), 88  
 port\_inj\_current\_jac() (*mp.form\_ac* method), 79  
 port\_inj\_current\_jac() (*mp.form\_acc* method), 84  
 port\_inj\_current\_jac() (*mp.form\_acp* method), 88  
 port\_inj\_current\_nln() (*mp.nme\_load\_ac* method), 120  
 port\_inj\_nln() (*mp.net\_model\_ac* method), 102  
 port\_inj\_nln\_hess() (*mp.net\_model\_ac* method), 103  
 port\_inj\_power() (*mp.form\_ac* method), 77  
 port\_inj\_power() (*mp.form\_dc* method), 91  
 port\_inj\_power\_hess() (*mp.form\_ac* method), 79  
 port\_inj\_power\_hess\_v() (*mp.form\_ac* method), 79  
 port\_inj\_power\_hess\_v() (*mp.form\_acc* method), 85  
 port\_inj\_power\_hess\_v() (*mp.form\_acp* method), 88  
 port\_inj\_power\_hess\_vz() (*mp.form\_ac* method), 80  
 port\_inj\_power\_hess\_vz() (*mp.form\_acc* method), 85  
 port\_inj\_power\_hess\_vz() (*mp.form\_acp* method), 89  
 port\_inj\_power\_jac() (*mp.form\_ac* method), 79  
 port\_inj\_power\_jac() (*mp.form\_acc* method), 85  
 port\_inj\_power\_jac() (*mp.form\_acp* method), 88  
 port\_inj\_power\_nln() (*mp.nme\_load\_ac* method), 120  
 port\_inj\_soln() (*mp.net\_model\_ac* method), 104  
 port\_inj\_soln() (*mp.net\_model\_dc* method), 108  
 pp\_binding\_rows\_lim() (*mp.dme\_branch\_opf* method), 49  
 pp\_binding\_rows\_lim() (*mp.dme\_bus\_opf* method), 52  
 pp\_binding\_rows\_lim() (*mp.dme\_gen\_opf* method), 54  
 pp\_binding\_rows\_lim() (*mp.dme\_legacy\_dcline\_opf* method), 207  
 pp\_binding\_rows\_lim() (*mp.dme\_reserve\_gen* method), 177  
 pp\_binding\_rows\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_data() (*mp.data\_model* method), 34  
 pp\_data() (*mp.dm\_element* method), 44  
 pp\_data\_cnt() (*mp.dm\_element* method), 45  
 pp\_data\_cnt() (*mp.dme\_branch* method), 48  
 pp\_data\_cnt() (*mp.dme\_bus* method), 51  
 pp\_data\_det() (*mp.dm\_element* method), 46  
 pp\_data\_ext() (*mp.dm\_element* method), 45  
 pp\_data\_ext() (*mp.dme\_bus* method), 51  
 pp\_data\_ext() (*mp.dme\_bus\_opf* method), 51  
 pp\_data\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_data\_other() (*mp.dme\_shared\_opf* method), 59  
 pp\_data\_row\_det() (*mp.dm\_element* method), 46  
 pp\_data\_row\_det() (*mp.dme\_branch* method), 48  
 pp\_data\_row\_det() (*mp.dme\_bus* method), 51  
 pp\_data\_row\_det() (*mp.dme\_bus3p* method), 184  
 pp\_data\_row\_det() (*mp.dme\_bus\_opf* method), 52  
 pp\_data\_row\_det() (*mp.dme\_buslink* method), 192  
 pp\_data\_row\_det() (*mp.dme\_gen* method), 53  
 pp\_data\_row\_det() (*mp.dme\_gen3p* method), 186  
 pp\_data\_row\_det() (*mp.dme\_legacy\_dcline* method), 207  
 pp\_data\_row\_det() (*mp.dme\_line3p* method), 189  
 pp\_data\_row\_det() (*mp.dme\_load* method), 56  
 pp\_data\_row\_det() (*mp.dme\_load3p* method), 187  
 pp\_data\_row\_det() (*mp.dme\_reserve\_gen* method), 177  
 pp\_data\_row\_det() (*mp.dme\_reserve\_zone* method), 178  
 pp\_data\_row\_det() (*mp.dme\_shunt* method), 58  
 pp\_data\_row\_det() (*mp.dme\_xfmr3p* method), 191  
 pp\_data\_row\_lim() (*mp.dme\_branch\_opf* method), 49  
 pp\_data\_row\_lim() (*mp.dme\_bus\_opf* method), 52  
 pp\_data\_row\_lim() (*mp.dme\_gen\_opf* method), 54  
 pp\_data\_row\_lim() (*mp.dme\_legacy\_dcline\_opf* method), 208  
 pp\_data\_row\_lim() (*mp.dme\_reserve\_gen* method), 177  
 pp\_data\_row\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_data\_sum() (*mp.dm\_element* method), 45  
 pp\_data\_sum() (*mp.dme\_branch* method), 48  
 pp\_data\_sum() (*mp.dme\_gen* method), 53  
 pp\_data\_sum() (*mp.dme\_gen3p* method), 186  
 pp\_data\_sum() (*mp.dme\_legacy\_dcline* method), 206  
 pp\_data\_sum() (*mp.dme\_line3p* method), 189  
 pp\_data\_sum() (*mp.dme\_load* method), 56  
 pp\_data\_sum() (*mp.dme\_load3p* method), 187  
 pp\_data\_sum() (*mp.dme\_reserve\_gen* method), 177  
 pp\_data\_sum() (*mp.dme\_shunt* method), 58  
 pp\_data\_sum() (*mp.dme\_xfmr3p* method), 191  
 pp\_flags() (*mp.data\_model* method), 32  
 pp\_flags() (*mp.data\_model\_opf* method), 36  
 pp\_get\_footers() (*mp.dm\_element* method), 44  
 pp\_get\_footers\_det() (*mp.dm\_element* method), 46  
 pp\_get\_footers\_det() (*mp.dme\_gen* method), 53  
 pp\_get\_footers\_det() (*mp.dme\_load* method), 56  
 pp\_get\_footers\_det() (*mp.dme\_reserve\_gen* method), 177  
 pp\_get\_footers\_det() (*mp.dme\_shunt* method), 58  
 pp\_get\_footers\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_get\_footers\_other() (*mp.dme\_shared\_opf* method), 59  
 pp\_get\_headers() (*mp.data\_model* method), 33  
 pp\_get\_headers() (*mp.dm\_element* method), 44  
 pp\_get\_headers\_cnt() (*mp.data\_model* method), 33  
 pp\_get\_headers\_det() (*mp.dm\_element* method), 46  
 pp\_get\_headers\_det() (*mp.dme\_branch* method), 48  
 pp\_get\_headers\_det() (*mp.dme\_bus* method), 51  
 pp\_get\_headers\_det() (*mp.dme\_bus3p* method), 184  
 pp\_get\_headers\_det() (*mp.dme\_bus\_opf* method), 52  
 pp\_get\_headers\_det() (*mp.dme\_buslink* method), 192  
 pp\_get\_headers\_det() (*mp.dme\_gen* method), 53  
 pp\_get\_headers\_det() (*mp.dme\_gen3p* method), 186  
 pp\_get\_headers\_det() (*mp.dme\_legacy\_dcline* method), 207



pp\_get\_headers\_det() (*mp.dme\_line3p* method), 189  
 pp\_get\_headers\_det() (*mp.dme\_load* method), 56  
 pp\_get\_headers\_det() (*mp.dme\_load3p* method), 187  
 pp\_get\_headers\_det() (*mp.dme\_reserve\_gen* method), 177  
 pp\_get\_headers\_det() (*mp.dme\_reserve\_zone* method), 178  
 pp\_get\_headers\_det() (*mp.dme\_shunt* method), 58  
 pp\_get\_headers\_det() (*mp.dme\_xfmr3p* method), 191  
 pp\_get\_headers\_ext() (*mp.data\_model* method), 34  
 pp\_get\_headers\_lim() (*mp.dme\_branch\_opf* method), 49  
 pp\_get\_headers\_lim() (*mp.dme\_bus\_opf* method), 52  
 pp\_get\_headers\_lim() (*mp.dme\_gen\_opf* method), 54  
 pp\_get\_headers\_lim() (*mp.dme\_legacy\_dcline\_opf* method), 207  
 pp\_get\_headers\_lim() (*mp.dme\_reserve\_gen* method), 177  
 pp\_get\_headers\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_get\_headers\_other() (*mp.data\_model* method), 34  
 pp\_get\_headers\_other() (*mp.data\_model\_opf* method), 36  
 pp\_get\_headers\_other() (*mp.dme\_shared\_opf* method), 59  
 pp\_get\_title\_det() (*mp.dm\_element* method), 45  
 pp\_get\_title\_lim() (*mp.dme\_branch\_opf* method), 49  
 pp\_get\_title\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_have\_section() (*mp.data\_model* method), 33  
 pp\_have\_section() (*mp.dm\_element* method), 43  
 pp\_have\_section\_cnt() (*mp.dm\_element* method), 44  
 pp\_have\_section\_det() (*mp.dm\_element* method), 45  
 pp\_have\_section\_det() (*mp.dme\_branch* method), 48  
 pp\_have\_section\_det() (*mp.dme\_bus* method), 51  
 pp\_have\_section\_det() (*mp.dme\_bus3p* method), 184  
 pp\_have\_section\_det() (*mp.dme\_buslink* method), 192  
 pp\_have\_section\_det() (*mp.dme\_gen* method), 53  
 pp\_have\_section\_det() (*mp.dme\_gen3p* method), 186  
 pp\_have\_section\_det() (*mp.dme\_legacy\_dcline* method), 207  
 pp\_have\_section\_det() (*mp.dme\_line3p* method), 189  
 pp\_have\_section\_det() (*mp.dme\_load* method), 56  
 pp\_have\_section\_det() (*mp.dme\_load3p* method), 187  
 pp\_have\_section\_det() (*mp.dme\_reserve\_gen* method), 177  
 pp\_have\_section\_det() (*mp.dme\_reserve\_zone* method), 178  
 pp\_have\_section\_det() (*mp.dme\_shunt* method), 58  
 pp\_have\_section\_det() (*mp.dme\_xfmr3p* method), 191  
 pp\_have\_section\_ext() (*mp.dm\_element* method), 45  
 pp\_have\_section\_ext() (*mp.dme\_bus* method), 51  
 pp\_have\_section\_lim() (*mp.dme\_branch\_opf* method), 49  
 pp\_have\_section\_lim() (*mp.dme\_bus\_opf* method), 52  
 pp\_have\_section\_lim() (*mp.dme\_gen\_opf* method), 54  
 pp\_have\_section\_lim() (*mp.dme\_legacy\_dcline\_opf* method), 207  
 pp\_have\_section\_lim() (*mp.dme\_reserve\_gen* method), 177  
 pp\_have\_section\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_have\_section\_other() (*mp.dme\_shared\_opf* method), 59  
 pp\_have\_section\_sum() (*mp.dm\_element* method), 45  
 pp\_have\_section\_sum() (*mp.dme\_branch* method), 48  
 pp\_have\_section\_sum() (*mp.dme\_gen* method), 53  
 pp\_have\_section\_sum() (*mp.dme\_gen3p* method), 186  
 pp\_have\_section\_sum() (*mp.dme\_legacy\_dcline* method), 206  
 pp\_have\_section\_sum() (*mp.dme\_line3p* method), 189  
 pp\_have\_section\_sum() (*mp.dme\_load* method), 56  
 pp\_have\_section\_sum() (*mp.dme\_load3p* method), 187  
 pp\_have\_section\_sum() (*mp.dme\_reserve\_gen* method), 177  
 pp\_have\_section\_sum() (*mp.dme\_shunt* method), 58  
 pp\_have\_section\_sum() (*mp.dme\_xfmr3p* method), 191  
 pp\_rows() (*mp.dm\_element* method), 44  
 pp\_rows\_lim() (*mp.dme\_shared\_opf* method), 59  
 pp\_rows\_other() (*mp.dme\_shared\_opf* method), 59  
 pp\_section() (*mp.data\_model* method), 33  
 pp\_section\_label() (*mp.data\_model* method), 32  
 pp\_section\_list() (*mp.data\_model* method), 32  
 pp\_section\_list() (*mp.data\_model\_opf* method), 36  
 pp\_set\_tols\_lim() (*mp.dme\_shared\_opf* method), 59  
 PQ (*mp.NODE\_TYPE* attribute), 170  
 pq\_capability\_constraint() (*mp.mme\_gen\_opf\_ac* method), 154

pqcost() (*built-in function*), 349  
 pretty\_print() (*mp.data\_model* method), 31  
 pretty\_print() (*mp.dm\_element* method), 43  
 pretty\_print() (*mp.dme\_branch\_opf* method), 49  
 pretty\_print() (*mp.dme\_gen\_opf* method), 54  
 pretty\_print() (*mp.dme\_legacy\_dcline\_opf* method), 207  
 pretty\_print() (*mp.dme\_line3p* method), 189  
 pretty\_print() (*mp.dme\_xfmr3p* method), 191  
 print\_soln() (*mp.task* method), 12  
 print\_soln\_header() (*mp.task* method), 12  
 print\_soln\_header() (*mp.task\_opf* method), 23  
 printpf() (*built-in function*), 251  
 psse2mpc() (*built-in function*), 251  
 psse\_convert() (*built-in function*), 367  
 psse\_convert\_hvdc() (*built-in function*), 367  
 psse\_convert\_xfmr() (*built-in function*), 368  
 psse\_parse() (*built-in function*), 369  
 psse\_parse\_line() (*built-in function*), 370  
 psse\_parse\_section() (*built-in function*), 370  
 psse\_read() (*built-in function*), 372  
 ptol (*mp.dme\_shared\_opf* attribute), 59  
 PV (*mp.NODE\_TYPE* attribute), 170  
 pw11 (*mp.dmece\_gen\_mpc2* attribute), 70  
 pwl\_params() (*mp.cost\_table* method), 164  
 pwl\_params() (*mp.cost\_table\_utils* static method), 166

## Q

q\_fr\_lb (*mp.dme\_legacy\_dcline* attribute), 206  
 q\_fr\_start (*mp.dme\_legacy\_dcline* attribute), 205  
 q\_fr\_ub (*mp.dme\_legacy\_dcline* attribute), 206  
 q\_to\_lb (*mp.dme\_legacy\_dcline* attribute), 206  
 q\_to\_start (*mp.dme\_legacy\_dcline* attribute), 206  
 q\_to\_ub (*mp.dme\_legacy\_dcline* attribute), 206  
 qd (*mp.dme\_load* attribute), 55  
 qd\_i (*mp.dme\_load* attribute), 55  
 qd\_z (*mp.dme\_load* attribute), 55  
 qq1\_start (*mp.dme\_buslink* attribute), 191  
 qq1\_start (*mp.dme\_gen3p* attribute), 185  
 qq2\_start (*mp.dme\_buslink* attribute), 191  
 qq2\_start (*mp.dme\_gen3p* attribute), 185  
 qq3\_start (*mp.dme\_buslink* attribute), 192  
 qq3\_start (*mp.dme\_gen3p* attribute), 185  
 qq\_lb (*mp.dme\_gen* attribute), 53  
 qq\_start (*mp.dme\_gen* attribute), 52  
 qq\_ub (*mp.dme\_gen* attribute), 53  
 qps\_matpower() (*built-in function*), 325

## R

r (*mp.dme\_branch* attribute), 47  
 r (*mp.dme\_xfmr3p* attribute), 190  
 r\_ub (*mp.dme\_reserve\_gen* attribute), 176  
 radial\_pf() (*built-in function*), 269  
 rate\_a (*mp.dme\_branch* attribute), 48  
 rebuild() (*mp.dm\_element* method), 43  
 REF (*mp.NODE\_TYPE* attribute), 170  
 ref (*mp.task\_pf* attribute), 20  
 ref0 (*mp.task\_pf* attribute), 20  
 remove\_userfcn() (*built-in function*), 305  
 req (*mp.dme\_reserve\_zone* attribute), 178  
 run() (*mp.task* method), 10  
 run\_cpf() (*built-in function*), 5  
 run\_mp() (*built-in function*), 4  
 run\_opf() (*built-in function*), 6  
 run\_pf() (*built-in function*), 5  
 run\_post() (*mp.task* method), 12  
 run\_post() (*mp.task\_cpf\_legacy* method), 25  
 run\_post() (*mp.task\_opf\_legacy* method), 26



run\_post() (*mp.task\_pf\_legacy* method), 24  
 run\_pre() (*mp.task* method), 12  
 run\_pre() (*mp.task\_cpf* method), 22  
 run\_pre() (*mp.task\_cpf\_legacy* method), 25  
 run\_pre() (*mp.task\_opf* method), 23  
 run\_pre() (*mp.task\_opf\_legacy* method), 26  
 run\_pre() (*mp.task\_pf* method), 20  
 run\_pre() (*mp.task\_pf\_legacy* method), 24  
 run\_pre\_legacy() (*mp.task\_shared\_legacy* method), 28  
 run\_userfcn() (*built-in* function), 305  
 runcpf() (*built-in* function), 228  
 rundcopf() (*built-in* function), 234  
 rundcpf() (*built-in* function), 233  
 runduopf() (*built-in* function), 235  
 runopf() (*built-in* function), 231  
 runopf\_w\_res() (*built-in* function), 236  
 runpf() (*built-in* function), 227  
 runuopf() (*built-in* function), 232

## S

s (*mp.form\_ac* attribute), 76  
 save() (*mp.dm\_converter* method), 61  
 save() (*mp.dm\_converter\_mpc2* method), 62  
 save2psse() (*built-in* function), 252  
 save\_soln() (*mp.task* method), 13  
 savecase() (*built-in* function), 253  
 savechgtab() (*built-in* function), 253  
 scale\_factor\_fcn() (*mp.dmce\_load\_mpc2* method), 71  
 scale\_load() (*built-in* function), 349  
 set\_bus\_type\_pq() (*mp.dme\_bus* method), 51  
 set\_bus\_type\_pv() (*mp.dme\_bus* method), 51  
 set\_bus\_type\_ref() (*mp.dme\_bus* method), 51  
 set\_bus\_v\_lims\_via\_vg() (*mp.data\_model* method), 34  
 set\_mpc() (*opf\_model* method), 222  
 set\_node\_type\_pq() (*mp.net\_model* method), 101  
 set\_node\_type\_pq() (*mp.nm\_element* method), 115  
 set\_node\_type\_pq() (*mp.nme\_bus* method), 117  
 set\_node\_type\_pv() (*mp.net\_model* method), 101  
 set\_node\_type\_pv() (*mp.nm\_element* method), 114  
 set\_node\_type\_pv() (*mp.nme\_bus* method), 117  
 set\_node\_type\_ref() (*mp.net\_model* method), 100  
 set\_node\_type\_ref() (*mp.nm\_element* method), 114  
 set\_node\_type\_ref() (*mp.nme\_bus* method), 117  
 set\_reorder() (*built-in* function), 260  
 set\_table() (*mp.table\_subclass* method), 162  
 set\_type\_idx\_map() (*mp.net\_model* method), 96  
 set\_type\_label() (*mp.net\_model* method), 97  
 size() (*mp.mapped\_array* method), 168  
 size() (*mp.table* method), 158  
 snln (*mp.form\_ac* attribute), 76  
 snln\_hess (*mp.form\_ac* attribute), 76  
 soln (*mp.nm\_element* attribute), 110  
 solve\_opts() (*mp.math\_model* method), 126  
 solve\_opts() (*mp.math\_model\_opf\_ac* method), 133  
 solve\_opts() (*mp.math\_model\_opf\_dc* method), 138  
 solve\_opts() (*mp.math\_model\_pf* method), 127  
 solve\_opts() (*mp.math\_model\_pf\_dc* method), 130  
 solve\_opts\_warmstart() (*mp.math\_model\_cpf\_acps* method), 132  
 source (*mp.data\_model* attribute), 29  
 stack\_matrix\_params() (*mp.net\_model* method), 94  
 stack\_vector\_params() (*mp.net\_model* method), 94  
 start\_cost\_export() (*mp.dmce\_gen\_mpc2* method), 71  
 start\_cost\_import() (*mp.dmce\_gen\_mpc2* method), 71  
 state (*mp.net\_model* attribute), 93  
 subsasgn() (*mp.mapped\_array* method), 170  
 subsasgn() (*mp.table* method), 159  
 subsref() (*mp.mapped\_array* method), 169

subsref() (*mp.table* method), 159  
 success (*mp.task* attribute), 10  
 symmat2vec() (*mp.dme\_line3p* method), 189  
 sys\_wide\_zip\_loads() (*mp.dmce\_load\_mpc2* method), 71

## T

t\_apply\_changes() (*built-in* function), 372  
 t\_auction\_case() (*built-in* function), 382  
 t\_auction\_minopf() (*built-in* function), 373  
 t\_auction\_mips() (*built-in* function), 373  
 t\_auction\_tspopf\_pdipm() (*built-in* function), 373  
 t\_case30\_userfcns() (*built-in* function), 382  
 t\_case3p\_a() (*built-in* function), 218  
 t\_case3p\_b() (*built-in* function), 218  
 t\_case3p\_c() (*built-in* function), 218  
 t\_case3p\_d() (*built-in* function), 218  
 t\_case3p\_e() (*built-in* function), 218  
 t\_case3p\_f() (*built-in* function), 219  
 t\_case3p\_g() (*built-in* function), 219  
 t\_case3p\_h() (*built-in* function), 219  
 t\_case9\_dcline() (*built-in* function), 382  
 t\_case9\_gizmo() (*built-in* function), 219  
 t\_case9\_opf() (*built-in* function), 382  
 t\_case9\_opfv2() (*built-in* function), 383  
 t\_case9\_pfv() (*built-in* function), 383  
 t\_case9\_pfv2() (*built-in* function), 383  
 t\_case9\_save2psse() (*built-in* function), 383  
 t\_case\_ext() (*built-in* function), 383  
 t\_case\_int() (*built-in* function), 383  
 t\_chgtab() (*built-in* function), 373  
 t\_cpf() (*built-in* function), 373  
 t\_cpf\_cb1() (*built-in* function), 384  
 t\_cpf\_cb2() (*built-in* function), 384  
 t\_dcline() (*built-in* function), 373  
 t\_dmc\_element() (*built-in* function), 215  
 t\_ext2int2ext() (*built-in* function), 373  
 t\_feval\_w\_path() (*built-in* function), 374  
 t\_get\_losses() (*built-in* function), 374  
 t\_hasPQcap() (*built-in* function), 374  
 t\_hessian() (*built-in* function), 374  
 t\_islands() (*built-in* function), 374  
 t\_jacobian() (*built-in* function), 374  
 t\_load2disp() (*built-in* function), 375  
 t\_loadcase() (*built-in* function), 375  
 t\_makeLODF() (*built-in* function), 375  
 t\_makePTDF() (*built-in* function), 375  
 t\_margcost() (*built-in* function), 375  
 t\_miops\_matpower() (*built-in* function), 375  
 t\_modcost() (*built-in* function), 375  
 t\_mp\_data\_model() (*built-in* function), 215  
 t\_mp\_dm\_converter\_mpc2() (*built-in* function), 215  
 t\_mp\_mapped\_array() (*built-in* function), 214  
 t\_mp\_table() (*built-in* function), 215  
 t\_mpopf() (*built-in* function), 376  
 t\_mpopf\_ov() (*built-in* function), 376  
 t\_mpxt\_legacy\_dcline() (*built-in* function), 217  
 t\_mpxt\_reserves() (*built-in* function), 217  
 t\_nm\_element() (*built-in* function), 215  
 t\_node\_test() (*built-in* function), 216  
 t\_off2case() (*built-in* function), 376  
 t\_opf\_dc\_bpmpd() (*built-in* function), 376  
 t\_opf\_dc\_clp() (*built-in* function), 376  
 t\_opf\_dc\_cplex() (*built-in* function), 376  
 t\_opf\_dc\_default() (*built-in* function), 376  
 t\_opf\_dc\_glpk() (*built-in* function), 377  
 t\_opf\_dc\_gurobi() (*built-in* function), 377  
 t\_opf\_dc\_ipopt() (*built-in* function), 377

t\_opf\_dc\_mips() (built-in function), 377  
 t\_opf\_dc\_mips\_sc() (built-in function), 377  
 t\_opf\_dc\_mosek() (built-in function), 377  
 t\_opf\_dc\_osqp() (built-in function), 377  
 t\_opf\_dc\_ot() (built-in function), 378  
 t\_opf\_default() (built-in function), 378  
 t\_opf\_fmincon() (built-in function), 378  
 t\_opf\_ipopt() (built-in function), 378  
 t\_opf\_knitro() (built-in function), 378  
 t\_opf\_minopf() (built-in function), 378  
 t\_opf\_mips() (built-in function), 378  
 t\_opf\_model() (built-in function), 379  
 t\_opf\_softlims() (built-in function), 379  
 t\_opf\_tspopf\_pdipm() (built-in function), 379  
 t\_opf\_tspopf\_scpdipm() (built-in function), 379  
 t\_opf\_tspopf\_tralm() (built-in function), 379  
 t\_opf\_userfncs() (built-in function), 379  
 t\_pf\_ac() (built-in function), 380  
 t\_pf\_dc() (built-in function), 380  
 t\_pf\_radial() (built-in function), 380  
 t\_port\_inj\_current\_acc() (built-in function), 215  
 t\_port\_inj\_current\_acp() (built-in function), 216  
 t\_port\_inj\_power\_acc() (built-in function), 216  
 t\_port\_inj\_power\_acp() (built-in function), 216  
 t\_pretty\_print() (built-in function), 217  
 t\_printf() (built-in function), 380  
 t\_psse() (built-in function), 380  
 t\_qps\_matpower() (built-in function), 380  
 t\_run\_mp() (built-in function), 216  
 t\_run\_mp\_3p() (built-in function), 216  
 t\_run\_opf\_default() (built-in function), 217  
 t\_runmarket() (built-in function), 380  
 t\_runopf\_w\_res() (built-in function), 381  
 t\_scale\_load() (built-in function), 381  
 t\_total\_load() (built-in function), 381  
 t\_totcost() (built-in function), 381  
 t\_vdep\_load() (built-in function), 381  
 ta (mp.dme\_branch attribute), 48  
 tab (mp.dm\_element attribute), 38  
 table\_exists() (mp.dm\_element method), 40  
 table\_var\_map() (mp.dmc\_element method), 66  
 table\_var\_map() (mp.dmce\_branch\_mpc2 method), 70  
 table\_var\_map() (mp.dmce\_bus3p\_mpc2 method), 181  
 table\_var\_map() (mp.dmce\_bus\_mpc2 method), 70  
 table\_var\_map() (mp.dmce\_buslink\_mpc2 method), 183  
 table\_var\_map() (mp.dmce\_gen3p\_mpc2 method), 181  
 table\_var\_map() (mp.dmce\_gen\_mpc2 method), 71  
 table\_var\_map() (mp.dmce\_legacy\_dcline\_mpc2 method), 204  
 table\_var\_map() (mp.dmce\_line3p\_mpc2 method), 182  
 table\_var\_map() (mp.dmce\_load3p\_mpc2 method), 182  
 table\_var\_map() (mp.dmce\_load\_mpc2 method), 71  
 table\_var\_map() (mp.dmce\_reserve\_gen\_mpc2 method), 175  
 table\_var\_map() (mp.dmce\_reserve\_zone\_mpc2 method), 176  
 table\_var\_map() (mp.dmce\_shunt\_mpc2 method), 72  
 table\_var\_map() (mp.dmce\_xfmr3p\_mpc2 method), 183  
 tag (mp.task attribute), 10  
 tag (mp.task\_pf attribute), 20  
 task (class in mp), 8  
 task\_class() (mp.extension method), 172  
 task\_cpf (class in mp), 21  
 task\_cpf() (mp.task\_cpf method), 21  
 task\_cpf\_legacy (class in mp), 25  
 task\_name() (mp.math\_model method), 123  
 task\_name() (mp.math\_model\_opf method), 132  
 task\_name() (mp.math\_model\_pf method), 127  
 task\_opf (class in mp), 22  
 task\_opf\_legacy (class in mp), 26  
 task\_pf (class in mp), 19

task\_pf\_legacy (class in mp), 23  
 task\_shared\_legacy (class in mp), 27  
 task\_tag() (mp.math\_model method), 123  
 task\_tag() (mp.math\_model\_opf method), 132  
 task\_tag() (mp.math\_model\_pf method), 127  
 tbus (mp.dme\_branch attribute), 47  
 tbus (mp.dme\_legacy\_dcline attribute), 205  
 tbus (mp.dme\_line3p attribute), 188  
 tbus (mp.dme\_xfmr3p attribute), 190  
 tbus\_on (mp.dme\_legacy\_dcline attribute), 205  
 test\_matpower() (built-in function), 214  
 the\_np (mp.net\_model attribute), 93  
 the\_nz (mp.net\_model attribute), 93  
 tm (mp.dme\_branch attribute), 48  
 toggle\_dcline() (built-in function), 305  
 toggle\_iflims() (built-in function), 306  
 toggle\_reserves() (built-in function), 307  
 toggle\_softlims() (built-in function), 308  
 total\_load() (built-in function), 351  
 totcost() (built-in function), 302  
 type (mp.dme\_bus attribute), 50  
 type (mp.dme\_bus3p attribute), 184

## U

uopf() (built-in function), 286  
 update\_mupq() (built-in function), 302  
 update\_nm\_vars() (mp.math\_model method), 126  
 update\_status() (mp.data\_model method), 30  
 update\_status() (mp.dm\_element method), 42  
 update\_status() (mp.dme\_branch method), 48  
 update\_status() (mp.dme\_bus method), 50  
 update\_status() (mp.dme\_bus3p method), 184  
 update\_status() (mp.dme\_buslink method), 192  
 update\_status() (mp.dme\_gen method), 53  
 update\_status() (mp.dme\_gen3p method), 186  
 update\_status() (mp.dme\_legacy\_dcline method), 206  
 update\_status() (mp.dme\_line3p method), 189  
 update\_status() (mp.dme\_load method), 56  
 update\_status() (mp.dme\_load3p method), 187  
 update\_status() (mp.dme\_reserve\_gen method), 177  
 update\_status() (mp.dme\_reserve\_zone method), 178  
 update\_status() (mp.dme\_shunt method), 58  
 update\_status() (mp.dme\_xfmr3p method), 191  
 update\_z() (mp.mm\_shared\_pfcpf\_ac method), 139  
 update\_z() (mp.mm\_shared\_pfcpf\_dc method), 143  
 userdata (mp.data\_model attribute), 29

## V

va (mp.net\_model\_dc attribute), 108  
 va1\_start (mp.dme\_bus3p attribute), 184  
 va2\_start (mp.dme\_bus3p attribute), 184  
 va3\_start (mp.dme\_bus3p attribute), 184  
 va\_fcn() (mp.form\_acc method), 85  
 va\_fcn() (mp.nme\_buslink\_opf\_acc method), 202  
 va\_hess() (mp.form\_acc method), 86  
 va\_hess() (mp.nme\_buslink\_opf\_acc method), 202  
 va\_ref0 (mp.task\_pf attribute), 20  
 va\_start (mp.dme\_bus attribute), 50  
 vec2symmat() (mp.dme\_line3p method), 189  
 vec2symmat\_stacked() (mp.nme\_line3p method), 196  
 vertcat() (mp.table method), 160  
 violated\_q\_lims() (mp.dme\_gen method), 53  
 vm1\_setpoint (mp.dme\_gen3p attribute), 185  
 vm1\_start (mp.dme\_bus3p attribute), 184  
 vm2\_fcn() (mp.form\_acc method), 86  
 vm2\_fcn() (mp.nme\_buslink\_opf\_acc method), 202  
 vm2\_hess() (mp.form\_acc method), 86

vm2\_hess() (*mp.mme\_buslink\_opf\_acc* method), 202  
vm2\_setpoint (*mp.dme\_gen3p* attribute), 185  
vm2\_start (*mp.dme\_bus3p* attribute), 184  
vm3\_setpoint (*mp.dme\_gen3p* attribute), 186  
vm3\_start (*mp.dme\_bus3p* attribute), 184  
vm\_control (*mp.dme\_bus* attribute), 50  
vm\_control (*mp.dme\_bus3p* attribute), 184  
vm\_lb (*mp.dme\_bus* attribute), 50  
vm\_setpoint (*mp.dme\_gen* attribute), 53  
vm\_setpoint\_fr (*mp.dme\_legacy\_dcline* attribute), 206  
vm\_setpoint\_to (*mp.dme\_legacy\_dcline* attribute), 206  
vm\_start (*mp.dme\_bus* attribute), 50  
vm\_ub (*mp.dme\_bus* attribute), 50  
voltage\_constraints() (*mp.mme\_buslink\_pf\_ac* method), 199  
voltage\_constraints() (*mp.nme\_buslink* method), 197

## W

warmstart (*mp.task\_cpf* attribute), 21

## X

x (*mp.dme\_branch* attribute), 47  
x (*mp.dme\_xfmr3p* attribute), 190  
x2vz() (*mp.nm\_element* method), 112  
xt\_3p (*class in mp*), 179  
xt\_legacy\_dcline (*class in mp*), 203  
xt\_oval\_cap\_curve (*class in mp*), 212  
xt\_reserves (*class in mp*), 174

## Y

Y (*mp.form\_ac* attribute), 76  
yc (*mp.dme\_line3p* attribute), 189  
ys (*mp.dme\_line3p* attribute), 189

## Z

z (*mp.net\_model\_dc* attribute), 108  
zg\_x\_update() (*mp.math\_model\_pf\_acps* method), 129  
zgausspf() (*built-in function*), 269  
zones (*mp.dme\_reserve\_zone* attribute), 178