Oxtimal:
Optimal Control of Networked Microgrids

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Contents

Chapter 1

Introduction

Oxtimal [oks-t*uh*-m*uh*l] is an open source research code designed for the optimal control of networked microgrids. It features

- **Flexible construction of microgrids**
  - Supports a combination of DC and AC components
  - Quickly combine new grids through a well-defined API
- **Open source**
  - Released under the MPL 2.0 license
  - Free and ready to use with both open and closed sourced codes
- **Robust computations and repeatability**
  - Built-in archiving of solutions
  - Archives assist in debugging the design of grid components

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1.2 Support

News, updates, and download information for Oxtimal can be found at

`http://www.optimojoe.com`

Our user forum can be found at

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Finally, if you are interested in paid support and consulting, please contact us at contact@optimojoe.com.

1.3 Referencing

We have published several papers that describe the algorithms behind Oxtimal. In order to cite Oxtimal, please reference one of the following:

- D. G. Wilson, W. W. Weaver, R. D. Robinett Iii, J. Young, S. F. Glover, M. A. Cook, S. Markle, T. J. McCoy. **Nonlinear Power Flow Control Design Methodology for Navy Electric Ship Microgrid Energy Storage Requirements**. INEC/iSCSS 2018: *To appear.* 2018.
- Joseph Young, Marvin A. Cook, David G. Wilson. **A Predictive Engine for On-Line Optimal Microgrid Control**. 2017 IEEE Electric Ship Technologies Symposium (ESTS): 564 - 571. 2017.
- D. G. Wilson, R. D. Robinett, W. W. Weaver, R. H. Byrne and J. Young. **Nonlinear Power Flow Control Design of High Penetration Renewable Sources for AC Inverter Based Microgrids**. 2016 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM): 701 - 708, 2016.
- David G. Wilson, Jason C. Neely, Marvin A. Cook, Steven F. Glover, Joseph Young, and Rush D. Robinett. **Hamiltonian control design for DC microgrids with stochastic sources and loads with applications**. 2014 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM): 1264 - 1271, 2014.

Chapter 2

Installation

Oxtimal can be downloaded from

`http://www.optimojoe.com/uploads/software/Oxtimal-1.0.0.zip`

as a zipped archive. We also give direct access to our code repository at

`https://github.com/optimojoe/oxtimal`

In order to install Oxtimal

1. Unzip the archive
2. Add the directory `code` to the MATLAB/Octave path

2.1 Dependencies

Oxtimal uses the following software packages

Package	Version	License
Oxtimal	1.2	MPL-2.0
Optizelle	1.2	BSD-2-Clause
MATLAB	R2018	Custom
Octave	4.4	GPL-3.0

Chapter 3

Usage

Oxtimal can be run in two different modes: direct or by scenario. We address each of these cases in their own section.

3.1 Direct

In direct mode, Oxtimal is run with the command

```
solution = runDirect(params);
```

Here we have

Name `params`

Type Structure array

Description Parameters that describe the optimization and microgrid setup. It requires two variables `Optizelle` and `microgrid`. The variable `Optizelle` may be empty or contain optimization parameters that are sent directly to Optizelle. For a description of these parameters, please see the Optizelle manual. The variable `microgrid` contains the microgrid parameters, which are discussed in Chapter 4.

Name `solution`

Type Structure array

Description Optimal control found by Optizelle. A complete description of these parameters is discussed in Chapter 4.

3.2 Scenario

In scenario mode, Oxtimal is run with the command

```
solution = runScenario(scenario,variant)
```

Here we have

Name `scenario`

Type String

Description Name of a scenario found in the `data` directory. In order to create a new scenario, create a folder in this directory named `myscenario`, which contains a single file named `microgrid.json`. This is a json formatted file that contains two sections: `Oxtimal` and `microgrid`. The section `Optizelle` may be empty or contain optimization parameters that are sent directly to Optizelle. For a description of these parameters, please see the Optizelle manual. The section `microgrid` contains the microgrid parameters, which are discussed in Chapter 4.

Name `variant`

Type String

Description Optional argument that refers to a section in the `microgrid.json` file. The parameters in this section overwrite the parameters in the `microgrid` section. In addition, the solution for this scenario will be written to the `solution.json` file in the `results/scenario` directory under the specified variant. This is useful for archiving runs for later study. If this archiving feature is desired without overwriting any parameters, simply make an empty section in the `microgrid.json` file.

Name `solution`

Type Structure array

Description Optimal control found by Optizelle. A complete description of these parameters is discussed in Chapter 4.

In addition, the last control produced is written to the file `results/scenario/last_solution.json` file. The last output created by Optizelle is written to the file `results/scenario/last_output.txt`.

Chapter 4

Parameters

In the following chapter, we discuss the parameters required to construct a microgrid. We use these parameters when running the optimal controller as described in Chapter 3.

4.1 Models

Within Oxtimal, we construct a microgrid from the components A-F found in Figures 4.1, 4.2, 4.3, 4.4, 4.5, and 4.6. More simply, component A represents a boost converter, B a DC bus, C a connector between DC buses, E a connector between a DC bus and an AC bus, F an AC bus, and G a three-phase inverter. In our notation, the numbers indicate how each of these components connects to each other. For example, we represent a single DC microgrid with two boost converters in Figure 4.7. For a single AC microgrid, we can see the setup in Figure 4.8.

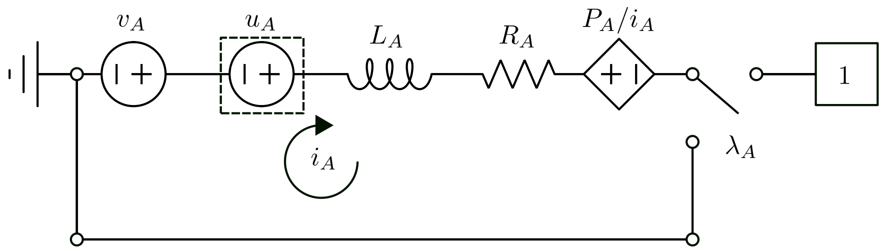

Figure 4.1: (A) Boost Converter

4.2 Optimization Formulation

Based on the grid components from Section 4.1, Oxtimal finds an optimal control for the grid by solving the optimization problem

Minimize

Objective Function

$$\frac{1}{2}\left(\|w_{A_{duty}}\dot{\lambda_A}\|^2 + \|w_{C_{duty}}\dot{\lambda_C}\|^2 + \|w_{E_{duty}}\dot{\lambda_E}\|^2 + \|w_{G_{duty}}\dot{\lambda_G}\|^2\right) +$$
$$\frac{1}{2}\big(\|w_{A_{control}} u_A u_{A_{switch}}\|^2 + \|w_{B_{control}} u_B u_{B\,switch}\|^2 + \|w_{C_{control}} u_C u_{C\,switch}\|^2$$
$$+\|w_{F_{control}} u_{F_d} u_{F\,switch}\|^2 + \|w_{F_{control}} u_{F_q} u_{F\,switch}\|^2 + \|w_{G_{control}} u_G u_{G\,switch}\|^2\big) +$$
$$\frac{1}{2}\big(\langle w_{A_{loss}} R_A i_A, i_A\rangle + \langle w_{C_{loss}} R_C i_C, i_C\rangle + \langle w_{E_{loss}} R_E i_{E_d}, i_{E_d}\rangle + \langle w_{E_{loss}} R_E i_{E_q}, i_{E_q}\rangle + \langle w_{G_{loss}} R_G i_G, i_G\rangle\big) +$$
$$\frac{1}{2}\big(\|w_{A_{power}} p_A u_{switch}\|^2 + \|w_{B_{power}} p_B u_{B\,switch}\|^2 + \|w_{C_{power}} p_C u_{C\,switch}\|^2$$
$$+\|w_{F_{power}} p_F u_{F\,switch}\|^2 + \|w_{G_{power}} p_G u_{G\,switch}\|^2\big)$$

Subject to

Boost Converters

$L_A \dot{i_A} = -R_A i_A - \frac{p_A}{i_A} + v_A + u_A u_{A_{switch}} - \lambda_A(\Phi_1 v_B)$

DC buses

$C_B \dot{v_B} = -\frac{v_B}{R_B} - \frac{p_B}{v_B} + u_B u_{B\,switch} + \Phi_1^T(\lambda_A i_A) - \Phi_2^T i_C + \Phi_3^T(\lambda_C i_C) - \Phi_5^T\left(\Xi\lambda_E(\xi_{E_c} i_{E_d} + \xi_{E_s} i_{E_q})\right)$

DC to DC Connectors

$L_C \dot{i_C} = -R_C i_C + u_C u_{C\,switch} + \Phi_2 v_B - \lambda_C(\Phi_3 v_B)$

AC to DC Connectors

$$\begin{aligned} L_E \dot{i_{E_d}} &= -R_E i_{E_d} + \Xi\lambda_E \xi_{E_c} \Phi_5 v_B + L_E i_{E_q} \Phi_6 \omega_F - \Phi_6 v_{F_d} \\ L_E \dot{i_{E_q}} &= -R_E i_{E_q} + \Xi\lambda_E \xi_{E_s} \Phi_5 v_B - L_E i_{E_d} \Phi_6 \omega_F - \Phi_6 v_{F_q} \end{aligned}$$

AC buses

$$\begin{aligned} C_F \dot{v_{F_d}} &= -\frac{v_{F_d}}{R_F} - \frac{p_{F_d}}{v_{F_d}} + \omega_F C_F v_{F_q} + u_{F_d} u_{F\,switch} + \Phi_6^T i_{E_d} + \Phi_7^T i_{G_d} \\ C_F \dot{v_{F_q}} &= -\frac{v_{F_q}}{R_F} - \frac{p_{F_q}}{v_{F_q}} - \omega_F C_F v_{F_d} + u_{F_q} u_{F\,switch} + \Phi_6^T i_{E_q} + \Phi_7^T i_{G_q} \end{aligned}$$

Inverters

$$\begin{aligned} R_{G_{dc}} i_G &= v_G + u_G u_{G_{switch}} - v_{G_{dc}} \\ C_{G_{dc}} \dot{v_{G_{dc}}} &= i_G - \Xi\lambda_G(\xi_{G_c} i_{G_d} + \xi_{G_s} i_{G_q}) \\ L_G \dot{i_{G_d}} &= -R_G i_{G_d} + \Xi\lambda_G \xi_{G_c} v_{G_{dc}} + L_G i_{G_q} \Phi_7 \omega_F - \Phi_7 v_{F_d} \\ L_G \dot{i_{G_q}} &= -R_G i_{G_q} + \Xi\lambda_G \xi_{G_s} v_{G_{dc}} - L_G i_{G_d} \Phi_7 \omega_F - \Phi_7 v_{F_q} \end{aligned}$$

Trigonometric

$\xi_{E_s}^2 + \xi_{E_c}^2 = e$

$\xi_{G_s}^2 + \xi_{G_c}^2 = e$

Power

$p_A = u_A i_A$

$p_B = v_B u_B$

$p_C = u_C i_C$

$p_F = v_{F_d} u_{F_d} + v_{F_q} u_{F_q}$

$p_G = u_G i_G$

Discretization

$i_{A\,k+1} = i_{A\,k} + \Delta t \dot{i}_{A\,k+1}, \qquad k = 0, \ldots, n_{time} - 1$

$e_{A\,k+1} = e_{A\,k} - \Delta t p_{A\,k+1}$

$\lambda_{A\,k+1} = \lambda_{A\,k} + \Delta t \dot{\lambda}_{A\,k+1}$

$v_{B\,k+1} = v_{B\,k} + \Delta t \dot{v}_{B\,k+1}$

$e_{B\,k+1} = e_{B\,k} - \Delta t p_{B\,k+1}$

$i_{C\,k+1} = i_{C\,k} + \Delta t \dot{i}_{C\,k+1}$

$\lambda_{C\,k+1} = \lambda_{C\,k} + \Delta t \dot{\lambda}_{C\,k+1}$

$e_{C\,k+1} = e_{C\,k} - \Delta t p_{C\,k+1}$

$i_{E_d\,k+1} = i_{E_d\,k} + \Delta t \dot{i}_{E_d\,k+1}$

$i_{E_q\,k+1} = i_{E_q\,k} + \Delta t \dot{i}_{E_q\,k+1}$

$\lambda_{E\,k+1} = \lambda_{E\,k} + \Delta t \dot{\lambda}_{E\,k+1}$

$v_{F_d\,k+1} = v_{F_d\,k} + \Delta t \dot{v}_{F_d\,k+1}$

$v_{F_q\,k+1} = v_{F_q\,k} + \Delta t \dot{v}_{F_q\,k+1}$

$e_{F\,k+1} = e_{F\,k} - \Delta t p_{F\,k+1}$

$i_{G_d\,k+1} = i_{G_d\,k} + \Delta t \dot{i}_{G_d\,k+1}$

$i_{G_q\,k+1} = i_{G_q\,k} + \Delta t \dot{i}_{G_q\,k+1}$

$v_{G_{dc}\,k+1} = v_{G_{dc}\,k} + \Delta t \dot{v}_{G_{dc}\,k+1}$

$\lambda_{G\,k+1} = \lambda_{G\,k} + \Delta t \dot{\lambda}_{G\,k+1}$
$e_{G\,k+1} = e_{G\,k} - \Delta t p_{G\,k+1}$

Bounds
$i_{A\min} \leq i_A \leq i_{A\max}$
$u_{A\min} \leq u_A \leq u_{A\max}$
$\lambda_{A\min} \leq \lambda_A \leq \lambda_{A\max}$
$e_{A\min} \leq e_A \leq e_{A\max}$

$v_{B\min} \leq v_B \leq v_{B\max}$
$u_{B\min} \leq u_B \leq u_{B\max}$
$e_{B\min} \leq e_B \leq e_{B\max}$

$i_{C\min} \leq i_C \leq i_{C\max}$
$u_{C\min} \leq u_C \leq u_{C\max}$
$\lambda_{C\min} \leq \lambda_C \leq \lambda_{C\max}$
$e_{C\min} \leq e_C \leq e_{C\max}$

$i_{E_d\min} \leq i_{E_d} \leq i_{E_d\max}$
$i_{E_q\min} \leq i_{E_q} \leq i_{E_q\max}$
$\lambda_{E\min} \leq \lambda_E \leq \lambda_{E\max}$

$v_{F_d\min} \leq v_{F_d} \leq v_{V_d\max}$
$v_{F_q\min} \leq v_{F_q} \leq v_{V_q\max}$
$u_{F_d\min} \leq u_{F_d} \leq u_{F_d\max}$
$u_{F_q\min} \leq u_{F_q} \leq u_{F_q\max}$
$e_{F\min} \leq e_F \leq e_{F\max}$
$i_{G\min} \leq i_G \leq i_{G\max}$
$v_{G_{dc}\min} \leq v_{G_{dc}} \leq v_{G_{dc}\max}$
$i_{G_d\min} \leq i_{G_d} \leq i_{G_d\max}$
$i_{G_q\min} \leq i_{G_q} \leq i_{G_q\max}$
$u_{G\min} \leq u_G \leq u_{G\max}$
$\lambda_{G\min} \leq \lambda_G \leq \lambda_{G\max}$
$e_{G\min} \leq e_G \leq e_{G\max}$

4.3 Parameters

In order to specify the microgrid, we require several parameters. In the following specification, we use the following schema

Name *Mathematical name*

Domain *Code name*

Type *Mathematical domain*

Description *Programming type*

Input/output Requirements for specification Description of parameter

In order to specify a matrix parameter, $x \in \mathbb{R}^{m\times n}$, we use a MATLAB/Octave matrix with m rows and n columns. In the json formatted parameter files, this becomes an array of arrays that specify the matrix in row-major format. For example, the matrix

$$x = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

becomes

```
"x" : [[1.0 2.0],[3.0 4.0]]
```

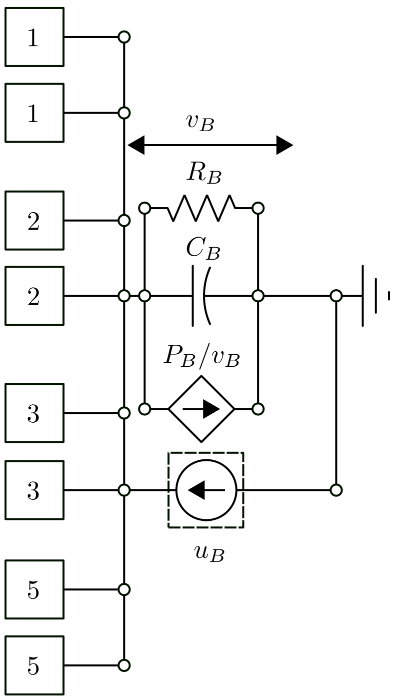

Figure 4.2: (B) DC Bus

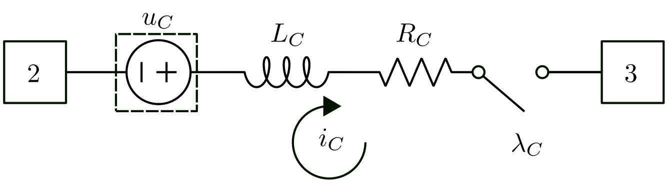

Figure 4.3: (C) DC to DC Bus Connector

in json format.

Finally, for parameters whose size is dependent on time, n_{time}, if the number of columns is 1, then the same parameter is repeated for all time steps. For example, both

```
"x" : [1.0,1.0,1.0,1.0]
```

and

```
"x" : [1.0]
```

are equivalent. If there is a matrix parameter, all rows must have the same number of columns. Hence, we disallow

```
"x" : [[1.0,2.0,3.0,4.0],
       [2.0]]
```

and instead require

```
"x" : [[1.0,2.0,3.0,4.0],
       [2.0,2.0,2.0,2.0]]
```

As for the parameters themselves, we specify that

Topology

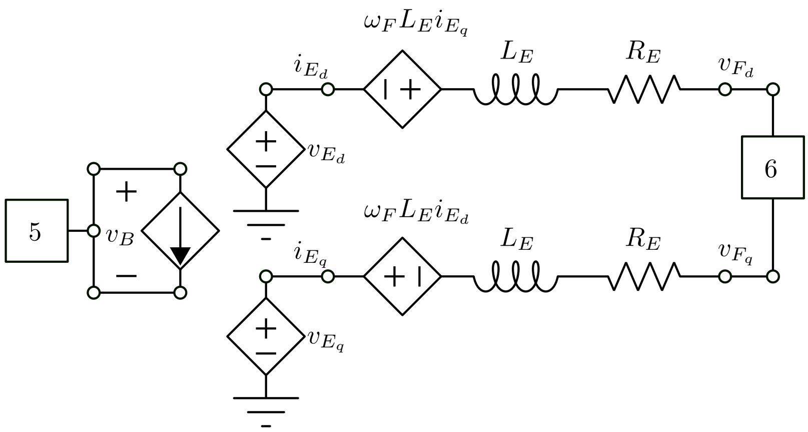

Figure 4.4: (E) AC to DC Bus Connector

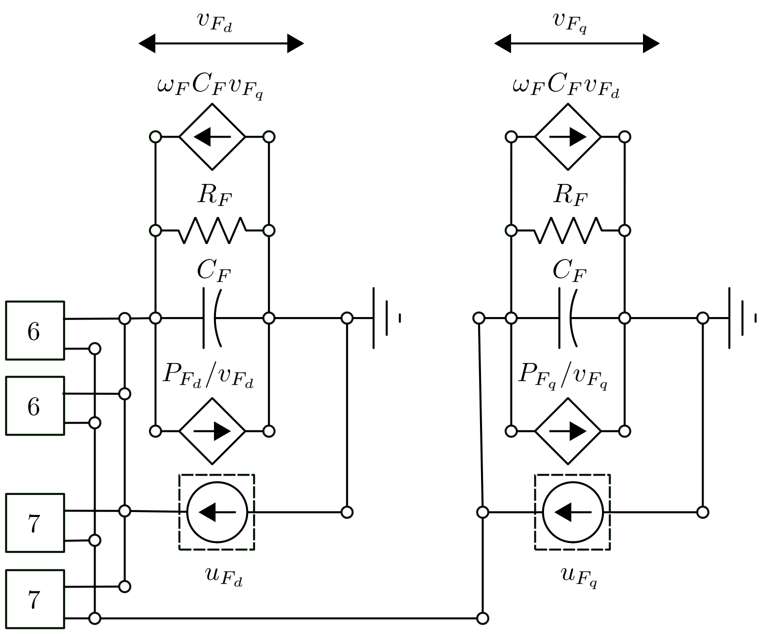

Figure 4.5: (F) AC Bus

Name n_{boost}

API Name `nboost`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

Description Number of boost converters, A

Name n_{dc}

API Name `ndc`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

Description Number of DC buses, B

Name n_{dcdc}

API Name `ndcdc`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

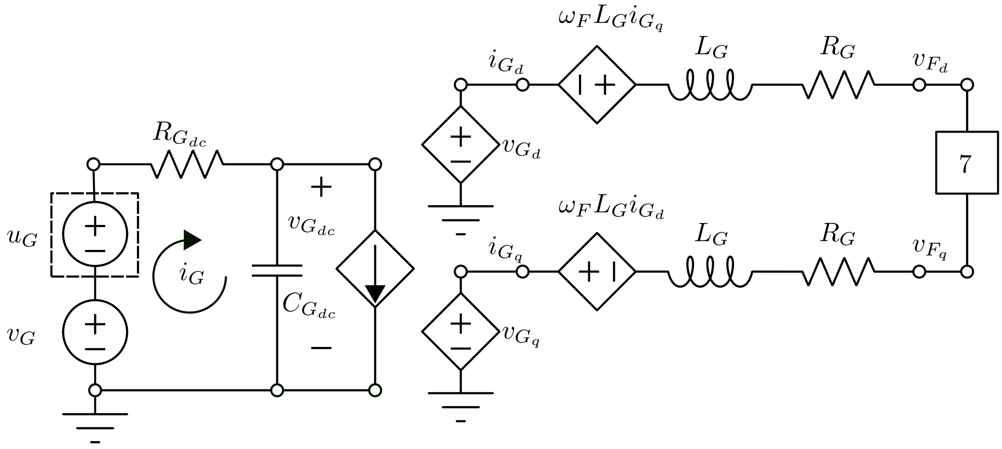

Figure 4.6: (G) Three-Phase Inverter

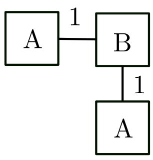

Figure 4.7: Single DC microgrid

Description Number of connections between DC buses, C

Name n_{load}

API Name `nload`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

Description Number of additional loads, D

Name n_{acdc}

API Name `nacdc`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

Description Number of connections between AC and DC buses, E

Name n_{ac}

API Name `nac`

Domain ℕ

Type `Integer`

I/O Input

Requirement None

Description Number of AC buses, F

Name n_{inv}

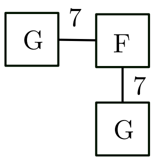

Figure 4.8: Single AC microgrid

API Name `ninv`

Domain $\mathbb{N}$

Type `Integer`

I/O Input

Requirement None

Description Number of three-phase inverters, G

Name n_{time}

API Name `ntime`

Domain $\mathbb{N}$

Type `Integer`

I/O Input

Requirement None

Description Number of time steps

Name Δt

API Name `Delta_t`

Domain $\mathbb{R}$

Type `Float`

I/O Input

Requirement None

Description Time step for the discretization of the differential equations

Name Φ_1

API Name `Phi_boost_dc_1`

Domain $\{0,1\}^{n_{boost} \times n_{dc}}$

Type `Integer`

I/O Input

Requirement $n_{dc} > 0$,$n_{boost} > 0$

Description Boost converter/DC bus expansion operator, $\Phi_{1ij} = 1$ when boost converter i is connected to DC bus j over the connection labeled 1

Name Φ_2

API Name `Phi_dcdc_dc_2`

Domain $\{0,1\}^{n_{dcdc} \times n_{dc}}$

Type `Integer`

I/O Input

Requirement $n_{dc} > 0$,$n_{dcdc} > 0$

Description DC-DC Connector/DC bus expansion operator, $\Phi_{2ij} = 1$ when connector i is connected to DC bus j over the connection labeled 2

Name Φ_3

API Name `Phi_dcdc_dc_3`

Domain $\{0,1\}^{n_{dcdc} \times n_{dc}}$

Type `Integer`

I/O Input

Requirement $n_{dc} > 0$,$n_{dcdc} > 0$

Description DC-DC Connector/DC bus expansion operator, $\Phi_{3ij} = 1$ when connector i is connected to DC bus j over the connection labeled 3

Name Φ_5

API Name `Phi_acdc_dc_5`

Domain $\{0,1\}^{n_{acdc} \times n_{dc}}$

Type `Integer`

I/O Input

Requirement $n_{dc} > 0$,$n_{acdc} > 0$,$n_{ac} > 0$

Description AC-DC Connector/DC bus expansion operator, $\Phi_{5ij} = 1$ when AC to DC connector i is connected to DC bus j over the connection labeled 5

Name Φ_6

API Name `Phi_acdc_ac_6`

Domain $\{0,1\}^{n_{acdc} \times n_{ac}}$

Type `Integer`

I/O Input

Requirement $n_{acdc} > 0$,$n_{ac} > 0$

Description AC-DC Connector/AC bus expansion operator, $\Phi_{6ij} = 1$ when AC to DC connector i is connected to AC bus j over the connection labeled 6

Name Φ_7

API Name `Phi_inv_ac_7`

Domain $\{0,1\}^{n_{inv} \times n_{ac}}$

Type `Integer`

I/O Input

Requirement $n_{ac} > 0$,$n_{inv} > 0$

Description Inverter/AC bus expansion operator, $\Phi_{7ij} = 1$ when three-phase inverter i is connected to AC bus j over the connection labeled 7

Boost Converter

Name u_A

API Name `u_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Controllable voltage source in the boost converters connected to the DC buses

Name $u_{A_{switch}}$

API Name `u_A_switch`

Domain $\{0,1\}^{n_{boost} \times n_{time}}$

Type `Integer`

I/O Input

Requirement $n_{boost} > 0$

Description Toggles whether the controllable voltage source is active

Name $u_{A\max}$

API Name `u_A_max`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Maximum voltage generated by the controllable source on the boost converter

Name $u_{A\min}$

API Name `u_A_min`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Minimum voltage generated by the controllable source on the boost converter

Name p_A

API Name `p_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Power at the controllable source u_A in the boost converter

Name e_A

API Name `e_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Energy in the controllable source u_A on the boost converter

Name e_{A0}

API Name e_A_0

Domain $\mathbb{R}^{n_{boost} \times 1}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Energy in the controllable source u_A on the boost converter at time 0

Name $e_{A\max}$

API Name e_A_max

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Maximum energy allowed in the controllable source u_A on the boost converters

Name $e_{A\min}$

API Name e_A_min

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Minimum energy allowed in the controllable source u_A on the boost converters

Name v_A

API Name v_A

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Constant voltage source in the boost converters connected to the DC buses

Name L_A

API Name L_A

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Inductance of the boost converters connected to the DC buses

Name R_A

API Name R_A

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description Resistance of the boost converters connected to the DC buses

Name P_A

API Name P_A

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{boost} > 0$

Description General load on the boost converters

Name i_A

API Name i_A

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{boost} > 0$

Description Current of the boost converters connected to the DC buses

Name $\dot{i}_A$

API Name i_A_dot

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Derivative of the current in boost converters connected to the DC buses

Name i_{A0}

API Name `i_A_0`

Domain $\mathbb{R}^{n_{boost} \times 1}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Current in the boost converters connected to the DC buses at time 0

Name $i_{A\max}$

API Name `i_A_max`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Maximum current on boost converters connected to the DC buses

Name $i_{A\min}$

API Name `i_A_min`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Minimum current on boost converters connected to the DC buses

Name λ_A

API Name `lambda_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Duty cycle in boost converters connected to the DC buses

Name $\dot{\lambda}_A$

API Name `lambda_A_dot`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Derivative of the duty cycle in the boost converters connected to the DC buses

Name λ_{A0}

API Name `lambda_A_0`

Domain $\mathbb{R}^{n_{boost} \times 1}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Initial duty cycle in the boost converters connected to the DC buses

Name $\lambda_{A\max}$

API Name `lambda_A_max`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Maximum duty cycle on the boost converters. Likely, 1.

Name $\lambda_{A\min}$

API Name `lambda_A_min`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Minimum duty cycle on the boost converters. Likely, 0.

Name $w_{A_{duty}}$

API Name `w_A_duty`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Duty cycle objective weighting for the boost converters connected to the DC buses

Name $w_{A_{control}}$

API Name `w_A_control`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Controllable source objective weighting for the boost converters connected to the DC buses

Name $w_{A_{loss}}$

API Name `w_A_loss`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Parasitic loss objective weighting for the boost converters connected to the DC buses

Name $w_{A_{power}}$

API Name `w_A_power`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{boost} > 0$

Description Controllable source power objective weighting for the boost converters connected to the DC buses

Name

API Name `derived.load_v_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Voltage across load terms L_A, R_A, and P_A, on the boost converters connected to the DC buses.

Name

API Name `derived.load_i_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Current on the boost converters connected to the DC bus

Name

API Name `derived.load_p_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Power consumed by the load terms on the boost converters connected to the DC bus

Name

API Name `derived.generation_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Power generated by the boost converters connected the DC bus

Name

API Name `derived.duty_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Duty cycle of the boost converters connected to the DC bus

Name

API Name `derived.storage_v_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Voltage of the storage on the boost converters connected to the DC bus

Name

API Name `derived.storage_i_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Current on the boost converters connected to the DC bus

Name

API Name `derived.storage_p_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Power consumed by the storage on boost converters connected to the DC bus

Name

API Name `derived.storage_e_A`

Domain $\mathbb{R}^{n_{boost} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{boost} > 0$

Description Energy within the storage on boost converters connected to the DC bus

DC Bus

Name u_B

API Name `u_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description $\mathbb{R}^{n_{dc} \times n_{time}}$

Float $n_{dc} > 0$ Controllable current source in the DC buses

Name $u_{B_{switch}}$

API Name `u_B_switch`

Domain $\{0, 1\}^{n_{dc} \times n_{time}}$

Type `Integer`

I/O Input

Requirement $n_{dc} > 0$

Description Toggles whether the controllable current source in the DC buses is active

Name $u_{B\max}$

API Name `u_B_max`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Maximum current generated by the controllable source on the DC bus

Name $u_{B\min}$

API Name `u_B_min`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Minimum current generated by the controllable source on the DC bus

Name p_B

API Name `p_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Power at the controllable source u_B on the DC bus

Name e_B

API Name `e_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Energy in the controllable source u_B on the DC bus

Name e_{B0}

API Name `e_B_0`

Domain $\mathbb{R}^{n_{dc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Energy in the controllable source u_B on the DC bus at time 0

Name $e_{B\max}$

API Name `e_B_max`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Maximum energy allowed in the controllable source u_B on the DC bus

Name $e_{B\min}$

API Name `e_B_min`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Minimum energy allowed in the controllable source u_B on the DC bus

Name v_B

API Name `v_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Voltage in the DC buses

Name $\dot{v_B}$

API Name `v_B_dot`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Derivative of the voltage in the DC bus

Name v_{B0}

API Name `v_B_0`

Domain $\mathbb{R}^{n_{dc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Voltage in the DC bus at time 0

Name $v_{B\max}$

API Name `v_B_max`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Maximum voltage on the DC buses

Name $v_{B\min}$

API Name `v_B_min`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Minimum voltage on the DC buses

Name R_B

API Name `R_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Resistance on the DC buses

Name C_B

API Name `C_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Capacitance on the DC buses

Name P_B

API Name `P_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description General load on the DC buses

Name $w_{B_{control}}$

API Name `w_B_control`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Controllable source objective weighting for the DC buses

Name $w_{B_{power}}$

API Name `w_B_power`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dc} > 0$

Description Controllable source power objective weighting for the DC buses

Name

API Name `derived.load_v_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Voltage on the DC bus

Name

API Name `derived.load_i_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Current consumed by the loads C_B, R_B, and P_B on the DC bus

Name

API Name `derived.load_p_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Power consumed by the load terms on the DC bus

Name

API Name `derived.generation_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Power generated by the DC bus

Name

API Name `derived.storage_v_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Voltage on the DC bus

Name

API Name `derived.storage_i_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Current of the storage on the DC bus

Name

API Name `derived.storage_p_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Power consumed by the storage on the DC bus

Name

API Name `derived.storage_e_B`

Domain $\mathbb{R}^{n_{dc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dc} > 0$

Description Energy within the storage on the DC bus

DC to DC Connector

Name u_C

API Name `u_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Controllable voltage source in the connections between the DC buses

Name $u_{C\max}$

API Name `u_C_max`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Maximum voltage generated by the controllable source on the connections between DC buses

Name $u_{C\min}$

API Name `u_C_min`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Minimum voltage generated by the controllable source on the connections between DC buses

Name $u_{C_{switch}}$

API Name `u_C_switch`

Domain $\{0,1\}^{n_{dcdc} \times n_{time}}$

Type `Integer`

I/O Input

Requirement $n_{dcdc} > 0$

Description Toggles whether the controllable voltage source in the connections between the DC buses is active

Name p_C

API Name `p_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Power at the controllable source u_C on the connector between DC buses

Name e_C

API Name `e_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Energy in the controllable source u_C on the connection between DC buses

Name e_{C0}

API Name `e_C_0`

Domain $\mathbb{R}^{n_{dcdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Energy in the controllable source u_C on the connection between DC buses at time 0

Name $e_{C\max}$

API Name `e_C_max`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Maximum energy allowed in the controllable source u_C on the connections between DC buses

Name $e_{C\min}$

API Name `e_C_min`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Minimum energy allowed in the controllable source u_C on the connections between DC buses

Name L_C

API Name `L_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Inductance in the connections between the DC buses

Name R_C

API Name `R_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Resistance in the connections between the DC buses

Name i_C

API Name `i_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Current in the connections between the DC buses

Name $\dot{i}_C$

API Name `i_C_dot`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Derivative of the current in the connections between the DC buses

Name i_{C0}

API Name `i_C_0`

Domain $\mathbb{R}^{n_{dcdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Current in the connections between the DC buses at time 0

Name $i_{C\max}$

API Name `i_C_max`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Maximum current on the connections between the DC buses

Name $i_{C\min}$

API Name `i_C_min`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Minimum current on the connections between the DC buses

Name λ_C

API Name `lambda_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Duty cycle in the connections between the DC buses

Name $\dot{\lambda_C}$

API Name `lambda_C_dot`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Derivative of the duty cycle in the connection between the DC buses

Name λ_{C0}

API Name `lambda_C_0`

Domain $\mathbb{R}^{n_{dcdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Initial duty cycle in the connection between the DC buses

Name $\lambda_{C\max}$

API Name `lambda_C_max`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Maximum duty cycle on the connections between DC buses

Name $\lambda_{C\min}$

API Name `lambda_C_min`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Minimum duty cycle on the connections between DC buses

Name $w_{C_{duty}}$

API Name `w_C_duty`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Duty cycle objective weighting for the for the connections between DC buses

Name $w_{C_{control}}$

API Name `w_C_control`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Controllable source objective weighting for the for the connections between DC buses

Name $w_{C_{loss}}$

API Name `w_C_loss`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Parasitic loss objective weighting for the for the connections between DC buses

Name $w_{C_{power}}$

API Name `w_C_power`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{dcdc} > 0$

Description Controllable source power objective weighting for the connections between DC buses

Name

API Name `derived.load_v_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Voltage across load terms L_C and R_C on the connections between DC buses

Name

API Name `derived.load_i_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Current on the connections between the DC buses

Name

API Name `derived.load_p_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Power consumed by the load terms on the connections between the DC buses

Name

API Name `derived.generation_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Power generated by the connections between the DC buses

Name

API Name `derived.duty_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Duty cycle of the connections between the DC buses

Name

API Name `derived.storage_v_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Voltage of the storage on the connections between the DC buses

Name

API Name `derived.storage_i_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Current on the connections between the DC buses

Name

API Name `derived.storage_p_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Power consumed by the storage on connections between the DC buses

Name

API Name `derived.storage_e_C`

Domain $\mathbb{R}^{n_{dcdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{dcdc} > 0$

Description Energy within the storage on connections between the DC buses

AC Components

Name Ξ

API Name `Xi`

Domain $\mathbb{R}$

Type `Float`

I/O Neither

Requirement None

Description Constant associated with the dq0 transformation, $\frac{1}{2}\sqrt{\frac{3}{2}}$

AC to DC connector

Name i_{E_q}

API Name `i_E_q`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Current associated with the quadrature axis in the connection between AC and DC buses

Name $\dot{i_{E_q}}$

API Name `i_E_q_dot`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Derivative of the current associated with the quadrature axis in the connector between AC and DC buses

Name $i_{E_q 0}$

API Name `i_E_q_0`

Domain $\mathbb{R}^{n_{acdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Current associated with the quadrature axis on the connection between AC and DC buses at time 0

Name $i_{E_q \max}$

API Name `i_E_q_max`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Maximum current associated with the quadrature axis on the connections between the AC and DC buses

Name $i_{E_q\min}$

API Name `i_E_q_min`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Minimum current associated with the quadrature axis on the connections between the AC and DC buses

Name i_{E_d}

API Name `i_E_d`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Current associated with the direct axis in the connection between AC and DC buses

Name $\dot{i}_{E_d}$

API Name `i_E_d_dot`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Derivative of the current associated with the direct axis in the connector between AC and DC buses

Name $i_{E_d 0}$

API Name `i_E_d_0`

Domain $\mathbb{R}^{n_{acdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Current associated with the direct axis on the connection between AC and DC buses at time 0

Name $i_{E_d\max}$

API Name `i_E_d_max`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Maximum current associated with the direct axis on the connections between the AC and DC buses

Name $i_{E_d\min}$

API Name `i_E_d_min`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Minimum current associated with the direct axis on the connections between the AC and DC buses

Name L_E

API Name `L_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Inductance on the AC side of the connector between AC and DC buses

Name R_E

API Name `R_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Resistance on the AC side of the connector between AC and DC buses

Name λ_E

API Name `lambda_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Duty cycle in the connector between AC and DC buses

Name $\dot{\lambda}_E$

API Name `lambda_E_dot`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Derivative of the duty cycle in the connection between the AC and DC buses

Name λ_{E0}

API Name `lambda_E_0`

Domain $\mathbb{R}^{n_{acdc} \times 1}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Initial duty cycle in the connection between the AC and DC buses

Name $\lambda_{E\max}$

API Name `lambda_E_max`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Maximum duty cycle on the connections between AC and DC buses. Likely, 1.

Name $\lambda_{E\min}$

API Name `lambda_E_min`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Minimum duty cycle on the connections between AC and DC buses. Likely, 0.

Name ξ_{E_s}

API Name `xi_E_s`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Sine of angle associated with the dq0 transformation in the connection between AC and DC buses

Name ξ_{E_c}

API Name `xi_E_c`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Cosine of angle associated with the dq0 transformation in the connection between AC and DC buses

Name $w_{E_{duty}}$

API Name `w_E_duty`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Duty cycle objective weighting for the for the connections between AC and DC buses

Name $w_{E_{loss}}$

API Name `w_E_loss`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{acdc} > 0$

Description Parasitic loss objective weighting for the for the connections between AC and DC buses

Name

API Name `derived.load_v_E_d`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Voltage across load terms L_E and R_E on the direct axis on the connections between AC and DC buses

Name

API Name `derived.load_i_E_d`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Current on the direct axis on connections between the AC and DC buses

Name

API Name `derived.load_v_E_q`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Voltage across load terms L_E and R_E on the quadrature axis on the connections between AC and DC buses

Name

API Name `derived.load_i_E_q`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Current on the quadrature axis on connections between the AC and DC buses

Name

API Name `derived.load_v_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Voltage across load terms L_E and R_E on the connections between AC and DC buses

Name

API Name `derived.load_i_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Current on the connections between the AC and DC buses

Name

API Name `derived.load_p_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Power consumed by the load terms on the connections between the DC buses

Name

API Name `derived.duty_E`

Domain $\mathbb{R}^{n_{acdc} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{acdc} > 0$

Description Duty cycle of the connections between the AC and DC buses

AC Bus

Name ω_F

API Name `omega_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Angular frequency of the AC bus

Name $u_{F_{switch}}$

API Name `u_F_switch`

Domain $\{0, 1\}^{n_{ac} \times n_{time}}$

Type `Integer`

I/O Input

Requirement $n_{ac} > 0$

Description Toggles whether the controllable current source on the AC bus is active

Name u_{F_q}

API Name `u_F_q`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Controllable current source associated with the quadrature axis on the AC bus

Name $u_{F_q \max}$

API Name `u_F_q_max`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Maximum current generated by the controllable source associated with the quadrature axis on the AC bus

Name $u_{F_q \min}$

API Name `u_F_q_min`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Minimum current generated by the controllable source associated with the quadrature axis on the AC bus

Name u_{F_d}

API Name u_F_d

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Controllable current source associated with the direct axis on the AC bus

Name $u_{F_d \max}$

API Name u_F_d_max

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Maximum current generated by the controllable source associated with the direct axis on the AC bus

Name $u_{F_d \min}$

API Name u_F_d_min

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Minimum current generated by the controllable source associated with the direct axis on the AC bus

Name p_F

API Name p_F

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Power at the controllable source u_{F_d} and u_{F_q} on the AC bus

Name e_F

API Name e_F

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Energy in the controllable source u_{F_d} and u_{F_q} on the AC bus

Name e_{F0}

API Name e_F_0

Domain $\mathbb{R}^{n_{ac} \times 1}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Energy in the controllable source u_{F_d} and u_{F_d} on the AC bus at time 0

Name $e_{F \max}$

API Name e_F_max

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Maximum energy allowed in the controllable source u_{F_d} and u_{F_q} on the AC bus

Name $e_{F \min}$

API Name e_F_min

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{ac} > 0$

Description Minimum energy allowed in the controllable source u_{F_d} and u_{F_q} on the AC bus

Name v_{F_q}

API Name v_F_q

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Voltage associated with the quadrature axis on the AC bus

Name $\dot{v_{F_q}}$

API Name v_F_q_dot

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Derivative of the voltage associated with the quadrature axis on the AC bus

Name v_{F_q0}

API Name v_F_q_0

Domain $\mathbb{R}^{n_{ac} \times 1}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Voltage associated with the quadrature axis on the AC bus at time 0

Name $v_{F_q\max}$

API Name v_F_q_max

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Maximum voltage associated with the quadrature axis on the AC bus

Name $v_{F_q\min}$

API Name v_F_q_min

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Minimum voltage associated with the quadrature axis on the AC bus

Name v_{F_d}

API Name v_F_d

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Voltage associated with the direct axis on the AC bus

Name $\dot{v_{F_d}}$

API Name v_F_d_dot

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Derivative of the voltage associated with the direct axis on the AC bus

Name v_{F_d0}

API Name v_F_d_0

Domain $\mathbb{R}^{n_{ac} \times 1}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Voltage associated with the quadrature axis on the AC bus at time 0

Name $v_{F_d\max}$

API Name v_F_d_max

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Maximum voltage associated with the direct axis on the AC bus

Name $v_{F_{d\,\mathrm{min}}}$

API Name v_F_d_min

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Minimum voltage associated with the direct axis on the AC bus

Name R_F

API Name R_F

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Resistance on the AC buses

Name P_F

API Name P_F

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description General load on the AC buses

Name C_F

API Name C_F

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Capacitance on the AC buses

Name $w_{F_{control}}$

API Name w_F_control

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Controllable source objective weighting for the AC buses

Name $w_{F_{power}}$

API Name w_F_power

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Input

Requirement $n_{ac} > 0$

Description Controllable source power objective weighting for the AC buses

Name

API Name derived.load_v_F_d

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Voltage on the direct axis on the AC bus

Name

API Name derived.load_v_F_q

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type Float

I/O Output

Requirement $n_{ac} > 0$

Description Voltage on the quadrature axis on the AC bus

Name

API Name `derived.load_v_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Voltage on the AC bus

Name

API Name `derived.load_i_F_d`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Current consumed by the loads C_F, R_F, and P_{F_d} on the direct axis on the AC bus

Name

API Name `derived.load_i_F_q`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Current consumed by the loads C_F, R_F, and P_{F_q} on the quadrature axis on the AC bus

Name

API Name `derived.load_i_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Current consumed by the loads on the AC bus

Name

API Name `derived.load_p_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Power consumed by the load terms on the AC bus

Name

API Name `derived.generation_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Power generated by the AC bus

Name

API Name `derived.storage_v_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Voltage on the AC bus

Name

API Name `derived.storage_i_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Current of the storage on the AC bus

Name

API Name `derived.storage_p_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Power consumed by the storage on the AC bus

Name

API Name `derived.storage_e_F`

Domain $\mathbb{R}^{n_{ac} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{ac} > 0$

Description Energy within the storage on the AC bus

Three-phase Inverter

Name u_G

API Name `u_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Controllable voltage source in the inverter connected to the AC bus

Name $u_{G_{switch}}$

API Name `u_G_switch`

Domain $\{0, 1\}^{n_{inv} \times n_{time}}$

Type `Integer`

I/O Input

Requirement $n_{inv} > 0$

Description $\{0, 1\}^{n_{inv} \times n_{time}}$

Toggles whether the controllable voltage source is active

Name $u_{G\max}$

API Name `u_G_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum voltage generated by the controllable source on the inverter

Name $u_{G\min}$

API Name `u_G_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum voltage generated by the controllable source on the inverter

Name p_G

API Name `p_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Power at the controllable source u_G in the inverter

Name e_G

API Name `e_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Energy in the controllable source u_G on the inverter

Name e_{G0}

API Name `e_G_0`

Domain $\mathbb{R}^{n_{inv} \times 1}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Energy in the controllable source u_G on the inverter at time 0

Name $e_{G\max}$

API Name `e_G_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum energy allowed in the controllable source u_G on the inverter

Name $e_{G\min}$

API Name `e_G_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum energy allowed in the controllable source u_G on the inverter

Name v_G

API Name `v_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Renewable and/or fossil source voltage in the inverter connected to the AC bus

Name i_G

API Name `i_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current on the DC side of the inverter

Name $i_{G\max}$

API Name `i_G_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum current on the inverters

Name $i_{G\min}$

API Name `i_G_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum current on the inverters

Name $C_{G_{dc}}$

API Name `C_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Capacitance on the DC side of the inverter

Name $R_{G_{dc}}$

API Name `R_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Resistance on the DC side of the inverter

Name $v_{G_{dc}}$

API Name `v_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage on the DC side of the inverter

Name $\dot{v_{G_{dc}}}$

API Name `v_G_dc_dot`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Derivative of the voltage in the inverter

Name $v_{G_{dc}0}$

API Name `v_G_dc_0`

Domain $\mathbb{R}^{n_{inv} \times 1}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Voltage in the inverter bus at time 0

Name $v_{G_{dc}\max}$

API Name `v_G_dc_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum voltage on the inverters

Name $v_{G_{dc}\min}$

API Name `v_G_dc_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum voltage on the inverters

Name i_{G_q}

API Name `i_G_q`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current associated with the quadrature axis in the inverter

Name $\dot{i_{G_q}}$

API Name `i_G_q_dot`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Derivative of the current associated with the quadrature axis on the inverter

Name i_{G_q0}

API Name `i_G_q_0`

Domain $\mathbb{R}^{n_{inv} \times 1}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Current associated with the quadrature axis on the inverter at time 0

Name $i_{G_q \max}$

API Name `i_G_q_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum current associated with the quadrature axis on the inverters

Name $i_{G_q \min}$

API Name `i_G_q_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum current associated with the quadrature axis on the inverters

Name i_{G_d}

API Name `i_G_d`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current associated with the direct axis in the inverter

Name $\dot{i}_{G_d}$

API Name `i_G_d_dot`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Derivative of the current associated with the direct axis on the inverter

Name $i_{G_d 0}$

API Name `i_G_d_0`

Domain $\mathbb{R}^{n_{inv} \times 1}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Current associated with the quadrature axis on the inverter at time 0

Name $i_{G_d \max}$

API Name `i_G_d_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum current associated with the direct axis on the inverters

Name $i_{G_d \min}$

API Name `i_G_d_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum current associated with the direct axis on the inverters

Name L_G

API Name `L_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Inductance on the AC side of the inverter

Name R_G

API Name `R_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Resistance on the AC side of the inverter

Name λ_G

API Name `lambda_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Duty cycle in inverters connected to the AC bus

Name $\dot{\lambda}_G$

API Name `lambda_G_dot`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Derivative of the duty cycle in the inverter

Name λ_{G0}

API Name `lambda_G_0`

Domain $\mathbb{R}^{n_{inv} \times 1}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Initial duty cycle in the inverter

Name $\lambda_{G\max}$

API Name `lambda_G_max`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Maximum duty cycle on the inverter. Likely, 1.

Name $\lambda_{G\min}$

API Name `lambda_G_min`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Minimum duty cycle on the inverter Likely, 0.

Name ξ_{G_s}

API Name `xi_G_s`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Sine of angle associated with the dq0 transformation in the inverter

Name ξ_{G_c}

API Name `xi_G_c`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Cosine of angle associated with the dq0 transformation in the inverter

Name $w_{G_{duty}}$

API Name `w_G_duty`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Duty cycle objective weighting for the inverter connected to the AC bus

Name $w_{G_{control}}$

API Name `w_G_control`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Controllable source objective weighting for the inverter connected to the AC bus

Name $w_{G_{loss}}$

API Name `w_G_loss`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Parasitic loss objective weighting for the inverter connected to the AC bus

Name $w_{G_{power}}$

API Name `w_G_power`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Input

Requirement $n_{inv} > 0$

Description Controllable source power objective weighting for the inverter connected to the AC bus

Name

API Name `derived.load_v_G_d`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage across the load terms L_G and R_G on the direct axis on the AC side of the three-phase inverter

Name

API Name `derived.load_v_G_q`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage across the load terms L_G and R_G on the quadrature axis on the AC side of the three-phase inverter

Name

API Name `derived.load_v_G_ac`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage on the AC side of the three-phase inverter

Name

API Name `derived.load_i_G_d`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current on the direct axis on the AC side of the three-phase inverter

Name

API Name `derived.load_i_G_q`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current on the quadrature axis on the AC side of the three-phase inverter

Name

API Name `derived.load_i_G_ac`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current on the AC side of the three-phase inverter

Name

API Name `derived.load_p_G_ac`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Power consumed by the load terms on the AC side of the three-phase inverter

Name

API Name `derived.load_v_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage on the DC side of the three-phase inverter bus

Name

API Name `derived.load_i_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current consumed by the loads $C_{G_{dc}}$ and $R_{G_{dc}}$ on the DC side of the three-phase inverter

Name

API Name `derived.load_p_G_dc`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Power consumed by the load terms on the DC side of the three-phase inverter

Name

API Name `derived.generation_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Power generated by the DC side of the three-phase inverter

Name

API Name `derived.duty_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Duty cycle of the three-phase inverter

Name

API Name `derived.storage_v_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Voltage of the storage on the three-phase inverter

Name

API Name `derived.storage_i_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Current on the DC side of the three-phase inverter

Name

API Name `derived.storage_p_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Power consumed by the storage on the three-phase inverter

Name

API Name `derived.storage_e_G`

Domain $\mathbb{R}^{n_{inv} \times n_{time}}$

Type `Float`

I/O Output

Requirement $n_{inv} > 0$

Description Energy within the storage on the three-phase inverter

Miscellaneous

Name

API Name `ineq_scaling`

Domain $\mathbb{R}$

Type `Float`

I/O Input

Requirement None

Description Scaling of the inequality constraints. This must be balanced against the rest of the objective.

Name

API Name `metrics.optimality`

Domain $\mathbb{R}$

Type `Float`

I/O Output

Requirement None

Description Norm of the optimality conditions. When this is small, the optimization problem is optimal.

Name

API Name `metrics.feasibility`

Domain $\mathbb{R}$

Type `Float`

I/O Output

Requirement None

Description Norm of the infeasibility. When this is small, the optimization problem satisfies the state conditions.

Name

API Name `metrics.barrier`

Domain $\mathbb{R}$

Type `Float`

I/O Output

Requirement None

Description Current barrier parameter. When this is small, the optimization problem satisfies the complementary slackness condition required for optimality.

Chapter 5

Examples

The following chapter presents two different simple examples of how to create and run an optimal control scenario for a given microgrid.

5.1 Single DC Microgrid

Recall, the single DC microgrid has a topology in Figure 4.7. We specify this with the parameter file

```
{
    "Optizelle" : {
        "iter_max" : 300
    },
    "microgrid": {
        "Delta_t": 1.0,
        "ntime" : 1,
        "nboost" : 2,
        "ndc" : 1,
        "Phi_boost_dc_1" : [
            [1],
            [1]
        ],
        "w_A_duty": [
            [1],
            [1]
        ],
        "w_A_control": [
            [0],
            [0]
        ],
        "w_A_loss": [
            [0],
            [0]
        ],
        "w_A_power": [
            [0],
            [0]
        ],
        "v_A": [
            [30],
            [30]
        ],
        "L_A": [
            [0.002],
            [0.002]
```

```
],
"R_A": [
    [0.036],
    [0.036]
],
"P_A": [
    [0.0],
    [0.0]
],
"i_A_0": [
    [15],
    [15]
],
"i_A_min": [
    [10],
    [10]
],
"i_A_max": [
    [40],
    [40]
],
"lambda_A_0": [
    [0.55],
    [0.55]
],
"lambda_A_min": [
    [0],
    [0]
],
"lambda_A_max": [
    [1],
    [1]
],
"u_A_switch" : [
    [1],
    [1]
],
"u_A_min": [
    [0],
    [0]
],
"u_A_max": [
    [100],
    [100]
],
"e_A_0": [
    [50],
    [50]
],
"e_A_min": [
    [0],
    [0]
],
"e_A_max": [
    [100],
    [100]
],
"w_B_control": [0],
```

```
        "w_B_power": [0],
        "v_B_0": [170],
        "v_B_min": [0],
        "v_B_max": [500],
        "R_B": [25],
        "P_B": [0.0],
        "C_B": [0.004],
        "u_B_switch" : [1],
        "u_B_min": [-50],
        "u_B_max": [100],
        "e_B_0": [50],
        "e_B_min": [0],
        "e_B_max": [100]
    },
    "tighter_bus": {
        "v_B_min": [150],
        "v_B_max": [200]
    },
    "tighter_boost" : {
        "i_A_max": [
            [20],
            [20]
        ]
    }
}
```


Note, this contains two different problem setups. We run both with the commands

```
solution=runScenario('single_dc','tighter_bus');
solution=runScenario('single_dc','tighter_boost');
```

This produces the solution


```
{
    "tighter_bus": {
        "u_A": [
            [4.999986786],
            [3.336407511]
        ],
        "i_A": [
            [10.00001783],
            [14.98616103]
        ],
        "i_A_dot": [
            [-4.99998217],
            [-0.0138389666]
        ],
        "lambda_A": [
            [0.2309998948],
            [0.2186462107]
        ],
        "lambda_A_dot": [
            [-0.3190001052],
            [-0.3313537893]
        ],
        "p_A": [
            [49.99995701],
            [49.99994024]
        ],
        "e_A": [
```

```
        [4.299323572e-05],
        [5.976117575e-05]
    ],
    "v_B": 150.0000082,
    "v_B_dot": -19.99999183,
    "u_B": 0.3333299698,
    "p_B": 49.9994982,
    "e_B": 0.0005018021289,
    "metrics": {
        "optimality": 1.877830374e-11,
        "feasibility": 1.640902151e-14,
        "barrier": 1e-08
    },
    "derived": {
        "load_v_A": [
            [0.3500006775],
            [0.5394741193]
        ],
        "load_i_A": [
            [10.00001783],
            [14.98616103]
        ],
        "load_p_A": [
            [3.500013016],
            [8.084646025]
        ],
        "generation_A": [
            [350.0004919],
            [499.5847712]
        ],
        "storage_v_A": [
            [4.999986786],
            [3.336407511]
        ],
        "storage_i_A": [
            [10.00001783],
            [14.98616103]
        ],
        "storage_p_A": [
            [49.99995701],
            [49.99994024]
        ],
        "storage_e_A": [
            [4.299323572e-05],
            [5.976117575e-05]
        ],
        "duty_A": [
            [0.2309998948],
            [0.2186462107]
        ],
        "load_v_B": 150.0000082,
        "load_i_B": 5.92000036,
        "load_p_B": 888.0001023,
        "generation_B": 49.9994982,
        "storage_v_B": 150.0000082,
        "storage_i_B": 0.3333299698,
        "storage_p_B": 49.9994982,
        "storage_e_B": 0.0005018021289
```

```
    }
},
"tighter_boost": {
    "u_A": [
        [4.999989611],
        [4.999989611]
    ],
    "i_A": [
        [10.00000228],
        [10.00000228]
    ],
    "i_A_dot": [
        [-4.999997725],
        [-4.999997725]
    ],
    "lambda_A": [
        [0.2688945834],
        [0.2688945834]
    ],
    "lambda_A_dot": [
        [-0.2811054166],
        [-0.2811054166]
    ],
    "p_A": [
        [49.99990749],
        [49.99990749]
    ],
    "e_A": [
        [9.251470286e-05],
        [9.251473122e-05]
    ],
    "v_B": 128.8608684,
    "v_B_dot": -41.13913163,
    "u_B": -0.3880146841,
    "p_B": -49.99990914,
    "e_B": 99.99990914,
    "metrics": {
        "optimality": 6.723195818e-11,
        "feasibility": 2.675706272e-09,
        "barrier": 1e-08
    },
    "derived": {
        "load_v_A": [
            [0.3500000865],
            [0.3500000865]
        ],
        "load_i_A": [
            [10.00000228],
            [10.00000228]
        ],
        "load_p_A": [
            [3.500001661],
            [3.500001661]
        ],
        "generation_A": [
            [349.9999757],
            [349.9999757]
        ],
```

```
            "storage_v_A": [
                [4.999989611],
                [4.999989611]
            ],
            "storage_i_A": [
                [10.00000228],
                [10.00000228]
            ],
            "storage_p_A": [
                [49.99990749],
                [49.99990749]
            ],
            "storage_e_A": [
                [9.251470286e-05],
                [9.251473122e-05]
            ],
            "duty_A": [
                [0.2688945834],
                [0.2688945834]
            ],
            "load_v_B": 128.8608684,
            "load_i_B": 4.989878208,
            "load_p_B": 643.000039,
            "generation_B": -49.99990914,
            "storage_v_B": 128.8608684,
            "storage_i_B": -0.3880146841,
            "storage_p_B": -49.99990914,
            "storage_e_B": 99.99990914
        }
    }
}
```

5.2 Single AC Microgrid

Recall, the single AC microgrid has a topology found in Figure 4.8. We specify this with the parameter file

```
{
    "Optizelle" : {
        "iter_max" : 200
    },
    "microgrid": {
        "ineq_scaling" : 1e-2,
        "Delta_t": 1.0,
        "ntime" : 1,
        "ninv" : 2,
        "nac" : 1,
        "Phi_inv_ac_7" : [
            [1],
            [1]
        ],
        "w_G_duty": [
            [1],
            [1]
        ],
        "w_G_control": [
            [0],
            [0]
```

```
],
"w_G_loss": [
    [0],
    [0]
],
"w_G_power": [
    [0],
    [0]
],
"v_G": [
    [30],
    [30]
],
"C_G_dc": [
    [0.004],
    [0.004]
],
"R_G_dc": [
    [25],
    [25]
],
"L_G": [
    [0.002],
    [0.002]
],
"R_G": [
    [0.036],
    [0.036]
],
"v_G_dc_0" : [
    [30],
    [30]
],
"v_G_dc_min": [
    [0],
    [0]
],
"v_G_dc_max": [
    [500],
    [500]
],
"i_G_d_0": [
    [15],
    [15]
],
"i_G_d_min": [
    [0],
    [0]
],
"i_G_d_max": [
    [40],
    [40]
],
"i_G_q_0": [
    [15],
    [15]
],
"i_G_q_min": [
```

```
        [10],
        [10]
    ],
    "i_G_q_max": [
        [40],
        [40]
    ],
    "lambda_G_0": [
        [0.55],
        [0.55]
    ],
    "lambda_G_min": [
        [0],
        [0]
    ],
    "lambda_G_max": [
        [1],
        [1]
    ],
    "u_G_switch" : [
        [1],
        [1]
    ],
    "u_G_min": [
        [0],
        [0]
    ],
    "u_G_max": [
        [100],
        [100]
    ],
    "e_G_0": [
        [50],
        [50]
    ],
    "e_G_min": [
        [0],
        [0]
    ],
    "e_G_max": [
        [100],
        [100]
    ],
    "w_F_control": [0],
    "w_F_power": [0],
    "omega_F": [376.9911184],
    "v_F_d_0": [170],
    "v_F_d_min": [0],
    "v_F_d_max": [500],
    "v_F_q_0": [170],
    "v_F_q_min": [0],
    "v_F_q_max": [500],
    "R_F": [25],
    "P_F_d": [0.0],
    "P_F_q": [0.0],
    "C_F": [0.004],
    "u_F_switch" : [1],
    "u_F_d_min": [-50],
```

```
        "u_F_d_max": [100],
        "u_F_q_min": [-50],
        "u_F_q_max": [100],
        "e_F_0": [50],
        "e_F_min": [0],
        "e_F_max": [100]
    },
    "default" : {}
}
```

and run it with the command

```
solution=runScenario('single_ac','default');
```

which produces the solution


```
{
    "default": {
        "v_F_d": 34.23299918,
        "v_F_q": 0.4331995667,
        "v_F_d_dot": -135.7670008,
        "v_F_q_dot": -169.5668004,
        "u_F_d": -0.7068348612,
        "u_F_q": 16.06807396,
        "p_F": -17.23639454,
        "e_F": 67.23639454,
        "u_G": [
            [49.34068309],
            [49.40569838]
        ],
        "i_G": [
            [0.6679797307],
            [0.6673053769]
        ],
        "v_G_dc": [
            [62.64118982],
            [62.72306396]
        ],
        "v_G_dc_dot": [
            [32.64118982],
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Index