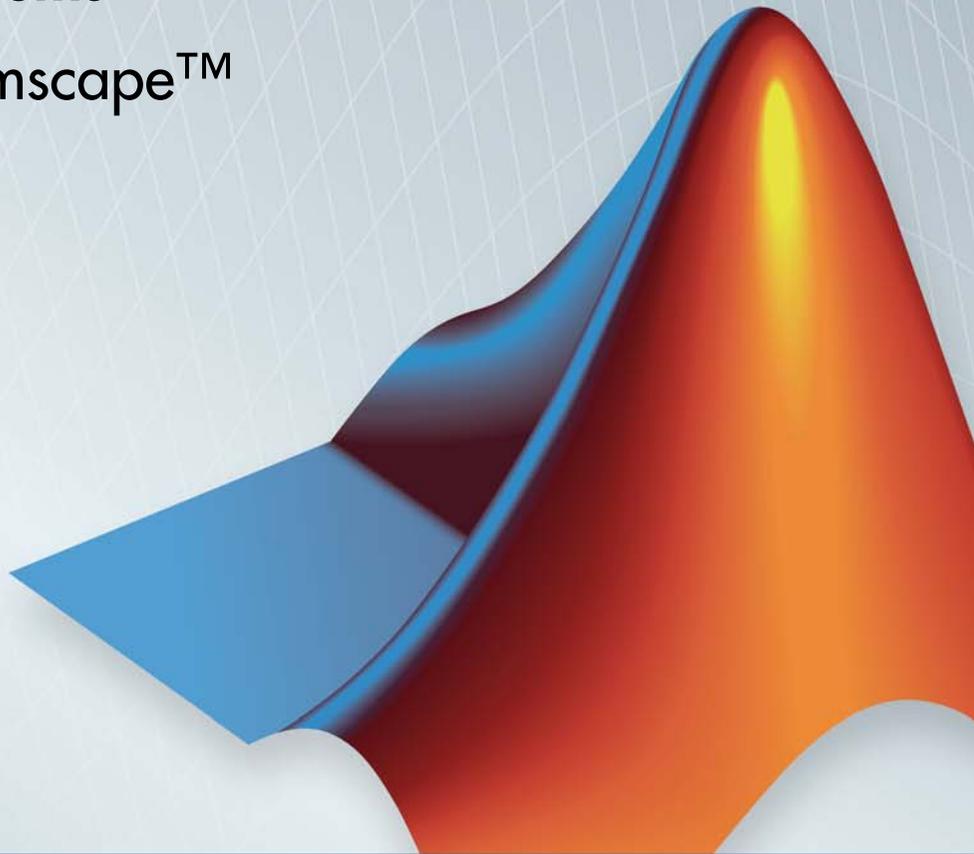


SimPowerSystems™

Reference (Simscape™ Components)

R2014a



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SimPowerSystems™ Reference (Simscape™ Components)

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Revision History

September 2013	Online only	New for Version 6.0 (Release 2013b)
March 2014	Online only	Revised for Version 6.1 (Release 2014a)(Renamed from <i>SimPowerSystems™ Reference (Third Generation)</i>)

Blocks — Alphabetical List

1

Functions — Alphabetical List

2

Abbreviations and Naming Conventions in Simscape Components Libraries

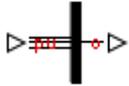
Blocks — Alphabetical List

Asynchronous Machine Measurement

Purpose Per-unit measurement from asynchronous machine

Library Machines

Description



The Asynchronous Machine Measurement block outputs a per-unit measurement associated with a connected Asynchronous Machine Squirrel Cage or Asynchronous Machine Wound Rotor block. The input of the Asynchronous Machine Measurement block connects to the pu output port of the asynchronous machine block.

You set the **Output** parameter to a per-unit measurement associated with the asynchronous machine. Based on the value you select, the Asynchronous Machine Measurement block:

- Directly outputs the value of an element in the input signal vector
- Calculates the per-unit measurement by using values of elements in the input signal vector in mathematical expressions

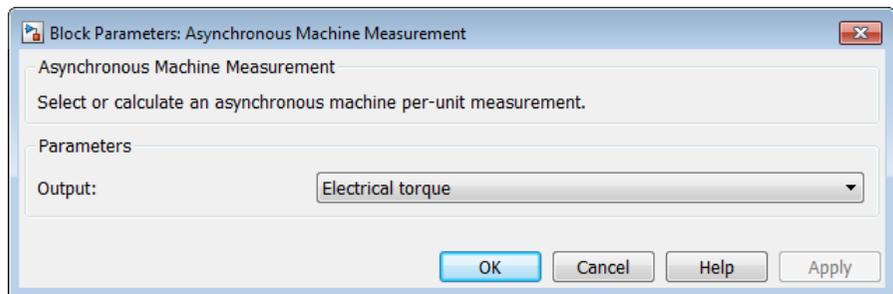
The Asynchronous Machine Measurement block outputs a per-unit measurement from the asynchronous machine according to the output value expressions in the table. For example, when you set **Output** to **Stator d-axis voltage**, the block directly outputs the value of the pu_vds element in the input signal vector. However, when you set **Output** to **Slip**, the block calculates the slip value by subtracting the value of the pu_velocity element from 1.

Output Parameter Setting	Output Value Expression
Electrical torque	pu_torque
Rotor velocity	pu_velocity
Stator d-axis voltage	pu_vds
Stator q-axis voltage	pu_vqs
Stator zero-sequence voltage	pu_v0s
Stator d-axis current	pu_ids

Asynchronous Machine Measurement

Output Parameter Setting	Output Value Expression
Stator q-axis current	pu_iqs
Stator zero-sequence current	pu_i0s
Slip	1-pu_velocity
Apparent power	$\sqrt{pu_Pt^2 + pu_Qt^2}$
Real power	pu_Pt = (pu_vds*pu_ids) + (pu_vqs*pu_iqs) + 2(pu_v0s*pu_i0s)
Reactive power	pu_Qt = (pu_vqs*pu_ids) - (pu_vds*pu_iqs)
Terminal voltage	$\sqrt{pu_vds^2 + pu_vqs^2}$
Terminal current	$\sqrt{pu_ids^2 + pu_iqs^2}$
Power factor angle (rad)	power_factor_angle = atan2(pu_Qt, pu_Pt)
Power factor	cos(power_factor_angle)

Dialog Box and Parameters



Asynchronous Machine Measurement

Output

Per-unit measurement from asynchronous machine. The default value is `Electrical torque`.

Ports

The block has the following ports:

`pu`

Physical signal vector port associated with per-unit measurements from a connected asynchronous machine. The vector elements are:

- `pu_torque`
- `pu_velocity`
- `pu_vds`
- `pu_vqs`
- `pu_v0s`
- `pu_ids`
- `pu_iqs`
- `pu_i0s`

`o`

Per-unit measurement output port.

See Also

[Asynchronous Machine Squirrel Cage \(fundamental\)](#)

[Asynchronous Machine Wound Rotor \(fundamental\)](#)

Asynchronous Machine Squirrel Cage (fundamental)

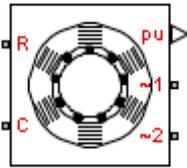
Purpose

Squirrel-cage-rotor asynchronous machine with fundamental parameterization

Library

Machines / Asynchronous Machine (Squirrel Cage)

Description



The Asynchronous Machine Squirrel Cage (fundamental) block models a squirrel-cage-rotor asynchronous machine with parameterization using fundamental parameters. A squirrel-cage-rotor asynchronous machine is a type of induction machine. All stator connections are accessible on the block. Therefore, you can model soft-start regimes using a switch between wye and delta configurations. If you need access to the rotor windings, use the Asynchronous Machine Wound Rotor (fundamental) block instead.

Connect port ~1 to a three-phase circuit. To connect the stator in delta configuration, connect a Phase Permute block between ports ~1 and ~2. To connect the stator in wye configuration, connect port ~2 to a Grounded Neutral or a Floating Neutral block.

Electrical Defining Equations

The asynchronous machine equations are expressed with respect to a synchronous reference frame, defined by

$$\theta_e(t) = \int_0^t 2\pi f_{rated} dt,$$

where f_{rated} is the value of the **Rated electrical frequency** parameter.

Park's transformation maps stator equations to a reference frame that is stationary with respect to the rated electrical frequency. Park's transformation is defined by

Asynchronous Machine Squirrel Cage (fundamental)

$$P_s = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin \theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix},$$

where θ_e is the electrical angle.

Park's transformation is used to define the per-unit asynchronous machine equations. The stator voltage equations are defined by

$$v_{ds} = \frac{1}{\omega_{base}} \frac{d\psi_{ds}}{dt} - \omega \psi_{qs} + R_s i_{ds},$$

$$v_{qs} = \frac{1}{\omega_{base}} \frac{d\psi_{qs}}{dt} + \omega \psi_{ds} + R_s i_{qs},$$

and

$$v_{0s} = \frac{1}{\omega_{base}} \frac{d\psi_{0s}}{dt} + R_s i_{0s},$$

where:

- v_{ds} , v_{qs} , and v_{0s} are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} v_{ds} \\ v_{qs} \\ v_{0s} \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages across ports ~1 and ~2.

- ω_{base} is the per-unit base electrical speed.

Asynchronous Machine Squirrel Cage (fundamental)

- ψ_{ds} , ψ_{qs} , and ψ_{0s} are the d-axis, q-axis, and zero-sequence stator flux linkages.
- R_s is the stator resistance.
- i_{ds} , i_{qs} , and i_{0s} are the d-axis, q-axis, and zero-sequence stator currents defined by

$$\begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{0s} \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port ~1 to port ~2.

The rotor voltage equations are defined by

$$v_{dr} = \frac{1}{\omega_{base}} \frac{d\psi_{dr}}{dt} - (\omega - \omega_r)\psi_{qr} + R_{rd}i_{dr} = 0$$

and

$$v_{qr} = \frac{1}{\omega_{base}} \frac{d\psi_{qr}}{dt} + (\omega - \omega_r)\psi_{dr} + R_{rd}i_{qr} = 0,$$

where:

- v_{dr} and v_{qr} are the d-axis and q-axis rotor voltages.
- ψ_{dr} and ψ_{qr} are the d-axis and q-axis rotor flux linkages.
- ω is the is the per-unit synchronous speed. For a synchronous reference frame, the value is 1.
- ω_r is the per-unit mechanical rotational speed.
- R_{rd} is the rotor resistance referred to the stator.
- i_{dr} and i_{qr} are the d-axis and q-axis rotor currents.

Asynchronous Machine Squirrel Cage (fundamental)

The stator flux linkage equations are defined by

$$\psi_{ds} = L_{ss}i_{ds} + L_m i_{dr},$$

$$\psi_{qs} = L_{ss}i_{qs} + L_m i_{qr},$$

and

$$\psi_{0s} = L_{ss}i_{0s},$$

where L_{ss} is the stator self-inductance and L_m is the magnetizing inductance.

The rotor flux linkage equations are defined by

$$\psi_{dr} = L_{rrd}i_{dr} + L_m i_{ds}$$

and

$$\psi_{qr} = L_{rrd}i_{qr} + L_m i_{qs},$$

where L_{rrd} is the rotor self-inductance referred to the stator.

The rotor torque is defined by

$$T = \psi_{ds}i_{qs} - \psi_{qs}i_{ds}.$$

The stator self-inductance L_{ss} , stator leakage inductance L_{ls} , and magnetizing inductance L_m are related by

$$L_{ss} = L_{ls} + L_m.$$

The rotor self-inductance L_{rrd} , rotor leakage inductance L_{lrd} , and magnetizing inductance L_m are related by

$$L_{rrd} = L_{lrd} + L_m.$$

Asynchronous Machine Squirrel Cage (fundamental)

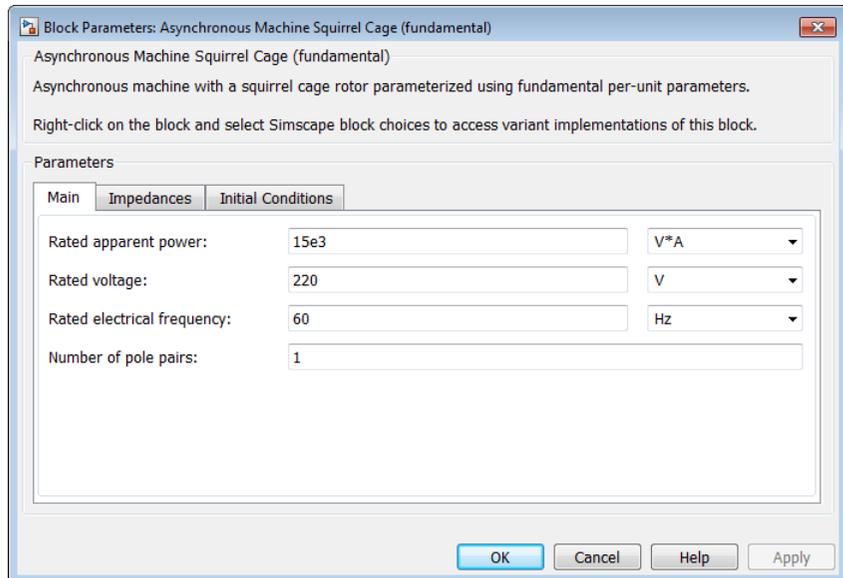
Plotting and Displaying Options

For an asynchronous machine block, you can perform plotting and display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Asynchronous Machine** menu:

- **Display Base Values** displays the machine per-unit base values in the MATLAB[®] Command Window.
- **Plot Torque Speed (SI)** plots torque versus speed (both measured in SI units) in a MATLAB figure window using the current machine parameters.
- **Plot Torque Speed (pu)** plots torque versus speed (both measured in per unit) in a MATLAB figure window using the current machine parameters.

Dialog Box and Parameters



Asynchronous Machine Squirrel Cage (fundamental)

All default parameter values are based on a machine delta-winding configuration.

- “Main Tab” on page 1-10
- “Impedances Tab” on page 1-10
- “Initial Conditions Tab” on page 1-11

Main Tab

Rated apparent power

Rated apparent power of the asynchronous machine. The default value is 15e3 VA.

Rated voltage

RMS line-line voltage. The default value is 220 V.

Rated electrical frequency

Nominal electrical frequency corresponding to the rated apparent power. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 1.

Impedances Tab

Stator resistance, R_s (pu)

Stator resistance. The default value is 0.0258.

Stator leakage inductance, L_{ls} (pu)

Stator leakage inductance. The default value is 0.0930.

Referred rotor resistance, R_r' (pu)

Rotor resistance referred to the stator. The default value is 0.0145.

Referred rotor leakage inductance, L_{lr}' (pu)

Rotor leakage inductance referred to the stator. The default value is 0.0424.

Asynchronous Machine Squirrel Cage (fundamental)

Magnetizing inductance, L_m (pu)

Magnetizing inductance, i.e., the peak value of stator-rotor mutual inductance. The default value is 1.7562.

Stator zero-sequence inductance, L_0 (pu)

Stator zero-sequence inductance. The default value is 0.0930.

Initial Conditions Tab

Initial rotor angle

Initial rotor angle. The default value is 0 deg.

Initial stator d-axis magnetic flux linkage

Initial stator d-axis flux linkage. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Initial stator q-axis flux linkage. The default value is 0 pu.

Initial stator zero-sequence magnetic flux linkage

Initial stator zero-sequence flux linkage. The default value is 0 pu.

Initial rotor d-axis magnetic flux linkage

Initial rotor d-axis flux linkage. The default value is 0 pu.

Initial rotor q-axis magnetic flux linkage

Initial stator q-axis flux linkage. The default value is 0 pu.

Ports

The block has the following ports:

R

Mechanical rotational conserving port associated with the machine rotor.

C

Mechanical rotational conserving port associated with the machine case.

~1

Expandable three-phase port associated with the stator positive-end connections.

Asynchronous Machine Squirrel Cage (fundamental)

~2

Expandable three-phase port associated with the stator negative-end connections.

pu

Physical signal vector port associated with the machine per-unit measurements. The vector elements are:

- pu_torque
- pu_velocity
- pu_vds
- pu_vqs
- pu_v0s
- pu_ids
- pu_iqs
- pu_i0s

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

See Also Asynchronous Machine MeasurementAsynchronous Machine Wound Rotor (fundamental)

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Asynchronous Machine Starting

Asynchronous Machine Wound Rotor (fundamental)

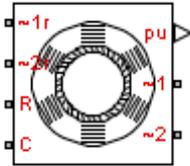
Purpose

Wound-rotor asynchronous machine with fundamental parameterization

Library

Machines / Asynchronous Machine (Wound Rotor)

Description



The Asynchronous Machine Wound Rotor (fundamental) block models a wound-rotor asynchronous machine with parameterization using fundamental parameters. A wound-rotor asynchronous machine is a type of induction machine. All stator and rotor connections are accessible on the block. Therefore, you can model soft-start regimes using a switch between wye and delta configurations or by increasing rotor resistance. If you do not need access to the rotor windings, use the Asynchronous Machine Squirrel Cage (fundamental) block instead.

Connect port ~1 to a three-phase circuit. To connect the stator in delta configuration, connect a Phase Permute block between ports ~1 and ~2. To connect the stator in wye configuration, connect port ~2 to a Grounded Neutral or a Floating Neutral block. If you do not need to vary rotor resistance, connect rotor port ~1r to a Floating Neutral block and rotor port ~2r to a Grounded Neutral block.

The rotor circuit is referred to the stator. Therefore, when you use the block in a circuit, you must also refer any additional circuit parameters to the stator.

Electrical Defining Equations

The asynchronous machine equations are expressed with respect to a synchronous reference frame, defined by

$$\theta_e(t) = \int_0^t 2\pi f_{rated} dt,$$

where f_{rated} is the value of the **Rated electrical frequency** parameter.

Park's transformation maps stator equations to a reference frame that is stationary with respect to the rated electrical frequency. Park's transformation is defined by

Asynchronous Machine Wound Rotor (fundamental)

$$P_s = \frac{2}{3} \begin{bmatrix} \cos\theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin\theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix},$$

where θ_e is the electrical angle.

The rotor equations are mapped to another reference frame, defined by the difference between the electrical angle and the product of rotor angle θ_r and number of pole pairs N :

$$P_r = \frac{2}{3} \begin{bmatrix} \cos(\theta_e - N\theta_r) & \cos(\theta_e - N\theta_r - \frac{2\pi}{3}) & \cos(\theta_e - N\theta_r + \frac{2\pi}{3}) \\ -\sin(\theta_e - N\theta_r) & -\sin(\theta_e - N\theta_r - \frac{2\pi}{3}) & -\sin(\theta_e - N\theta_r + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}.$$

Park's transformation is used to define the per-unit asynchronous machine equations. The stator voltage equations are defined by

$$v_{ds} = \frac{1}{\omega_{base}} \frac{d\psi_{ds}}{dt} - \omega\psi_{qs} + R_s i_{ds},$$

$$v_{qs} = \frac{1}{\omega_{base}} \frac{d\psi_{qs}}{dt} + \omega\psi_{ds} + R_s i_{qs},$$

and

$$v_{0s} = \frac{1}{\omega_{base}} \frac{d\psi_{0s}}{dt} + R_s i_{0s},$$

where:

Asynchronous Machine Wound Rotor (fundamental)

- v_{ds} , v_{qs} , and v_{0s} are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} v_{ds} \\ v_{qs} \\ v_{0s} \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages across ports ~1 and ~2.

- ω_{base} is the per-unit base electrical speed.
- ψ_{ds} , ψ_{qs} , and ψ_{0s} are the d-axis, q-axis, and zero-sequence stator flux linkages.
- R_s is the stator resistance.
- i_{ds} , i_{qs} , and i_{0s} are the d-axis, q-axis, and zero-sequence stator currents, defined by

$$\begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{0s} \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port ~1 to port ~2.

The rotor voltage equations are defined by

$$v_{dr} = \frac{1}{\omega_{base}} \frac{d\psi_{dr}}{dt} - (\omega - \omega_r)\psi_{qr} + R_{rd}i_{dr},$$

$$v_{qr} = \frac{1}{\omega_{base}} \frac{d\psi_{qr}}{dt} + (\omega - \omega_r)\psi_{dr} + R_{rd}i_{qr},$$

and

Asynchronous Machine Wound Rotor (fundamental)

$$v_{0r} = \frac{1}{\omega_{base}} \frac{d\psi_{0r}}{dt} + R_{rd}i_{0s},$$

where:

- v_{dr} , v_{qr} , and v_{0r} are the d-axis, q-axis, and zero-sequence rotor voltages, defined by

$$\begin{bmatrix} v_{dr} \\ v_{qr} \\ v_{0r} \end{bmatrix} = P_r \begin{bmatrix} v_{ar} \\ v_{br} \\ v_{cr} \end{bmatrix},$$

where v_{ar} , v_{br} , and v_{cr} are the rotor voltages across ports ~1r and ~2r.

- ψ_{dr} , ψ_{qr} , and ψ_{0r} are the d-axis, q-axis, and zero-sequence rotor flux linkages.
- ω is the per-unit synchronous speed. For a synchronous reference frame, the value is 1.
- ω_r is the per-unit mechanical rotational speed.
- R_{rd} is the rotor resistance referred to the stator.
- i_{dr} , i_{qr} , and i_{0r} are the d-axis, q-axis, and zero-sequence rotor currents, defined by

$$\begin{bmatrix} i_{dr} \\ i_{qr} \\ i_{0r} \end{bmatrix} = P_r \begin{bmatrix} i_{ar} \\ i_{br} \\ i_{cr} \end{bmatrix},$$

where i_{ar} , i_{br} , and i_{cr} are the rotor currents flowing from port ~1r to port ~2r.

The stator flux linkage equations are defined by

$$\psi_{ds} = L_{ss}i_{ds} + L_m i_{dr},$$

Asynchronous Machine Wound Rotor (fundamental)

$$\psi_{qs} = L_{ss}i_{qs} + L_m i_{qr},$$

and

$$\psi_{0s} = L_{ss}i_{0s},$$

where L_{ss} is the stator self-inductance and L_m is the magnetizing inductance.

The rotor flux linkage equations are defined by

$$\psi_{dr} = L_{rrd}i_{dr} + L_m i_{ds}$$

$$\psi_{qr} = L_{rrd}i_{qr} + L_m i_{qs},$$

and

$$\psi_{0r} = L_{rrd}i_{0r},$$

where L_{rrd} is the rotor self-inductance referred to the stator.

The rotor torque is defined by

$$T = \psi_{ds}i_{qs} - \psi_{qs}i_{ds}.$$

The stator self-inductance L_{ss} , stator leakage inductance L_{ls} , and magnetizing inductance L_m are related by

$$L_{ss} = L_{ls} + L_m.$$

The rotor self-inductance L_{rrd} , rotor leakage inductance L_{lr} , and magnetizing inductance L_m are related by

$$L_{rrd} = L_{lr} + L_m.$$

Asynchronous Machine Wound Rotor (fundamental)

Plotting and Displaying Options

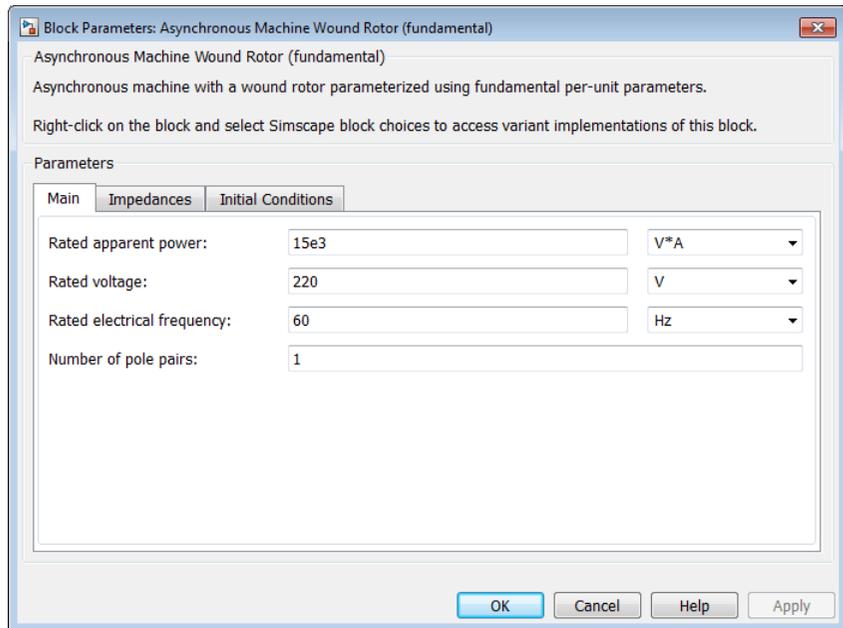
For an asynchronous machine block, you can perform plotting and display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Asynchronous Machine** menu:

- **Display Base Values** displays the machine per-unit base values in the MATLAB Command Window.
- **Plot Torque Speed (SI)** plots torque versus speed (both measured in SI units) in a MATLAB figure window using the current machine parameters.
- **Plot Torque Speed (pu)** plots torque versus speed (both measured in per unit) in a MATLAB figure window using the current machine parameters.

Asynchronous Machine Wound Rotor (fundamental)

Dialog Box and Parameters



All default parameter values are based on a machine delta-winding configuration.

- “Main Tab” on page 1-19
- “Impedances Tab” on page 1-20
- “Initial Conditions Tab” on page 1-20

Main Tab

Rated apparent power

Rated apparent power of the asynchronous machine. The default value is 15e3 VA.

Rated voltage

RMS line-line voltage. The default value is 220 V.

Asynchronous Machine Wound Rotor (fundamental)

Rated electrical frequency

Nominal electrical frequency corresponding to the rated apparent power. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 1.

Impedances Tab

Stator resistance, R_s (pu)

Stator resistance. The default value is 0.0258.

Stator leakage inductance, L_{ls} (pu)

Stator leakage inductance. The default value is 0.0930.

Referred rotor resistance, R_r' (pu)

Rotor resistance referred to the stator. The default value is 0.0145.

Referred rotor leakage inductance, L_{lr}' (pu)

Rotor leakage inductance referred to the stator. The default value is 0.0424.

Magnetizing inductance, L_m (pu)

Magnetizing inductance, i.e., the peak value of stator-rotor mutual inductance. The default value is 1.7562.

Stator zero-sequence inductance, L_0 (pu)

Stator zero-sequence inductance. The default value is 0.0930.

Initial Conditions Tab

Initial rotor angle

Initial rotor angle. The default value is 0 deg.

Initial stator d-axis magnetic flux linkage

Initial stator d-axis flux linkage. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Initial stator q-axis flux linkage. The default value is 0 pu.

Asynchronous Machine Wound Rotor (fundamental)

Initial stator zero-sequence magnetic flux linkage

Initial stator zero-sequence flux linkage. The default value is 0 pu.

Initial rotor d-axis magnetic flux linkage

Initial rotor d-axis flux linkage. The default value is 0 pu.

Initial rotor q-axis magnetic flux linkage

Initial stator q-axis flux linkage. The default value is 0 pu.

Initial rotor zero-sequence magnetic flux linkage

Initial rotor zero-sequence flux linkage. The default value is 0 pu.

Ports

The block has the following ports:

R

Mechanical rotational conserving port associated with the machine rotor.

C

Mechanical rotational conserving port associated with the machine case.

~1

Expandable three-phase port associated with the stator positive-end connections.

~2

Expandable three-phase port associated with the stator negative-end connections.

~1r

Expandable three-phase port associated with the rotor positive-end connections.

~2r

Expandable three-phase port associated with the rotor negative-end connections.

pu

Physical signal vector port associated with the machine per-unit measurements. The vector elements are:

Asynchronous Machine Wound Rotor (fundamental)

- pu_torque
- pu_velocity
- pu_vds
- pu_vqs
- pu_v0s
- pu_ids
- pu_iqs
- pu_i0s

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

See Also Asynchronous Machine Measurement Asynchronous Machine Squirrel Cage (fundamental)

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Asynchronous Machine Starting

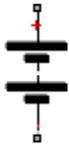
Purpose

Simple battery as finite, charge-dependent voltage source with resistance

Library

Sources

Description



The Battery block models a finite, charge-dependent voltage source with a series resistance. The voltage has a reciprocal relationship with charge defined by the equation

$$V = V_0 \left[1 - \frac{\alpha(1-x)}{1-\beta(1-x)} \right],$$

where:

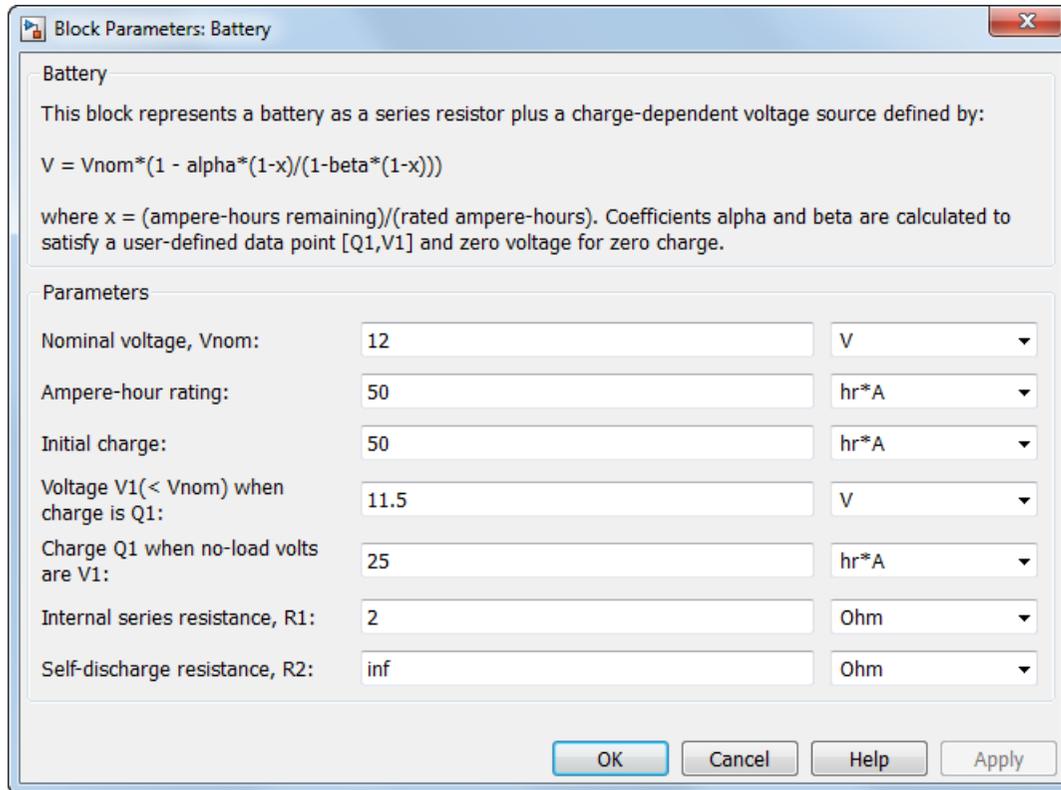
- x is the ratio of the charge left to the rated or full charge for the battery.
- V_0 is the voltage when the battery is fully charged, which you specify using the **Nominal Voltage, Vnom** block parameter.
- α and β are curve-fitting constants. The block fits the voltage-charge equation above onto the points (0, 0) and (Q1, V1) on a charge-voltage graph and computes α and β accordingly. Specify Q1 and V1 in the block dialog box.

Note This equation is an approximation of actual discharge dynamics in a real battery but is easy to parameterize as you only have to provide voltage-charge data for a single discharge point.

The block includes a self-discharge resistance across the battery terminals. By default, self-discharging is disabled, as the parameter **Self-discharge resistance, R2** is set to inf.

Battery

Dialog Box and Parameters



Nominal voltage, Vnom

Voltage of the battery at full charge. The default value is 12 V.

Ampere-Hour rating

Maximum battery charge. The default value is 50 hr*A.

Initial charge

Charge on the battery at the start of the simulation. The default value is 50 hr*A.

Voltage V1< Vnom when charge is Q1

Voltage when the battery charge is at the rated value. The default value is 11.5 V.

Charge Q1 when no-load volts are V1

Charge when the battery potential is V1 Volts. The default value is 25 hr*A.

Internal series resistance, R1

Internal connection resistance of the battery. The default value is 2 Ω .

Self-discharge resistance, R2

Self-discharge resistance of the battery, connected between the two terminals. The default value is inf Ω (self-discharging disabled).

Ports

The block has the following ports:

-

Negative battery terminal

+

Positive battery terminal

See Also

Voltage Source | Current Source

Brushless DC Motor

Purpose

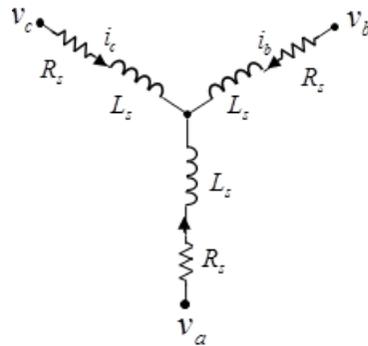
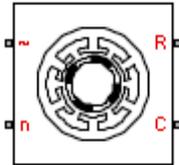
Three-winding brushless DC motor with trapezoidal flux distribution

Library

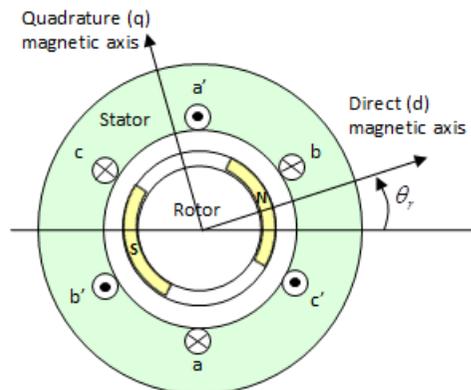
Machines / Permanent Magnet Rotor

Description

The Brushless DC Motor block models a permanent magnet synchronous machine with a three-phase wye-wound stator. The figure shows the equivalent electrical circuit for the stator windings.



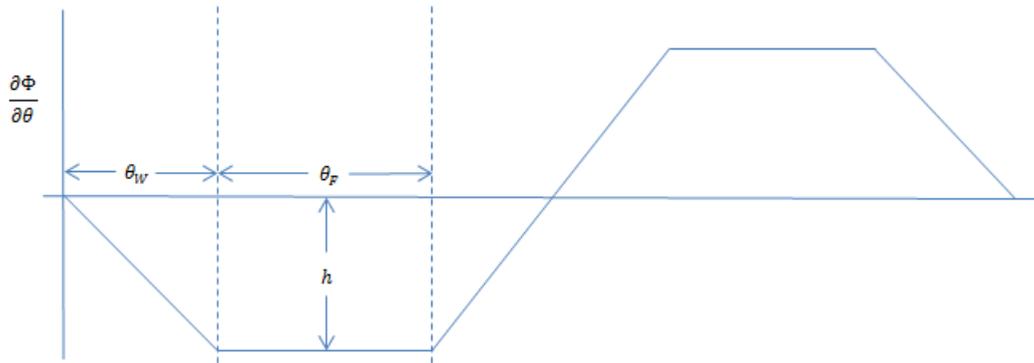
This figure shows the motor construction with a single pole-pair on the rotor.



For the axes convention in the preceding figure, the a-phase and permanent magnet fluxes are aligned when rotor angle θ_r is zero. The

block supports a second rotor axis definition in which rotor angle is defined as the angle between the a-phase magnetic axis and the rotor q axis.

The rotor magnetic field due to the permanent magnet(s) creates a trapezoidal rate of change of flux with rotor angle. The figure shows this rate of change of flux.



Back emf is the rate of change of flux, defined by

$$\frac{d\Phi}{dt} = \frac{\partial\Phi}{\partial\theta} \frac{d\theta}{dt} = \frac{\partial\Phi}{\partial\theta} \omega,$$

where:

- Φ is the permanent magnet flux linkage.
- θ is the rotor angle.
- ω is the mechanical rotational speed.

The height h of the trapezoidal rate of change of flux profile is derived from the permanent magnet peak flux.

Integrating $\frac{\partial\Phi}{\partial\theta}$ over the range 0 to $\pi/2$,

Brushless DC Motor

$$\Phi_{max} = \frac{h}{2}(\theta_F + \theta_W),$$

where:

- Φ_{max} is the permanent magnet flux linkage.
- h is the rate of change of flux profile height.
- θ_F is the rotor angle range over which the back emf that the permanent magnet flux induces in the stator is constant.
- θ_W is the rotor angle range over which back emf increases or decreases linearly when the rotor moves at constant speed.

Rearranging the preceding equation,

$$h = 2\Phi_{max} / (\theta_F + \theta_W).$$

Electrical Defining Equations

Voltages across the stator windings are defined by

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \frac{d\psi_a}{dt} \\ \frac{d\psi_b}{dt} \\ \frac{d\psi_c}{dt} \end{bmatrix},$$

where:

- v_a , v_b , and v_c are the external voltages applied to the three motor electrical connections.
- R_s is the equivalent resistance of each stator winding.
- i_a , i_b , and i_c are the currents flowing in the stator windings.

- $\frac{d\psi_a}{dt}$, $\frac{d\psi_b}{dt}$, and $\frac{d\psi_c}{dt}$

are the rates of change of magnetic flux in each stator winding.

The permanent magnet and the three windings contribute to the total flux linking each winding. The total flux is defined by

$$\begin{bmatrix} \psi_a \\ \psi_b \\ \psi_c \end{bmatrix} = \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \psi_{am} \\ \psi_{bm} \\ \psi_{cm} \end{bmatrix},$$

where:

- ψ_a , ψ_b , and ψ_c are the total fluxes linking each stator winding.
- L_{aa} , L_{bb} , and L_{cc} are the self-inductances of the stator windings.
- L_{ab} , L_{ac} , L_{ba} , etc. are the mutual inductances of the stator windings.
- ψ_{am} , ψ_{bm} , and ψ_{cm} are the permanent magnet fluxes linking the stator windings.

The inductances in the stator windings are functions of rotor angle, defined by

$$L_{aa} = L_s + L_m \cos(2\theta_r),$$

$$L_{bb} = L_s + L_m \cos(2(\theta_r - 2\pi / 3)),$$

$$L_{cc} = L_s + L_m \cos(2(\theta_r + 2\pi / 3)),$$

$$L_{ab} = L_{ba} = -M_s - L_m \cos(2(\theta_r + \pi / 6)),$$

Brushless DC Motor

$$L_{bc} = L_{cb} = -M_s - L_m \cos(2(\theta_r + \pi / 6 - 2\pi / 3)),$$

and

$$L_{ca} = L_{ac} = -M_s - L_m \cos(2(\theta_r + \pi / 6 + 2\pi / 3)),$$

where:

- L_s is the stator self-inductance per phase. This is the average self-inductance of each of the stator windings.
- L_m is the stator inductance fluctuation. This is the amplitude of the fluctuation in self-inductance and mutual inductance with changing rotor angle.
- M_s is the stator mutual inductance. This is the average mutual inductance between the stator windings.

The permanent magnet flux linking each stator winding follows the trapezoidal profile shown in the figure. The block implements the trapezoidal profile using lookup tables to calculate permanent magnet flux values.

Simplified Equations

The defining voltage and torque equations for the block are

$$\begin{bmatrix} v_d \\ v_q \\ v_0 \end{bmatrix} = P \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} - N\omega \begin{bmatrix} \frac{\partial \psi_a}{\partial \theta_r} \\ \frac{\partial \psi_b}{\partial \theta_r} \\ \frac{\partial \psi_c}{\partial \theta_r} \end{bmatrix},$$

$$v_d = R_s i_d + L_d \frac{di_d}{dt} - N\omega i_q L_q,$$

$$v_q = R_s i_q + L_q \frac{di_q}{dt} + N \omega i_d L_d,$$

$$v_0 = R_s i_0 + L_0 \frac{di_0}{dt},$$

and

$$T = \frac{3}{2} N (i_q i_d L_d - i_d i_q L_q) + [i_a \quad i_b \quad i_c] \begin{bmatrix} \frac{\partial \psi_a}{\partial \theta_r} \\ \frac{\partial \psi_b}{\partial \theta_r} \\ \frac{\partial \psi_c}{\partial \theta_r} \end{bmatrix},$$

where:

- v_d , v_q , and v_0 are the d-axis, q-axis, and zero-sequence voltages.
- P is Park's Transformation, defined by

$$P = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - 2\pi / 3) & \cos(\theta_e + 2\pi / 3) \\ -\sin \theta_e & -\sin(\theta_e - 2\pi / 3) & -\sin(\theta_e + 2\pi / 3) \\ 0.5 & 0.5 & 0.5 \end{bmatrix}.$$

- N is the number of rotor permanent magnet pole pairs.
- ω is the rotor mechanical rotational speed.

- $\frac{\partial \psi_a}{\partial \theta_r}$, $\frac{\partial \psi_b}{\partial \theta_r}$, and $\frac{\partial \psi_c}{\partial \theta_r}$

are the partial derivatives of instantaneous permanent magnet flux linking each phase winding.

- i_d , i_q , and i_0 are the d-axis, q-axis, and zero-sequence currents, defined by

Brushless DC Motor

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}.$$

- $L_d = L_s + M_s + 3/2 L_m$. L_d is the stator d-axis inductance.
- $L_q = L_s + M_s - 3/2 L_m$. L_q is the stator q-axis inductance.
- $L_0 = L_s - 2M_s$. L_0 is the stator zero-sequence inductance.
- T is the rotor torque. Torque flows from the motor case (block physical port C) to the motor rotor (block physical port R).

Dialog Box and Parameters

Block Parameters: Brushless DC Motor

Brushless DC Motor

This block represents a three-winding brushless DC motor with a trapezoidal back emf profile.

Right-click on the block and select Simscape block choices to access variant implementations of this block.

Parameters

Main Initial Conditions

Number of pole pairs: 6

Maximum permanent magnet flux linkage: 0.03 Wb

Rotor angle over which back emf is constant: pi / 12 rad

Stator parameterization: Specify Ld, Lq and L0

Stator d-axis inductance, Ld: 0.00022 H

Stator q-axis inductance, Lq: 0.00022 H

Stator zero-sequence inductance, L0: 0.00016 H

Stator resistance per phase, Rs: 0.013 Ohm

OK Cancel Help Apply

Main Tab

Number of pole pairs

Number of permanent magnet pole pairs on the rotor. The default value is 6.

Maximum permanent magnet flux linkage

Peak permanent magnet flux linkage with any of the stator windings. The default value is 0.03 Wb.

Rotor angle over which back emf is constant

Rotor angle range over which the permanent magnet flux linking the stator winding is constant. This is θ_F in the trapezoidal rate of change of flux figure. The default value is $\pi/12$ rad.

Stator parameterization

Set of stator parameters that the block dialog box shows. The default value is Specify Ld, Lq and L0.

Stator d-axis inductance, Ld

D-axis inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00022 H.

Stator q-axis inductance, Lq

Q-axis inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00022 H.

Stator zero-sequence inductance, L0

Zero-sequence inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00016 H.

Stator self-inductance per phase, Ls

Average self-inductance of each of the three stator windings. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0.00002 H.

Brushless DC Motor

Stator inductance fluctuation, Lm

Amplitude of the fluctuation in self-inductance and mutual inductance of the stator windings with rotor angle. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0 H.

Stator mutual inductance, Ms

Average mutual inductance between the stator windings. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0.00002 H.

Stator resistance per phase, Rs

Resistance of each of the stator windings. The default value is 0.013 Ω .

Initial Conditions Tab

Initial currents, [i_d i_q i_0]

Initial d-axis, q-axis, and zero-sequence currents. The default value is [0, 0, 0] A.

Rotor angle definition

Reference point for the rotor angle measurement. The default value is Angle between the a-phase magnetic axis and the d axis. This definition is shown in the motor construction figure. When you select this value, the rotor and a-phase fluxes are aligned when the rotor angle is zero.

The other value you can choose for this parameter is Angle between the a-phase magnetic axis and the q axis. When you select this value, the a-phase current generates maximum torque when the rotor angle is zero.

Initial rotor angle

Initial angle of the rotor. The default value is 0 deg.

Ports

~

Expandable three-phase port.

- n Electrical conserving port associated with the neutral phase.
- R Mechanical rotational conserving port associated with the motor rotor.
- C Mechanical rotational conserving port associated with the motor case.

References

- [1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.
- [2] Anderson, P. M. *Analysis of Faulted Power Systems*. Hoboken, NJ: Wiley-IEEE Press, 1995.

Related Examples

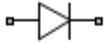
- “Expand and Collapse Three-Phase Ports on a Block”

Commutation Diode

Purpose Piecewise linear diode with charge dynamics and junction capacitance

Library Semiconductors / Fundamental Components

Description The Commutation Diode block augments the Diode block with a model of charge dynamics. For a description of the piecewise linear diode operation that the Commutation Diode block uses, see Diode.



Use the Commutation Diode block in place of the Diode block when you want to specify precisely the charge dynamics of the device as it operates in reverse mode. For example, suppose your model uses the diode to divert inductive currents from a motor drive or inverter. In this case, precise reverse-mode operation is important and an appropriate time to use the Commutation Diode block.

The Commutation Diode uses a charge model proposed by Lauritzen and Ma [1]. The defining expressions for this charge model are:

$$i = \frac{q_E - q_M}{T_M} \quad (1-1)$$

$$\frac{dq_M}{dt} + \frac{q_M}{\tau} - \frac{q_E - q_M}{T_M} = 0 \quad (1-2)$$

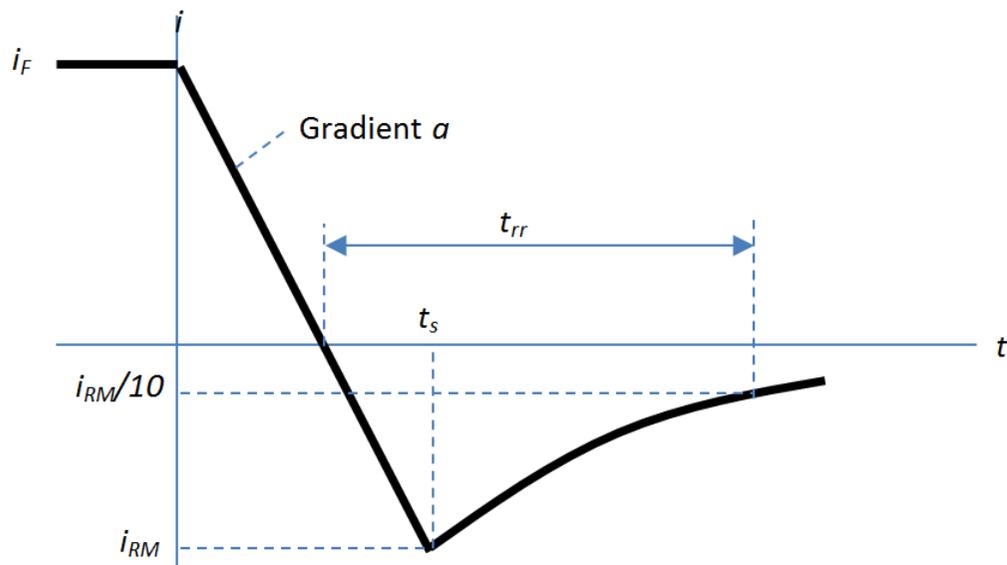
$$\begin{aligned} q_E &= (\tau + T_M)(v_D - v_F(1 - RG)) / R & \text{if } v_D > v_F \\ q_E &= (\tau + T_M)Gv_D & \text{if } v_D \leq v_F \end{aligned} \quad (1-3)$$

where:

- i is the diode current.
- q_E is the junction charge.
- q_M is the total stored charge.
- T_M is the transit time.
- τ is the carrier lifetime.

- v_D is the voltage across the diode.
- v_F is the diode forward voltage.
- R is the diode on resistance.
- G is the diode off conductance.

This graphic shows a typical reverse-mode current characteristic for a diode device.



where:

- i_{RM} is the peak reverse current.
- i_F is the starting forward current when measuring i_{RM} .
- a is the rate of change of current when measuring i_{RM} .
- t_{rr} is the reverse recovery time.

Commutation Diode

On the Charge Dynamics tab of the block, you specify characteristics of your diode device. The block uses these values to calculate the diode charge dynamics expressed in equations 1-1, 1-2, and 1-3.

Data sheets for diodes quote values for peak reverse current for an initial forward current and a steady rate of change of current. The data sheet might also provide values for reverse recovery time and total recovery charge.

How the Block Calculates T_M and Tau

The block calculates transit time T_M and carrier lifetime τ based on the values you enter on the Charge Dynamics tab of the block dialog box. The block uses T_M and τ to solve the charge dynamics equations 1-1, 1-2, and 1-3.

During initial current drop in reverse mode, the diode is still on, and the rate of change of current is determined by an external test circuit.

Using Equation 1-1,

$$i_F + at = \frac{q_E - q_M}{T_M}. \quad (1-4)$$

Substituting Equation 1-4 into Equation 1-2,

$$\frac{dq_M}{dt} + \frac{q_M}{\tau} = i_F + at. \quad (1-5)$$

Solving Equation 1-5 for q_M ,

$$q_M = i_F\tau - a\tau^2 + \frac{k}{\exp\left(\frac{t}{\tau}\right)} + a\tau t, \quad (1-6)$$

where k is a constant.

When t is zero, $i = i_F$ and $q_M = \tau i_F$ because the system is in steady state.

Substituting these relationships into Equation 1-6 and solving the equation gives $k = a\tau^2$.

Therefore,

$$q_M = i_F\tau + a\tau^2 \left(\frac{1}{\exp\left(\frac{t}{\tau}\right)} - 1 \right) + a\tau t. \quad (1-7)$$

At time $t = t_s$, the current is i_{RM} and the junction charge q_E is zero.

Substituting these values into Equation 1-1,

$$i_{RM} = \frac{-q_M}{T_M}. \quad (1-8)$$

Rearranging Equation 1-8 to solve for q_M and substituting the result into Equation 1-7,

$$-T_M i_{RM} = i_F\tau + a\tau^2 \left(\frac{1}{\exp\left(\frac{t_s}{\tau}\right)} - 1 \right) + a\tau t_s. \quad (1-9)$$

Expressing time t_s in terms of i_{RM} , i_F , and a ,

$$t_s = \frac{i_{RM} - i_F}{a}. \quad (1-10)$$

Consider the diode recovery, i.e., when $t > t_s$. The diode is reverse biased, and current and junction charge are effectively zero.

The current is defined by

Commutation Diode

$$i = i_{RM} \exp\left[\frac{-(t - t_s)}{\tau_{rr}}\right], \quad (1-11)$$

where

$$\frac{1}{\tau_{rr}} = \frac{1}{\tau} + \frac{1}{T_M}. \quad (1-12)$$

The block now relates the expression in Equation 1-12 to the reverse recovery time t_{rr} .

When $t = \frac{i_{RM}}{a} + t_{rr}$, the current is $\frac{i_{RM}}{10}$.

Therefore,

$$\exp\left(-\frac{t - t_s}{\tau_{rr}}\right) = 0.1 \quad (1-13)$$

and

$$t_{rr} = \tau_{rr} \log(10) + \frac{i_{RM}}{a}. \quad (1-14)$$

The block uses equations 1-9 and 1-14 to calculate values for T_M and τ . The calculation uses an iterative scheme because of the exponential term in Equation 1-9.

Alternatives to Specifying t_{rr} Directly

As well as allowing you to specify reverse recovery time t_{rr} directly, the block supports two alternative parameterizations. The block can derive t_{rr} from either of these parameters:

- Reverse recovery time stretch factor λ
- Reverse recovery charge Q_{rr} , when the data sheet specifies this value instead of the reverse recovery time.

The relationship between reverse recovery time stretch factor λ and t_{rr} is expressed by the equation

$$\lambda = \frac{t_{rr}a}{i_{RM}}$$

Reverse recovery time must be greater than $\frac{i_{RM}}{a}$ and a typical value is $3\left(\frac{i_{RM}}{a}\right)$.

Therefore, a typical value for λ is 3. λ must be greater than 1.

Reverse recovery charge Q_{rr} is the integral over time of the reverse current from the point where the current goes negative until it decays back to zero.

The initial charge, to time t_s (as shown in the figure), is expressed by the equation

$$Q_s = \frac{1}{2} \times -i_{RM} \times \frac{i_{RM}}{a} \quad (1-15)$$

Integrating Equation 1-11 gives the charge between times t_s and inf. This charge is equal to

$$\tau_{rr}i_{RM}$$

Therefore, total reverse recovery charge is given by the equation

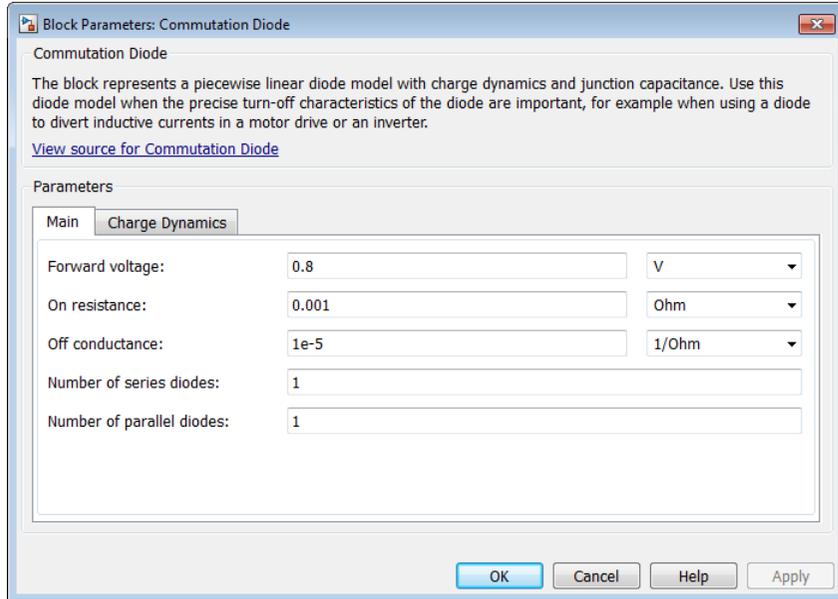
$$Q_{rr} = -\frac{i_{RM}^2}{2a} + \tau_{rr}i_{RM} \quad (1-16)$$

Rearranging Equation 1-16 to solve for τ_{rr} and substituting the result into Equation 1-14 gives an equation that expresses t_{rr} in terms of Q_{rr} :

Commutation Diode

Dialog Box and Parameters

$$t_{rr} = \left(\frac{Q_{rr}}{i_{RM}} + \frac{i_{RM}}{2a} \right) \log(10) + \frac{i_{RM}}{a}.$$



- “Main Tab” on page 1-42
- “Charge Dynamics Tab” on page 1-43

Main Tab

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Number of series diodes

The number of diodes connected in series between the + and - block ports. Each diode has the forward voltage, on resistance, and off conductance that you specify in the block dialog box. The default value is 1.

Number of parallel diodes

The number of parallel diodes, or number of parallel paths of series-connected diodes, between the + and - block ports. Each diode has the forward voltage, on resistance, and off conductance that you specify in the block dialog box. The default value is 1.

Charge Dynamics Tab**Junction capacitance**

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring iRM

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to

Commutation Diode

derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, trr

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, trr** parameter must be greater than the value of the **Peak reverse current, iRM** parameter divided by the value of the **Rate of change of current when measuring iRM** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, trr**. This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Qrr

Value that the block uses to calculate **Reverse recovery time, trr**. Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, iRM**.
- a is the value specified for **Rate of change of current when measuring iRM**.

The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

Ports

The block has the following ports:

+

Electrical conserving port associated with the diode positive terminal

-

Electrical conserving port associated with the diode negative terminal

References

- [1] Lauritzen, P.O. & C.L. Ma, "A Simple Diode Model with Reverse Recovery." *IEEE® Transactions on Power Electronics*. Vol. 6, No. 2, 1991, pp. 188–191.

Converter

Purpose Connect three-phase AC network to DC network

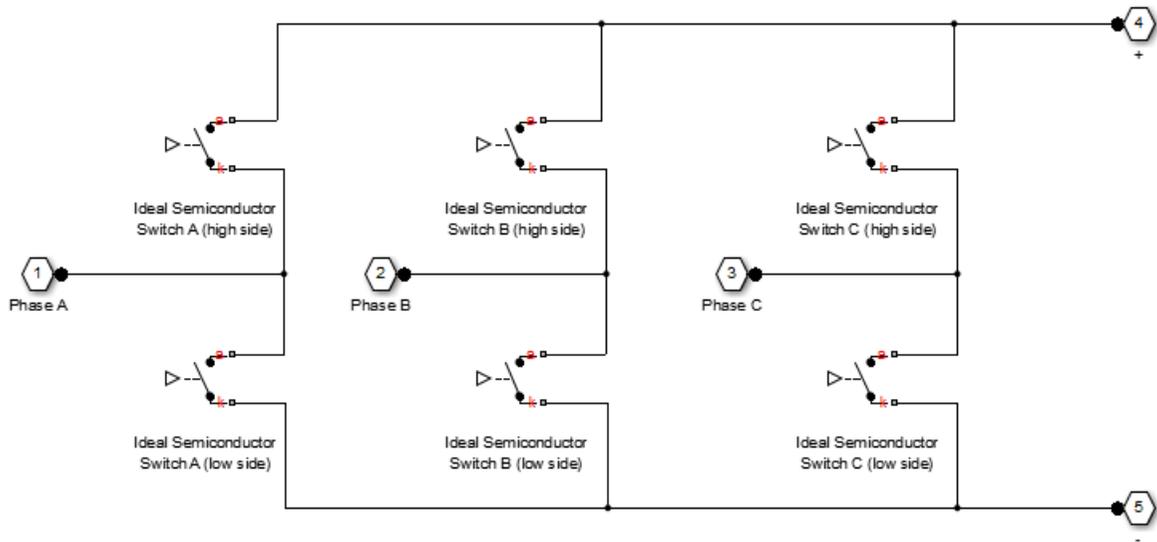
Library Semiconductors

Description The Converter block models a three-arm converter circuit that connects a three-phase AC network to a DC network.



Each component in the three-arm circuit is the same switching device, which you specify using an option on the Converter block dialog box. The switching devices are in the **Semiconductors > Fundamental Components** sublibrary.

The figure shows the equivalent circuit for the block using an Ideal Semiconductor block as the switching device.



You control the gate ports of the six switching devices via an input to the Converter block G port. To do this:

- 1 Use a Six-Pulse Gate Multiplexer block to multiplex all six gate signals into a single vector.

- 2 Connect the output of the Six-Pulse Gate Multiplexer block to the Converter block G port.

Using the Integral Diodes tab of the block dialog box, you can include an integral protection diode for each switching device. An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

The table shows you how to set the **Integral protection diode** parameter based on your goals.

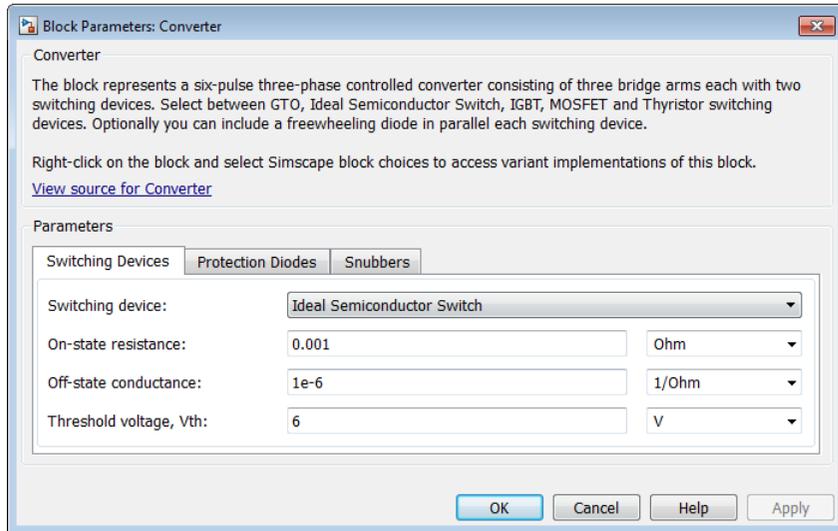
Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating to the Commutation Diode block.

Using the Snubbers tab of the block dialog box, you can include a snubber circuit for each switching device, consisting of a resistor and capacitor connected in series. Typically, a snubber circuit protects a switching device against very high voltages produced by an inductive load when the device turns off the voltage supply to the load. Snubber

Converter

circuits also prevent excessive rates of change of current when a switching device turns on.

Dialog Box and Parameters



- “Switching Devices Tab” on page 1-48
- “Protection Diodes Tab” on page 1-52
- “Snubbers Tab” on page 1-56

Switching Devices Tab

Switching device

Converter switching device. The default value is Ideal Semiconductor Switch.

The switching devices you can select are:

- GTO
- Ideal Semiconductor Switch
- IGBT

- MOSFET
- Thyristor

GTO Parameters

When you select GTO, parameters for the GTO block appear.

Additional GTO Parameters

Forward voltage, Vf

Minimum voltage required across the anode and cathode block ports for the gradient of the device i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On-state resistance**. The default value is 0.8 V.

On-state resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Gate trigger voltage, Vgt

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 1 V.

Gate turn-off voltage, Vgt_off

Gate-cathode voltage threshold. The device turns off when the gate-cathode voltage is below this value. The default value is -1 V.

Holding current

Current threshold. The device stays on when the current is above this value, even when the gate-cathode voltage falls below the gate trigger voltage. The default value is 1 A.

For more information, see GTO.

Ideal Semiconductor Switch Parameters

When you select Ideal Semiconductor Switch, parameters for the Ideal Semiconductor Switch block appear.

Additional Ideal Semiconductor Switch Parameters

On-state resistance

Anode-cathode resistance when the device is on. The default value is 0.001 Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Threshold voltage, Vth

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 6 V.

For more information, see Ideal Semiconductor Switch.

IGBT Parameters

When you select IGBT, parameters for the IGBT block appear.

Additional IGBT Parameters

Forward voltage, Vf

Minimum voltage required across the collector and emitter block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On-state resistance**. The default value is 0.8 V.

On-state resistance

Collector-emitter resistance when the device is on. The default value is 0.001 Ω .

Off-state conductance

Collector-emitter conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Threshold voltage, V_{th}

Collector-emitter voltage at which the device turns on. The default value is 6 V.

For more information, see IGBT.

MOSFET Parameters

When you select MOSFET, parameters for the MOSFET block appear.

Additional MOSFET Parameters

On-state resistance, $R_{DS(on)}$

Drain-source resistance when the device is on. The default value is 0.001Ω .

Off-state conductance

Drain-source conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Threshold voltage, V_{th}

Gate-source voltage threshold. The device turns on when the gate-source voltage is above this value. The default value is 6 V.

For more information, see MOSFET.

Thyristor Parameters

When you select Thyristor, parameters for the Thyristor block appear.

Additional Thyristor Parameters

Forward voltage, V_f

Forward voltage at which the device turns on. The default value is 0.8 V.

On-state resistance

Anode-cathode resistance when the device is on. The default value is 0.001 Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Gate trigger voltage, Vgt

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 1 V.

Holding current

Current threshold. The device stays on when the current is above this value, even when the gate-cathode voltage falls below the gate trigger voltage. The default value is 1 A.

For more information, see Thyristor.

Protection Diodes Tab**Integral protection diode**

Integral protection diode for each switching device. The default value is None.

The diodes you can select are:

- Protection diode with no dynamics
- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, i_{RM}

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring i_{RM}

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring i_{RM}

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, t_{rr}

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, t_{rr}** parameter must be greater than the value of the **Peak reverse current, i_{RM}** parameter divided by the value of the **Rate of change of current when measuring i_{RM}** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, trr**. This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Qrr

Value that the block uses to calculate **Reverse recovery time, trr**. Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, iRM**.
- a is the value specified for **Rate of change of current when measuring iRM**.

The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Snubbers Tab

Snubber

Snubber for each switching device. The default value is None.

Snubber resistance

Snubber resistance. This parameter is visible only if you set **Snubber** to RC snubber. The default value is 0.1 Ω .

Snubber capacitance

Snubber capacitance. This parameter is visible only if you set **Snubber** to RC snubber. The default value is 1e-7 F.

Ports

The block has the following ports:

G

Vector input port associated with the gate terminals of the switching devices. Connect this port to a Six-Pulse Gate Multiplexer block.

~

Expandable three-phase port

+

Electrical conserving port associated with the DC positive terminal

-

Electrical conserving port associated with the DC negative terminal

See Also

Six-Pulse Gate Multiplexer | Rectifier

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

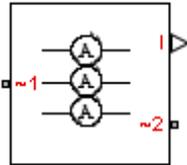
Purpose

Measure phase currents in three-phase system

Library

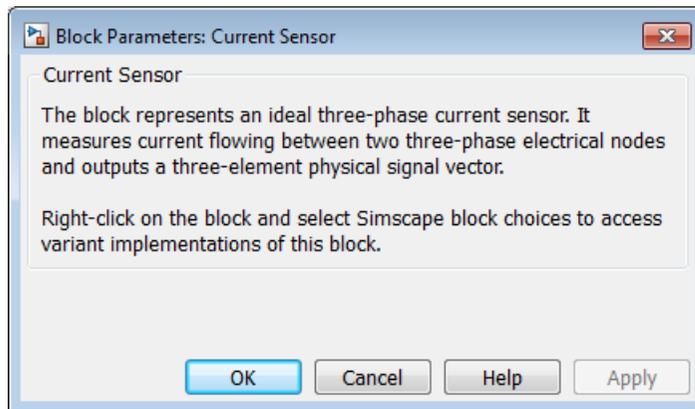
Sensors

Description



The Current Sensor block represents an ideal three-phase current sensor. The block measures each of the three currents flowing from port ~1 to port ~2 and outputs a single three-element, physical signal vector. Each element of the physical signal output vector is proportional to the current in its respective phase.

Dialog Box and Parameters



The block has no parameters.

Ports

The block has the following ports:

- ~1 Expandable three-phase port.
- ~2 Expandable three-phase port.

Current Sensor

I

Three-element physical signal vector output port associated with the phase currents.

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

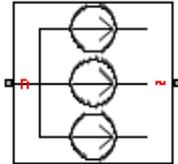
Purpose

Ideal three-phase current source

Library

Sources

Description



The Current Source block models an ideal three-phase current source that maintains sinusoidal currents of the specified magnitude through its terminals, independent of the voltage across the source.

The output current is defined by the following equations:

$$I_0 = \sqrt{2} \cdot i_{phase_rms}$$

$$i_a = I_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi)$$

$$i_b = I_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi - 120^\circ)$$

$$i_c = I_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi + 120^\circ),$$

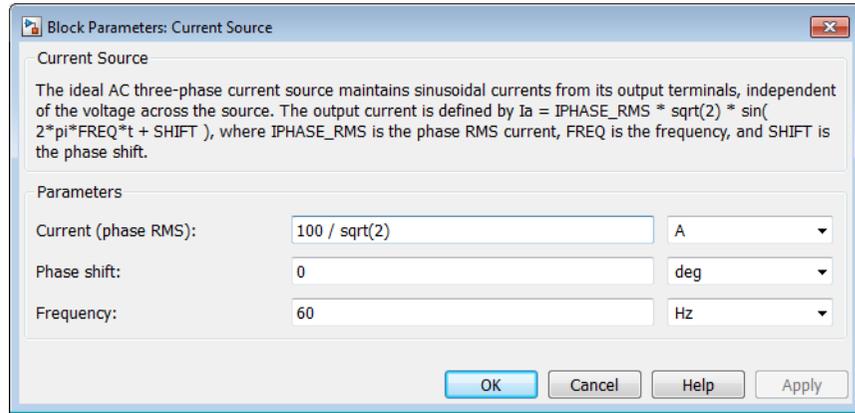
where:

- I_0 is the peak phase current.
- i_{phase_rms} is the RMS phase current.
- i_a , i_b , i_c are the respective phase currents.
- f is the frequency.
- φ is the phase shift.
- t is the time.

The arrow indicates the positive direction of the current flow. The source has a wye configuration, and port n provides a connection to the center of the wye. Port ~ is an expandable three-phase port representing the three phases, a, b, and c.

Current Source

Dialog Box and Parameters



Current (phase RMS)

RMS phase current. The default value is $100/\sqrt{2}$, or 70.7107, A.

Phase shift

Phase shift in angular units. The default value is 0 deg.

Frequency

Current frequency, specified in Hz or units directly convertible to Hz (where Hz is defined as 1/s). For example, kHz and MHz are valid units, but rad/s is not. The default value is 60 Hz.

Ports

The block has the following ports:

~

Expandable three-phase port

n

Electrical conserving port associated with the center of the wye

See Also Voltage Source

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Purpose

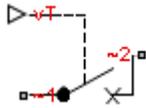
Three-phase circuit breaker controlled by external signal

Library

Switches & Breakers

Description

The Circuit Breaker block models a three-phase circuit breaker that uses an external signal and phase current information to break an electrical circuit.



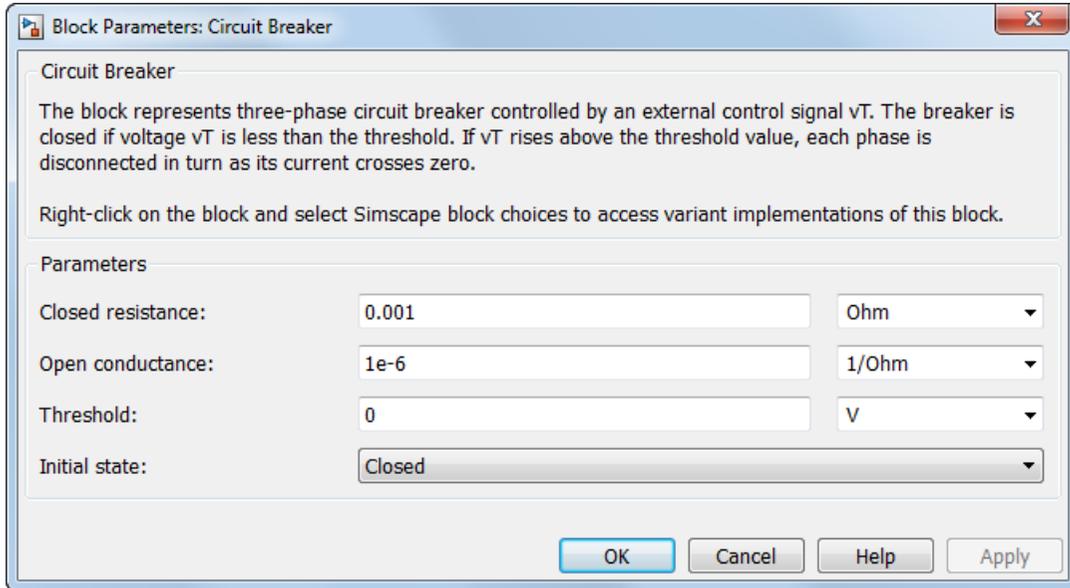
The table shows how the external signal vT controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$vT < \text{Threshold}$	The breaker is closed. Each phase in the composite three-phase port ~1 connects to the corresponding phase in the port ~2.	Closed Resistance
$vT \geq \text{Threshold}$	When the current in any phase of the composite port ~1 crosses zero, the phase disconnects from the corresponding phase at port ~2. The breaker is open.	Open Conductance

Set the block **Initial State** parameter to match the behavior in the table. If, for example, you set **Initial State** to Open and vT to less than **Threshold**, the block produces invalid results the first time vT exceeds **Threshold**.

Circuit Breaker

Dialog Box and Parameters



Closed resistance

Resistance between ports ~1 and ~2 when the breaker is closed. The default value is 0.001 Ω .

Open conductance

Conductance between ports ~1 and ~2 when the breaker is open. The default value is 1e-6 Ω^{-1} .

Threshold

Threshold voltage for the control port v_T . When the voltage rises above the threshold, the breaker opens each phase as its current crosses zero. When the control port voltage falls below the threshold, the breaker closes. The default value is 0 V.

Initial state

Set the initial condition of the circuit breaker to Open or Closed.
The default value is Closed.

Ports

The block has the following ports:

~1

Expandable three-phase port

~2

Expandable three-phase port

vT

Scalar control port, which is either a physical signal or an electrical port.

See Also Single-Phase Circuit Breaker

Related Examples

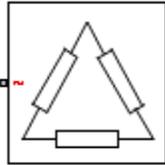
- “Switch Between Physical Signal and Electrical Ports”
- “Expand and Collapse Three-Phase Ports on a Block”

Delta-Connected Load

Purpose Three-phase load wired in delta configuration

Library Passive Devices

Description The Delta-Connected Load block models a three-phase load wired in a delta configuration. Each limb of the load can include any combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel.

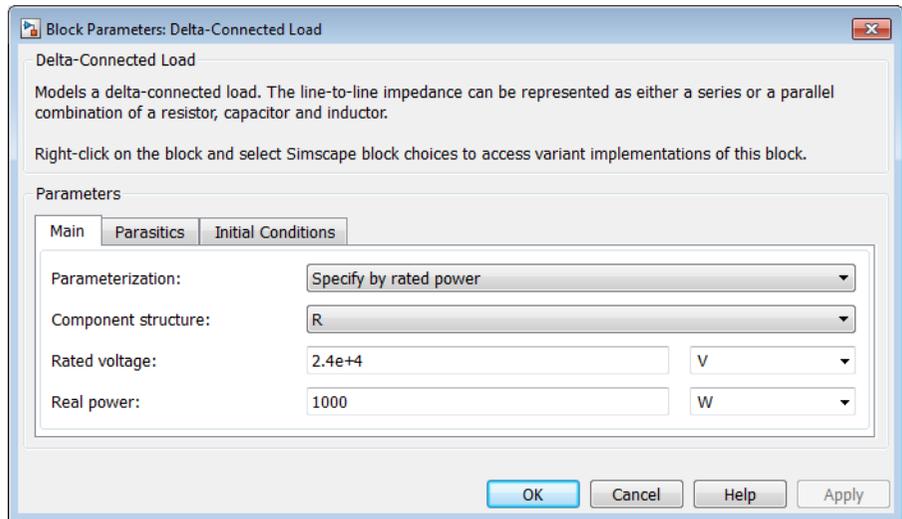


You can specify values for the R, L, and C components directly in terms of resistance, inductance, and capacitance, or by rated powers at a rated voltage and frequency.

- If you parameterize the block directly in terms of R, L, and C values, then for initialization you must provide a three-element row vector of initial voltages for a capacitor, and a three-element row vector of initial currents for an inductor.
- If you parameterize the block in terms of rated powers, then you must specify initial conditions in terms of an initial voltage, initial voltage phase, and initial frequency. For example, if the load is connected directly to a three-phase voltage source, then the initial conditions are identical to the source values for RMS line voltage, frequency, and phase shift. To specify zero initial voltage magnitude, set the initial voltage to 0.

For certain combinations of R, L, and C, you must specify parasitic resistance or conductance values, which can help numerical convergence when simulating some circuit topologies. These parasitic terms ensure that an inductor has a small parallel resistive path and that a capacitor has a small series resistance. When you parameterize the block in terms of rated powers, the rated power values do not account for these small parasitic terms. The rated powers represent only the R, L, and C values of the load itself.

Dialog Box and Parameters



- “Main Tab” on page 1-65
- “Parasitics Tab” on page 1-67
- “Initial Conditions Tab” on page 1-67

Main Tab

Parameterization

Select one of these values:

- **Specify by rated power** — Specify values for the R, L, and C components by rated powers at a rated voltage and frequency. This is the default.
- **Specify component values directly** — Specify values for the R, L, and C components directly in terms of resistance, inductance, and capacitance.

Switching the **Parameterization** value resets the **Component structure** value. Select the component parameterization option first, and then the component structure. If you later switch the

Delta-Connected Load

Parameterization value, check the **Component structure** value and reselect it, if necessary.

Component structure

Select the desired combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel. The default is R, resistor.

Rated voltage

Voltage for which load powers are specified. This parameter is visible only when you specify values by rated power. The default value is 2.4×10^4 V.

Real power

Total real power dissipated by three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes a resistor. The value must be greater than 0. The default value is 1000 W.

Rated electrical frequency

Frequency for which reactive load powers are specified. This parameter is visible only when you specify values by rated power. The default value is 60 Hz.

Inductive reactive power

Total inductive reactive power taken by the three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes an inductor. The value must be greater than 0. The default value is $100 \text{ V} \cdot \text{A}$.

Capacitive reactive power

Total capacitive reactive power taken by the three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes a capacitor. The value must be less than 0. The default value is $-100 \text{ V} \cdot \text{A}$.

Resistance

The resistance of each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes a resistor. The default value is 1 Ω .

Inductance

Inductance of each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes an inductor. The default value is 0.001 H.

Capacitance

Capacitance in each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes a capacitor. The default value is 1e-6 F.

Parasitics Tab

Parasitic series resistance

Represents small parasitic effects. The parameter value corresponds to the series resistance value added to all instances of capacitors in the load. The default value is 1e-6 Ω .

Parasitic parallel conductance

Represents small parasitic effects. The parameter value corresponds to the parallel conductance value added across all instances of inductors in the load. The default value is 1e-6 Ω^{-1} .

Initial Conditions Tab

Terminal voltage magnitude

Expected initial RMS line voltage at the load. This parameter is visible only when you specify values by rated power. The default value is 2.4e4 V.

Delta-Connected Load

Terminal voltage angle

Expected initial phase of the voltage at the load. This parameter is visible only when you specify values by rated power. The default value is 0 deg.

Frequency

Expected initial frequency at the load. This parameter is visible only when you specify values by rated power. The default value is 60 Hz.

Initial inductor current [Ia Ib Ic]

Initial current in the a, b, and c phase inductors, respectively. This parameter is visible only when you specify component values directly and select a component structure that includes an inductor. The default value is [0 0 0] A.

Initial capacitor voltage [Va Vb Vc]

Initial voltage across the a, b, and c phase capacitors, respectively. This parameter is visible only when you specify component values directly and select a component structure that includes a capacitor. The default value is [0 0 0] V.

Block Parameterization

The following two tables list the block parameters for each **Component structure**, based on the selected **Parameterization** option:

- Specify by rated power
- Specify component values directly

Specify by Rated Power

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
R	Rated voltage Real power	None	None
L	Rated voltage Rated electrical frequency Inductive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency
C	Rated voltage Rated electrical frequency Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Series RL	Rated voltage Rated electrical frequency Real power Inductive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency

Delta-Connected Load

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Series RC	Rated voltage Rated electrical frequency Real power Capacitive reactive power	None	Terminal voltage magnitude Terminal voltage angle Frequency
Series LC	Rated voltage Rated electrical frequency Inductive reactive power Capacitive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency
Series RLC	Rated voltage Rated electrical frequency Real power Inductive reactive power Capacitive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Parallel RL	Rated voltage Rated electrical frequency Real power Inductive reactive power	None	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel RC	Rated voltage Rated electrical frequency Real power Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel LC	Rated voltage Rated electrical frequency Inductive reactive power Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel RLC	Rated voltage Rated electrical frequency Real power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle

Delta-Connected Load

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
	Inductive reactive power Capacitive reactive power		Frequency

Specify Component Values Directly

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
R	Resistance	None	None
L	Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
C	Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]
Series RL	Resistance Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
Series RC	Resistance Capacitance	None	Initial capacitor voltage [Va Vb Vc]

Specify Component Values Directly (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Series LC	Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Series RLC	Resistance Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RL	Resistance Inductance	None	Initial inductor current [Ia Ib Ic]
Parallel RC	Resistance Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]

Delta-Connected Load

Specify Component Values Directly (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Parallel LC	Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RLC	Resistance Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]

Ports

The block has one expandable three-phase port, ~.

See Also

RLC | Wye-Connected Load

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Delta-Delta Transformer

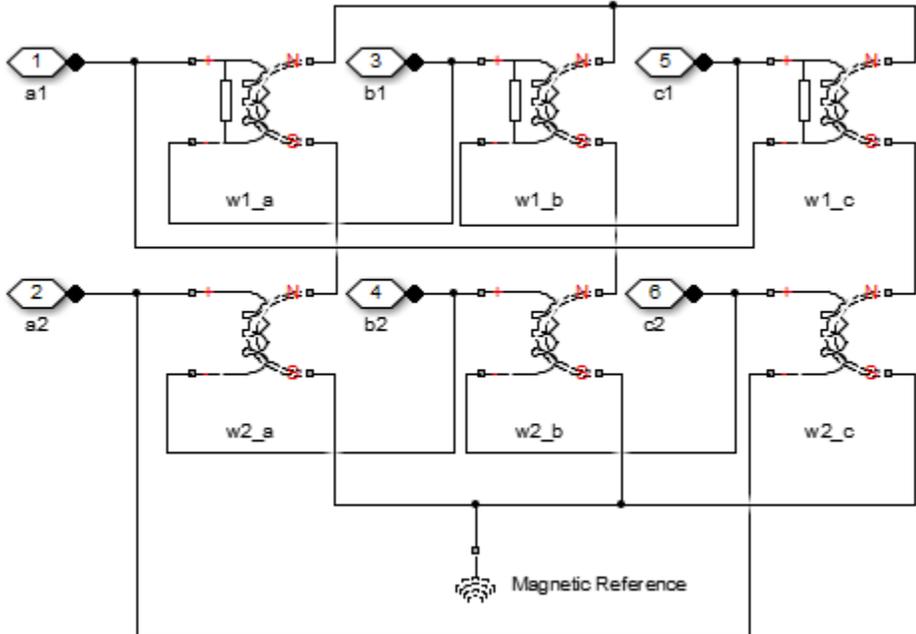
Purpose Linear non-ideal delta-delta transformer with three-limb core

Library Passive Devices / Transformers

Description The Delta-Delta Transformer block models a linear non-ideal transformer with a three-limb core, in which both the primary and the secondary windings are configured in a delta connection. It includes linear winding leakage and linear core magnetization effects.



The figure shows the equivalent circuit diagram for the delta-delta transformer.

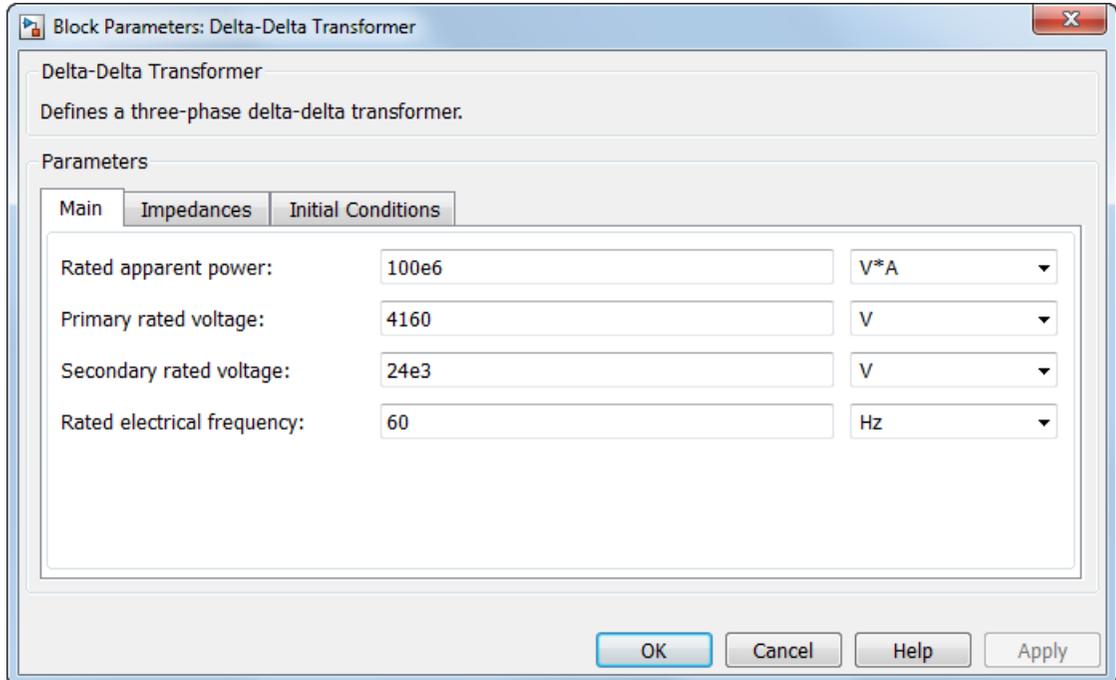


- $w1_a$ is the primary winding connected between the a-phase and the b-phase.

Delta-Delta Transformer

- $w1_b$ is the primary winding connected between the b-phase and the c-phase.
- $w1_c$ is the primary winding connected between the c-phase and the a-phase.
- $w2_a$ is the secondary winding connected between the a-phase and the b-phase.
- $w2_b$ is the secondary winding connected between the b-phase and the c-phase.
- $w2_c$ is the secondary winding connected between the c-phase and the a-phase.

Dialog Box and Parameters



- “Main Tab” on page 1-77
- “Impedances Tab” on page 1-78
- “Initial Conditions Tab” on page 1-79

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Delta-Delta Transformer

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Secondary rated voltage

RMS line voltage applied to the secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Secondary leakage resistance (pu)

Power loss in the secondary winding. The default value is 0.01.

Secondary leakage reactance (pu)

Magnetic flux loss in the secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial secondary currents

Current through the secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

~1

Expandable three-phase port for primary winding

~2

Expandable three-phase port for secondary winding

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Delta1-Delta1-Wye Transformer

Purpose

Linear non-ideal delta1-delta1-wye transformer with three-limb core

Library

Passive Devices / Transformers

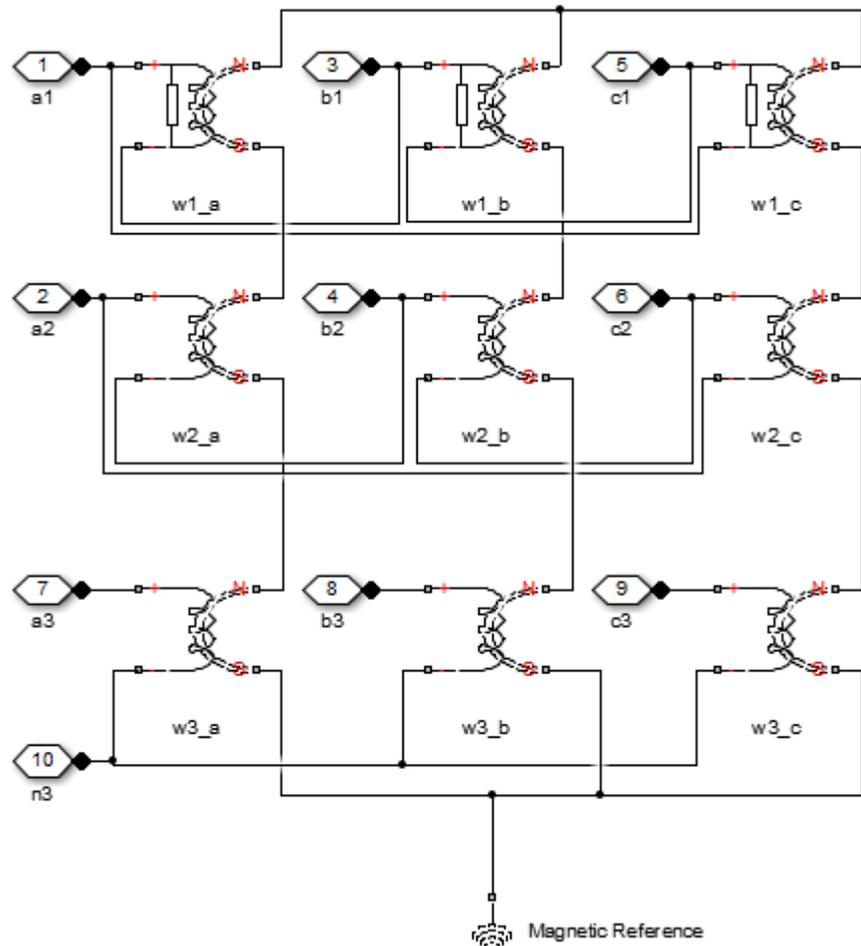
Description



The Delta1-Delta1-Wye Transformer block models a linear non-ideal transformer with a three-limb core, in which the primary windings are configured in a delta connection, and there are delta secondary windings and wye secondary windings. The delta voltages lag the wye voltages by 30 degrees, hence the name 1 o'clock delta. It includes linear winding leakage and linear core magnetization effects.

The figure shows the equivalent circuit diagram for the delta1-delta1-wye transformer.

Delta1-Delta1-Wye Transformer



- $w1_a$ is the primary winding connected between the a-phase and the b-phase.
- $w1_b$ is the primary winding connected between the b-phase and the c-phase.

Delta1-Delta1-Wye Transformer

- $w1_c$ is the primary winding connected between the c-phase and the a-phase.
- $w2_a$ is the delta secondary winding connected between the a-phase and the b-phase.
- $w2_b$ is the delta secondary winding connected between the b-phase and the c-phase.
- $w2_c$ is the delta secondary winding connected between the c-phase and the a-phase.
- $w3_a$ is the wye secondary winding connected between the a-phase and the secondary neutral point.
- $w3_b$ is the wye secondary winding connected between the b-phase and the secondary neutral point.
- $w3_c$ is the wye secondary winding connected between the c-phase and the secondary neutral point.

Delta1-Delta1-Wye Transformer

Dialog Box and Parameters

Block Parameters: Delta1-Delta1-Wye Transformer

Delta1-Delta1-Wye Transformer
Defines a three-phase delta1-delta1-wye transformer.

Parameters

Main Impedances Initial Conditions

Rated apparent power:	100e6	V*A
Primary rated voltage:	4160	V
Delta secondary rated voltage:	24e3	V
Wye secondary rated voltage:	24e3	V
Rated electrical frequency:	60	Hz

OK Cancel Help Apply

- “Main Tab” on page 1-84
- “Impedances Tab” on page 1-84
- “Initial Conditions Tab” on page 1-85

Delta1-Delta1-Wye Transformer

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is $100\text{e}6$ VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Delta secondary rated voltage

RMS line voltage applied to the delta secondary winding under normal operating conditions. The default value is $24\text{e}3$ V.

Wye secondary rated voltage

RMS line voltage applied to the wye secondary winding under normal operating conditions. The default value is $24\text{e}3$ V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01 .

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001 .

Delta secondary leakage resistance (pu)

Power loss in the delta secondary winding. The default value is 0.01 .

Delta secondary leakage reactance (pu)

Magnetic flux loss in the delta secondary winding. The default value is 0.001 .

Delta1-Delta1-Wye Transformer

Wye secondary leakage resistance (pu)

Power loss in the wye secondary winding. The default value is 0.01.

Wye secondary leakage reactance (pu)

Magnetic flux loss in the wye secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial delta secondary currents

Current through the delta secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial wye secondary currents

Current through the wye secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

-1

Expandable three-phase port for primary winding

Delta1-Delta1-Wye Transformer

- 2 Expandable three-phase port for delta secondary winding
- 3 Expandable three-phase port for wye secondary winding
- n3 Electrical conserving port associated with the wye secondary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Delta11-Delta11-Wye Transformer

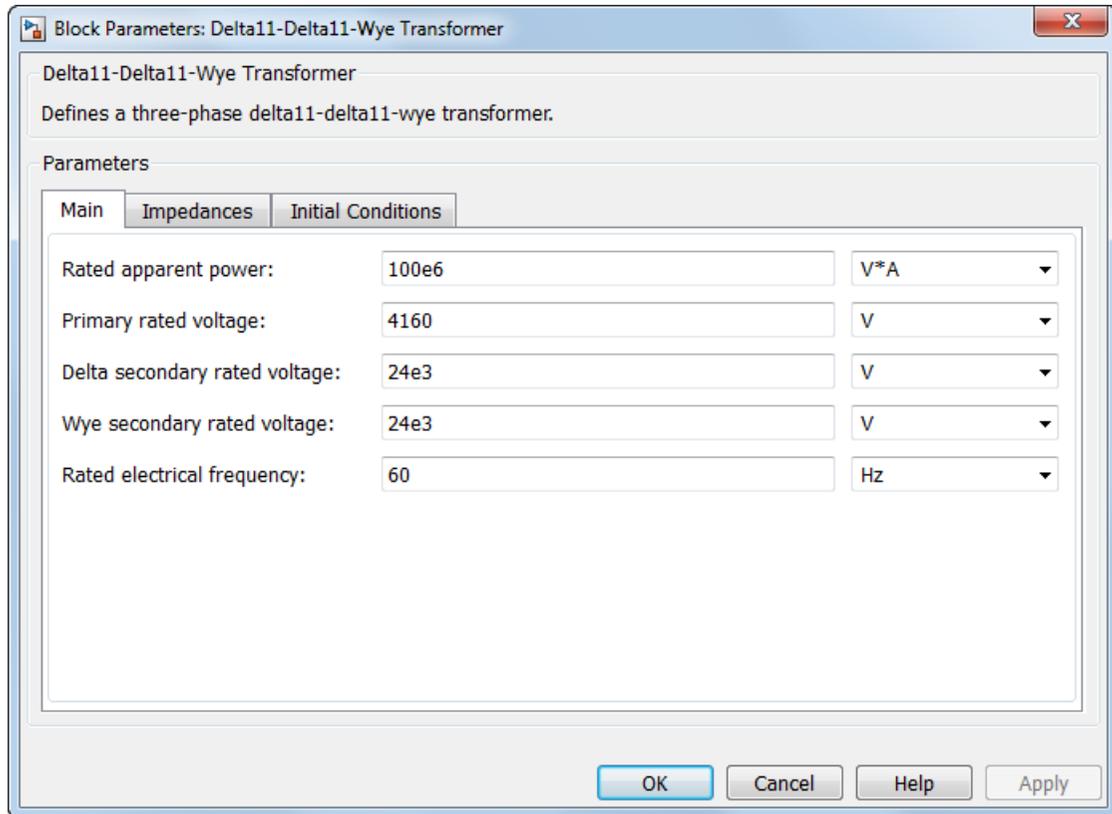
Purpose	Linear non-ideal delta11-delta11-wye transformer with three-limb core
Library	Passive Devices / Transformers

Delta 11-Delta 11-Wye Transformer

- $w1_a$ is the primary winding connected between the a-phase and the c-phase.
- $w1_b$ is the primary winding connected between the b-phase and the a-phase.
- $w1_c$ is the primary winding connected between the c-phase and the b-phase.
- $w2_a$ is the delta secondary winding connected between the a-phase and the c-phase.
- $w2_b$ is the delta secondary winding connected between the b-phase and the a-phase.
- $w2_c$ is the delta secondary winding connected between the c-phase and the b-phase.
- $w3_a$ is the wye secondary winding connected between the a-phase and the secondary neutral point.
- $w3_b$ is the wye secondary winding connected between the b-phase and the secondary neutral point.
- $w3_c$ is the wye secondary winding connected between the c-phase and the secondary neutral point.

Delta11-Delta11-Wye Transformer

Dialog Box and Parameters



- “Main Tab” on page 1-91
- “Impedances Tab” on page 1-91
- “Initial Conditions Tab” on page 1-92

Delta 11-Delta 11-Wye Transformer

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Delta secondary rated voltage

RMS line voltage applied to the delta secondary winding under normal operating conditions. The default value is 24e3 V.

Wye secondary rated voltage

RMS line voltage applied to the wye secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per-unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Delta secondary leakage resistance (pu)

Power loss in the delta secondary winding. The default value is 0.01.

Delta secondary leakage reactance (pu)

Magnetic flux loss in the delta secondary winding. The default value is 0.001.

Delta11-Delta11-Wye Transformer

Wye secondary leakage resistance (pu)

Power loss in the wye secondary winding. The default value is 0.01.

Wye secondary leakage reactance (pu)

Magnetic flux loss in the wye secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial delta secondary currents

Current through the delta secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial wye secondary currents

Current through the wye secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

-1

Expandable three-phase port for primary winding

Delta 1 1-Delta 1 1-Wye Transformer

- 2 Expandable three-phase port for delta secondary winding
- 3 Expandable three-phase port for wye secondary winding
- n3 Electrical conserving port associated with the wye secondary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Delta Reference

Purpose Reference point for delta-connected network

Library Connections

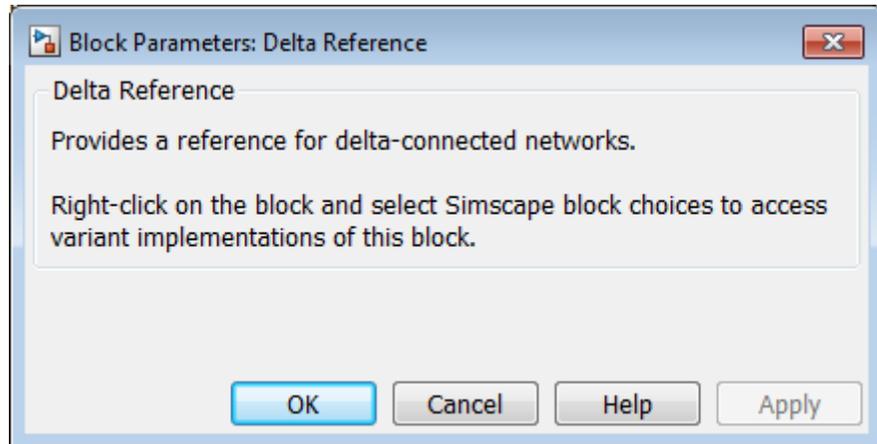
Description



In a SimPowerSystems™ Simscape™ Components model, you must connect a Delta Reference block to any part of the three-phase system that is connected in a delta winding configuration. The block provides a reference point for the delta winding, representing the center of the line-to-line vector voltage triangle. The software calculates absolute node voltages relative to the voltage at this reference point.

For example, suppose you model a transmission system that consists of a generator connected in a wye configuration, a wye-delta transformer, a delta-wye transformer, and a load connected in wye. You must connect a Delta Reference block to the part of the circuit between the two transformers.

Dialog Box and Parameters



The block has no parameters.

Ports

The block has the following ports:

~ Expandable three-phase port

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Diode

Purpose

Piecewise linear diode

Library

Semiconductors / Fundamental Components

Description



The Diode block models a piecewise linear diode.

If the voltage across the diode exceeds the value specified in the block **Forward voltage** parameter, then the diode behaves like a linear resistor plus a series voltage source. The value of the block **On resistance** parameter specifies the resistance of the linear resistor.

If the voltage across the diode is less than the forward voltage, then the diode behaves like a linear resistor with low conductance specified by the value of the block **Off conductance** parameter.

When forward biased, the series voltage source is described by the equation

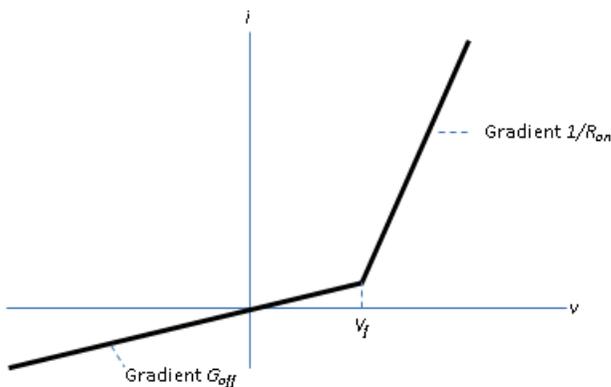
$$V = V_f(1 - R_{on}G_{off}),$$

where:

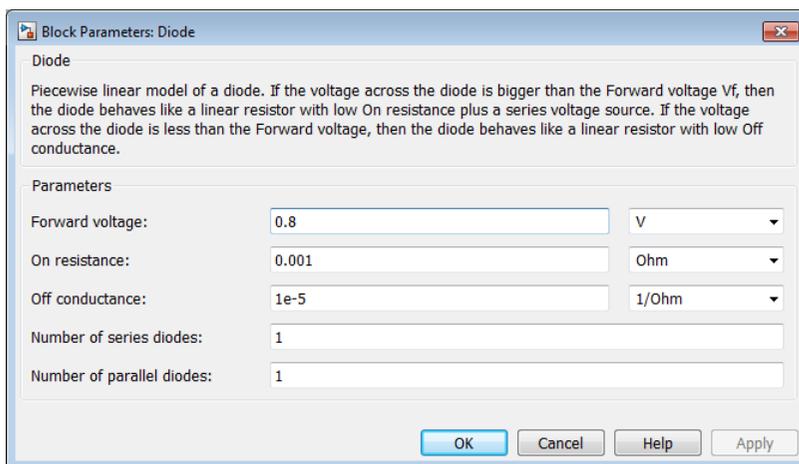
- V is the voltage supplied by the series voltage source.
- V_f is the forward voltage.
- R_{on} is the on resistance.
- G_{off} is the off conductance.

The $R_{on} * G_{off}$ term ensures that the diode current is exactly zero when the voltage across it is zero.

The figure shows a typical *i-v characteristic* for a diode device.



Dialog Box and Parameters



Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i - v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Diode

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Number of series diodes

The number of diodes connected in series between the + and - block ports. Each diode has the forward voltage, on resistance, and off conductance that you specify in the block dialog box. The default value is 1.

Number of parallel diodes

The number of parallel diodes, or number of parallel paths of series-connected diodes, between the + and - block ports. Each diode has the forward voltage, on resistance, and off conductance that you specify in the block dialog box. The default value is 1.

Ports

The block has the following ports:

+

Electrical conserving port associated with the diode positive terminal

-

Electrical conserving port associated with the diode negative terminal

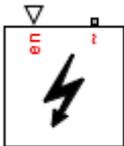
Purpose

Signal-enabled single-phase, two-phase, or three-phase grounded or ungrounded fault

Library

Passive Devices / Faults

Description



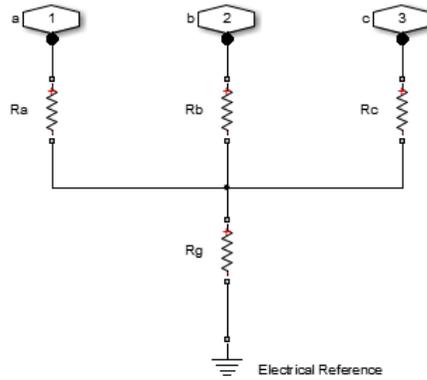
The Enabled Fault models any permutation of a single-phase, two-phase, or three-phase grounded or ungrounded fault. You specify the fault activation threshold using the block **Threshold** parameter. An external control signal *en* enables the fault. The fault is active when *en* is greater than the threshold. The fault is inactive when *en* is less than or equal to the threshold.

You can set the Enabled Fault block to represent any of these:

- Single-phase-to-ground fault (a-g, b-g or c-g)
- Two-phase fault (a-b, b-c or c-a)
- Two-phase-to-ground fault (a-b-g, b-c-g or c-a-g)
- Three-phase fault (a-b-c)
- Three-phase-to-ground fault (a-b-c-g)

The figure shows the equivalent circuit diagram for the Enabled Fault block.

Enabled Fault



You can determine the resistance in the equivalent circuit using the equations in the table.

Fault type	Value of R_a	Value of R_b	Value of R_c	Value of R_g
None / inactive	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	Infinity / open circuit
a-g	R_{pn}	$\frac{1}{G_{nn}}$	$\frac{1}{G_{nn}}$	R_{ng}
b-g	$\frac{1}{G_{nn}}$	R_{pn}	$\frac{1}{G_{nn}}$	R_{ng}
c-g	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	R_{pn}	R_{ng}
a-b	R_{pn}	R_{pn}	$\frac{1}{G_{pn}}$	Infinity / open circuit

Fault type	Value of R_a	Value of R_b	Value of R_c	Value of R_g
b-c	$\frac{1}{G_{pn}}$	R_{pn}	R_{pn}	Infinity / open circuit
c-a	R_{pn}	$\frac{1}{G_{pn}}$	R_{pn}	Infinity / open circuit
a-b-g	R_{pn}	R_{pn}	$\frac{1}{G_{pn}}$	R_{ng}
b-c-g	$\frac{1}{G_{pn}}$	R_{pn}	R_{pn}	R_{ng}
c-a-g	R_{pn}	$\frac{1}{G_{pn}}$	R_{pn}	R_{ng}
a-b-c	R_{pn}	R_{pn}	R_{pn}	Infinity / open circuit
a-b-c-g	R_{pn}	R_{pn}	R_{pn}	R_{ng}

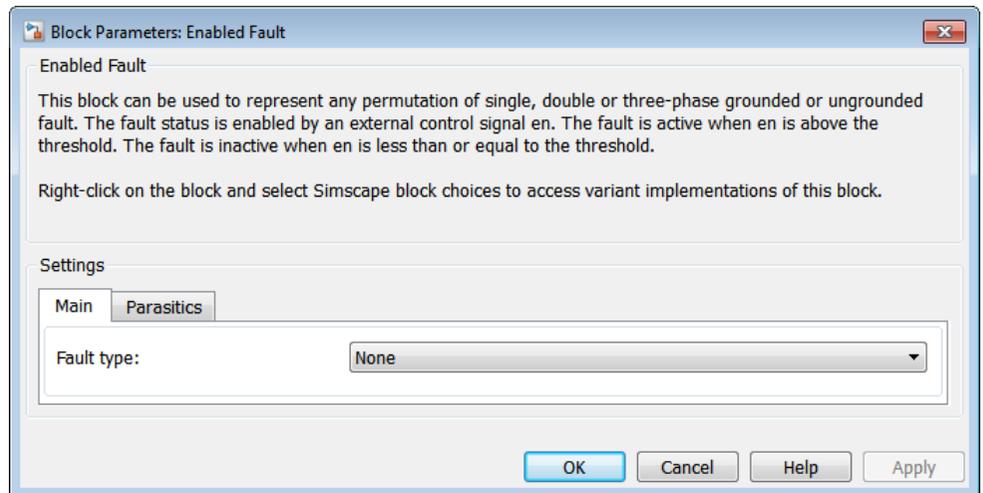
where:

- R_a is the resistance between the a-phase and the neutral point of a wye connection.
- R_b is the resistance between the b-phase and the neutral point of a wye connection.
- R_c is the resistance between the c-phase and the neutral point of a wye connection.

Enabled Fault

- R_g is the resistance between the neutral point of a wye connection and electrical reference.
- R_{pn} is the value of the **Faulted phase-neutral resistance** parameter.
- R_{ng} is the value of the **Faulted neutral-ground resistance** parameter.
- G_{pn} is the value of the **Unfaulted phase-neutral conductance** parameter.

Dialog Box and Parameters



- “Main Tab” on page 1-102
- “Parasitics Tab” on page 1-104

Main Tab

Fault type

Select one of the following:

- None — Specifies that the fault is not active. This is the default value.

- Single-phase to ground (a-g)
- Single-phase to ground (b-g)
- Single-phase to ground (c-g)
- Two-phase (a-b)
- Two-phase (b-c)
- Two-phase (c-a)
- Two-phase to ground (a-b-g)
- Two-phase to ground (b-c-g)
- Two-phase to ground (c-a-g)
- Three-phase (a-b-c)
- Three-phase to ground (a-b-c-g)

Faulted phase-neutral resistance

Resistance between the phase connection and the neutral point when the fault is active. This parameter is visible if the **Fault type** parameter is set to anything other than None. The default value is $1e-3 \Omega$.

Faulted neutral-ground resistance

Resistance between the neutral point and the electrical reference when fault is active. This parameter is visible if the **Fault type** parameter is set to any fault which includes a ground connection. The default value is $1e-3 \Omega$.

Threshold

Threshold for activating the fault. If the input *en* is above the value for the **Threshold** parameter, then the fault is active. If the input *en* is equal to or less than the value for the **Threshold** parameter, then the fault is not active. This parameter is visible if the **Fault type** parameter is set to anything other than None. The default value is 0.

Enabled Fault

Parasitics Tab

Unfaulted phase-neutral conductance

Conductance between the phase connections and the neutral point when a phase is not involved in the fault. The default value is $1\text{e-}6\ \Omega^{-1}$.

Ports

The block has the following ports:

~

Expandable three-phase port for connecting the fault to the system

en

Physical signal scalar control input port for enabling the fault

See Also Time-Based Fault

Purpose Floating neutral point for phases of three-phase system

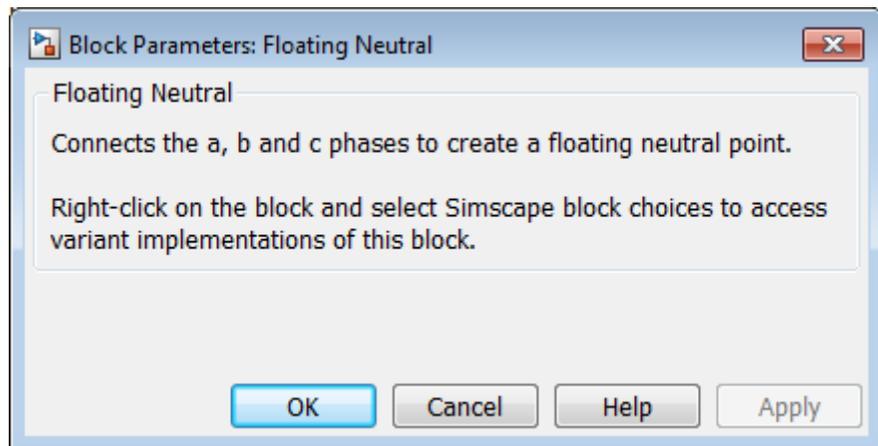
Library Connections

Description The Floating Neutral block connects the individual phases of a three-phase system to form a floating neutral point.



Note If you want to create a neutral point that you can connect to other blocks, use the Neutral Port block. If you want to create a neutral point that is connected to ground, use the Grounded Neutral block.

Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

~

Expandable three-phase port

See Also Neutral Port | Grounded Neutral

Floating Neutral

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Purpose Ground connection for phases of three-phase system

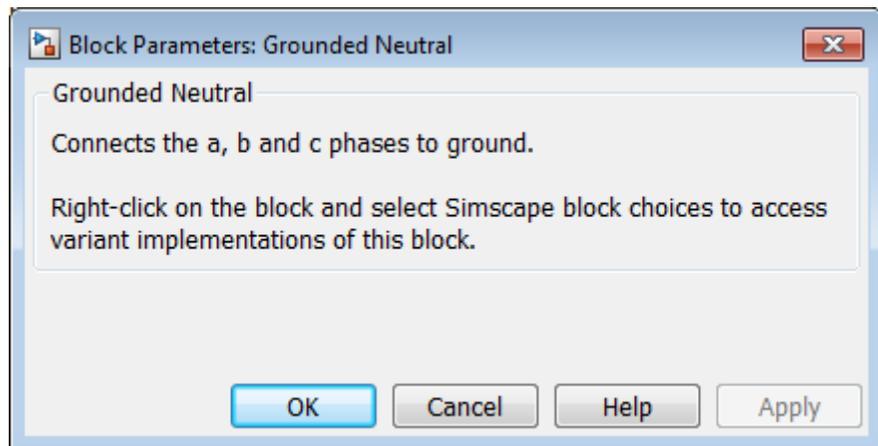
Library Connections

Description The Grounded Neutral block connects the phases of a three-phase system to ground.



Note If you want to connect the neutral point of the three-phase system to other blocks, use the Neutral Port block instead. If you want to create a floating neutral point, use the Floating Neutral block.

Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

~

Expandable three-phase port

See Also Neutral Port | Floating Neutral

Grounded Neutral

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Purpose

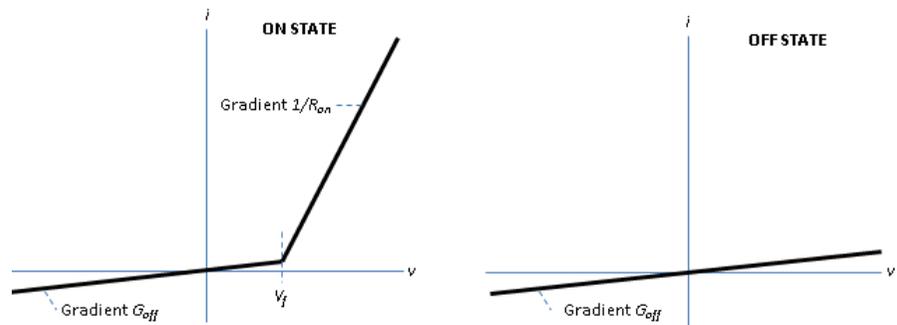
Gate Turn-Off Thyristor

Library

Semiconductors / Fundamental Components

Description

The GTO block models a GTO (gate turn-off thyristor). This figure shows a typical *i-v characteristic* for a GTO.



The GTO turns on if the gate-cathode voltage exceeds the specified gate trigger voltage. The device turns off if the gate-cathode voltage falls below the specified gate turn-off voltage value, or if the load current falls below the specified holding-current value.

In the on state, the anode-cathode path behaves like a linear diode with forward-voltage drop V_f and on-resistance R_{on} .

In the off state, the anode-cathode path behaves like a linear resistor with a low off-state conductance value G_{off} .

The defining Simscape equations for the block are:

```

if ((v > Vf)&&((G>Vgt)|| (i>Ih)))&&(G>Vgt_off)
    i == (v - Vf*(1-Ron*Goff))/Ron;
else
    i == v*Goff;
end

```

where:

- v is the anode-cathode voltage.
- V_f is the forward voltage.
- G is the gate voltage.
- V_{gt} is the gate trigger voltage.
- i is the anode-cathode current.
- I_h is the holding current.
- V_{gt_off} is the gate turn-off voltage.
- R_{on} is the on-state resistance.
- G_{off} is the off-state conductance.

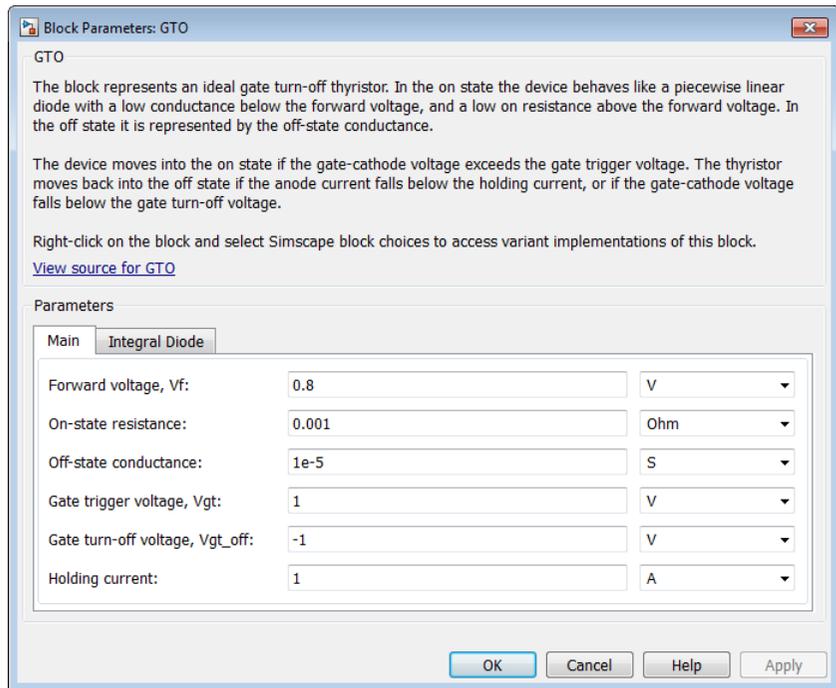
Using the Integral Diode tab of the block dialog box, you can include an integral cathode-anode diode. A GTO that includes an integral cathode-anode diode is known as an asymmetrical GTO (A-GTO) or reverse-conducting GTO (RCGTO). An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

The table shows you how to set the **Integral protection diode** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters

Goal	Value to Select	Block Behavior
		relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating to the Commutation Diode block.

Dialog Box and Parameters



- “Main Tab” on page 1-112

- “Integral Diode Tab” on page 1-112

Main Tab

Forward voltage, Vf

Minimum voltage required across the anode and cathode block ports for the gradient of the device i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On-state resistance**. The default value is 0.8 V.

On-state resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-5 \Omega^{-1}$.

Gate trigger voltage, Vgt

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 1 V.

Gate turn-off voltage, Vgt_off

Gate-cathode voltage threshold. The device turns off when the gate-cathode voltage is below this value. The default value is -1 V.

Holding current

Current threshold. The device stays on when the current is above this value, even when the gate-cathode voltage falls below the gate trigger voltage. The default value is 1 A.

Integral Diode Tab

Integral protection diode

Block integral protection diode. The default value is None.

The diodes you can select are:

- Protection diode with no dynamics

- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, i_{RM}

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring i_{RM}

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring i_{RM}

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, t_{rr}

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, trr** parameter must be greater than the value of the **Peak reverse current, iRM** parameter divided by the value of the **Rate of change of current when measuring iRM** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, trr**. This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Qrr

Value that the block uses to calculate **Reverse recovery time, trr**. Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, iRM**.
- a is the value specified for **Rate of change of current when measuring iRM**.

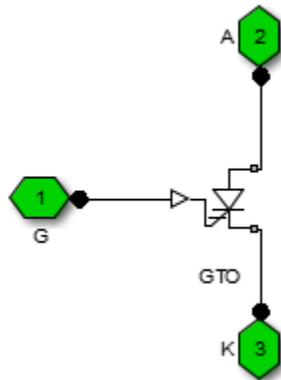
The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

This figure shows the block port names.



G

Port associated with the gate terminal. You can set the port to either a physical signal or electrical port.

A

Electrical conserving port associated with the anode terminal.

K

Electrical conserving port associated with the cathode terminal.

Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Purpose

Ideal Semiconductor Switch

Library

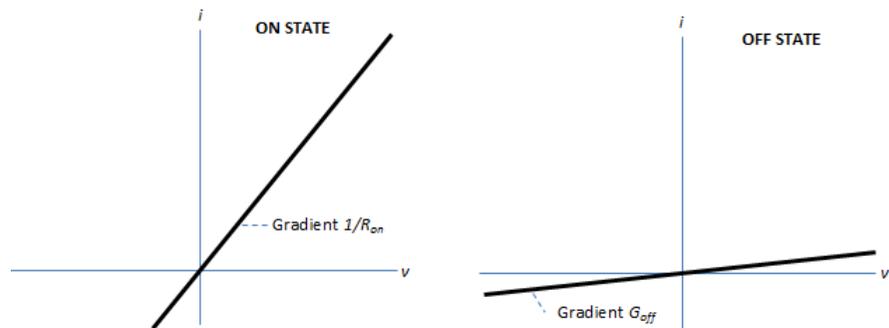
Semiconductors / Fundamental Components

Description

The Ideal Semiconductor Switch block models an ideal semiconductor switching device.



The figure shows a typical *i-v characteristic* for an ideal semiconductor switch.



The ideal semiconductor switch is in the on state if the gate-cathode voltage exceeds the specified threshold voltage. Otherwise the device is in the off state.

In the on state, the anode-cathode path behaves like a linear resistor with on-resistance R_{on} .

In the off state, the anode-cathode path behaves like a linear resistor with a low off-state conductance G_{off} .

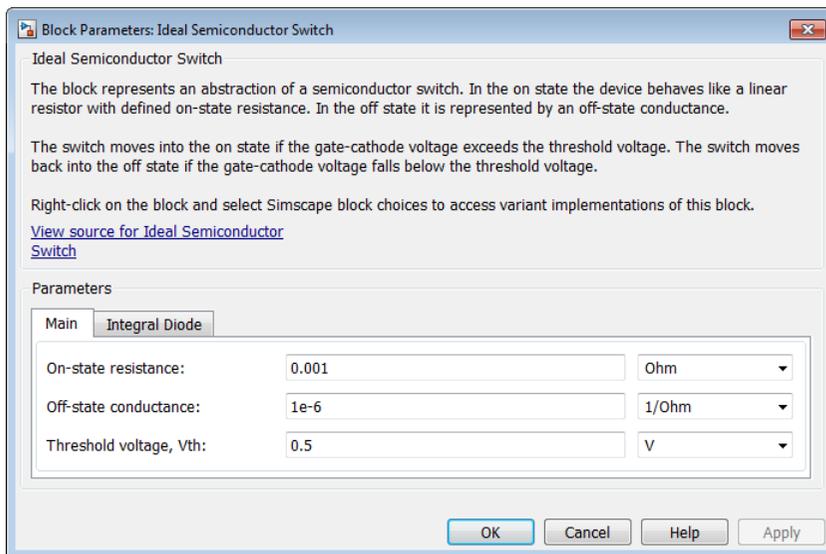
Using the Integral Diode tab of the block dialog box, you can include an integral cathode-anode diode. An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

Ideal Semiconductor Switch

The table shows you how to set the **Integral protection diode** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating to the Commutation Diode block.

Dialog Box and Parameters



- “Main Tab” on page 1-119
- “Integral Diode Tab” on page 1-120

Main Tab

On-state resistance

Anode-cathode resistance when the device is on. The default value is 0.001Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Threshold voltage, Vth

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 0.5 V .

Ideal Semiconductor Switch

Integral Diode Tab

Integral protection diode

Specify whether the block includes an integral protection diode. The default value is None.

If you want to include an integral protection diode, there are two options:

- Protection diode with no dynamics
- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring iRM

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Ideal Semiconductor Switch

Reverse recovery time, t_{rr}

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μs .

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, t_{rr}** parameter must be greater than the value of the **Peak reverse current, i_{RM}** parameter divided by the value of the **Rate of change of current when measuring i_{RM}** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, t_{rr}** . This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Q_{rr}

Value that the block uses to calculate **Reverse recovery time, t_{rr}** . Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, iRM**.
- α is the value specified for **Rate of change of current when measuring iRM**.

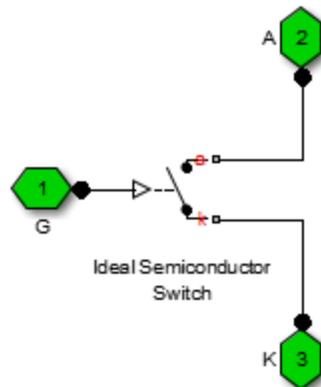
The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

This figure shows the block port names.



G Port associated with the gate terminal. You can set the port to either a physical signal or electrical port.

A Electrical conserving port associated with the anode terminal.

K Electrical conserving port associated with the cathode terminal.

Ideal Semiconductor Switch

Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Purpose

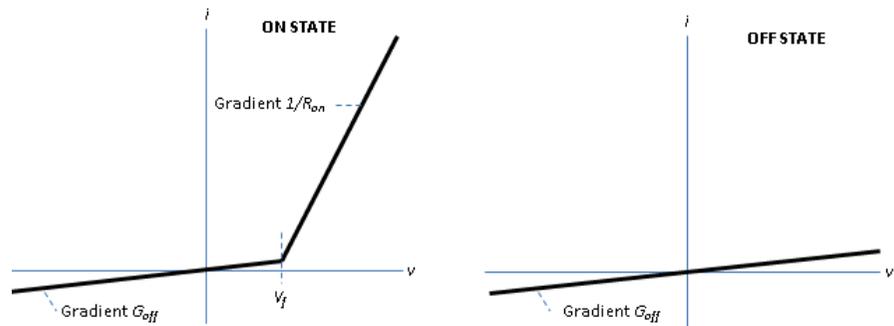
Insulated-Gate Bipolar Transistor

Library

Semiconductors / Fundamental Components

Description

The IGBT block models an IGBT (insulated-gate bipolar transistor). This graphic shows a typical *i-v characteristic* for an IGBT.



The IGBT is in the on state if the gate-emitter voltage exceeds the specified threshold voltage V_{th} . Otherwise, the device is in the off state.

In the on state, the collector-emitter path behaves like a linear diode with forward-voltage drop V_f and on-resistance R_{on} .

In the off state, the collector-emitter path behaves like a linear resistor with a low off-state conductance value G_{off} .

The defining Simscape equations for the block are:

```

if (v>Vf)&&(G>Vth)
    i == (v - Vf*(1-Ron*Goff))/Ron;
else
    i == v*Goff;
end

```

where:

- v is the collector-emitter voltage.

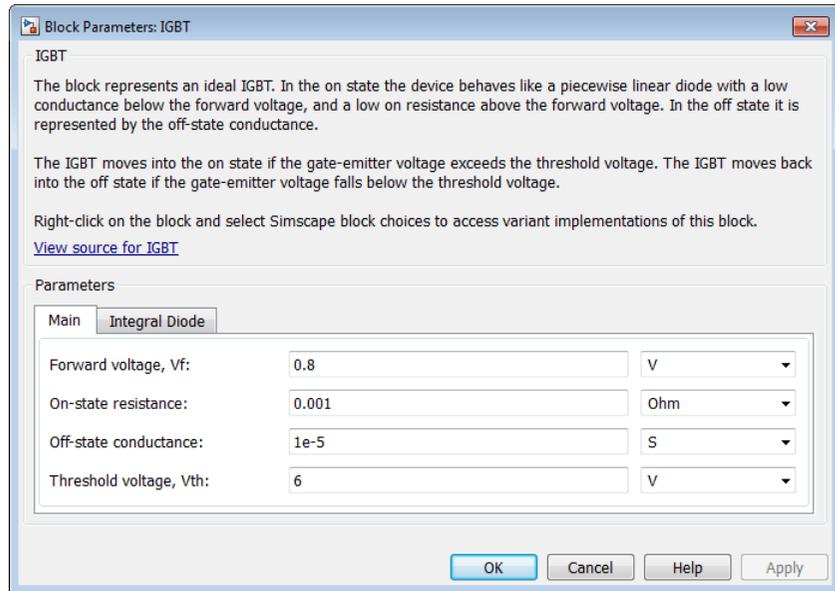
- V_f is the forward voltage.
- G is the gate-emitter voltage.
- V_{th} is the threshold voltage.
- i is the collector-emitter current.
- R_{on} is the on-state resistance.
- G_{off} is the off-state conductance.

Using the Integral Diode tab of the block dialog box, you can include an integral emitter-collector diode. An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

The table shows you how to set the **Integral protection diode** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating to the Commutation Diode block.

Dialog Box and Parameters



- “Main Tab” on page 1-127
- “Integral Diode Tab” on page 1-128

Main Tab

Forward voltage, Vf

Minimum voltage required across the collector and emitter block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On-state resistance**. The default value is 0.8 V.

On-state resistance

Collector-emitter resistance when the device is on. The default value is 0.001 Ω .

Off-state conductance

Collector-emitter conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-5 \Omega^{-1}$.

Threshold voltage, V_{th}

Collector-emitter voltage at which the device turns on. The default value is 6 V.

Integral Diode Tab

Integral protection diode

Block integral protection diode. The default value is None.

The diodes you can select are:

- Protection diode with no dynamics
- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics**Forward voltage**

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring iRM

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select **Specify stretch factor** or **Specify reverse recovery charge**, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, t_{rr}

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to **Specify reverse recovery time directly**.

The value of the **Reverse recovery time, t_{rr}** parameter must be greater than the value of the **Peak reverse current, i_{RM}** parameter divided by the value of the **Rate of change of current when measuring i_{RM}** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, t_{rr}** . This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to **Specify stretch factor**.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Q_{rr}

Value that the block uses to calculate **Reverse recovery time, t_{rr}** . Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, iRM**.
- a is the value specified for **Rate of change of current when measuring iRM**.

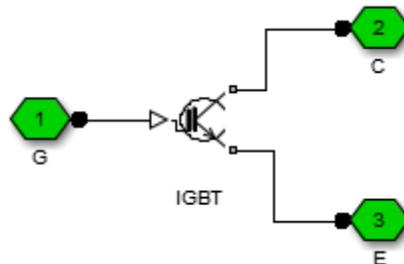
The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

This figure shows the block port names.



G

Port associated with the gate terminal. You can set the port to either a physical signal or electrical port.

C

Electrical conserving port associated with the collector terminal.

E
Electrical conserving port associated with the emitter terminal.

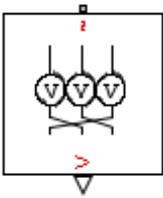
Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Purpose Measure line voltages in three-phase system

Library Sensors

Description

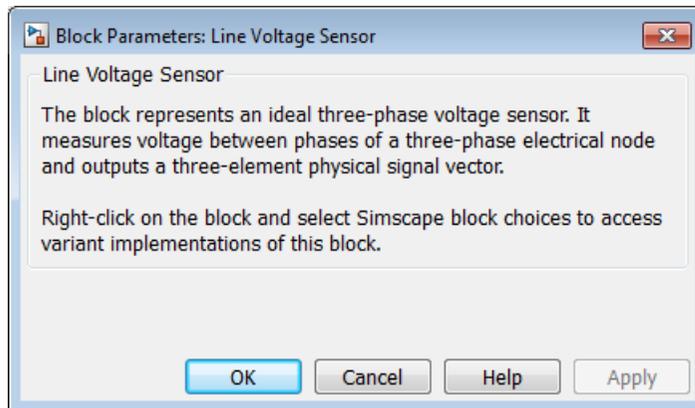


The Line Voltage Sensor block represents an ideal three-phase line voltage sensor. The block measures the line-line voltages of a three-phase system and outputs a three-element physical signal vector. Each element of the physical signal output vector is proportional to the voltage between the phases as follows:

- Element 1: $V_{ab} = V_a - V_b$
- Element 2: $V_{bc} = V_b - V_c$
- Element 3: $V_{ca} = V_c - V_a$

where V_a , V_b and V_c are the absolute phase voltages.

Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

- ~1 Expandable three-phase port

Line Voltage Sensor

V

Three-element physical signal vector output port associated with the voltages between the phases

See Also Phase Voltage Sensor

Related Examples

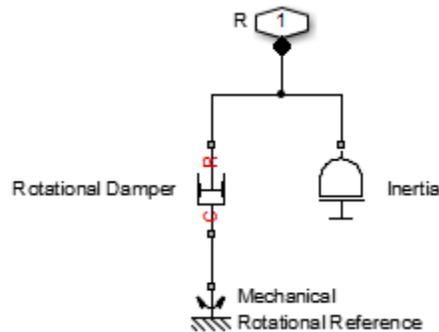
- “Expand and Collapse Three-Phase Ports on a Block”

Purpose Machine inertia

Library Machines

Description

The Machine Inertia block models inertia and damping that you connect to the mechanical rotational R port of a three-phase machine. The block has an internal connection to a mechanical rotational reference. The figure shows an equivalent configuration to the Machine Inertia block using Simscape mechanical rotational components.



Based on the value you select for the Specify inertia parameterization by parameter, you specify inertia J directly or using the machine inertia constant H .

If you specify the inertia constant, the block calculates inertia by

$$J = \frac{2HS_{rated}}{2\pi F_{rated} / N},$$

where:

- J is inertia in kgm^2 .
- H is the inertia constant in sW/VA .
- S_{rated} is the machine rated apparent power in VA .
- F_{rated} is the machine rated electrical frequency in Hz .

Machine Inertia

- N is the number of machine pole pairs.

You specify damping that represents viscous friction between the machine rotor and mechanical rotational reference. Based on the value you select for the **Specify damper parameterization** by parameter, you specify a damping coefficient in SI units or in per unit. If you specify the damping coefficient in per unit, the block calculates the damping coefficient in SI units by

$$\omega_{base} = \frac{2\pi F_{rated}}{N},$$

$$T_{base} = \frac{S_{rated}}{\omega_{base}},$$

$$D_{base} = \frac{T_{base}}{\omega_{base}},$$

and

$$D = D_{pu} D_{base},$$

where:

- ω_{base} is the base mechanical speed in rad/s.
- T_{base} is the base damping torque in Nm.
- D_{base} is the base damping coefficient in Nm/(rad/s).
- D_{pu} is the damping coefficient in per unit.
- D is the damping coefficient in SI units of Nm/(rad/s).

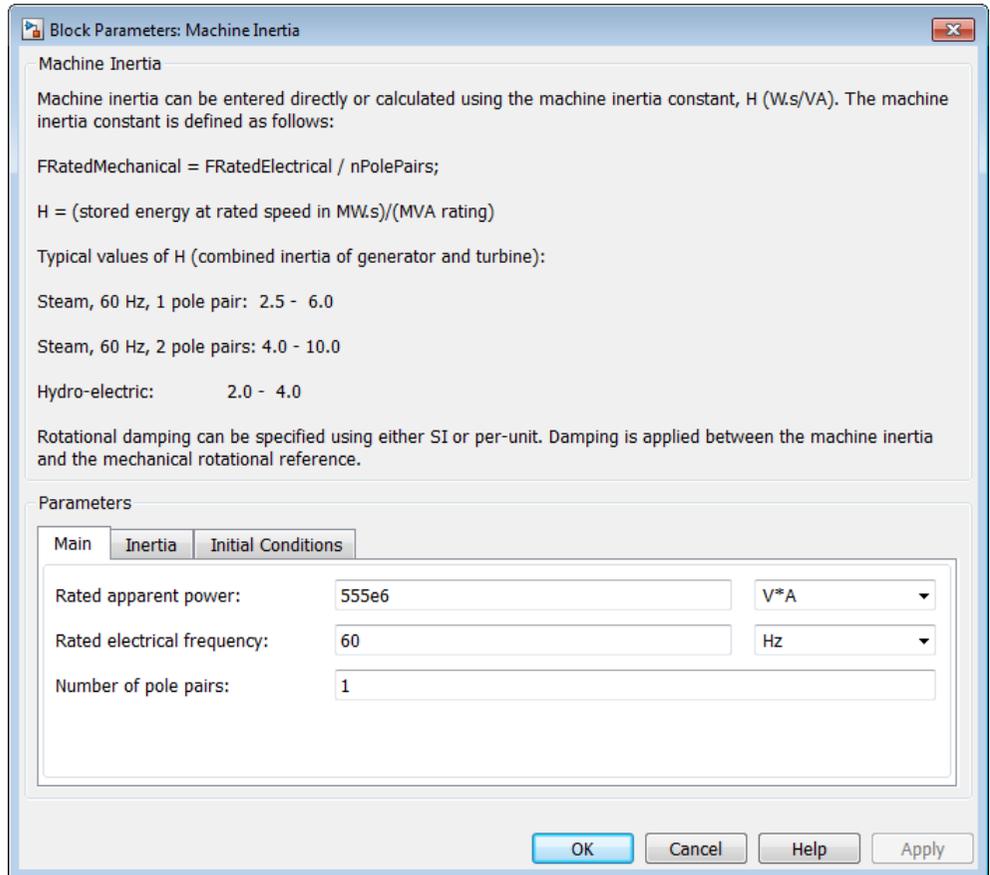
Parameter Display Option

You can display the inertia parameter and per-unit base values using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select **Display Parameters** on the **Power Systems > Machine Inertia** menu.

The block displays parameter values in the MATLAB Command Window.

Dialog Box and Parameters



- “Main Tab” on page 1-138
- “Inertia Tab” on page 1-138
- “Initial Conditions Tab” on page 1-139

Machine Inertia

Main Tab

Rated apparent power

Machine rated apparent power. The default value is 555e6 VA.

Rated electrical frequency

Nominal electrical frequency corresponding to the machine rated apparent power. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 1.

Inertia Tab

Specify inertia parameterization by

Inertia specification. The default value is Inertia constant, H.

Inertia constant, H

Inertia constant. This parameter is visible only if you set **Specify inertia parameterization by** to Inertia constant, H. The default value is 3.525 sW/VA.

Actual inertia, J

Inertia. This parameter is visible only if you set **Specify inertia parameterization by** to Actual inertia, J. The default value is 27548 kgm².

Specify damper parameterization by

Damping specification. The default value is Per-unit damping coefficient, pu_D.

Per-unit damping coefficient

Damping coefficient in per unit. This parameter is visible only if you set **Specify damper parameterization by** to Per-unit damping coefficient, pu_D. The default value is 0.01.

SI damping coefficient

Damping coefficient in SI units. This parameter is visible only if you set **Specify damper parameterization by** to SI damping coefficient, D. The default value is 39.0509 Nm/(rad/s).

Initial Conditions Tab

Specify initialization by

Frequency initialization. The default value is Initial electrical frequency.

Initial electrical frequency

Initial electrical frequency. This parameter is visible only if you set **Specify initialization by** to Initial electrical frequency. The default value is 60 Hz.

Initial mechanical frequency

Initial mechanical frequency. This parameter is visible only if you set **Specify initialization by** to Initial mechanical frequency. The default value is 60 Hz.

Ports

The block has the following ports:

R

Mechanical rotational conserving port associated with the machine rotor

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

MOSFET

Purpose

N-channel MOSFET

Library

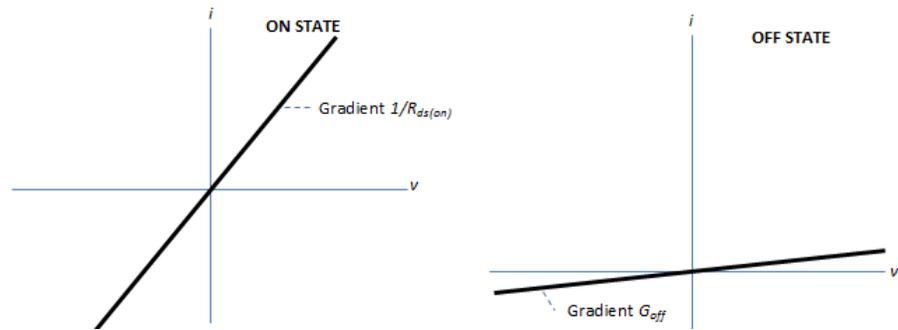
Semiconductors / Fundamental Components

Description

The MOSFET block models an n-channel MOSFET (metal-oxide-semiconductor field-effect transistor).



The figure shows typical *i-v characteristic* for an n-channel MOSFET.



The MOSFET is in the on state if the gate-source voltage exceeds the specified threshold voltage. Otherwise the device is in the off state.

In the on state, the drain-source path behaves like a linear resistor with resistance R_{ds_on} .

In the off state, the drain-source path behaves like a linear resistor with low off-state conductance G_{off} .

The defining Simscape equations for the block are:

```
if G > Vth
    v == i*Rds_on;
else
    v == i/Goff;
end
```

where:

- G is the gate-source voltage.
- V_{th} is the threshold voltage.
- v is the drain-source voltage.
- i is the drain-source current.
- R_{ds_on} is the on-state resistance.
- G_{off} is the off-state conductance.

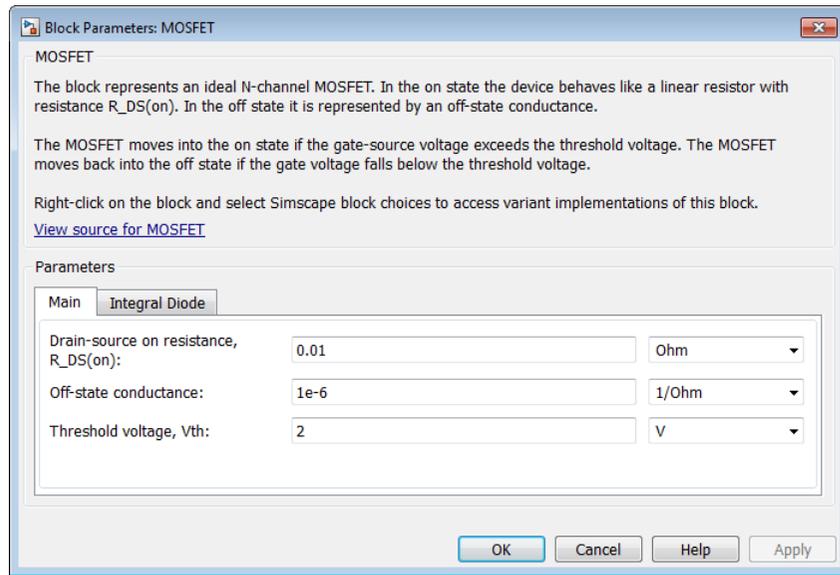
Using the Integral Diode tab of the block dialog box, you can include an integral source-drain diode. An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

The table shows you how to set the **Integral protection diode** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating to the Commutation Diode block.

MOSFET

Dialog Box and Parameters



- “Main Tab” on page 1-142
- “Integral Diode Tab” on page 1-143

Main Tab

On-state resistance, $R_{DS(on)}$

Drain-source resistance when the device is on. The default value is 0.01Ω .

Off-state conductance

Drain-source conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-6 \Omega^{-1}$.

Threshold voltage, V_{th}

Gate-source voltage threshold. The device turns on when the gate-source voltage is above this value. The default value is $2 V$.

Integral Diode Tab

Integral protection diode

Block integral protection diode. The default value is Protection diode with no dynamics.

The diodes you can select are:

- Protection diode with no dynamics
- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring iRM

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, trr

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, trr** parameter must be greater than the value of the **Peak reverse current, iRM** parameter divided by the value of the **Rate of change of current when measuring iRM** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, trr**. This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Qrr

Value that the block uses to calculate **Reverse recovery time, trr**. Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

MOSFET

where:

- i_{RM} is the value specified for **Peak reverse current, i_{RM}** .
- α is the value specified for **Rate of change of current when measuring i_{RM}** .

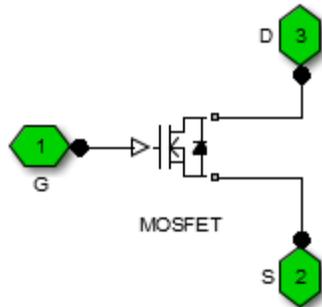
The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

This figure shows the block port names.



G

Port associated with the gate terminal. You can set the port to either a physical signal or electrical port.

S

Electrical conserving port associated with the source terminal.

D

Electrical conserving port associated with the drain terminal.

Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Neutral Port

Purpose

Connect phases of three-phase system to electrical conserving port

Library

Connections

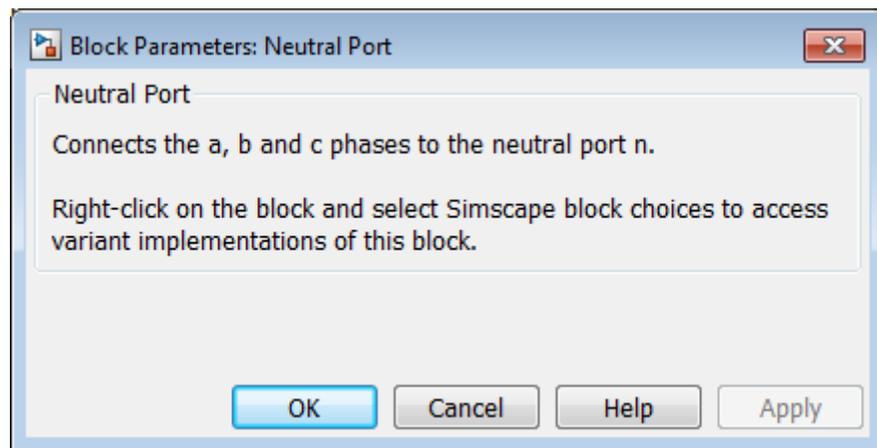
Description

The Neutral Port block connects the phases of a three-phase system to an electrical conserving port. You can connect the electrical port to electrical components from the Simscape and SimElectronics® libraries.



Note If you do not need to connect the neutral port to other blocks, use a Floating Neutral block instead. If you want to ground the neutral port, use a Grounded Neutral block.

Dialog Box and Parameters



The block has no parameters.

Ports

The block has the following ports:

~

Expandable three-phase port

n
Electrical conserving port associated with the neutral point

See Also

Neutral Port | Floating Neutral

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Open Circuit

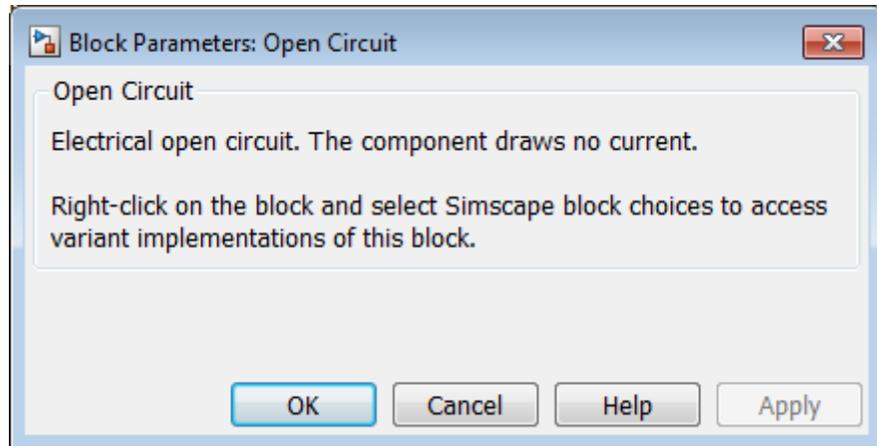
Purpose Three-phase connection that draws no current

Library Connections

Description The Open Circuit block models a three-phase connection that draws no current on any of the three phases. In Simscape, physical network block diagrams do not allow unconnected conserving ports. Therefore, use the Open Circuit block to terminate three-phase electrical ports on other blocks that you want to leave open-circuit.



Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

~
Expandable three-phase port

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Permanent Magnet Synchronous Motor

Purpose

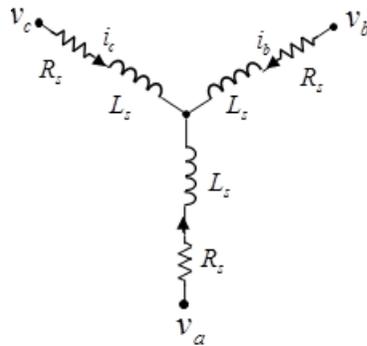
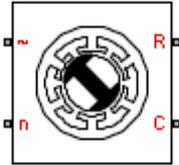
Permanent magnet synchronous motor with sinusoidal flux distribution

Library

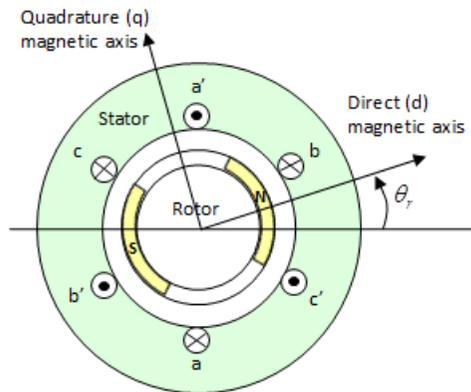
Machines / Permanent Magnet Rotor

Description

The Permanent Magnet Synchronous Motor block models a permanent magnet synchronous motor with a three-phase wye-wound stator. The figure shows the equivalent electrical circuit for the stator windings.



This figure shows the motor construction with a single pole-pair on the rotor.



Permanent Magnet Synchronous Motor

The rotor magnetic field due to the permanent magnet(s) creates a sinusoidal rate of change of flux with rotor angle.

For the axes convention in the preceding figure, the a-phase and permanent magnet fluxes are aligned when rotor angle θ_r is zero. The block supports a second rotor axis definition in which rotor angle is defined as the angle between the a-phase magnetic axis and the rotor q axis.

Electrical Defining Equations

Voltages across the stator windings are defined by

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \frac{d\psi_a}{dt} \\ \frac{d\psi_b}{dt} \\ \frac{d\psi_c}{dt} \end{bmatrix},$$

where:

- v_a , v_b , and v_c are the individual phase voltages across the stator windings.
- R_s is the equivalent resistance of each stator winding.
- i_a , i_b , and i_c are the currents flowing in the stator windings.
- $\frac{d\psi_a}{dt}$, $\frac{d\psi_b}{dt}$, and $\frac{d\psi_c}{dt}$

are the rates of change of magnetic flux in each stator winding.

The permanent magnet and the three windings contribute to the total flux linking each winding. The total flux is defined by

Permanent Magnet Synchronous Motor

$$\begin{bmatrix} \psi_a \\ \psi_b \\ \psi_c \end{bmatrix} = \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \psi_{am} \\ \psi_{bm} \\ \psi_{cm} \end{bmatrix},$$

where:

- ψ_a , ψ_b , and ψ_c are the total fluxes linking each stator winding.
- L_{aa} , L_{bb} , and L_{cc} are the self-inductances of the stator windings.
- L_{ab} , L_{ac} , L_{ba} , etc. are the mutual inductances of the stator windings.
- ψ_{am} , ψ_{bm} , and ψ_{cm} are the permanent magnet fluxes linking the stator windings.

The inductances in the stator windings are functions of rotor angle, defined by

$$L_{aa} = L_s + L_m \cos(2\theta_r),$$

$$L_{bb} = L_s + L_m \cos(2(\theta_r - 2\pi / 3)),$$

$$L_{cc} = L_s + L_m \cos(2(\theta_r + 2\pi / 3)),$$

$$L_{ab} = L_{ba} = -M_s - L_m \cos(2(\theta_r + \pi / 6)),$$

$$L_{bc} = L_{cb} = -M_s - L_m \cos(2(\theta_r + \pi / 6 - 2\pi / 3)),$$

and

$$L_{ca} = L_{ac} = -M_s - L_m \cos(2(\theta_r + \pi / 6 + 2\pi / 3)),$$

where:

- L_s is the stator self-inductance per phase. This is the average self-inductance of each of the stator windings.

Permanent Magnet Synchronous Motor

- L_m is the stator inductance fluctuation. This is the amplitude of the fluctuation in self-inductance and mutual inductance with changing rotor angle.
- M_s is the stator mutual inductance. This is the average mutual inductance between the stator windings.

The permanent magnet flux linking winding a is a maximum when $\theta_r = 0^\circ$ and zero when $\theta_r = 90^\circ$. Therefore, the linked motor flux is defined by

$$\begin{bmatrix} \psi_{am} \\ \psi_{bm} \\ \psi_{cm} \end{bmatrix} = \begin{bmatrix} \psi_m \cos \theta_r \\ \psi_m \cos(\theta_r - 2\pi / 3) \\ \psi_m \cos(\theta_r + 2\pi / 3) \end{bmatrix}.$$

Simplified Electrical Equations

Applying Park's transformation to the block electrical defining equations produces an expression for torque that is independent of rotor angle.

Park's transformation is defined by

$$P = 2/3 \begin{bmatrix} \cos \theta_e & \cos(\theta_e - 2\pi / 3) & \cos(\theta_e + 2\pi / 3) \\ -\sin \theta_e & -\sin(\theta_e - 2\pi / 3) & -\sin(\theta_e + 2\pi / 3) \\ 0.5 & 0.5 & 0.5 \end{bmatrix}.$$

where θ_e is the electrical angle defined as $N\theta_r$. N is the number of pole pairs.

The inverse of Park's transformation is defined by

$$P^{-1} = \begin{bmatrix} \cos \theta_e & -\sin \theta_e & 1 \\ \cos(\theta_e - 2\pi / 3) & -\sin(\theta_e - 2\pi / 3) & 1 \\ \cos(\theta_e + 2\pi / 3) & -\sin(\theta_e + 2\pi / 3) & 1 \end{bmatrix}.$$

Permanent Magnet Synchronous Motor

Applying Park's transformation to the first two electrical defining equations produces the following equations that define the block behavior:

$$v_d = R_s i_d + L_d \frac{di_d}{dt} - N \omega i_q L_q,$$

$$v_q = R_s i_q + L_q \frac{di_q}{dt} + N \omega (i_d L_d + \psi_m),$$

$$v_0 = R_s i_0 + L_0 \frac{di_0}{dt},$$

and

$$T = \frac{3}{2} N (i_q (i_d L_d + \psi_m) - i_d i_q L_q),$$

where:

- v_d , v_q , and v_0 are the d-axis, q-axis, and zero-sequence voltages, defined by

$$\begin{bmatrix} v_d \\ v_q \\ v_0 \end{bmatrix} = P \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}.$$

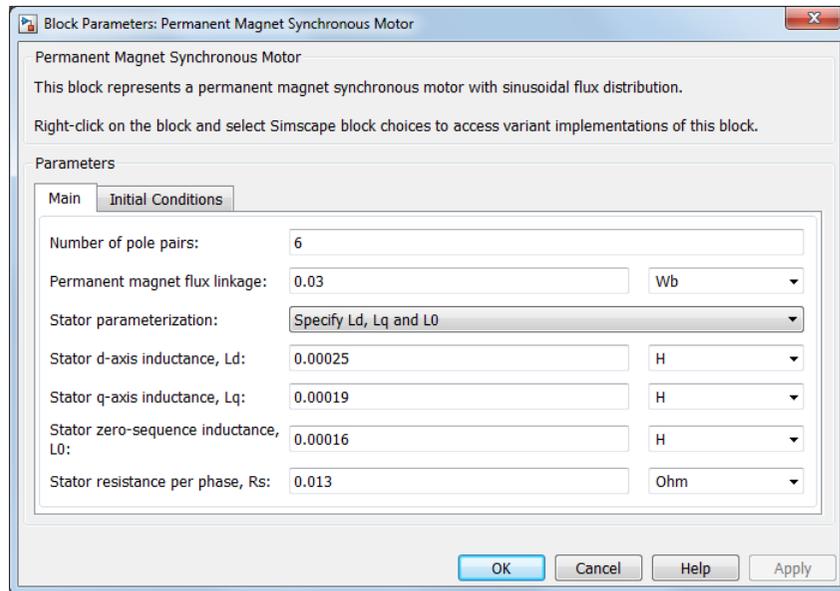
- i_d , i_q , and i_0 are the d-axis, q-axis, and zero-sequence currents, defined by

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}.$$

Permanent Magnet Synchronous Motor

- $L_d = L_s + M_s + 3/2 L_m$. L_d is the stator d-axis inductance.
- $L_q = L_s + M_s - 3/2 L_m$. L_q is the stator q-axis inductance.
- $L_0 = L_s - 2M_s$. L_0 is the stator zero-sequence inductance.
- ω is the rotor mechanical rotational speed.
- N is the number of rotor permanent magnet pole pairs.
- T is the rotor torque. Torque flows from the motor case (block physical port C) to the motor rotor (block physical port R).

Dialog Box and Parameters



Main Tab

Number of pole pairs

Number of permanent magnet pole pairs on the rotor. The default value is 6.

Permanent Magnet Synchronous Motor

Permanent magnet flux linkage

Peak permanent magnet flux linkage with any of the stator windings. The default value is 0.03 Wb.

Stator parameterization

Set of stator parameters that the block dialog box shows. The default value is Specify Ld, Lq and L0.

Stator d-axis inductance, Ld

D-axis inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00025 H.

Stator q-axis inductance, Lq

Q-axis inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00019 H.

Stator zero-sequence inductance, L0

Zero-sequence inductance. This parameter is visible only if you set **Stator parameterization** to Specify Ld, Lq and L0. The default value is 0.00016 H.

Stator self-inductance per phase, Ls

Average self-inductance of each of the three stator windings. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0.0002 H.

Stator inductance fluctuation, Lm

Amplitude of the fluctuation in self-inductance and mutual inductance of the stator windings with rotor angle. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0.00002 H.

Stator mutual inductance, Ms

Average mutual inductance between the stator windings. This parameter is visible only if you set **Stator parameterization** to Specify Ls, Lm and Ms. The default value is 0.00002 H.

Permanent Magnet Synchronous Motor

Stator resistance per phase, R_s

Resistance of each of the stator windings. The default value is 0.013 Ω .

Initial Conditions Tab

Initial currents, $[i_d \ i_q \ i_0]$

Initial d-axis, q-axis, and zero-sequence currents. The default value is [0, 0, 0] A.

Rotor angle definition

Reference point for the rotor angle measurement. The default value is Angle between the a-phase magnetic axis and the d axis. This definition is shown in the motor construction figure. When you select this value, the rotor and a-phase fluxes are aligned when the rotor angle is zero.

The other value you can choose for this parameter is Angle between the a-phase magnetic axis and the q axis. When you select this value, the a-phase current generates maximum torque when the rotor angle is zero.

Initial rotor angle

Initial angle of the rotor. The default value is 0 deg.

Ports

~	Expandable three-phase port.
n	Electrical conserving port associated with the neutral phase.
R	Mechanical rotational conserving port associated with the motor rotor.
C	Mechanical rotational conserving port associated with the motor case.

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Anderson, P. M. *Analysis of Faulted Power Systems*. Hoboken, NJ: Wiley-IEEE Press, 1995.

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Phase Permute

Purpose

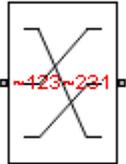
Permute phases of three-phase system

Library

Connections

Description

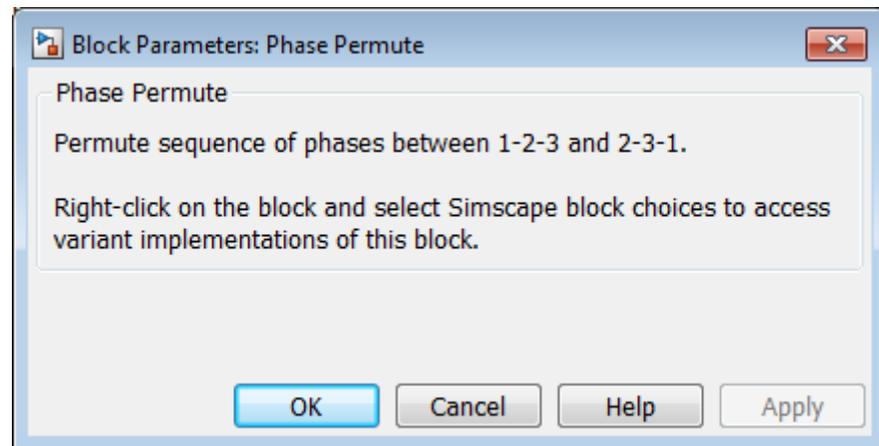
The Phase Permute block cyclically permutes (changes the order of) the phases of a three-phase system.



The block has two three-phase connections associated with its terminals. If you consider the side of the block labeled ~ 123 ($a1, b1, c1$ in expanded view) as side 1 and the side of the block labeled ~ 231 ($a2, b2, c2$) as side 2, then the block connects phases as shown in the table.

Side 1 Phase	Connects to Side 2 Phase
a1	c2
b1	a2
c1	b2

Dialog Box and Parameters



The block has no parameters.

Ports

The block has the following ports:

~123

Expandable three-phase port

~231

Expandable three-phase port

Related Examples

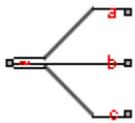
- “Expand and Collapse Three-Phase Ports on a Block”

Phase Splitter

Purpose Expand composite three-phase port

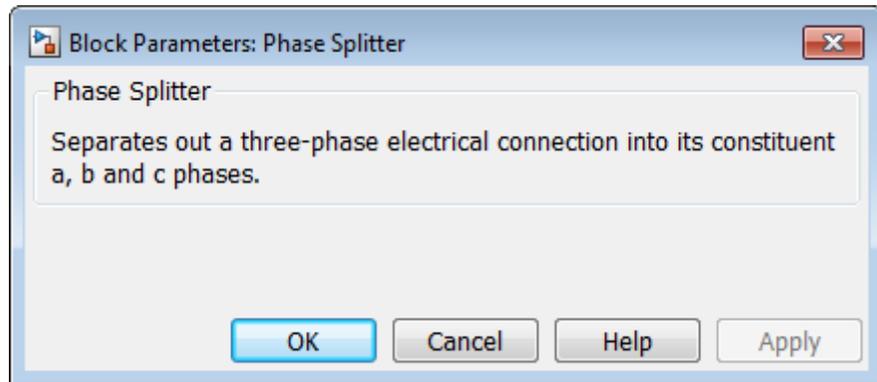
Library Connections

Description The Phase Splitter block expands a composite three-phase port into its constituent phases.



The expanded output ports are electrical conserving ports. Therefore, you can connect the output ports to electrical components from the Simscape and SimElectronics® libraries.

Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

~

Composite three-phase port

a, b, c

Constituent phases of the expanded three-phase port

Related Examples

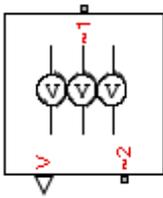
- “Expand and Collapse Three-Phase Ports on a Block”

Phase Voltage Sensor

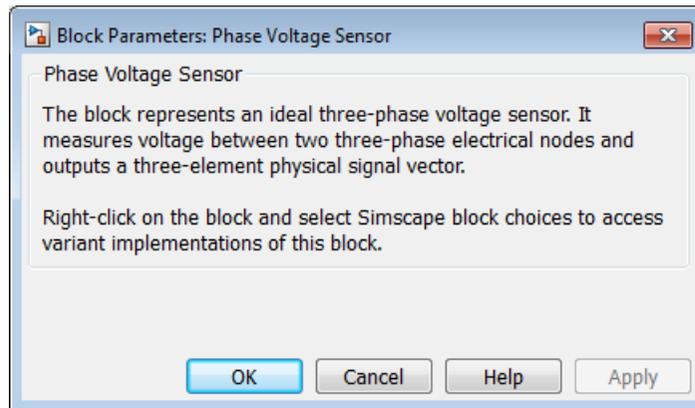
Purpose Measure phase voltages in three-phase system

Library Sensors

Description The Phase Voltage Sensor block represents an ideal three-phase voltage sensor. It measures the voltages across the three-phase ports ~1 and ~2 and outputs a single three-element, physical signal vector. Each element of the physical signal output vector is equal to the voltage in the respective phase.



Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

- 1 Expandable three-phase port
- 2 Expandable three-phase port

V

Three-element physical signal vector output port associated with the phase voltages

See Also [Line Voltage Sensor](#)

Related Examples

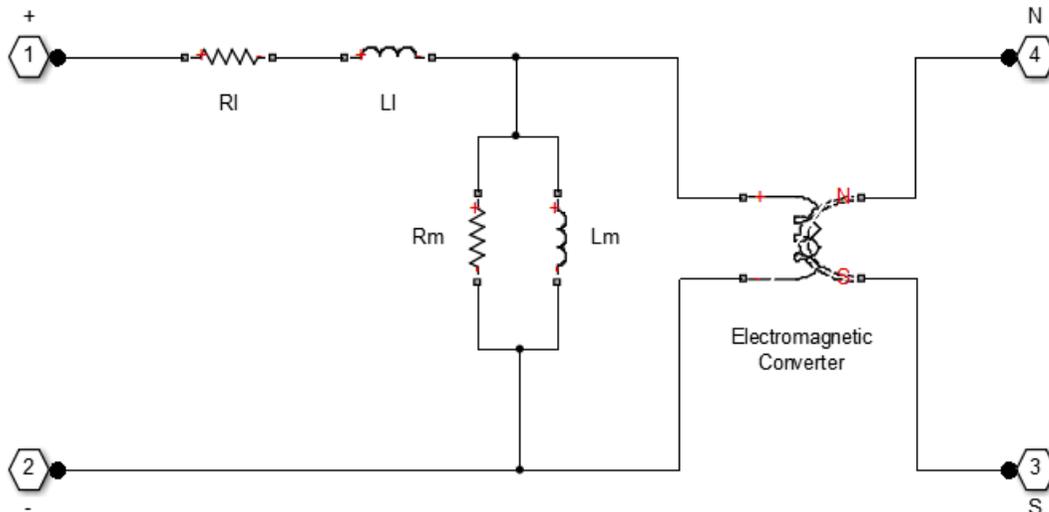
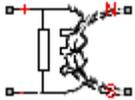
- [“Expand and Collapse Three-Phase Ports on a Block”](#)

Primary Winding

Purpose Linear non-ideal transformer winding

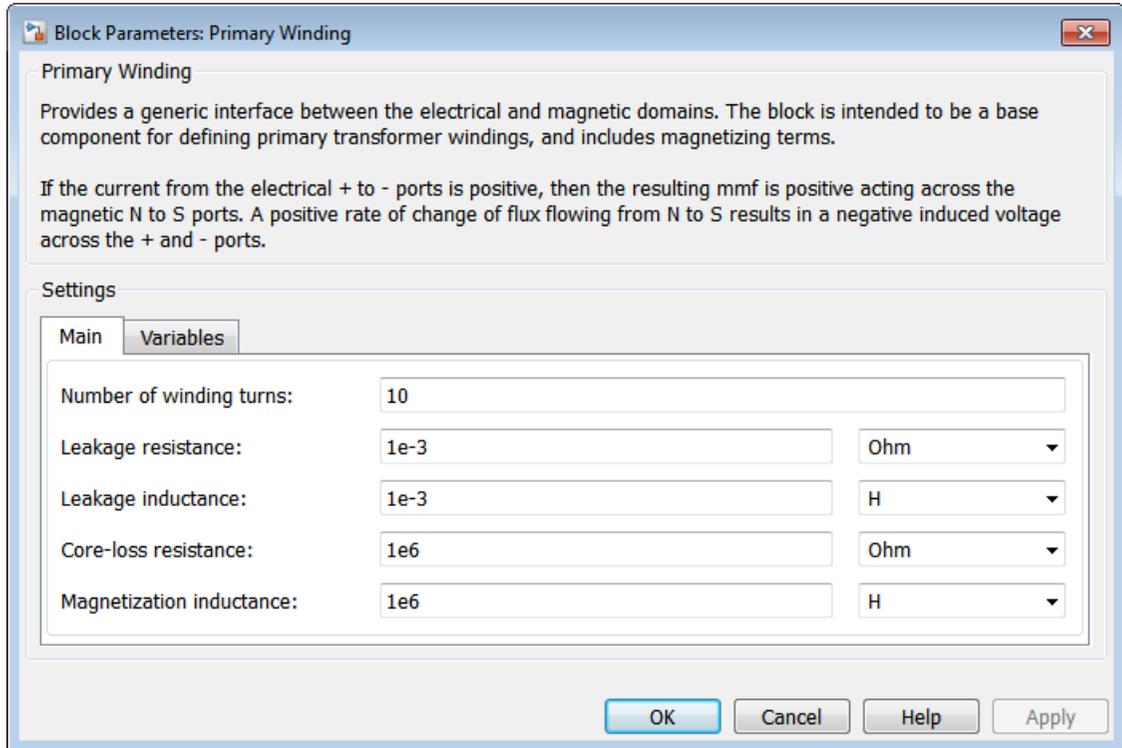
Library Passive Devices / Transformers / Fundamental Components

Description The Primary Winding block models linear non-ideal winding of a transformer with linear winding leakage and linear core magnetization effects. Although magnetization effects occur in the magnetic core, it is common practice to place mathematically equivalent electrical components on the electrical winding and parameterize them using electrical parameters. The figure shows the equivalent circuit diagram for the primary winding.



- R_1 is the leakage resistance.
- L_1 is the leakage inductance.
- R_m is the magnetization resistance.
- L_m is the magnetization inductance.

Dialog Box and Parameters



- “Main Tab” on page 1-167
- “Variables Tab” on page 1-168

Main Tab

Number of winding turns

Number of wire turns on the transformer winding. The default value is 10.

Primary Winding

Leakage resistance

Power loss in the winding. The default value is $1e-3 \Omega$.

Leakage inductance

Magnetic flux loss in the winding. The default value is $1e-3$ H.

Core-loss resistance

Magnetic losses in the transformer core. The default value is $1e6 \Omega$.

Magnetization inductance

Magnetic effects in the transformer core when operating in its linear region. The default value is $1e6$ H.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see the Simscape topic, “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

- + Positive electrical conserving port
- Negative electrical conserving port
- N North magnetic conserving port
- S South magnetic conserving port

See Also

Electromagnetic Converter | Secondary Winding

Purpose

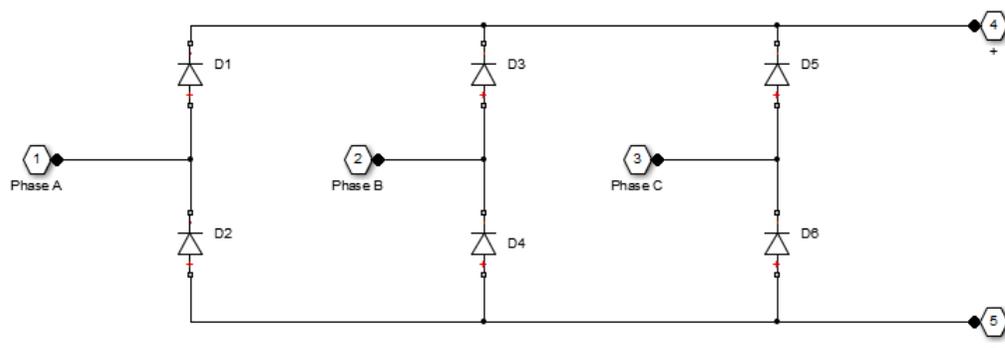
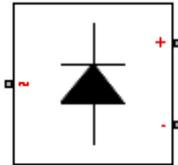
Convert three-phase AC voltage to fixed DC voltage

Library

Semiconductors

Description

The Rectifier block models a three-arm diode bridge circuit that converts a three-phase AC voltage to a fixed DC voltage. The figure shows the equivalent circuit for the three-arm diode bridge.



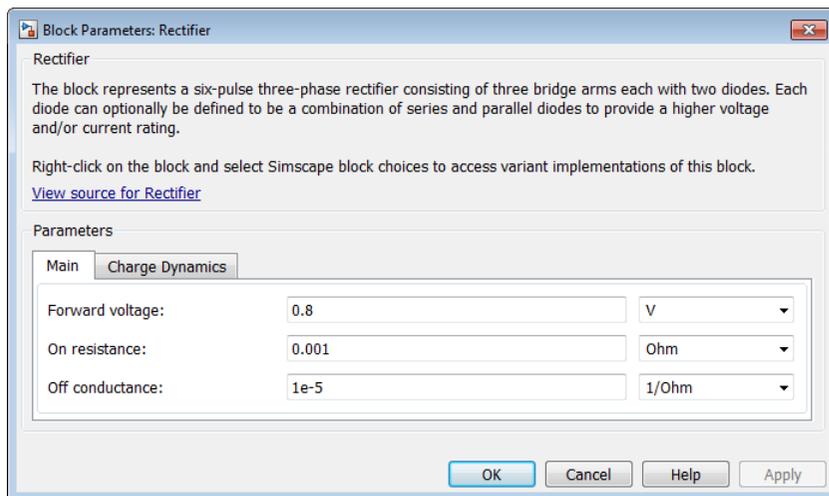
Using the Charge Dynamics tab of the block dialog box, you can choose the type of diode that the three-arm bridge circuit uses. The table shows you how to set the **Model dynamics** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	No dynamics	Each arm of the bridge circuit uses a copy of the Diode block. The block dialog box does not display additional parameters.
Precisely specify reverse-mode charge dynamics.	Model charge dynamics	Each arm of the bridge circuit uses a copy of the Commutation Diode

Rectifier

Goal	Value to Select	Block Behavior
		block. The block dialog box shows parameters relating to the Commutation Diode block.

Dialog Box and Parameters



- “Main Tab” on page 1-170
- “Charge Dynamics Tab” on page 1-171

Main Tab

Forward voltage

Minimum voltage required across the + and - ports of each diode for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default forward voltage value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage for each diode. The default value is 0.001 Ω .

Off conductance

Conductance of each reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Charge Dynamics Tab**Model dynamics**

Diode charge dynamics. The default value is No dynamics.

The charge dynamics options you can select are:

- No dynamics
- Model charge dynamics

Parameters for Model charge dynamics

When you select Model charge dynamics, additional parameters appear.

Additional Parameters for Model charge dynamics**Junction capacitance**

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring iRM

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is -50 A/ μ s.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is **Specify reverse recovery time directly**.

If you select **Specify stretch factor** or **Specify reverse recovery charge**, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, trr

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is 15 μ s.

This parameter is visible only if you set **Reverse recovery time parameterization** to **Specify reverse recovery time directly**.

The value of the **Reverse recovery time, trr** parameter must be greater than the value of the **Peak reverse current, iRM** parameter divided by the value of the **Rate of change of current when measuring iRM** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, trr**. This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to **Specify stretch factor**.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge. The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Q_{rr}

Value that the block uses to calculate **Reverse recovery time**, trr . Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current, i_{RM}** .
- a is the value specified for **Rate of change of current when measuring i_{RM}** .

The default value is 1500 μ As.

The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

The block has the following ports:

- ~ Expandable three-phase port
- + Electrical conserving port associated with the positive terminal
- Electrical conserving port associated with the negative terminal

See Also Converter

Rectifier

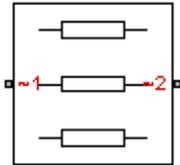
Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Purpose Three-phase line impedance

Library Passive Devices

Description

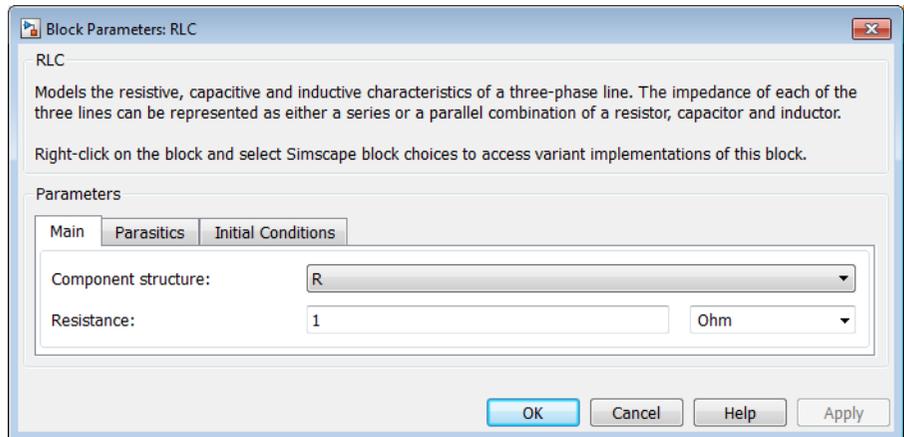


The RLC block models a three-phase impedance with two three-phase connections. Each of the three identical impedance components can include any combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel.

Define the values for the R, L, and C components by specifying the appropriate block parameters. Do not set the parameter values to zero or infinity to remove terms; instead, select the correct option for the **Component structure** parameter.

For certain combinations of R, L, and C, you must specify parasitic resistance or conductance values, which can help numerical convergence when simulating some circuit topologies. These parasitic terms ensure that an inductor has a small parallel resistive path and that a capacitor has a small series resistance.

Dialog Box and Parameters



- “Main Tab” on page 1-176
- “Parasitics Tab” on page 1-176

- “Initial Conditions Tab” on page 1-177

Main Tab

Component structure

Select the desired combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel. The default is R, resistor.

Resistance

Resistance of each of the line impedances. This parameter is visible only when you select a component structure that includes a resistor. The default value is 1 Ω .

Inductance

Inductance of each of the line impedances. This parameter is visible only when you select a component structure that includes an inductor. The default value is 0.001 H.

Capacitance

Capacitance in each of the line impedances. This parameter is visible only when you select a component structure that includes a capacitor. The default value is 1e-6 F.

Parasitics Tab

Parasitic series resistance

Represents small parasitic effects. The parameter value corresponds to the series resistance value added to all instances of capacitors in the load. The default value is 1e-6 Ω .

Parasitic parallel conductance

Represents small parasitic effects. The parameter value corresponds to the parallel conductance value added across all instances of inductors in the load. The default value is 1e-6 1/ Ω .

Initial Conditions Tab

Initial inductor current [Ia Ib Ic]

Initial current in the a, b, and c phase inductors, respectively. This parameter is visible only when you select a component structure that includes an inductor. The default value is [0 0 0] A.

Initial capacitor voltage [Va Vb Vc]

Initial voltage across the a, b, and c phase capacitors, respectively. This parameter is visible only when you select a component structure that includes a capacitor. The default value is [0 0 0] V.

Block Parameterization

The following table lists the block parameters for each of the configurations, based on the selected **Component structure** option.

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
R	Resistance	None	None
L	Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
C	Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]
Series RL	Resistance Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
Series RC	Resistance Capacitance	None	Initial capacitor voltage [Va Vb Vc]

RLC

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Series LC	Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Series RLC	Resistance Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RL	Resistance Inductance	None	Initial inductor current [Ia Ib Ic]
Parallel RC	Resistance Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]
Parallel LC	Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RLC	Resistance Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]

Ports

The block has two expandable three-phase ports, ~1 and ~2, representing the two terminals of the three-phase line.

See Also

Delta-Connected Load | Wye-Connected Load

Related Examples

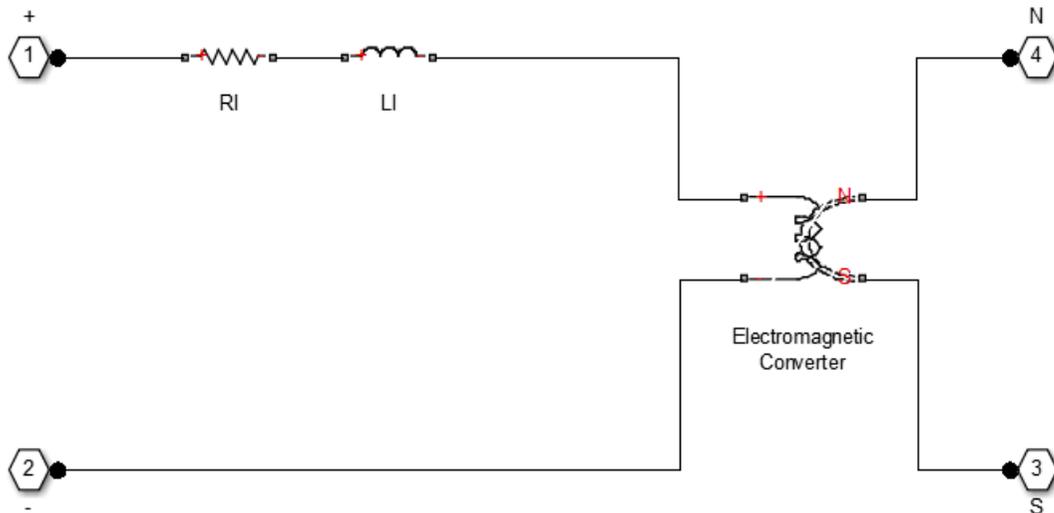
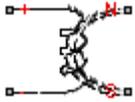
- “Expand and Collapse Three-Phase Ports on a Block”

Secondary Winding

Purpose Linear non-ideal transformer winding

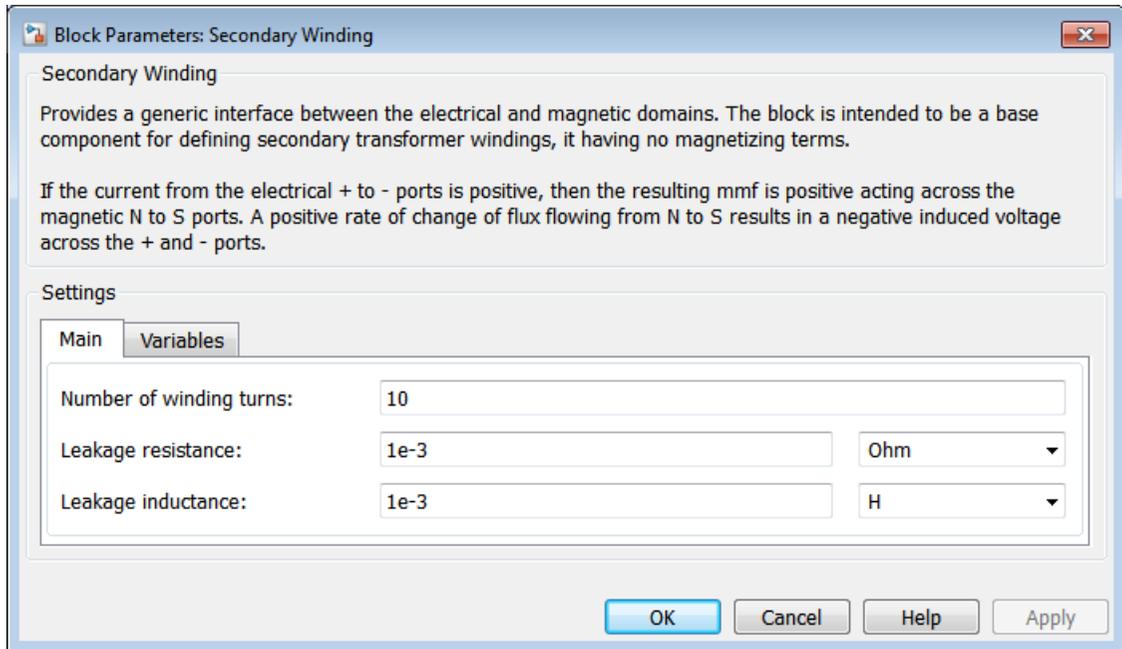
Library Passive Devices / Transformers / Fundamental Components

Description The Secondary Winding block models linear non-ideal winding of a transformer with linear winding leakage effects. The figure shows the equivalent circuit diagram for the secondary winding.



- R_1 is the leakage resistance.
- L_1 is the leakage inductance.

Dialog Box and Parameters



- “Main Tab” on page 1-181
- “Variables Tab” on page 1-182

Main Tab

Number of winding turns

Number of wire turns on the transformer winding. The default value is 10.

Leakage resistance

Power loss in the winding. The default value is $1e-3 \Omega$.

Secondary Winding

Leakage inductance

Magnetic flux loss in the winding. The default value is $1e-3$ H.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see the Simscape topic, “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

- + Positive electrical conserving port
- Negative electrical conserving port
- N North magnetic conserving port
- S South magnetic conserving port

See Also

Electromagnetic Converter | Primary Winding

Single-Phase Circuit Breaker

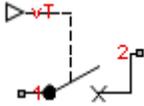
Purpose

Single-pole single-throw circuit breaker

Library

Switches & Breakers / Fundamental Components

Description



The Single-Phase Circuit Breaker block models a single-phase circuit breaker that uses an external signal and phase current information to break an electrical circuit.

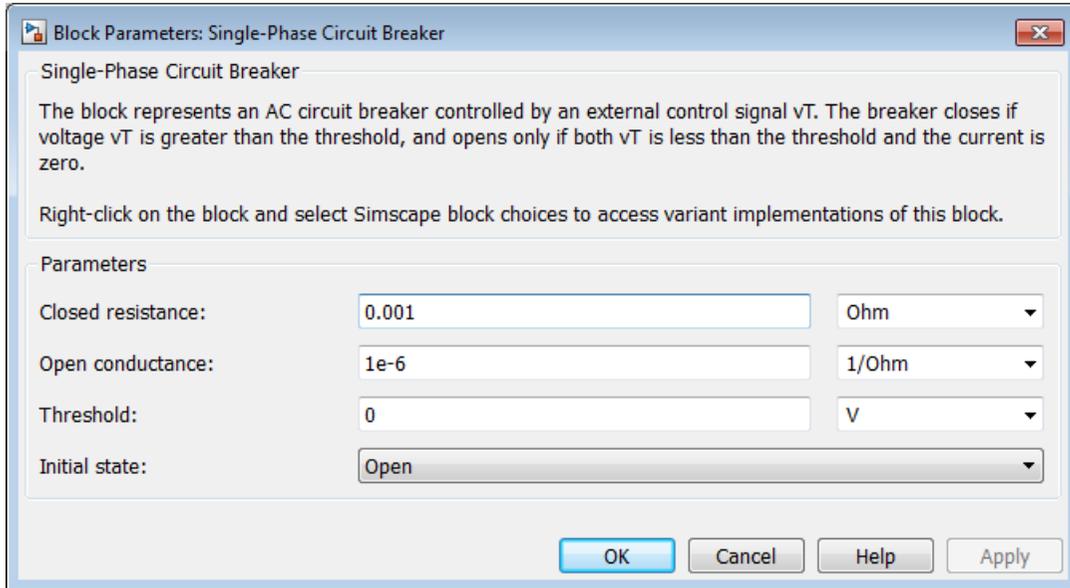
The table shows how the external signal vT controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$vT < \text{Threshold}$	The breaker is closed. Port 1 connects to port 2.	Closed Resistance
$vT \geq \text{Threshold}$	When the current in port 1 goes through zero, the phase disconnects from port 2. The breaker is open. When $vT < \text{Threshold}$ and the current in port 1 is zero, it connects to port 2. The breaker is closed.	Open Conductance

Set the block **Initial State** parameter to match the behavior in the table. If, for example, you set **Initial State** to **Open** and vT to less than **Threshold**, the block produces invalid results the first time vT exceeds **Threshold**.

Single-Phase Circuit Breaker

Dialog Box and Parameters



Closed resistance

Resistance between ports 1 and 2 when the breaker is closed. The default value is 0.001 Ω .

Open conductance

Conductance between ports 1 and 2 when the breaker is open. The default value is $1e-6 \Omega^{-1}$.

Threshold

Threshold voltage for the control port v_T . When the voltage rises above the threshold, the breaker opens as the phase current goes through zero. When the control port voltage falls below the threshold, the breaker closes. The default value is 0 V.

Initial state

Set the initial condition of the circuit breaker to Open or Closed.
The default value is Closed.

Ports

The block has the following ports:

1

Single-phase port

2

Single-phase port

vT

Scalar control port, which is either a physical signal or an electrical port.

See Also [Circuit Breaker](#)

Related Examples

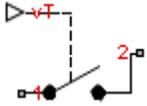
- “Switch Between Physical Signal and Electrical Ports”

Single-Phase Switch

Purpose Single-pole single-throw switch

Library Switches & Breakers / Fundamental Components

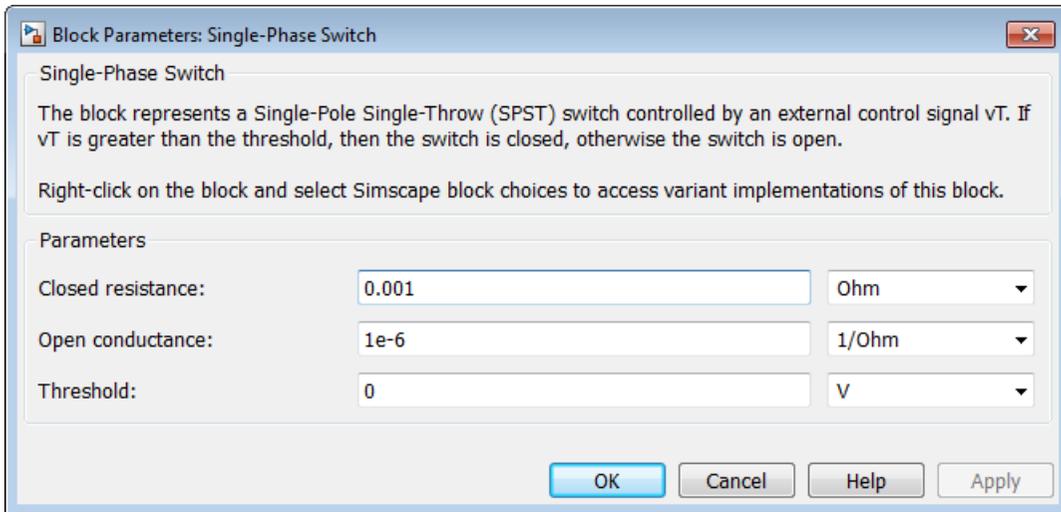
Description The Single-Phase Switch block models a single-pole single-throw switch that uses an external signal to connect port 1 to port 2 via internal resistance.



The table shows how the external signal v_T controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$v_T \leq$ Threshold	The switch is open. Port 1 is connected to port 2 via large internal resistance.	Open conductance
$v_T >$ Threshold	The switch is closed. Port 1 is connected to port 2 via small internal resistance.	Closed resistance

Dialog Box and Parameters



Closed resistance

Resistance between ports 1 and 2 when the switch is closed. The default value is 0.001 Ω .

Open conductance

Conductance between ports 1 and 2 when the switch is open. The default value is 1e-6 Ω^{-1} .

Threshold

Threshold voltage for the control port v_T . When the voltage is above the threshold, the switch is closed. The default value is 0 V.

Ports

The block has the following ports:

- 1 Single-phase port

Single-Phase Switch

2

Single-phase port

vT

Scalar control port, which is either a physical signal or an electrical port.

See Also

[Single-Phase Two-Way Switch](#) | [Switch](#) | [Two-Way Switch](#)

Related Examples

- [“Switch Between Physical Signal and Electrical Ports”](#)

Single-Phase Two-Way Switch

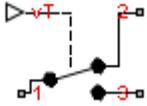
Purpose

Single-pole double-throw switch

Library

Switches & Breakers / Fundamental Components

Description



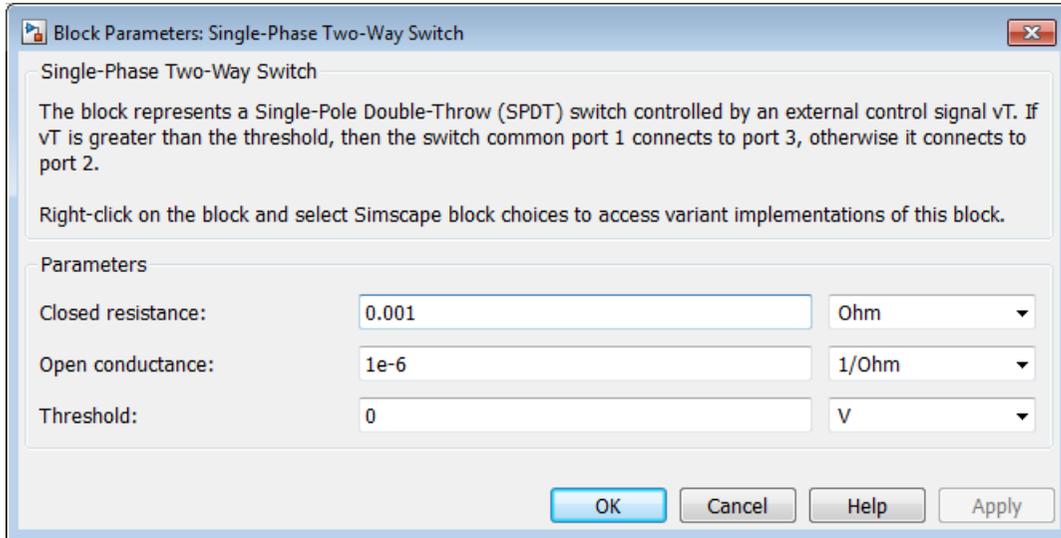
The Single-Phase Two-Way Switch block models a single-pole double-throw switch that uses an external signal to connect the port 1 to either of two ports 2 or 3 via internal resistance.

The table shows how the external signal vT controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$vT \leq$ Threshold	Port 1 is connected to port 2 via internal resistance. Port 3 is unconnected.	Open conductance (port 1 to port 3). Closed resistance (port 1 to port 2)
$vT >$ Threshold	Port 1 is connected to port 3 via internal resistance. Port 2 is unconnected.	Open conductance (port 1 to port 2). Closed resistance (port 1 to port 3)

Single-Phase Two-Way Switch

Dialog Box and Parameters



Closed resistance

Resistance between ports 1 and 3 when the switch is closed. The default value is 0.001Ω .

Open conductance

Conductance between ports 1 and 2 when the switch is open. The default value is $1e-6 \Omega^{-1}$.

Threshold

Threshold voltage for the control port v_T . When the voltage is above the threshold, the switch is closed. The default value is 0 V .

Ports

The block has the following ports:

- 1 Single-phase port

Single-Phase Two-Way Switch

2

Single-phase port

3

Single-phase port

vT

Scalar control port, which is either a physical signal or an electrical port.

See Also

[Single-Phase Switch](#) | [Switch](#) | [Two-Way Switch](#)

Related Examples

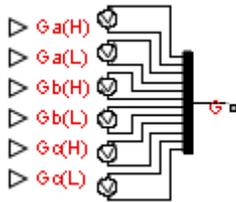
- “Switch Between Physical Signal and Electrical Ports”

Six-Pulse Gate Multiplexer

Purpose Multiplex gate input signals to Converter block

Library Semiconductors

Description

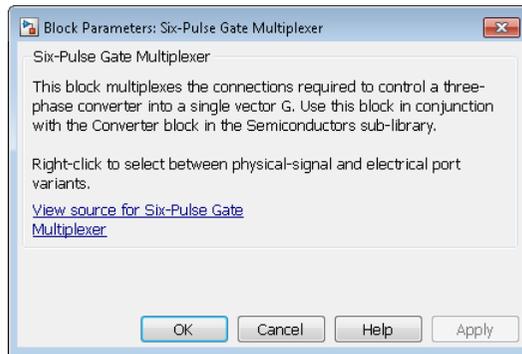


The Six-Pulse Gate Multiplexer block routes gate voltage signals to the six switching devices in a Converter block. The block multiplexes the six separate gate signals into a single vector.

If you want to use SimElectronics to model the electronics that drive the Converter block, you can switch the input ports of the Six-Pulse Gate Multiplexer block from physical signal ports to electrical ports.

When you switch the block inputs to electrical ports, the block shows additional electrical reference input ports. The additional electrical reference ports are associated with the individual phase voltages that connect to the high-side switching devices in the Converter block and the negative DC voltage common to each low-side switching device in the Converter block.

Dialog Box and Parameters



The block has no parameters.

Ports

The block has the following ports:

Ga(H) , Gb(H) , Gc(H)

Ports associated with the gate terminals of the Converter block high-side switching devices. You can set the ports to either physical signal or electrical ports.

Ga(L) , Gb(L) , Gc(L)

Ports associated with the gate terminals of the Converter block low-side switching devices. You can set the ports to either physical signal or electrical ports.

G

Vector output port associated with the multiplexed gate signals. Connect this port to the G port of the Converter block.

a, b, c

Electrical conserving ports associated with the individual phase voltages that connect to the high-side switching devices of the Converter block. These ports are visible only if you set the input ports of the Six-Pulse Gate Multiplexer block to electrical ports.

L

Electrical conserving port associated with the negative DC voltage common to each low-side switching device in the Converter block.

Six-Pulse Gate Multiplexer

These ports are visible only if you set the input ports of the Six-Pulse Gate Multiplexer block to electrical ports.

See Also Converter

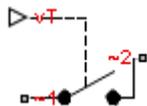
Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Purpose Three-phase single-throw switch

Library Switches & Breakers

Description



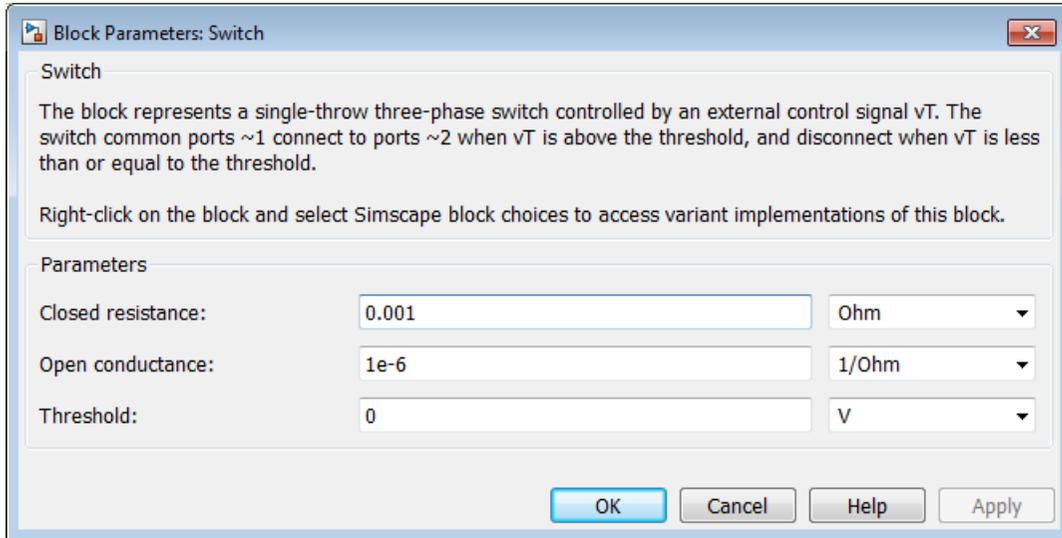
The Switch block models a three-phase single-throw switch that uses an external signal to connect each phase of port ~1 with the corresponding phase of port ~2 via internal resistance.

The table shows how the external signal vT controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$vT \leq$ Threshold	The switch is open. Each phase in the composite three-phase port ~1 connects to the corresponding phase in the port ~2 via large internal resistance.	Open conductance
$vT >$ Threshold	The switch is closed. Each phase in the composite three-phase port ~1 connects to the corresponding phase in the port ~2 via small internal resistance.	Closed resistance

Switch

Dialog Box and Parameters



Closed resistance

Resistance between ports ~1 and ~2 when the switch is closed.
The default value is 0.001 Ω .

Open conductance

Conductance between ports ~1 and ~2 when the switch is open.
The default value is 1e-6 Ω^{-1} .

Threshold

Threshold voltage for the control port vT . When the voltage is above the threshold, the switch is closed. The default value is 0 V.

Ports

The block has the following ports:

- ~1
Expandable three-phase port

-2

Expandable three-phase port

vT

Scalar control port, which is either a physical signal or an electrical port.

See Also

[Single-Phase Two-Way Switch](#) | [Single-Phase Switch](#) | [Two-Way Switch](#)

Related Examples

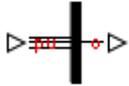
- [“Expand and Collapse Three-Phase Ports on a Block”](#)
- [“Switch Between Physical Signal and Electrical Ports”](#)

Synchronous Machine Measurement

Purpose Per-unit measurement from synchronous machine

Library Machines

Description The Synchronous Machine Measurement block outputs a per-unit measurement associated with a connected Synchronous Machine Round Rotor or Synchronous Machine Salient Pole block. The input of the Synchronous Machine Measurement block connects to the pu output port of the synchronous machine block.



You set the **Output** parameter to a per-unit measurement associated with the synchronous machine. Based on the value you select, the Synchronous Machine Measurement block:

- Directly outputs the value of an element in the input signal vector
- Calculates the per-unit measurement by using values of elements in the input signal vector in mathematical expressions

The Synchronous Machine Measurement block outputs a per-unit measurement from the synchronous machine according to the output value expressions in the table. For example, when you set **Output** to **Stator d-axis voltage**, the block directly outputs the value of the `pu_ed` element in the input signal vector. However, when you set **Output** to **Reactive power**, the block calculates the value from the `pu_ed`, `pu_eq`, `pu_id`, and `pu_iq` elements.

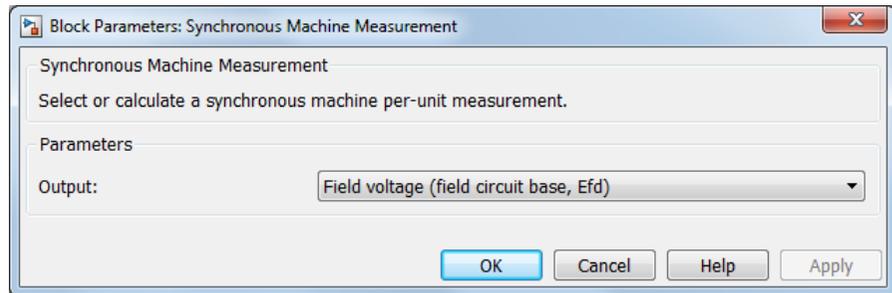
Output Parameter Setting	Output Value Expression
Field voltage (field circuit base, <code>Efd</code>)	<code>pu_fd_Efd</code>
Field current (field circuit base, <code>Ifd</code>)	<code>pu_fd>Ifd</code>
Electrical torque	<code>pu_torque</code>
Rotor velocity	<code>pu_velocity</code>
Stator d-axis voltage	<code>pu_ed</code>

Synchronous Machine Measurement

Output Parameter Setting	Output Value Expression
Stator q-axis voltage	pu_eq
Stator zero-sequence voltage	pu_e0
Stator d-axis current	pu_id
Stator q-axis current	pu_iq
Stator zero-sequence current	pu_i0
Apparent power	$\sqrt{pu_Pt^2 + pu_Qt^2}$
Real power	pu_Pt = (pu_ed*pu_id) + (pu_eq*pu_iq) + 2(pu_e0*pu_i0)
Reactive power	pu_Qt = (pu_eq*pu_id) (pu_ed*pu_iq)
Terminal voltage	$\sqrt{(pu_ed^2 + pu_eq^2)}$
Terminal current	$\sqrt{(pu_id^2 + pu_iq^2)}$
Power factor angle (rad)	power_factor_angle = atan2(pu_Qt, pu_Pt)
Power factor	cos(power_factor_angle)
Load angle (rad)	load_angle(rad) = atan2(pu_ed, pu_eq)

Synchronous Machine Measurement

Dialog Box and Parameters



Output

Per-unit measurement from synchronous machine. The default value is `Field voltage (field circuit base, Efd)`.

Ports

The block has the following ports:

`pu`

Physical signal vector port associated with per-unit measurements from a connected synchronous machine. The vector elements are:

- `pu_fd_Efd`
- `pu_fd_Ifd`
- `pu_torque`
- `pu_velocity`
- `pu_ed`
- `pu_eq`
- `pu_e0`
- `pu_id`
- `pu_iq`
- `pu_i0`

`o`

Per-unit measurement output port.

See Also

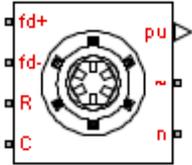
Synchronous Machine Round Rotor (standard) | Synchronous Machine Round Rotor (fundamental) | Synchronous Machine Salient Pole (standard) | Synchronous Machine Salient Pole (fundamental)

Synchronous Machine Round Rotor (fundamental)

Purpose Round-rotor synchronous machine with fundamental parameterization

Library Machines / Synchronous Machine (Round Rotor)

Description The Synchronous Machine Round Rotor (fundamental) block models a round-rotor synchronous machine with parameterization using fundamental parameters.



Electrical Defining Equations

The synchronous machine equations are expressed with respect to a rotating reference frame defined by the equation

$$\theta_e(t) = N * \theta_r(t),$$

where:

- θ_e is the electrical angle.
- N is the number of pole pairs.
- θ_r is the rotor angle.

Park's transformation maps the synchronous machine equations to the rotating reference frame with respect to the electrical angle. Park's transformation is defined by

$$P_s = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin \theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}.$$

Synchronous Machine Round Rotor (fundamental)

Park's transformation is used to define the per-unit synchronous machine equations. The stator voltage equations are defined by

$$e_d = \frac{1}{\omega_{base}} \frac{d\psi_d}{dt} - \Psi_q \omega_r - R_a i_d,$$

$$e_q = \frac{1}{\omega_{base}} \frac{d\psi_q}{dt} + \Psi_d \omega_r - R_a i_q,$$

and

$$e_0 = \frac{1}{\omega_{base}} \frac{d\Psi_0}{dt} - R_a i_0,$$

where:

- e_d , e_q , and e_0 are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} e_d \\ e_q \\ e_0 \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages measured from port \sim to neutral port n.

- ω_{base} is the per-unit base electrical speed.
- ψ_d , ψ_q , and ψ_0 are the d-axis, q-axis, and zero-sequence stator flux linkages.
- ω_r is the per-unit rotor rotational speed.
- R_a is the stator resistance.
- i_d , i_q and i_0 are the d-axis, q-axis, and zero-sequence stator currents, defined by

Synchronous Machine Round Rotor (fundamental)

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port \sim to port n.

The rotor voltage equations are defined by

$$e_{fd} = \frac{1}{\omega_{base}} \frac{d\Psi_{fd}}{dt} + R_{fd}i_{fd},$$

$$e_{1d} = \frac{1}{\omega_{base}} \frac{d\Psi_{1d}}{dt} + R_{1d}i_{1d} = 0,$$

$$e_{1q} = \frac{1}{\omega_{base}} \frac{d\Psi_{1q}}{dt} + R_{1q}i_{1q} = 0,$$

and

$$e_{2q} = \frac{1}{\omega_{base}} \frac{d\Psi_{2q}}{dt} + R_{2q}i_{2q} = 0,$$

where:

- e_{fd} is the field voltage.
- e_{1d} , e_{1q} , and e_{2q} are the voltages across the d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2. They are all equal to 0.
- Ψ_{fd} , Ψ_{1d} , Ψ_{1q} , and Ψ_{2q} are the magnetic fluxes linking the field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.
- R_{fd} , R_{1d} , R_{1q} , and R_{2q} are the resistances of rotor field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.

Synchronous Machine Round Rotor (fundamental)

- i_{fd} , i_{1d} , i_{1q} , and i_{2q} are the currents flowing in the field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.

The saturation equations are defined by

$$\psi_{at} = \sqrt{\psi_d^2 + \psi_q^2},$$

$$K_s = 1 \quad (\text{If saturation is disabled}),$$

$$K_s = f(\psi_{at}) \quad (\text{If saturation is enabled}),$$

$$L_{ad} = K_s * L_{adu},$$

and

$$L_{aq} = K_s * L_{aqu},$$

where:

- ψ_{at} is the air-gap flux linkage.
- K_s is the saturation factor.
- L_{adu} is the unsaturated mutual inductance of the stator d-axis.
- L_{ad} is the mutual inductance of the stator d-axis.
- L_{aqu} is the unsaturated mutual inductance of the stator q-axis.
- L_{aq} is the mutual inductance of the stator q-axis.

The saturation factor function, f , is calculated from the per-unit open-circuit lookup table as:

$$L_{ad} = \frac{d\psi_{at}}{di_{fd}},$$

$$V_{ag} = g(i_{fd}),$$

Synchronous Machine Round Rotor (fundamental)

and

$$L_{ad} = \frac{dg(i_{fd})}{di_{fd}} = \frac{dV_{ag}}{di_{fd}},$$

where:

- V_{ag} is the per-unit air-gap voltage.

In per-unit,

$$K_s = \frac{L_{ad}}{L_{adu}},$$

and

$$\psi_{at} = V_{ag}$$

can be rearranged to

$$K_s = f(\psi_{at}).$$

The stator flux linkage equations are defined by

$$\Psi_d = -(L_{ad} + L_i)i_d + L_{ad}i_{fd} + L_{ad}i_{1d},$$

$$\Psi_q = -(L_{aq} + L_i)i_q + L_{aq}i_{1q} + L_{aq}i_{2q},$$

and

$$\Psi_0 = -L_0i_0,$$

where:

- L_i is the stator leakage inductance.
- L_{ad} and L_{aq} are the mutual inductances of the stator d-axis and q-axis.

The rotor flux linkage equations are defined by

Synchronous Machine Round Rotor (fundamental)

$$\Psi_{fd} = L_{ffd}i_{fd} + L_{f1d}i_{1d} - L_{ad}i_d,$$

$$\Psi_{1d} = L_{f1d}i_{fd} + L_{11d}i_{1d} - L_{ad}i_d,$$

$$\Psi_{1q} = L_{11q}i_{1q} + L_{aq}i_{2q} - L_{aq}i_q,$$

and

$$\Psi_{2q} = L_{aq}i_{1q} + L_{22q}i_{2q} - L_{aq}i_q,$$

where:

- L_{ffd} , L_{11d} , L_{11q} , and L_{22q} are the self-inductances of the rotor field circuit, d-axis damper winding 1, q-axis damper winding 1 and q-axis damper winding 2. L_{f1d} is the rotor field circuit and d-axis damper winding 1 mutual inductance. They are defined by the following equations.

- $L_{ffd} = L_{ad} + L_{fd}$

- $L_{f1d} = L_{ffd} - L_{fd}$

- $L_{11d} = L_{f1d} + L_{1d}$

- $L_{11q} = L_{aq} + L_{1q}$

- $L_{22q} = L_{aq} + L_{2q}$

These equations assume that per-unit mutual inductance $L_{12q} = L_{aq}$, i.e., the stator and rotor currents in the q-axis all link a single mutual flux represented by L_{aq} .

The rotor torque is defined by

$$T_e = \Psi_d i_q - \Psi_q i_d.$$

Synchronous Machine Round Rotor (fundamental)

Display Options

For synchronous machine blocks, you can perform display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Synchronous Machine** menu:

- **Display Base Values** displays the machine per-unit base values at the MATLAB command prompt.
- **Display Associated Base Values** displays associated per-unit base values at the MATLAB command prompt.
- **Associated Initial Conditions** displays associated initial conditions at the MATLAB command prompt.
- **Plot Open-Circuit Saturation (pu)** plots air-gap voltage, V_{ag} , versus field current, i_{fd} , (both measured in per-unit) in a MATLAB figure window. The plot contains three traces:
 - Unsaturated: **Stator d-axis mutual inductance (unsaturated), L_{ad}** you specify
 - Saturated: **Per-unit open-circuit lookup table (Vag versus ifd)** you specify
 - Derived: Open-circuit lookup table (per-unit) derived from the **Per-unit open-circuit lookup table (Vag versus ifd)** you specify. This data is used to calculate the saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , characteristic.
- **Plot Saturation Factor (pu)** plots saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , (both measured in per-unit) in a MATLAB figure window using the present machine parameters. This is derived from parameters you specify:
 - **Stator d-axis mutual inductance (unsaturated), L_{ad}**
 - **Per-unit field current saturation data, ifd**
 - **Per-unit air-gap voltage saturation data, Vag**

Synchronous Machine Round Rotor (fundamental)

Dialog Box and Parameters

Block Parameters: Synchronous Machine Round Rotor (fundamental)

Synchronous Machine Round Rotor (fundamental)

Synchronous machine with a round rotor parameterized using fundamental per-unit parameters.

Right-click on the block and select Simscape block choices to access variant implementations of this block.

Settings

Main Impedances Saturation Initial Conditions

Rated apparent power: 555e6 V*A

Rated voltage: 24e3 V

Rated electrical frequency: 60 Hz

Number of pole pairs: 1

Specify field circuit input required to produce rated terminal voltage at no load by: Field circuit current

Field circuit current: 1300 A

OK Cancel Help Apply

- “Main Tab” on page 1-210
- “Impedances Tab” on page 1-210
- “Saturation Tab” on page 1-212

Synchronous Machine Round Rotor (fundamental)

- “Initial Conditions Tab” on page 1-212

Main Tab

Rated apparent power

Rated apparent power, S_{Rated} . The default value is 555e6 VA.

Rated voltage

RMS rated line-line voltage, V . The default value is 24e3 V.

Rated electrical frequency

Nominal electrical frequency, S_{Rated} , at which rated apparent power is quoted. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs, $nPolePairs$. The default value is 1.

Specify field circuit input required to produce rated terminal voltage at no load by

Select between

- Field circuit voltage
- Field circuit current

The default value is Field circuit current.

Field circuit current

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit current. The default value is 1300 A.

Field circuit voltage

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit voltage. The default value is 92.95 V.

Impedances Tab

Stator d-axis mutual inductance (unsaturated), L_{adu}

Unsaturated stator d-axis mutual inductance, L_{adu} . If **Magnetic saturation representation** is set to None, this is equivalent

Synchronous Machine Round Rotor (fundamental)

to the stator d-axis mutual inductance, L_{ad} . The default value is 1.66 pu.

Stator q-axis mutual inductance (unsaturated), L_{aqu}

Unsaturated stator q-axis mutual inductance, L_{aqu} . If **Magnetic saturation representation** is set to None, this is equivalent to the stator q-axis mutual inductance, L_{aq} . The default value is 1.61 pu.

Stator zero-sequence inductance, L_0

Stator zero-sequence inductance, L_0 . The default value is 0 pu.

Stator leakage inductance, L_l

Stator leakage inductance, L_l . The default value is 0.15 pu.

Stator resistance, R_a

Stator resistance, R_a . The default value is 0.003 pu.

Rotor field circuit inductance, L_{fd}

Rotor field circuit inductance, L_{fd} . The default value is 0.165 pu.

Rotor field circuit resistance, R_{fd}

Rotor field circuit resistance, R_{fd} . The default value is 0.0006 pu.

Rotor d-axis damper winding 1 inductance, L_{1d}

Rotor d-axis damper winding 1 inductance, L_{1d} . The default value is 0.1713 pu.

Rotor d-axis damper winding 1 resistance, R_{1d}

Rotor d-axis damper winding 1 resistance, R_{1d} . The default value is 0.0284 pu.

Rotor q-axis damper winding 1 inductance, L_{1q}

Rotor q-axis damper winding 1 inductance, L_{1q} . The default value is 0.7252 pu.

Rotor q-axis damper winding 1 resistance, R_{1q}

Rotor q-axis damper winding 1 resistance, R_{1q} . The default value is 0.00619 pu.

Synchronous Machine Round Rotor (fundamental)

Rotor q-axis damper winding 2 inductance, L2q

Rotor q-axis damper winding 2 inductance, L_{2q} . The default value is 0.125 pu.

Rotor q-axis damper winding 2 resistance, R2q

Rotor q-axis damper winding 2 resistance, R_{2q} . The default value is 0.02368 pu.

Saturation Tab

Magnetic saturation representation

Block magnetic saturation representation. Options are:

- None
- Per-unit open-circuit lookup table (Vag versus ifd)

The default value is None.

Per-unit field current saturation data, ifd

The field current, i_{fd} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.48, 0.76, 1.38, 1.79] pu.

Per-unit air-gap voltage saturation data, Vag

The air-gap voltage, V_{ag} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.80, 1.08, 1.31, 1.40] pu.

Initial Conditions Tab

Specify initialization by

Options include:

- Electrical power and voltage output

Synchronous Machine Round Rotor (fundamental)

- Mechanical and magnetic states

The default value is Electrical power and voltage output.

Terminal voltage magnitude

Initial RMS line-line voltage. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 24e3 V.

Terminal voltage angle

Initial voltage angle. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 deg.

Terminal active power

Initial active power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 500e6 VA.

Terminal reactive power

Initial reactive power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 VA.

Initial rotor angle

Initial rotor angle. During steady-state operation, set this parameter to the sum of the load angle and required terminal voltage offset. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 deg.

Initial stator d-axis magnetic flux linkage

Stator d-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Stator q-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Synchronous Machine Round Rotor (fundamental)

Initial stator zero-sequence magnetic flux linkage

Zero-sequence initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial field circuit magnetic flux linkage

Field circuit initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial d-axis damper winding 1 magnetic flux linkage

d-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 1 magnetic flux linkage

The q-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 2 magnetic flux linkage

The q-axis damper winding 2 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Ports

The block has the following ports:

fd+

Electrical conserving port corresponding to the field winding positive terminal

fd-

Electrical conserving port corresponding to the field winding negative terminal

R

Mechanical rotational conserving port associated with the machine rotor

Synchronous Machine Round Rotor (fundamental)

C

Mechanical rotational conserving port associated with the machine case

pu

Physical signal vector port associated with the machine per-unit measurements. The vector elements are:

- pu_fd_Efd
- pu_fd_Ifd
- pu_torque
- pu_velocity
- pu_ed
- pu_ed
- pu_e0
- pu_id
- pu_iq
- pu_i0

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Expandable three-phase port associated with the stator windings

n

Electrical conserving port associated with the neutral point of the wye winding configuration

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

Synchronous Machine Round Rotor (fundamental)

See Also

Synchronous Machine Measurement | Synchronous Machine Round Rotor (Standard) | Synchronous Machine Salient Pole (Standard) | Synchronous Machine Salient Pole (Fundamental)

Related Examples

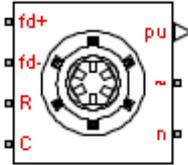
- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Synchronous Machine Control

Synchronous Machine Round Rotor (standard)

Purpose Round-rotor synchronous machine with standard parameterization

Library Machines / Synchronous Machine (Round Rotor)

Description The Synchronous Machine Round Rotor (standard) block models a round-rotor synchronous machine with parameterization using standard parameters.



Electrical Defining Equations

The synchronous machine equations are expressed with respect to a rotating reference frame defined by the equation

$$\theta_e(t) = N * \theta_r(t),$$

where:

- θ_e is the electrical angle.
- N is the number of pole pairs.
- θ_r is the rotor angle.

Park's transformation maps the synchronous machine equations to the rotating reference frame with respect to the electrical angle. Park's transformation is defined by

$$P_s = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin \theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e - \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}.$$

Synchronous Machine Round Rotor (standard)

Park's transformation is used to define the per-unit synchronous machine equations. The stator voltage equations are defined by

$$e_d = \frac{1}{\omega_{base}} \frac{d\psi_d}{dt} - \Psi_q \omega_r - R_a i_d,$$

$$e_q = \frac{1}{\omega_{base}} \frac{d\psi_q}{dt} + \Psi_d \omega_r - R_a i_q,$$

and

$$e_0 = \frac{1}{\omega_{base}} \frac{d\Psi_0}{dt} - R_a i_0,$$

where:

- e_d , e_q , and e_0 are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} e_d \\ e_q \\ e_0 \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages measured from port \sim to neutral port n.

- ω_{base} is the per-unit base electrical speed.
- ψ_d , ψ_q , and ψ_0 are the d-axis, q-axis, and zero-sequence stator flux linkages.
- ω_r is the per-unit rotor rotational speed.
- R_a is the stator resistance.
- i_d , i_q and i_0 are the d-axis, q-axis, and zero-sequence stator currents, defined by

Synchronous Machine Round Rotor (standard)

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port \sim to port n .

The rotor voltage equations are defined by

$$e_{fd} = \frac{1}{\omega_{base}} \frac{d\Psi_{fd}}{dt} + R_{fd}i_{fd},$$

$$e_{1d} = \frac{1}{\omega_{base}} \frac{d\Psi_{1d}}{dt} + R_{1d}i_{1d} = 0,$$

$$e_{1q} = \frac{1}{\omega_{base}} \frac{d\Psi_{1q}}{dt} + R_{1q}i_{1q} = 0,$$

and

$$e_{2q} = \frac{1}{\omega_{base}} \frac{d\Psi_{2q}}{dt} + R_{2q}i_{2q} = 0,$$

where:

- e_{fd} is the field voltage.
- e_{1d} , e_{1q} , and e_{2q} are the voltages across the d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2. They are all equal to 0.
- Ψ_{fd} , Ψ_{1d} , Ψ_{1q} , and Ψ_{2q} are the magnetic fluxes linking the field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.
- R_{fd} , R_{1d} , R_{1q} , and R_{2q} are the resistances of rotor field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.

Synchronous Machine Round Rotor (standard)

- i_{fd} , i_{1d} , i_{1q} , and i_{2q} are the currents flowing in the field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2.

The saturation equations are defined by

$$\psi_{at} = \sqrt{\psi_d^2 + \psi_q^2},$$

$$K_s = 1 \quad (\text{If saturation is disabled}),$$

$$K_s = f(\psi_{at}) \quad (\text{If saturation is enabled}),$$

$$L_{ad} = K_s * L_{adu},$$

and

$$L_{aq} = K_s * L_{aqu},$$

where:

- ψ_{at} is the air-gap flux linkage.
- K_s is the saturation factor.
- L_{adu} is the unsaturated mutual inductance of the stator d-axis.
- L_{ad} is the mutual inductance of the stator d-axis.
- L_{aqu} is the unsaturated mutual inductance of the stator q-axis.
- L_{aq} is the mutual inductance of the stator q-axis.

The saturation factor function, f , is calculated from the per-unit open-circuit lookup table as:

$$L_{ad} = \frac{d\psi_{at}}{di_{fd}},$$

$$V_{ag} = g(i_{fd}),$$

Synchronous Machine Round Rotor (standard)

and

$$L_{ad} = \frac{dg(i_{fd})}{di_{fd}} = \frac{dV_{ag}}{di_{fd}},$$

where:

- V_{ag} is the per-unit air-gap voltage.

In per-unit,

$$K_s = \frac{L_{ad}}{L_{adu}},$$

and

$$\psi_{at} = V_{ag}$$

can be rearranged to

$$K_s = f(\psi_{at}).$$

The stator flux linkage equations are defined by

$$\Psi_d = -(L_{ad} + L_i)i_d + L_{ad}i_{fd} + L_{ad}i_{1d},$$

$$\Psi_q = -(L_{aq} + L_i)i_q + L_{aq}i_{1q} + L_{aq}i_{2q},$$

and

$$\Psi_0 = -L_0i_0,$$

where:

- L_i is the stator leakage inductance.
- L_{ad} and L_{aq} are the mutual inductances of the stator d-axis and q-axis.

The rotor flux linkage equations are defined by

Synchronous Machine Round Rotor (standard)

$$\psi_{fd} = L_{ffd}i_{fd} + L_{f1d}i_{1d} - L_{ad}i_d,$$

$$\psi_{1d} = L_{f1d}i_{fd} + L_{11d}i_{1d} - L_{ad}i_d,$$

$$\psi_{1q} = L_{11q}i_{1q} + L_{aq}i_{2q} - L_{aq}i_q,$$

and

$$\psi_{2q} = L_{aq}i_{1q} + L_{22q}i_{2q} - L_{aq}i_q,$$

where:

- L_{ffd} , L_{11d} , L_{11q} , and L_{22q} are the self-inductances of the rotor field circuit, d-axis damper winding 1, q-axis damper winding 1, and q-axis damper winding 2. L_{f1d} is the rotor field circuit and d-axis damper winding 1 mutual inductance. They are defined by the following equations.

$$L_{ffd} = L_{ad} + L_{fd}$$

$$L_{f1d} = L_{ffd} - L_{fd}$$

$$L_{11d} = L_{f1d} + L_{1d}$$

$$L_{11q} = L_{aq} + L_{1q}$$

$$L_{22q} = L_{aq} + L_{2q}$$

These equations assume that per-unit mutual inductance $L_{12q} = L_{aq}$, i.e., the stator and rotor currents in the q-axis all link a single mutual flux represented by L_{aq} .

The rotor torque is defined by

$$T_e = \Psi_d i_q - \Psi_q i_d.$$

These defining equations do not describe the time constants you can set in the dialog box. To see their relationship with the equation coefficients, see [1].

Synchronous Machine Round Rotor (standard)

Display Options

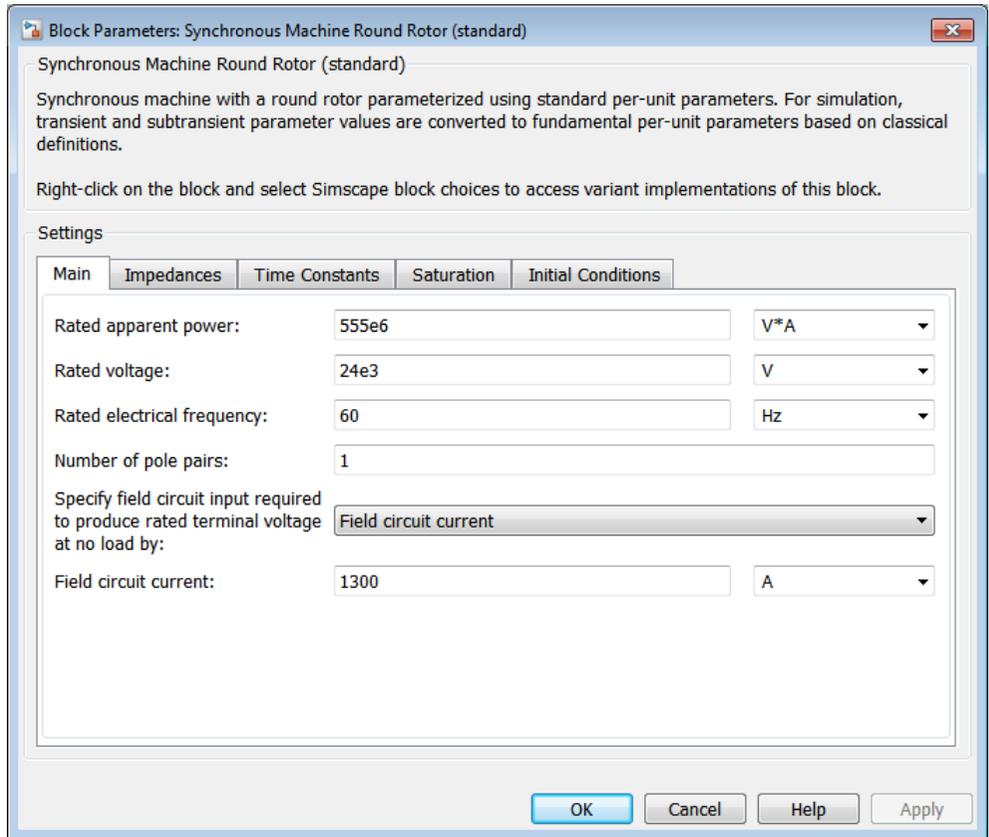
For synchronous machine blocks, you can perform display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Synchronous Machine** menu:

- **Display Base Values** displays the machine per-unit base values at the MATLAB command prompt.
- **Display Associated Base Values** displays associated per-unit base values at the MATLAB command prompt.
- **Associated Initial Conditions** displays associated initial conditions at the MATLAB command prompt.
- **Plot Open-Circuit Saturation (pu)** plots air-gap voltage, V_{ag} , versus field current, i_{fd} , (both measured in per-unit) in a MATLAB figure window. The plot contains three traces:
 - Unsaturated: **Stator d-axis mutual inductance (unsaturated), L_{ad}** you specify
 - Saturated: **Per-unit open-circuit lookup table (Vag versus ifd)** you specify
 - Derived: Open-circuit lookup table (per-unit) derived from the **Per-unit open-circuit lookup table (Vag versus ifd)** you specify. This data is used to calculate the saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , characteristic.
- **Plot Saturation Factor (pu)** plots saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , (both measured in per-unit) in a MATLAB figure window using the present machine parameters. This is derived from parameters you specify:
 - **Stator d-axis mutual inductance (unsaturated), L_{ad}**
 - **Per-unit field current saturation data, ifd**
 - **Per-unit air-gap voltage saturation data, Vag**

Synchronous Machine Round Rotor (standard)

Dialog Box and Parameters



- “Main Tab” on page 1-225
- “Impedances Tab” on page 1-225
- “Time Constants Tab” on page 1-226
- “Saturation Tab” on page 1-228
- “Initial Conditions Tab” on page 1-228

Synchronous Machine Round Rotor (standard)

Main Tab

Rated apparent power

Rated apparent power. The default value is 555e6 VA.

Rated voltage

RMS rated line-line voltage. The default value is 24e3 V.

Rated electrical frequency

Nominal electrical frequency at which rated apparent power is quoted. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 1.

Specify field circuit input required to produce rated terminal voltage at no load by

Choose between Field circuit voltage and Field circuit current. The default value is Field circuit current.

Field circuit current

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit current. The default value is 1300 A.

Field circuit voltage

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit voltage. The default value is 92.95 V.

Impedances Tab

Stator resistance, Ra

Stator resistance. The default value is 0.003 pu.

Stator leakage reactance, Xl

Stator leakage reactance. The default value is 0.15 pu.

d-axis synchronous reactance, Xd

The d-axis synchronous reactance. The default value is 1.81 pu.

Synchronous Machine Round Rotor (standard)

q-axis synchronous reactance, X_q

The q-axis synchronous reactance. The default value is 1.76 pu.

zero-sequence reactance, X_0

The zero-sequence reactance. The default value is 0 pu.

d-axis transient reactance, X_d'

The d-axis transient reactance. The default value is 0.3 pu.

q-axis transient reactance, X_q'

The q-axis transient reactance. The default value is 0 pu.

d-axis subtransient reactance, X_d''

The d-axis subtransient reactance. The default value is 0.23 pu.

q-axis subtransient reactance, X_q''

The q-axis subtransient reactance. The default value is 0.25 pu.

Time Constants Tab

Specify d-axis transient time constant

Select between Open circuit value and Short circuit value.
The default value is Open circuit value.

d-axis transient open circuit, T_{d0}'

The d-axis transient open circuit time constant. This parameter is visible only when **Specify d-axis transient time constant** is set to Open circuit value. The default value is 8 s.

d-axis transient short circuit, T_d'

The d-axis transient short circuit time constant. This parameter is visible only when **Specify d-axis transient time constant** is set to Short circuit value. The default value is 1.326 s.

Specify d-axis subtransient time constant

Select between Open circuit value and Short circuit value.
The default value is Open circuit value.

d-axis subtransient open circuit, T_{d0}''

The d-axis subtransient open circuit time constant. This parameter is visible only when **Specify d-axis subtransient**

Synchronous Machine Round Rotor (standard)

time constant is set to Open circuit value. The default value is 0.03 s.

d-axis subtransient short circuit, Td”

The d-axis subtransient short circuit time constant. This parameter is visible only when **Specify d-axis subtransient time constant** is set to Short circuit value. The default value is 0.023 s.

Specify q-axis transient time constant

Select between Open circuit value and Short circuit value. The default value is Open circuit value.

q-axis transient open circuit, Tq0’

The q-axis transient open circuit time constant. This parameter is visible only when **Specify q-axis transient time constant** is set to Open circuit value. The default value is 1 s.

q-axis transient short circuit, Tq’

The q-axis transient short circuit time constant. This parameter is visible only when **Specify q-axis transient time constant** is set to Short circuit value. The default value is 0.3693 s.

Specify q-axis subtransient time constant

Select between Open circuit value and Short circuit value. The default value is Open circuit value.

q-axis subtransient open circuit, Tq0”

The q-axis subtransient open circuit time constant. This parameter is visible only when **Specify q-axis subtransient time constant** is set to Open circuit value. The default value is 0.07 s.

q-axis subtransient short circuit, Tq”

The q-axis subtransient short circuit time constant. This parameter is visible only when **Specify q-axis subtransient time constant** is set to Short circuit value. The default value is 0.0269 s.

Synchronous Machine Round Rotor (standard)

Saturation Tab

Magnetic saturation representation

Block magnetic saturation representation. Options are:

- None
- Per-unit open-circuit lookup table (Vag versus ifd)

The default value is None.

Per-unit field current saturation data, ifd

The field current, i_{fd} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.48, 0.76, 1.38, 1.79] pu.

Per-unit air-gap voltage saturation data, Vag

The air-gap voltage, V_{ag} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.80, 1.08, 1.31, 1.40] pu.

Initial Conditions Tab

Specify initialization by

Options include:

- Electrical power and voltage output
- Mechanical and magnetic states

The default value is Electrical power and voltage output.

Synchronous Machine Round Rotor (standard)

Terminal voltage magnitude

Initial RMS line-line voltage. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 24e3 V.

Terminal voltage angle

Initial voltage angle. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 deg.

Terminal active power

Initial active power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 500e6 VA.

Terminal reactive power

Initial reactive power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 VA.

Initial rotor angle

Initial rotor angle. During steady-state operation, set this parameter to the sum of the load angle and required terminal voltage offset. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 deg.

Initial stator d-axis magnetic flux linkage

Stator d-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Stator q-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Synchronous Machine Round Rotor (standard)

Initial stator zero-sequence magnetic flux linkage

Zero-sequence initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial field circuit magnetic flux linkage

Field circuit initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial d-axis damper winding 1 magnetic flux linkage

d-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 1 magnetic flux linkage

The q-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 2 magnetic flux linkage

The q-axis damper winding 2 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Ports

The block has the following ports:

fd+

Electrical conserving port corresponding to the field winding positive terminal

fd-

Electrical conserving port corresponding to the field winding negative terminal

R

Mechanical rotational conserving port associated with the machine rotor

Synchronous Machine Round Rotor (standard)

C

Mechanical rotational conserving port associated with the machine case

pu

Physical signal vector port associated with the machine per-unit measurements. The vector elements are:

- pu_fd_Efd
- pu_fd_Ifd
- pu_torque
- pu_velocity
- pu_ed
- pu_ed
- pu_e0
- pu_id
- pu_iq
- pu_i0

~

Expandable three-phase port associated with the stator windings

n

Electrical conserving port associated with the neutral point of the wye winding configuration

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

Synchronous Machine Round Rotor (standard)

See Also

Synchronous Machine Measurement | Synchronous Machine Round Rotor (Fundamental) | Synchronous Machine Salient Pole (Standard) | Synchronous Machine Salient Pole (Fundamental)

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Synchronous Machine Control

Synchronous Machine Salient Pole (fundamental)

Purpose

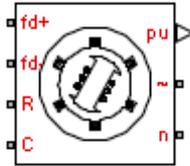
Salient-pole synchronous machine with fundamental parameterization

Library

Machines / Synchronous Machine (Salient Pole)

Description

The Synchronous Machine Salient Pole (fundamental) block models a salient-pole synchronous machine with parameterization using fundamental parameters.



Electrical Defining Equations

The synchronous machine equations are expressed with respect to a rotating reference frame defined by the equation

$$\theta_e(t) = N * \theta_r(t),$$

where:

- θ_e is the electrical angle.
- N is the number of pole pairs.
- θ_r is the rotor angle.

Park's transformation maps the synchronous machine equations to the rotating reference frame with respect to the electrical angle. Park's transformation is defined by

$$P_s = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin \theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e - \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}.$$

Synchronous Machine Salient Pole (fundamental)

Park's transformation is used to define the per-unit synchronous machine equations. The stator voltage equations are defined by

$$e_d = \frac{1}{\omega_{base}} \frac{d\psi_d}{dt} - \Psi_q \omega_r - R_a i_d,$$

$$e_q = \frac{1}{\omega_{base}} \frac{d\psi_q}{dt} + \Psi_d \omega_r - R_a i_q,$$

and

$$e_0 = \frac{1}{\omega_{base}} \frac{d\Psi_0}{dt} - R_a i_0,$$

where:

- e_d , e_q , and e_0 are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} e_d \\ e_q \\ e_0 \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages measured from port \sim to neutral port n.

- ω_{base} is the per-unit base electrical speed.
- ψ_d , ψ_q , and ψ_0 are the d-axis, q-axis, and zero-sequence stator flux linkages.
- ω_r is the per-unit rotor rotational speed.
- R_a is the stator resistance.
- i_d , i_q and i_0 are the d-axis, q-axis, and zero-sequence stator currents, defined by

Synchronous Machine Salient Pole (fundamental)

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port \sim to port n .

The rotor voltage equations are defined by

$$e_{fd} = \frac{1}{\omega_{base}} \frac{d\Psi_{fd}}{dt} + R_{fd}i_{fd},$$

$$e_{1d} = \frac{1}{\omega_{base}} \frac{d\Psi_{1d}}{dt} + R_{1d}i_{1d} = 0,$$

and

$$e_{1q} = \frac{1}{\omega_{base}} \frac{d\Psi_{1q}}{dt} + R_{1q}i_{1q} = 0,$$

where:

- e_{fd} is the field voltage.
- e_{1d} , and e_{1q} are the voltages across the d-axis damper winding 1 and q-axis damper winding 1. They are equal to 0.
- Ψ_{fd} , Ψ_{1d} , and Ψ_{1q} are the magnetic fluxes linking the field circuit, d-axis damper winding 1, and q-axis damper winding 1.
- R_{fd} , R_{1d} , and R_{1q} are the resistances of rotor field circuit, d-axis damper winding 1, and q-axis damper winding 1.
- i_{fd} , i_{1d} , and i_{1q} are the currents flowing in the field circuit, d-axis damper winding 1, and q-axis damper winding 1.

The saturation equations are defined by

Synchronous Machine Salient Pole (fundamental)

$$\psi_{at} = \sqrt{\psi_d^2 + \psi_q^2},$$

$$K_s = 1 \text{ (If saturation is disabled),}$$

$$K_s = f(\psi_{at}) \text{ (If saturation is enabled),}$$

and

$$L_{ad} = K_s * L_{adu},$$

where:

- ψ_{at} is the air-gap flux linkage.
- K_s is the saturation factor.
- L_{adu} is the unsaturated mutual inductance of the stator d-axis.
- L_{ad} is the mutual inductance of the stator d-axis.

The saturation factor function, f , is calculated from the per-unit open-circuit lookup table as:

$$L_{ad} = \frac{d\psi_{at}}{di_{fd}},$$

$$V_{ag} = g(i_{fd}),$$

and

$$L_{ad} = \frac{dg(i_{fd})}{di_{fd}} = \frac{dV_{ag}}{di_{fd}},$$

where:

- V_{ag} is the per-unit air-gap voltage.

In per-unit,

Synchronous Machine Salient Pole (fundamental)

$$K_s = \frac{L_{ad}}{L_{adu}},$$

and

$$\psi_{at} = V_{ag}$$

can be rearranged to

$$K_s = f(\psi_{at}).$$

The stator flux linkage equations are defined by

$$\Psi_d = -(L_{ad} + L_l)i_d + L_{ad}i_{fd} + L_{ad}i_{1d},$$

$$\Psi_q = -(L_{aq} + L_l)i_q + L_{aq}i_{1q},$$

and

$$\Psi_0 = -L_0i_0.$$

where:

- L_l is the stator leakage inductance.
- L_{ad} and L_{aq} are the mutual inductances of the stator d-axis and q-axis.

The rotor flux linkage equations are defined by

$$\psi_{fd} = L_{ffd}i_{fd} + L_{f1d}i_{1d} - L_{ad}i_d,$$

$$\psi_{1d} = L_{f1d}i_{fd} + L_{11d}i_{1d} - L_{ad}i_d,$$

and

$$\psi_{1q} = L_{11q}i_{1q} - L_{aq}i_q,$$

where:

- L_{ffd} , L_{11d} , and L_{11q} are the self-inductances of the rotor field circuit, d-axis damper winding 1, and q-axis damper winding 1. L_{f1d} is the

Synchronous Machine Salient Pole (fundamental)

rotor field circuit and d-axis damper winding 1 mutual inductance. They are defined by the following equations.

$$L_{ffd} = L_{ad} + L_{fd}$$

$$L_{f1d} = L_{ffd} - L_{fd}$$

$$L_{11d} = L_{f1d} + L_{1d}$$

$$L_{11q} = L_{aq} + L_{1q}$$

These equations assume that per-unit mutual inductance $L_{12q} = L_{aq}$, i.e., the stator and rotor currents in the q-axis all link a single mutual flux represented by L_{aq} .

The rotor torque is defined by

$$T_e = \Psi_d i_q - \Psi_q i_d.$$

Display Options

For synchronous machine blocks, you can perform display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Synchronous Machine** menu:

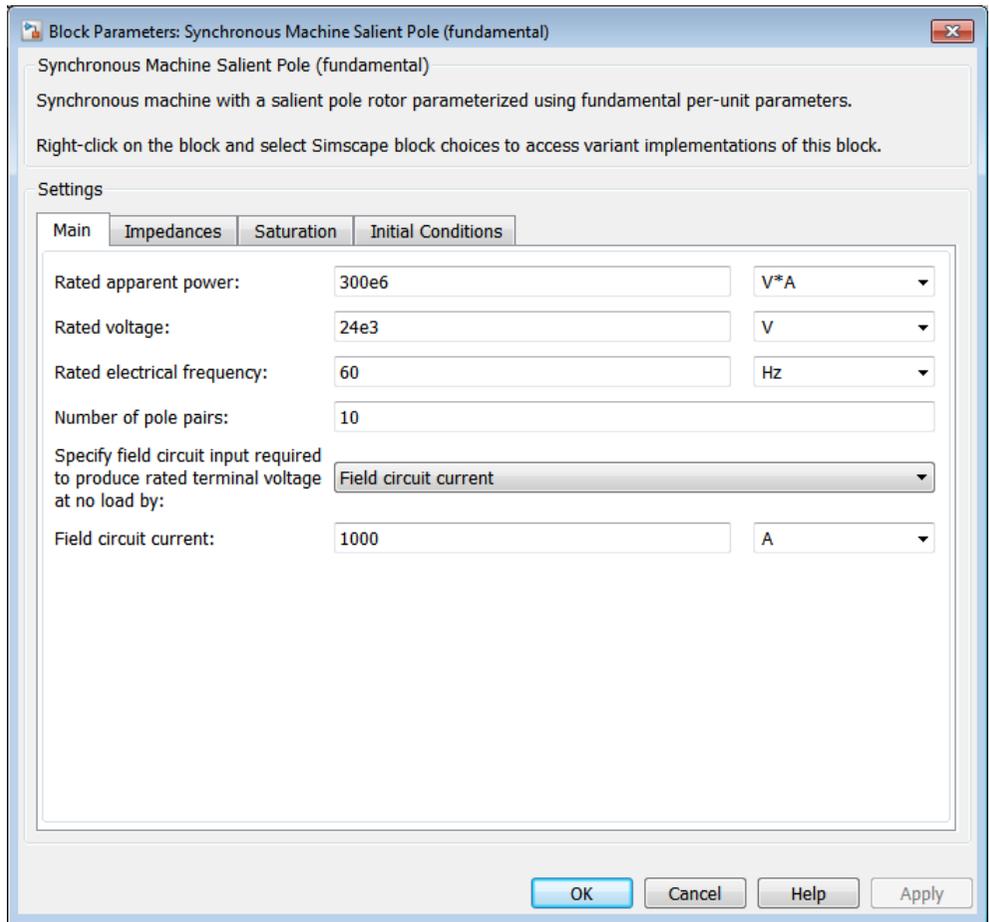
- **Display Base Values** displays the machine per-unit base values at the MATLAB command prompt.
- **Display Associated Base Values** displays associated per-unit base values at the MATLAB command prompt.
- **Associated Initial Conditions** displays associated initial conditions at the MATLAB command prompt.
- **Plot Open-Circuit Saturation (pu)** plots air-gap voltage, V_{ag} , versus field current, i_{fd} , (both measured in per-unit) in a MATLAB figure window. The plot contains three traces:

Synchronous Machine Salient Pole (fundamental)

- Unsaturated: **Stator d-axis mutual inductance (unsaturated), L_{ad}** you specify
- Saturated: **Per-unit open-circuit lookup table (V_{ag} versus ifd)** you specify
- Derived: Open-circuit lookup table (per-unit) derived from the **Per-unit open-circuit lookup table (V_{ag} versus ifd)** you specify. This data is used to calculate the saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , characteristic.
- **Plot Saturation Factor (pu)** plots saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , (both measured in per-unit) in a MATLAB figure window using the present machine parameters. This is derived from parameters you specify:
 - **Stator d-axis mutual inductance (unsaturated), L_{ad}**
 - **Per-unit field current saturation data, ifd**
 - **Per-unit air-gap voltage saturation data, V_{ag}**

Synchronous Machine Salient Pole (fundamental)

Dialog Box and Parameters



- “Main Tab” on page 1-241
- “Impedances Tab” on page 1-241
- “Saturation Tab” on page 1-242
- “Initial Conditions Tab” on page 1-243

Synchronous Machine Salient Pole (fundamental)

Main Tab

Rated apparent power

Rated apparent power. The default value is 300e6 VA.

Rated voltage

RMS rated line-line voltage. The default value is 24e3 V.

Rated electrical frequency

Nominal electrical frequency at which rated apparent power is quoted. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 10.

Specify field circuit input required to produce rated terminal voltage at no load by

Choose between Field circuit voltage and Field circuit current. The default value is Field circuit current.

Field circuit current

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit current. The default value is 1000 A.

Field circuit voltage

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit voltage. The default value is 216.54 V.

Impedances Tab

Stator d-axis mutual inductance (unsaturated), L_{adu}

Unsaturated stator d-axis mutual inductance, L_{adu} . If **Magnetic saturation representation** is set to None, this is equivalent to the stator d-axis mutual inductance, L_{ad} . The default value is 0.9 pu.

Stator q-axis mutual inductance, L_{aq}

Stator q-axis mutual inductance, L_{aq} . The default value is 0.55 pu.

Synchronous Machine Salient Pole (fundamental)

Stator zero-sequence inductance, L0

Stator zero-sequence inductance, L0. The default value is 0 pu.

Stator leakage inductance, Ll

Stator leakage inductance. The default value is 0.15 pu.

Stator resistance, Ra

Stator resistance. The default value is 0.011 pu.

Rotor field circuit inductance, Lfd

Rotor field circuit inductance. The default value is 0.2571 pu.

Rotor field circuit resistance, Rfd

Rotor field circuit resistance. The default value is 0.0006 pu.

Rotor d-axis damper winding 1 inductance, L1d

Rotor d-axis damper winding 1 inductance. The default value is 0.2 pu.

Rotor d-axis damper winding 1 resistance, R1d

Rotor d-axis damper winding 1 resistance. The default value is 0.0354 pu.

Rotor q-axis damper winding 1 inductance, L1q

Rotor q-axis damper winding 1 inductance. The default value is 0.2567 pu.

Rotor q-axis damper winding 1 resistance, R1q

Rotor q-axis damper winding 1 resistance. The default value is 0.0428 pu.

Saturation Tab

Magnetic saturation representation

Block magnetic saturation representation. Options are:

- None
- Per-unit open-circuit lookup table (Vag versus ifd)

The default value is None.

Synchronous Machine Salient Pole (fundamental)

Per-unit field current saturation data, ifd

The field current, i_{fd} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.48, 0.76, 1.38, 1.79] pu.

Per-unit air-gap voltage saturation data, Vag

The air-gap voltage, V_{ag} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00 0.43 0.59 0.71 0.76] pu.

Initial Conditions Tab

Specify initialization by

Options include:

- Electrical power and voltage output
- Mechanical and magnetic states

The default value is Electrical power and voltage output.

Terminal voltage magnitude

Initial RMS line-line voltage. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 24e3 V.

Terminal voltage angle

Initial voltage angle. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 deg.

Synchronous Machine Salient Pole (fundamental)

Terminal active power

Initial active power. This parameter is visible only when **Specify initialization by** is set to Electrical power and voltage output. The default value is 270e6 VA.

Terminal reactive power

Initial reactive power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 VA.

Initial rotor angle

Initial rotor angle. During steady-state operation, set this parameter to the sum of the load angle and required terminal voltage offset. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 deg.

Initial stator d-axis magnetic flux linkage

Stator d-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Stator q-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator zero-sequence magnetic flux linkage

Zero-sequence initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial field circuit magnetic flux linkage

Field circuit initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Synchronous Machine Salient Pole (fundamental)

Initial d-axis damper winding 1 magnetic flux linkage

d-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 1 magnetic flux linkage

The q-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 2 magnetic flux linkage

The q-axis damper winding 2 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Ports

The block has the following ports:

fd+

Electrical conserving port corresponding to the field winding positive terminal

fd-

Electrical conserving port corresponding to the field winding negative terminal

R

Mechanical rotational conserving port associated with the machine rotor

C

Mechanical rotational conserving port associated with the machine case

pu

Physical signal vector port associated with the machine per-unit measurements. The vector elements are:

- pu_fd_Efd
- pu_fd_Ifd

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- pu_torque
- pu_velocity
- pu_ed
- pu_ed
- pu_e0
- pu_id
- pu_iq
- pu_i0

~

Expandable three-phase port associated with the stator windings

n

Electrical conserving port associated with the neutral point of the wye winding configuration

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

See Also

Synchronous Machine Measurement | Synchronous Machine Salient Pole (standard) | Synchronous Machine Round Rotor (standard) | Synchronous Machine Round Rotor (fundamental)

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Synchronous Machine Control

Synchronous Machine Salient Pole (standard)

Purpose

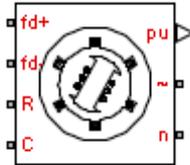
Salient-pole synchronous machine with standard parameterization

Library

Machines / Synchronous Machine (Salient Pole)

Description

The Synchronous Machine Salient Pole (standard) block models a salient-pole synchronous machine with parameterization using standard parameters.



Electrical Defining Equations

The synchronous machine equations are expressed with respect to a rotating reference frame defined by the equation

$$\theta_e(t) = N * \theta_r(t),$$

where:

- θ_e is the electrical angle.
- N is the number of pole pairs.
- θ_r is the rotor angle.

Park's transformation maps the synchronous machine equations to the rotating reference frame with respect to the electrical angle. Park's transformation is defined by

$$P_s = \frac{2}{3} \begin{bmatrix} \cos \theta_e & \cos(\theta_e - \frac{2\pi}{3}) & \cos(\theta_e + \frac{2\pi}{3}) \\ -\sin \theta_e & -\sin(\theta_e - \frac{2\pi}{3}) & -\sin(\theta_e - \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}.$$

Synchronous Machine Salient Pole (standard)

Park's transformation is used to define the per-unit synchronous machine equations. The stator voltage equations are defined by

$$e_d = \frac{1}{\omega_{base}} \frac{d\psi_d}{dt} - \Psi_q \omega_r - R_a i_d,$$

$$e_q = \frac{1}{\omega_{base}} \frac{d\psi_q}{dt} + \Psi_d \omega_r - R_a i_q,$$

and

$$e_0 = \frac{1}{\omega_{base}} \frac{d\Psi_0}{dt} - R_a i_0,$$

where:

- e_d , e_q , and e_0 are the d-axis, q-axis, and zero-sequence stator voltages, defined by

$$\begin{bmatrix} e_d \\ e_q \\ e_0 \end{bmatrix} = P_s \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix},$$

where v_a , v_b , and v_c are the stator voltages measured from port \sim to neutral port n.

- ω_{base} is the per-unit base electrical speed.
- ψ_d , ψ_q , and ψ_0 are the d-axis, q-axis, and zero-sequence stator flux linkages.
- ω_r is the per-unit rotor rotational speed.
- R_a is the stator resistance.
- i_d , i_q and i_0 are the d-axis, q-axis, and zero-sequence stator currents, defined by

Synchronous Machine Salient Pole (standard)

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = P_s \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix},$$

where i_a , i_b , and i_c are the stator currents flowing from port \sim to port n.

The rotor voltage equations are defined by

$$e_{fd} = \frac{1}{\omega_{base}} \frac{d\Psi_{fd}}{dt} + R_{fd}i_{fd},$$

$$e_{1d} = \frac{1}{\omega_{base}} \frac{d\Psi_{1d}}{dt} + R_{1d}i_{1d} = 0,$$

and

$$e_{1q} = \frac{1}{\omega_{base}} \frac{d\Psi_{1q}}{dt} + R_{1q}i_{1q} = 0,$$

where:

- e_{fd} is the field voltage.
- e_{1d} , and e_{1q} are the voltages across the d-axis damper winding 1 and q-axis damper winding 1. They are equal to 0.
- Ψ_{fd} , Ψ_{1d} , and Ψ_{1q} , are the magnetic fluxes linking the field circuit, d-axis damper winding 1, and q-axis damper winding 1.
- R_{fd} , R_{1d} , and R_{1q} are the resistances of rotor field circuit, d-axis damper winding 1, and q-axis damper winding 1.
- i_{fd} , i_{1d} , and i_{1q} are the currents flowing in the field circuit, d-axis damper winding 1, and q-axis damper winding 1.

The saturation equations are defined by

Synchronous Machine Salient Pole (standard)

$$\psi_{at} = \sqrt{\psi_d^2 + \psi_q^2},$$

$$K_s = 1 \text{ (If saturation is disabled),}$$

$$K_s = f(\psi_{at}) \text{ (If saturation is enabled),}$$

and

$$L_{ad} = K_s * L_{adu},$$

where:

- ψ_{at} is the air-gap flux linkage.
- K_s is the saturation factor.
- L_{adu} is the unsaturated mutual inductance of the stator d-axis.
- L_{ad} is the mutual inductance of the stator d-axis.

The saturation factor function, f , is calculated from the per-unit open-circuit lookup table as:

$$L_{ad} = \frac{d\psi_{at}}{di_{fd}},$$

$$V_{ag} = g(i_{fd}),$$

and

$$L_{ad} = \frac{dg(i_{fd})}{di_{fd}} = \frac{dV_{ag}}{di_{fd}},$$

where:

- V_{ag} is the per-unit air-gap voltage.

In per-unit,

Synchronous Machine Salient Pole (standard)

$$K_s = \frac{L_{ad}}{L_{adu}},$$

and

$$\psi_{at} = V_{ag}$$

can be rearranged to

$$K_s = f(\psi_{at}).$$

The stator flux linkage equations are defined by

$$\Psi_d = -(L_{ad} + L_l)i_d + L_{ad}i_{fd} + L_{ad}i_{1d},$$

$$\Psi_q = -(L_{aq} + L_l)i_q + L_{aq}i_{1q},$$

and

$$\Psi_0 = -L_0i_0.$$

where:

- L_l is the stator leakage inductance.
- L_{ad} and L_{aq} are the mutual inductances of the stator d-axis and q-axis.

The rotor flux linkage equations are defined by

$$\psi_{fd} = L_{ffd}i_{fd} + L_{f1d}i_{1d} - L_{ad}i_d,$$

$$\psi_{1d} = L_{f1d}i_{fd} + L_{11d}i_{1d} - L_{ad}i_d,$$

and

$$\psi_{1q} = L_{11q}i_{1q} - L_{aq}i_q,$$

where:

- L_{ffd} , L_{11d} , and L_{11q} are the self-inductances of the rotor field circuit, d-axis damper winding 1, and q-axis damper winding 1. L_{f1d} is the

Synchronous Machine Salient Pole (standard)

rotor field circuit and d-axis damper winding 1 mutual inductance. They are defined by the following equations.

$$L_{ffd} = L_{ad} + L_{fd}$$

$$L_{f1d} = L_{ffd} - L_{fd}$$

$$L_{11d} = L_{f1d} + L_{1d}$$

$$L_{11q} = L_{aq} + L_{1q}$$

These equations assume that per-unit mutual inductance $L_{12q} = L_{aq}$, i.e., the stator and rotor currents in the q-axis all link a single mutual flux represented by L_{aq} .

The rotor torque is defined by

$$T_e = \Psi_d i_q - \Psi_q i_d.$$

These defining equations do not describe the time constants you can set in the dialog box. To see their relationship with the equation coefficients, see [1].

Display Options

For synchronous machine blocks, you can perform display actions using the **Power Systems** menu on the block context menu.

Right-click the block. From the context menu, select one of the following from the **Power Systems > Synchronous Machine** menu:

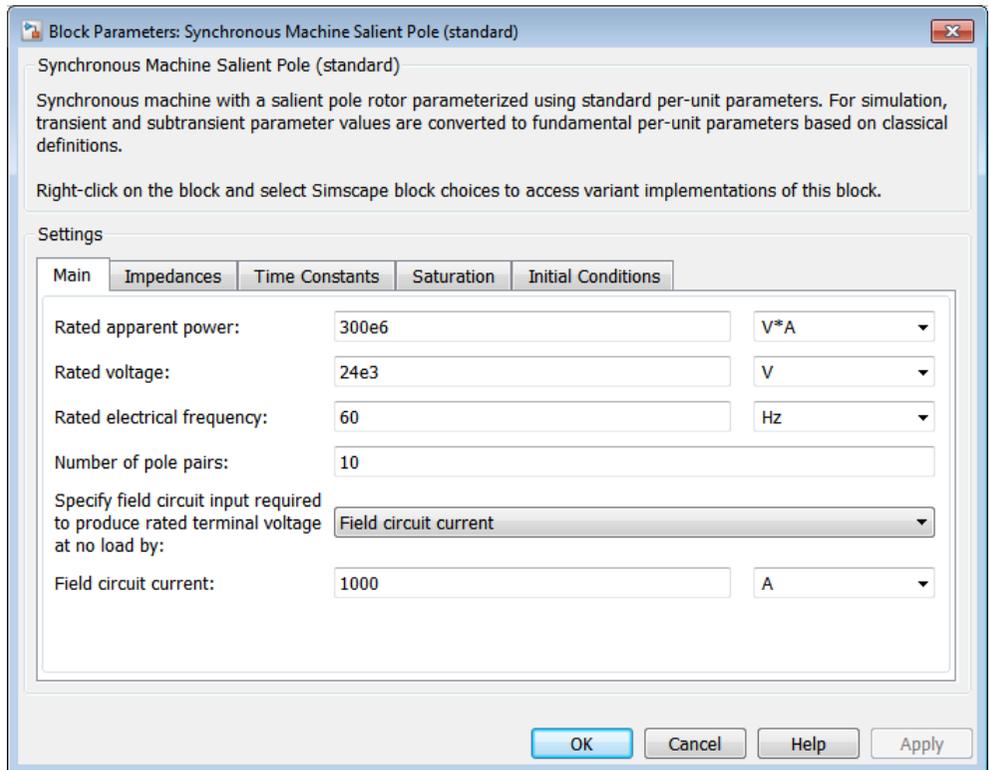
- **Display Base Values** displays the machine per-unit base values at the MATLAB command prompt.
- **Display Associated Base Values** displays associated per-unit base values at the MATLAB command prompt.
- **Associated Initial Conditions** displays associated initial conditions at the MATLAB command prompt.

Synchronous Machine Salient Pole (standard)

- **Plot Open-Circuit Saturation (pu)** plots air-gap voltage, V_{ag} , versus field current, i_{fd} , (both measured in per-unit) in a MATLAB figure window. The plot contains three traces:
 - Unsaturated: **Stator d-axis mutual inductance (unsaturated), L_{ad}** you specify
 - Saturated: **Per-unit open-circuit lookup table (Vag versus ifd)** you specify
 - Derived: Open-circuit lookup table (per-unit) derived from the **Per-unit open-circuit lookup table (Vag versus ifd)** you specify. This data is used to calculate the saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , characteristic.
- **Plot Saturation Factor (pu)** plots saturation factor, K_s , versus magnetic flux linkage, ψ_{at} , (both measured in per-unit) in a MATLAB figure window using the present machine parameters. This is derived from parameters you specify:
 - **Stator d-axis mutual inductance (unsaturated), L_{ad}**
 - **Per-unit field current saturation data, ifd**
 - **Per-unit air-gap voltage saturation data, Vag**

Synchronous Machine Salient Pole (standard)

Dialog Box and Parameters



- “Main Tab” on page 1-254
- “Impedances Tab” on page 1-255
- “Time Constants Tab” on page 1-256
- “Saturation Tab” on page 1-257
- “Initial Conditions Tab” on page 1-258

Main Tab

Rated apparent power

Rated apparent power. The default value is 300e6 VA.

Synchronous Machine Salient Pole (standard)

Rated voltage

RMS rated line-line voltage. The default value is 24e3 V.

Rated electrical frequency

Nominal electrical frequency at which rated apparent power is quoted. The default value is 60 Hz.

Number of pole pairs

Number of machine pole pairs. The default value is 10.

Specify field circuit input required to produce rated terminal voltage at no load by

Choose between Field circuit voltage and Field circuit current. The default value is Field circuit current.

Field circuit current

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit current. The default value is 1000 A.

Field circuit voltage

This parameter is visible only when **Specify field circuit input required to produce rated terminal voltage at no load by** is set to Field circuit voltage. The default value is 216.54 V.

Impedances Tab

Stator resistance, Ra

Stator resistance. The default value is 0.011 pu.

Stator leakage reactance, Xl

Stator leakage reactance. The default value is 0.15 pu.

d-axis synchronous reactance, Xd

The d-axis synchronous reactance. The default value is 1.05 pu.

q-axis synchronous reactance, Xq

The q-axis synchronous reactance. The default value is 0.7 pu.

zero-sequence reactance, X0

The zero-sequence reactance. The default value is 0 pu.

Synchronous Machine Salient Pole (standard)

d-axis transient reactance, X_d'

The d-axis transient reactance. The default value is 0.35 pu.

d-axis subtransient reactance, X_d''

The d-axis subtransient reactance. The default value is 0.25 pu.

q-axis subtransient reactance, X_q''

The q-axis subtransient reactance. The default value is 0.325 pu.

Time Constants Tab

Specify d-axis transient time constant

Select between Open circuit value and Short circuit value.
The default value is Open circuit value.

d-axis transient open circuit, T_{d0}'

The d-axis transient open circuit time constant. This parameter is visible only when **Specify d-axis transient time constant** is set to Open circuit value. The default value is 5.25 s.

d-axis transient short circuit, T_d'

The d-axis transient short circuit time constant. This parameter is visible only when **Specify d-axis transient time constant** is set to Short circuit value. The default value is 1.75 s.

Specify d-axis subtransient time constant

Select between Open circuit value and Short circuit value.
The default value is Open circuit value.

d-axis subtransient open circuit, T_{d0}''

The d-axis subtransient open circuit time constant. This parameter is visible only when **Specify d-axis subtransient time constant** is set to Open circuit value. The default value is 0.03 s.

d-axis subtransient short circuit, T_d''

The d-axis subtransient short circuit time constant. This parameter is visible only when **Specify d-axis subtransient time constant** is set to Short circuit value. The default value is 0.0214 s.

Synchronous Machine Salient Pole (standard)

Specify q-axis subtransient time constant

Select between Open circuit value and Short circuit value.
The default value is Open circuit value.

q-axis subtransient open circuit, Tq0”

The q-axis subtransient open circuit time constant. This parameter is visible only when **Specify q-axis subtransient time constant** is set to Open circuit value. The default value is 0.05 s.

q-axis subtransient short circuit, Tq”

The q-axis subtransient short circuit time constant. This parameter is visible only when **Specify q-axis subtransient time constant** is set to Short circuit value. The default value is 0.0232 s.

Saturation Tab

Magnetic saturation representation

Block magnetic saturation representation. Options are:

- None
- Per-unit open-circuit lookup table (Vag versus ifd)

The default value is None.

Per-unit field current saturation data, ifd

The field current, i_{fd} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd). This parameter must contain a vector with at least five elements. The default value is [0.00, 0.48, 0.76, 1.38, 1.79] pu.

Per-unit air-gap voltage saturation data, Vag

The air-gap voltage, V_{ag} , data populates the air-gap voltage, V_{ag} , versus field current, i_{fd} , lookup table. This parameter is only visible when you set **Magnetic saturation representation** to Per-unit open-circuit lookup table (Vag versus ifd).

Synchronous Machine Salient Pole (standard)

This parameter must contain a vector with at least five elements.
The default value is [0.00 0.43 0.59 0.71 0.76] pu.

Initial Conditions Tab

Specify initialization by

Options include:

- Electrical power and voltage output
- Mechanical and magnetic states

The default value is Electrical power and voltage output.

Terminal voltage magnitude

Initial RMS line-line voltage. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 24e3 V.

Terminal voltage angle

Initial voltage angle. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 deg.

Terminal active power

Initial active power. This parameter is visible only when **Specify initialization by** is set to Electrical power and voltage output. The default value is 270e6 VA.

Terminal reactive power

Initial reactive power. This parameter is visible only when you set **Specify initialization by** to Electrical power and voltage output. The default value is 0 VA.

Initial rotor angle

Initial rotor angle. During steady-state operation, set this parameter to the sum of the load angle and required terminal voltage offset. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 deg.

Synchronous Machine Salient Pole (standard)

Initial stator d-axis magnetic flux linkage

Stator d-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator q-axis magnetic flux linkage

Stator q-axis initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial stator zero-sequence magnetic flux linkage

Zero-sequence initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial field circuit magnetic flux linkage

Field circuit initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial d-axis damper winding 1 magnetic flux linkage

d-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 1 magnetic flux linkage

The q-axis damper winding 1 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Initial q-axis damper winding 2 magnetic flux linkage

The q-axis damper winding 2 initial flux linkage. This parameter is visible only when you set **Specify initialization by** to Mechanical and magnetic states. The default value is 0 pu.

Ports

The block has the following ports:

fd+

Electrical conserving port corresponding to the field winding positive terminal

Synchronous Machine Salient Pole (standard)

fd-	Electrical conserving port corresponding to the field winding negative terminal
R	Mechanical rotational conserving port associated with the machine rotor
C	Mechanical rotational conserving port associated with the machine case
pu	Physical signal vector port associated with the machine per-unit measurements. The vector elements are: <ul style="list-style-type: none">• pu_fd_Efd• pu_fd_Ifd• pu_torque• pu_velocity• pu_ed• pu_ed• pu_e0• pu_id• pu_iq• pu_i0
~	Expandable three-phase port associated with the stator windings
n	Electrical conserving port associated with the neutral point of the wye winding configuration

Synchronous Machine Salient Pole (standard)

References

[1] Kundur, P. *Power System Stability and Control*. New York, NY: McGraw Hill, 1993.

[2] Lyshevski, S. E. *Electromechanical Systems, Electric Machines and Applied Mechatronics*. Boca Raton, FL: CRC Press, 1999.

See Also

Synchronous Machine Measurement | Synchronous Machine Round Rotor (Standard) | Synchronous Machine Round Rotor (Fundamental) | Synchronous Machine Salient Pole (Fundamental)

Related Examples

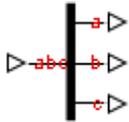
- “Expand and Collapse Three-Phase Ports on a Block”
- Three-Phase Synchronous Machine Control

Three Element Demux

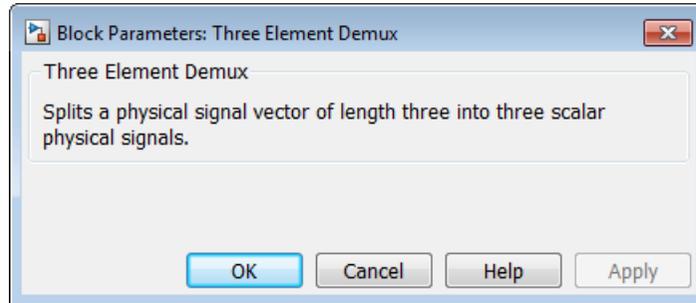
Purpose Convert three-element physical signal vector into scalar physical signals

Library Sensors

Description The Three Element Demux block splits a three-element physical signal vector into three scalar physical signals.



Dialog Box and Parameters



The block has no parameters.

Ports The block has the following ports:

- abc Three-element physical signal input port.
- a Scalar physical signal output port.
- b Scalar physical signal output port.
- c Scalar physical signal output port.

Purpose

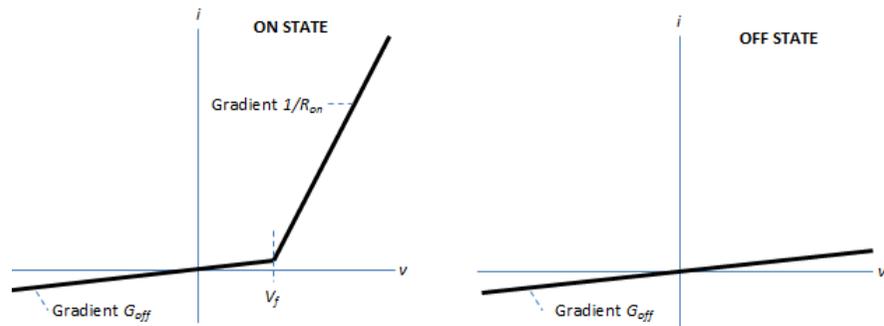
Thyristor

Library

Semiconductors / Fundamental Components

Description

The Thyristor block models a thyristor. The figure shows a typical i - v characteristic for a thyristor.



The thyristor turns on if the gate-cathode voltage exceeds the specified gate trigger voltage. The device turns off if the load current falls below the specified holding-current value.

In the on state, the anode-cathode path behaves like a linear diode with forward-voltage drop V_f and on-resistance R_{on} .

In the off state, the anode-cathode path behaves like a linear resistor with a low off-state conductance G_{off} .

The defining Simscape equations for the block are:

```

if (v > Vf)&&((G>Vgt) || (i>Ih))
    i == (v - Vf*(1-Ron*Goff))/Ron;
else
    i == v*Goff;
end

```

where:

- v is the anode-cathode voltage.

Thyristor

- V_f is the forward voltage.
- G is the gate voltage.
- V_{gt} is the gate trigger voltage.
- i is the anode-cathode current.
- I_h is the holding current.
- R_{on} is the on-state resistance.
- G_{off} is the off-state conductance.

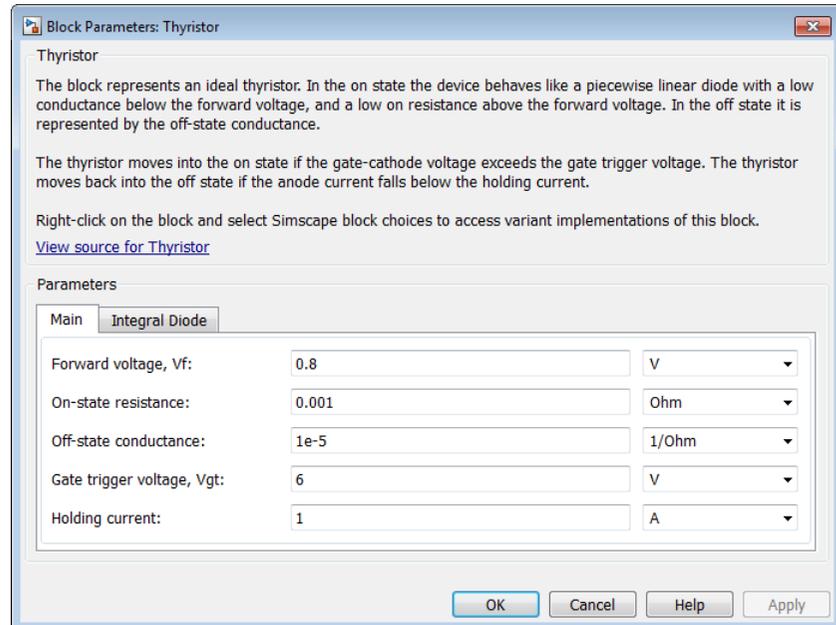
Using the Integral Diode tab of the block dialog box, you can include an integral cathode-anode diode. An integral diode protects the semiconductor device by providing a conduction path for reverse current. An inductive load can produce a high reverse-voltage spike when the semiconductor device suddenly switches off the voltage supply to the load.

The table shows you how to set the **Integral protection diode** parameter based on your goals.

Goal	Value to Select	Block Behavior
Prioritize simulation speed.	Protection diode with no dynamics	The block includes an integral copy of the Diode block. The block dialog box shows parameters relating to the Diode block.
Precisely specify reverse-mode charge dynamics.	Protection diode with charge dynamics	The block includes an integral copy of the Commutation Diode block. The block dialog box shows parameters relating

Goal	Value to Select	Block Behavior
		to the Commutation Diode block.

Dialog Box and Parameters



- “Main Tab” on page 1-265
- “Integral Diode Tab” on page 1-266

Main Tab

Forward voltage, Vf

Forward voltage at which the device turns on. The default value is 0.8 V.

Thyristor

On-state resistance

Anode-cathode resistance when the device is on. The default value is 0.001 Ω .

Off-state conductance

Anode-cathode conductance when the device is off. The value must be less than $1/R$, where R is the value of **On-state resistance**. The default value is $1e-5 \Omega^{-1}$.

Gate trigger voltage, Vgt

Gate-cathode voltage threshold. The device turns on when the gate-cathode voltage is above this value. The default value is 6 V.

Holding current

Current threshold. The device stays on when the current is above this value, even when the gate-cathode voltage falls below the gate trigger voltage. The default value is 1 A.

Integral Diode Tab

Integral protection diode

Block integral protection diode. The default value is None.

The diodes you can select are:

- Protection diode with no dynamics
- Protection diode with charge dynamics

Parameters for Protection diode with no dynamics

When you select Protection diode with no dynamics, additional parameters appear.

Additional Parameters for Protection diode with no dynamics

Forward voltage

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

For more information on these parameters, see Diode.

Parameters for Protection diode with charge dynamics

When you select Protection diode with charge dynamics, additional parameters appear.

Additional Parameters for Protection diode with charge dynamics**Forward voltage**

Minimum voltage required across the + and - block ports for the gradient of the diode i-v characteristic to be $1/R_{on}$, where R_{on} is the value of **On resistance**. The default value is 0.8 V.

On resistance

Rate of change of voltage versus current above the forward voltage. The default value is 0.001 Ω .

Off conductance

Conductance of the reverse-biased diode. The default value is $1e-5 \Omega^{-1}$.

Junction capacitance

Diode junction capacitance. The default value is 50 nF.

Peak reverse current, iRM

Peak reverse current measured by an external test circuit. This value must be less than zero. The default value is -235 A.

Initial forward current when measuring iRM

Initial forward current when measuring peak reverse current. This value must be greater than zero. The default value is 300 A.

Rate of change of current when measuring i_{RM}

Rate of change of current when measuring peak reverse current. This value must be less than zero. The default value is $-50 \text{ A}/\mu\text{s}$.

Reverse recovery time parameterization

Determines how you specify reverse recovery time in the block. The default value is Specify reverse recovery time directly.

If you select Specify stretch factor or Specify reverse recovery charge, you specify a value that the block uses to derive the reverse recovery time. For more information on these options, see “Alternatives to Specifying t_{rr} Directly” on page 1-40.

Reverse recovery time, t_{rr}

Interval between the time when the current initially goes to zero (when the diode turns off) and the time when the current falls to less than 10% of the peak reverse current. The default value is $15 \mu\text{s}$.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery time directly.

The value of the **Reverse recovery time, t_{rr}** parameter must be greater than the value of the **Peak reverse current, i_{RM}** parameter divided by the value of the **Rate of change of current when measuring i_{RM}** parameter.

Reverse recovery time stretch factor

Value that the block uses to calculate **Reverse recovery time, t_{rr}** . This value must be greater than 1. The default value is 3.

This parameter is visible only if you set **Reverse recovery time parameterization** to Specify stretch factor.

Specifying the stretch factor is an easier way to parameterize the reverse recovery time than specifying the reverse recovery charge.

The larger the value for the stretch factor, the longer it takes for the reverse recovery current to dissipate.

Reverse recovery charge, Q_{rr}

Value that the block uses to calculate **Reverse recovery time**, t_{rr} . Use this parameter if the data sheet for your diode device specifies a value for reverse recovery charge instead of a value for reverse recovery time.

Reverse recovery charge is the total charge that remains to dissipate when the diode turns off. The value must be less than

$$-\frac{i_{RM}^2}{2a},$$

where:

- i_{RM} is the value specified for **Peak reverse current**, i_{RM} .
- a is the value specified for **Rate of change of current when measuring i_{RM}** .

The default value is 1500 μ As.

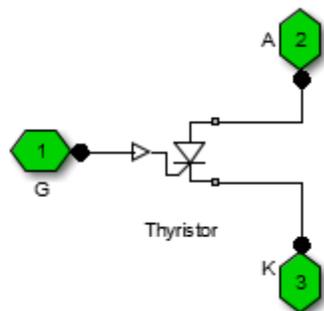
The parameter is visible only if you set **Reverse recovery time parameterization** to Specify reverse recovery charge.

For more information on these parameters, see Commutation Diode.

Ports

This figure shows the block port names.

Thyristor



- G Port associated with the gate terminal. You can set the port to either a physical signal or electrical port.
- A Electrical conserving port associated with the anode terminal.
- K Electrical conserving port associated with the cathode terminal.

Related Examples

- “Switch Between Physical Signal and Electrical Ports”

Purpose

Time-based single-phase, two-phase or three-phase grounded or ungrounded fault

Library

Passive Devices / Faults

Description

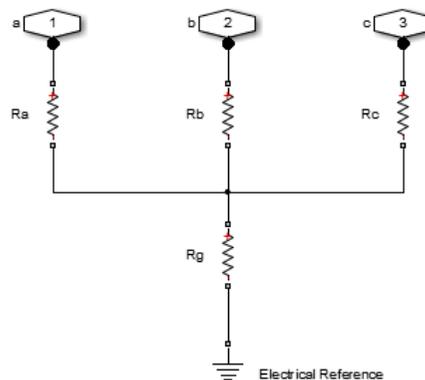


The Time-Based Fault block models any permutation of a single-phase, two-phase, or three-phase grounded or ungrounded fault. You specify the fault activation time using the block **Fault start time** parameter. The fault becomes inactive when the fault duration that you specify elapses.

You can set the Time-Based Fault block to represent any of these:

- Single-phase-to-ground fault (a-g, b-g or c-g)
- Two-phase fault (a-b, b-c or c-a)
- Two-phase-to-ground fault (a-b-g, b-c-g or c-a-g)
- Three-phase fault (a-b-c)
- Three-phase-to-ground fault (a-b-c-g)

The figure shows the equivalent circuit diagram for the Time-Based Fault block.



Time-Based Fault

You can determine the resistance in the equivalent circuit using the equations in the table.

Fault type	Value of R_a	Value of R_b	Value of R_c	Value of R_g
None / inactive	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	Infinity / open circuit
a-g	R_{pn}	$\frac{1}{G_{nn}}$	$\frac{1}{G_{nn}}$	R_{ng}
b-g	$\frac{1}{G_{nn}}$	R_{pn}	$\frac{1}{G_{nn}}$	R_{ng}
c-g	$\frac{1}{G_{pn}}$	$\frac{1}{G_{pn}}$	R_{pn}	R_{ng}
a-b	R_{pn}	R_{pn}	$\frac{1}{G_{nn}}$	Infinity / open circuit
b-c	$\frac{1}{G_{pn}}$	R_{pn}	R_{pn}	Infinity / open circuit
c-a	R_{pn}	$\frac{1}{G_{pn}}$	R_{pn}	Infinity / open circuit
a-b-g	R_{pn}	R_{pn}	$\frac{1}{G_{pn}}$	R_{ng}
b-c-g	$\frac{1}{G_{pn}}$	R_{pn}	R_{pn}	R_{ng}

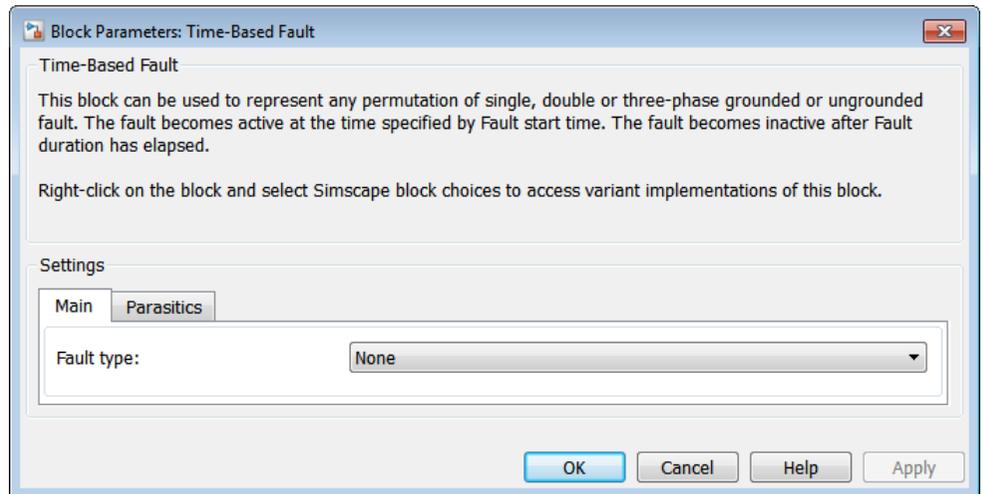
Fault type	Value of R_a	Value of R_b	Value of R_c	Value of R_g
c-a-g	R_{pn}	$\frac{1}{G_{pn}}$	R_{pn}	R_{ng}
a-b-c	R_{pn}	R_{pn}	R_{pn}	Infinity / open circuit
a-b-c-g	R_{pn}	R_{pn}	R_{pn}	R_{ng}

where:

- R_a is the resistance between the a-phase and the neutral point of a wye connection.
- R_b is the resistance between the b-phase and the neutral point of a wye connection.
- R_c is the resistance between the c-phase and the neutral point of a wye connection.
- R_g is the resistance between the neutral point of a wye connection and electrical reference.
- R_{pn} is the value of the **Faulted phase-neutral resistance** parameter.
- R_{ng} is the value of the **Faulted neutral-ground resistance** parameter.
- G_{pn} is the value of the **Unfaulted phase-neutral conductance** parameter.

Time-Based Fault

Dialog Box and Parameters



- “Main Tab” on page 1-274
- “Parasitics Tab” on page 1-275

Main Tab

Fault type

Select one of the following:

- None — Specifies that the fault is not active. This is the default value.
- Single-phase to ground (a-g)
- Single-phase to ground (b-g)
- Single-phase to ground (c-g)
- Two-phase (a-b)
- Two-phase (b-c)
- Two-phase (c-a)
- Two-phase to ground (a-b-g)

- Two-phase to ground (b-c-g)
- Two-phase to ground (c-a-g)
- Three-phase (a-b-c)
- Three-phase to ground (a-b-c-g)

Faulted phase-neutral resistance

Resistance between the phase connection and the neutral point when the fault is active. This parameter is visible if the **Fault type** parameter is set to anything other than None. The default value is $1\text{e-}3\ \Omega$.

Faulted neutral-ground resistance

Resistance between the neutral point and the electrical reference when fault is active. This parameter is visible if the **Fault type** parameter is set to any fault which includes a ground connection. The default value is $1\text{e-}3\ \Omega$.

Fault start time

Simulation time when the fault becomes active. This parameter is visible if the **Fault type** parameter is set to anything other than None. The default value is 1 s.

Fault duration

Period of time that the fault is active. This parameter is visible if the **Fault type** parameter is set to anything other than None. The default value is 0.1 s.

Parasitics Tab

Unfaulted phase-neutral conductance

Conductance between the phase connections and the neutral point when a phase is not involved in the fault. The default value is $1\text{e-}6\ \Omega^{-1}$.

Ports

The block has one expandable three-phase port for connecting the fault to the system.

See Also Enabled Fault

Transmission Line

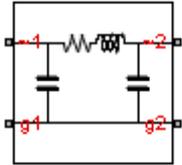
Purpose

Three-phase transmission line using lumped-parameter pi-line model

Library

Passive Devices

Description



The Transmission Line block models a three-phase transmission line using the lumped-parameter pi-line model. This model takes into account phase resistance, phase self-inductance, line-line mutual inductance, line-line capacitance, and line-ground capacitance.

To simplify the block-defining equations, Clarke's transformation is used. The resulting equations are:

$$V_1' - V_2' = \begin{bmatrix} R & & \\ & R & \\ & & R \end{bmatrix} I_1' + \begin{bmatrix} L + 2M & & \\ & L - M & \\ & & L - M \end{bmatrix} \frac{dI_1'}{dt}$$

$$I_1' + I_2' = \begin{bmatrix} C_g & & \\ & C_g + 3C_l & \\ & & C_g + 3C_l \end{bmatrix} \frac{dV_2'}{dt}$$

$$I_1' = T' I_1$$

$$I_2' = T' I_2$$

$$V_1' = T' V_1$$

$$V_2' = T' V_2$$

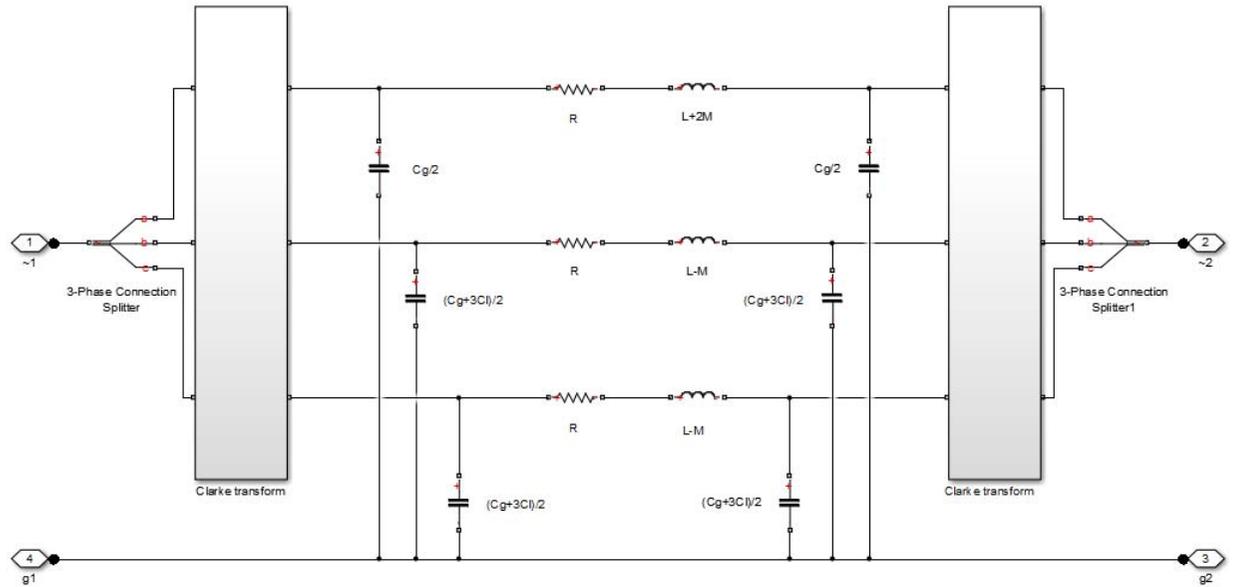
$$T = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & \sqrt{2} & 0 \\ 1 & -1/\sqrt{2} & \sqrt{3}/2 \\ 1 & -1/\sqrt{2} & -\sqrt{3}/2 \end{bmatrix}$$

where:

- R is the line resistance for the segment.
- L is the line inductance for the segment.
- C_g is the line-ground capacitance for the segment.
- C_l is the line-line capacitance for the segment.
- T is the Clarke's transformation matrix.
- $I1$ is the three-phase current flowing into the ~1 port.
- $I2$ is the three-phase current flowing into the ~2 port.
- $V1$ is the three-phase voltage at the ~1 port.
- $V2$ is the three-phase voltage at the ~2 port.

The figure shows the equivalent electrical circuit for a single-segment pi-line model using Clarke's transformation.

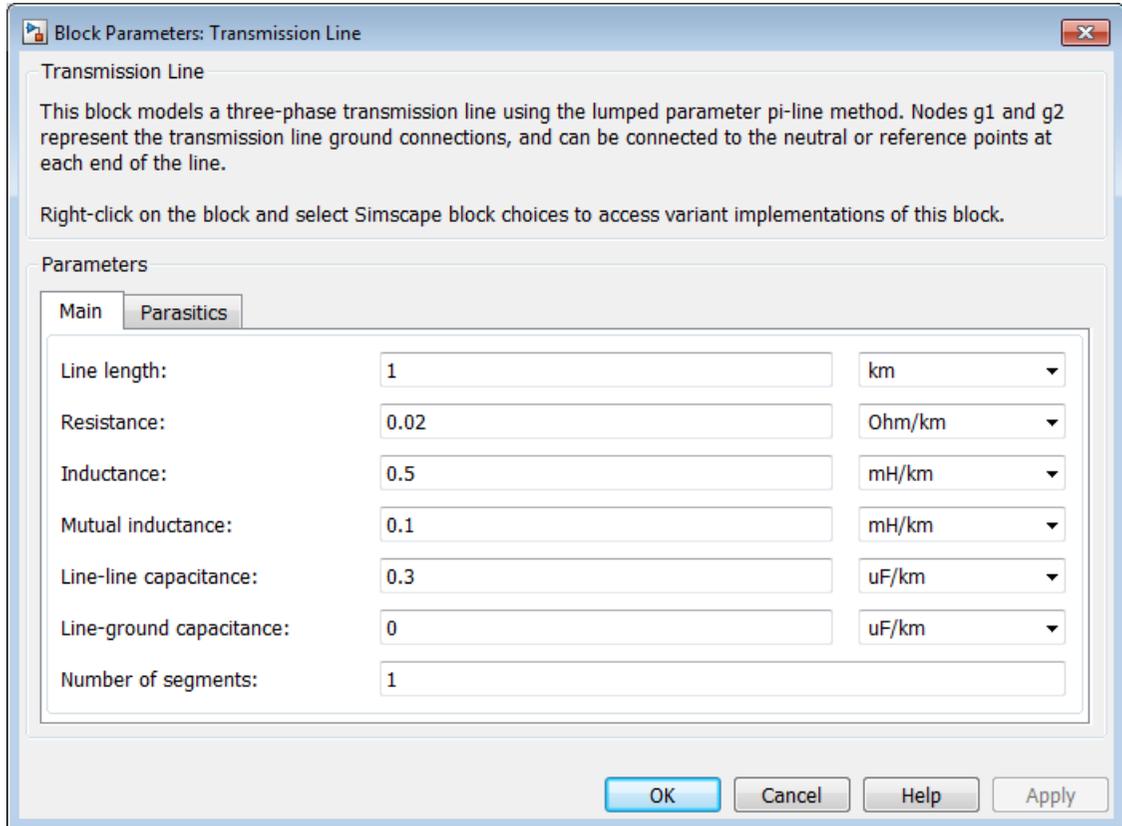
Transmission Line



To increase fidelity, you can use the **Number of segments** parameter to repeat the pi-section N times, resulting in an N -segment transmission line model. More segments significantly slows down your simulation.

To improve numerical performance, you can add parasitic resistance and conductance components. Choosing large values for these components improves simulation speed but decreases simulation accuracy.

Dialog Box and Parameters



- “Main tab” on page 1-280
- “Parasitics tab” on page 1-280

Transmission Line

Main tab

Line length

Length of the transmission line. The default value is 1 km.

Resistance

Resistance of the transmission line per phase per unit length.
The default value is 0.02 Ω /km.

Inductance

Self-inductance of the transmission line per phase per unit length.
The default value is 0.5 mH/km.

Mutual inductance

Line-line mutual inductance per unit length. Set this to 0 to remove mutual inductance. The default value is 0.1 mH/km.

Line-line capacitance

Line-line capacitance per unit length. The default value is 0.3 μ F/km.

Line-ground capacitance

Line-ground capacitance per unit length. The default value is 0 μ F/km (no line-ground capacitance).

Number of segments

Number of segments in the pi-line model. The default value is 1.

Parasitics tab

Parasitic series resistance

Resistance value, divided by the number of segments, that is added in series with every capacitor in the model. The default value is $1e-6 \Omega$.

Parasitic parallel conductance

Conductance value, divided by the number of segments, that is added in parallel with every series resistor and inductor in the model. The default value is $1e-6 \Omega^{-1}$.

Ports

The block has the following ports:

- ~1 Expandable three-phase port
- ~2 Expandable three-phase port
- g1 Electrical conserving port corresponding to ground connection at ~1 end of the transmission line
- g2 Electrical conserving port corresponding to ground connection at ~2 end of the transmission line

Related Examples

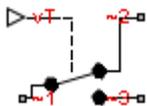
- “Expand and Collapse Three-Phase Ports on a Block”

Two-Way Switch

Purpose Three-phase double-throw switch

Library Switches & Breakers

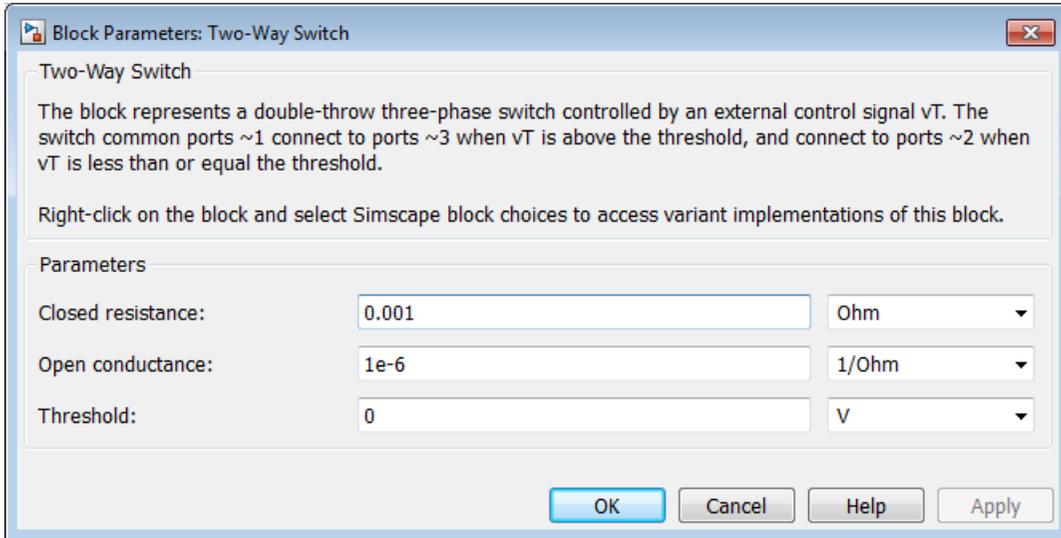
Description The Two-Way Switch block models a three-phase double-throw switch that uses an external signal to connect each phase of the port ~1 with the corresponding phase of either port ~2 or ~3.



The table shows how the external signal vT controls the block behavior.

Condition	Block Behavior	Resistance Parameter Used
$vT \leq$ Threshold	Each phase of port ~1 is connected to the corresponding phase of port ~2 via internal resistance. Port ~3 is unconnected.	Open conductance (port ~1 to port ~3). Closed resistance (port ~1 to port ~2)
$vT >$ Threshold	Each phase of port ~1 is connected to the corresponding phase of port ~3 via internal resistance. Port ~2 is unconnected.	Open conductance (port ~1 to port ~2). Closed resistance (port ~1 to port ~3)

Dialog Box and Parameters



Closed resistance

Resistance between ports ~1 and ~3 when the switch is closed.
The default value is 0.001 Ω .

Open conductance

Conductance between ports ~1 and ~2 when the switch is open.
The default value is 1e-6 Ω^{-1} .

Threshold

Threshold voltage for the control port v_T . When the voltage is above the threshold, the switch is closed. The default value is 0 V.

Ports

The block has the following ports:

~1

Expandable three-phase port

Two-Way Switch

- ~2 Expandable three-phase port
- ~3 Expandable three-phase port
- vT Scalar control port, which is either a physical signal or an electrical port.

See Also

Single-Phase Switch | Switch | Single-Phase Two-Way Switch

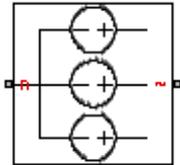
Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”
- “Switch Between Physical Signal and Electrical Ports”

Purpose Ideal three-phase voltage source

Library Sources

Description



The Voltage Source block models an ideal three-phase voltage source that maintains sinusoidal voltage of the specified magnitude across its terminals, independent of the current flowing through the source.

The output voltage is defined by the following equations:

$$V_0 = \frac{\sqrt{2}}{\sqrt{3}} \cdot v_{line_rms}$$

$$v_a = V_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi)$$

$$v_b = V_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi - 120^\circ)$$

$$v_c = V_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi + 120^\circ),$$

where:

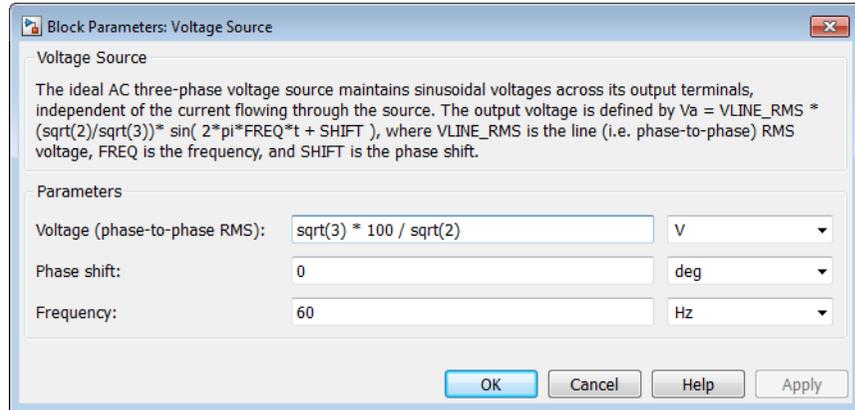
- V_0 is the peak phase voltage.
- v_{line_rms} is the RMS phase-to-phase voltage.
- v_a , v_b , v_c are the respective phase voltages.
- f is the frequency.
- φ is the phase shift.
- t is the time.

The source has a wye configuration, and port n provides a connection to the center of the wye. Port ~ is an expandable three-phase port representing the three phases, a, b, and c. The current is positive if it flows from positive to the center of the wye, and the voltage across

Voltage Source

each phase is equal to the difference between the voltage at the positive terminal and the center of the wye, $V(+)-V_n$.

Dialog Box and Parameters



Voltage (phase-to-phase RMS)

RMS phase-to-phase, or line, voltage. The default value is $\sqrt{3} * 100 / \sqrt{2}$, or 122.4745, V.

Phase shift

Phase shift in angular units. The default value is 0 deg.

Frequency

Voltage frequency, specified in Hz or units directly convertible to Hz (where Hz is defined as 1/s). For example, kHz and MHz are valid units, but rad/s is not. The default value is 60 Hz.

Ports

The block has the following ports:

~

Expandable three-phase port

n

Electrical conserving port associated with the center of the wye

See Also Current Source

Related Examples

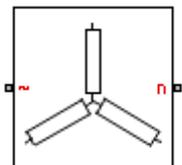
- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Connected Load

Purpose Three-phase load wired in wye configuration

Library Passive Devices

Description



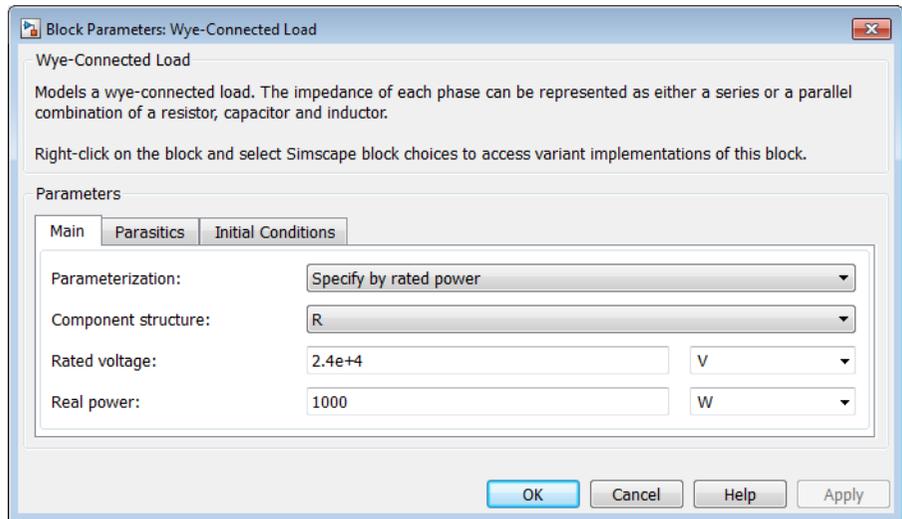
The Wye-Connected Load block models a three-phase load wired in a wye configuration. Each limb of the load can include any combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel.

You can specify values for the R, L, and C components directly in terms of resistance, inductance, and capacitance, or by rated powers at a rated voltage and frequency.

- If you parameterize the block directly in terms of R, L, and C values, then for initialization you must provide a three-element row vector of initial voltages for a capacitor, and a three-element row vector of initial currents for an inductor.
- If you parameterize the block in terms of rated powers, then you must specify initial conditions in terms of an initial voltage, initial voltage phase, and initial frequency. For example, if the load is connected directly to a three-phase voltage source, then the initial conditions are identical to the source values for RMS line voltage, frequency, and phase shift. To specify zero initial-voltage magnitude, set the initial voltage to 0.

For certain combinations of R, L, and C, you must specify parasitic resistance or conductance values, which can help numerical convergence when simulating some circuit topologies. These parasitic terms ensure that an inductor has a small parallel resistive path and that a capacitor has a small series resistance. When you parameterize the block in terms of rated powers, the rated power values do not account for these small parasitic terms. The rated powers represent only the R, L, and C values of the load itself.

Dialog Box and Parameters



- “Main Tab” on page 1-289
- “Parasitics Tab” on page 1-291
- “Initial Conditions Tab” on page 1-291

Main Tab

Parameterization

Select one of these values:

- **Specify by rated power** — Specify values for the R, L, and C components by rated powers at a rated voltage and frequency. This is the default.
- **Specify component values directly** — Specify values for the R, L, and C components directly in terms of resistance, inductance, and capacitance.

Switching the **Parameterization** value resets the **Component structure** value. Select the component parameterization option first, and then the component structure. If you later switch the

Wye-Connected Load

Parameterization value, check the **Component structure** value and reselect it, if necessary.

Component structure

Select the desired combination of a resistor (R), capacitor (C), and inductor (L), connected in series or in parallel. The default is R, resistor.

Rated voltage

Voltage for which load powers are specified. This parameter is visible only when you specify values by rated power. The default value is 2.4×10^4 V.

Real power

Total real power dissipated by three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes a resistor. The value must be greater than 0. The default value is 1000 W.

Rated electrical frequency

Frequency for which reactive load powers are specified. This parameter is visible only when you specify values by rated power. The default value is 60 Hz.

Inductive reactive power

Total inductive reactive power taken by the three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes an inductor. The value must be greater than 0. The default value is $100 \text{ V} \cdot \text{A}$.

Capacitive reactive power

Total capacitive reactive power taken by the three-phase load when supplied at the rated voltage. This parameter is visible only when you specify values by rated power and select a component structure that includes a capacitor. The value must be less than 0. The default value is $-100 \text{ V} \cdot \text{A}$.

Resistance

Resistance of each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes a resistor. The default value is 1 Ω .

Inductance

Inductance of each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes an inductor. The default value is 0.001 H.

Capacitance

Capacitance in each of the load limbs. This parameter is visible only when you specify component values directly and select a component structure that includes a capacitor. The default value is 1e-6 F.

Parasitics Tab

Parasitic series resistance

Represents small parasitic effects. The parameter value corresponds to the series resistance value added to all instances of capacitors in the load. The default value is 1e-6 Ω .

Parasitic parallel conductance

Represents small parasitic effects. The parameter value corresponds to the parallel conductance value added across all instances of inductors in the load. The default value is 1e-6 Ω^{-1} .

Initial Conditions Tab

Terminal voltage magnitude

Expected initial RMS line voltage at the load. This parameter is visible only when you specify values by rated power. The default value is 2.4e4 V.

Wye-Connected Load

Terminal voltage angle

Expected initial phase of the voltage at the load. This parameter is visible only when you specify values by rated power. The default value is 0 deg.

Frequency

Expected initial frequency at the load. This parameter is visible only when you specify values by rated power. The default value is 60 Hz.

Initial inductor current [Ia Ib Ic]

Initial current in the a, b, and c phase inductors, respectively. This parameter is visible only when you specify component values directly and select a component structure that includes an inductor. The default value is [0 0 0] A.

Initial capacitor voltage [Va Vb Vc]

Initial voltage across the a, b, and c phase capacitors, respectively. This parameter is visible only when you specify component values directly and select a component structure that includes a capacitor. The default value is [0 0 0] V.

Block Parameterization

The following two tables list the block parameters for each **Component structure**, based on the selected **Parameterization** option:

- Specify by rated power
- Specify component values directly

Specify by Rated Power

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
R	Rated voltage Real power	None	None
L	Rated voltage Rated electrical frequency Inductive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency
C	Rated voltage Rated electrical frequency Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Series RL	Rated voltage Rated electrical frequency Real power Inductive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency

Wye-Connected Load

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Series RC	Rated voltage Rated electrical frequency Real power Capacitive reactive power	None	Terminal voltage magnitude Terminal voltage angle Frequency
Series LC	Rated voltage Rated electrical frequency Inductive reactive power Capacitive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency
Series RLC	Rated voltage Rated electrical frequency Real power Inductive reactive power Capacitive reactive power	Parasitic parallel conductance	Terminal voltage magnitude Terminal voltage angle Frequency

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Parallel RL	Rated voltage Rated electrical frequency Real power Inductive reactive power	None	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel RC	Rated voltage Rated electrical frequency Real power Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel LC	Rated voltage Rated electrical frequency Inductive reactive power Capacitive reactive power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle Frequency
Parallel RLC	Rated voltage Rated electrical frequency Real power	Parasitic series resistance	Terminal voltage magnitude Terminal voltage angle

Wye-Connected Load

Specify by Rated Power (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
	Inductive reactive power Capacitive reactive power		Frequency

Specify Component Values Directly

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
R	Resistance	None	None
L	Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
C	Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]
Series RL	Resistance Inductance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic]
Series RC	Resistance Capacitance	None	Initial capacitor voltage [Va Vb Vc]

Specify Component Values Directly (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Series LC	Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Series RLC	Resistance Inductance Capacitance	Parasitic parallel conductance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RL	Resistance Inductance	None	Initial inductor current [Ia Ib Ic]
Parallel RC	Resistance Capacitance	Parasitic series resistance	Initial capacitor voltage [Va Vb Vc]

Wye-Connected Load

Specify Component Values Directly (Continued)

Component Structure	Main Tab	Parasitics Tab	Initial Conditions Tab
Parallel LC	Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]
Parallel RLC	Resistance Inductance Capacitance	Parasitic series resistance	Initial inductor current [Ia Ib Ic] Initial capacitor voltage [Va Vb Vc]

Ports

The block has the following ports:

~

Expandable three-phase port

n

Electrical conserving port associated with the neutral phase

See Also

Delta-Connected Load | RLC

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Delta1 Transformer

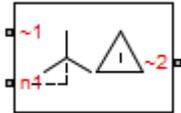
Purpose

Linear non-ideal wye-delta1 transformer with three-limb core

Library

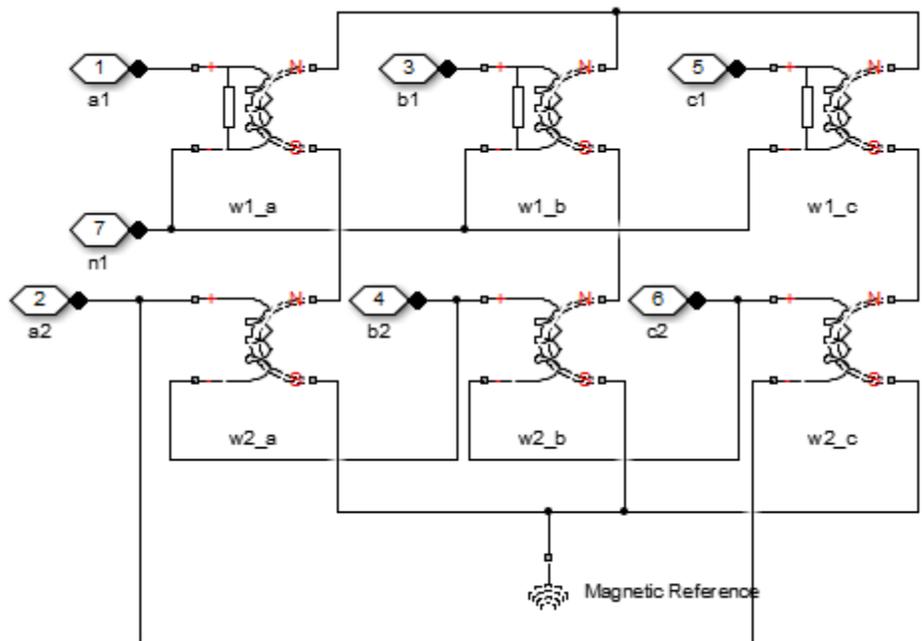
Passive Devices / Transformers

Description



The Wye-Delta1 Transformer block models a linear non-ideal transformer with a three-limb core, in which the primary windings are configured in a wye connection and the secondary windings are configured in a delta connection. The delta voltages lag the wye voltages by 30 degrees, hence the name 1 o'clock delta. It includes linear winding leakage and linear core magnetization effects.

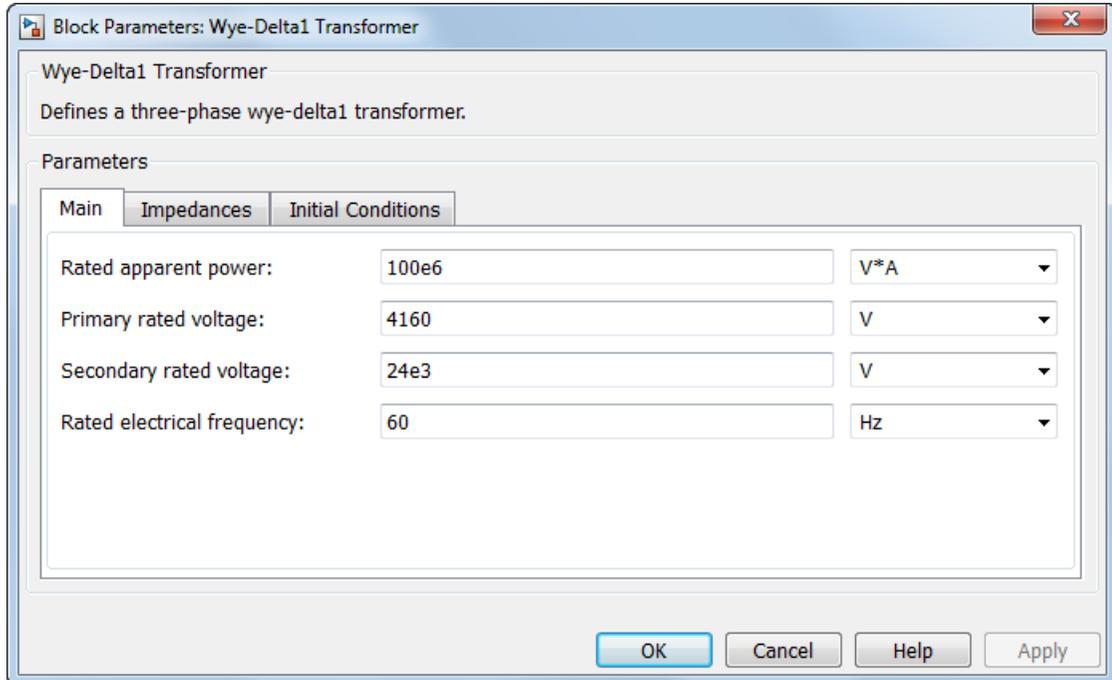
The figure shows the equivalent circuit diagram for the wye-delta1 transformer.



Wye-Delta 1 Transformer

- $w1_a$ is the primary winding connected between the a-phase and the primary neutral point.
- $w1_b$ is the primary winding connected between the b-phase and the primary neutral point.
- $w1_c$ is the primary winding connected between the c-phase and the primary neutral point.
- $w2_a$ is the secondary winding connected between the a-phase and the b-phase.
- $w2_b$ is the secondary winding connected between the b-phase and the c-phase.
- $w2_c$ is the secondary winding connected between the c-phase and the a-phase.

Dialog Box and Parameters



- “Main Tab” on page 1-301
- “Impedances Tab” on page 1-302
- “Initial Conditions Tab” on page 1-303

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Wye-Delta 1 Transformer

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Secondary rated voltage

RMS line voltage applied to the secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Secondary leakage resistance (pu)

Power loss in the secondary winding. The default value is 0.01.

Secondary leakage reactance (pu)

Magnetic flux loss in the secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial secondary currents

Current through the secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

~1

Expandable three-phase port for primary winding

~2

Expandable three-phase port for secondary winding

n1

Electrical conserving port associated with the primary winding neutral point

Related Examples

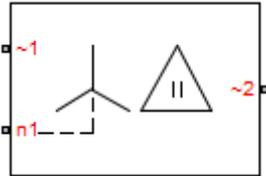
- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Delta11 Transformer

Purpose Linear non-ideal wye-delta11 transformer with three-limb core

Library Passive Devices / Transformers

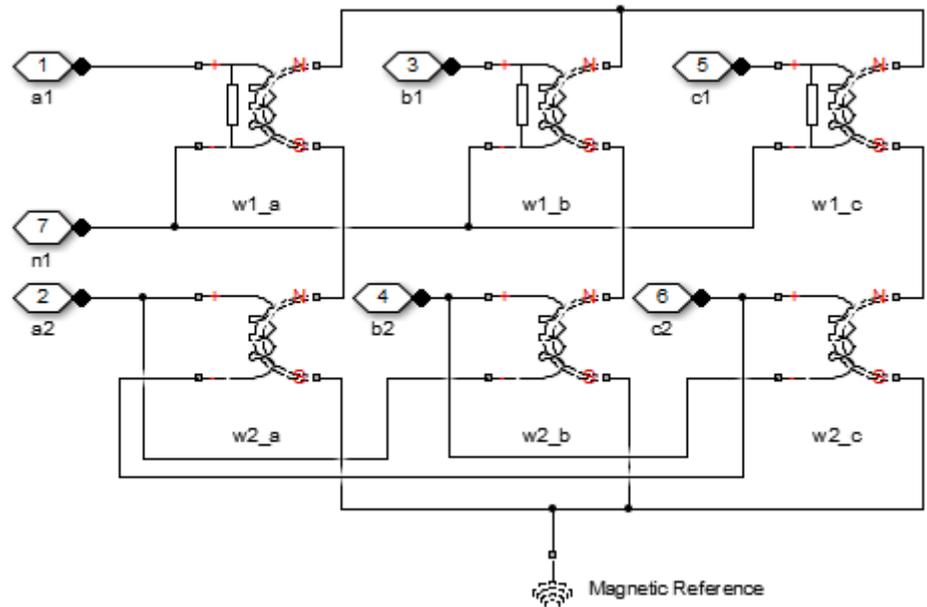
Description



The Wye-Delta11 Transformer block models a linear non-ideal transformer with a three-limb core, in which the primary windings are configured in a wye connection and the secondary windings are configured in a delta connection. The delta voltages lead the wye voltages by 30 degrees, hence the name 11 o'clock delta. It includes linear winding leakage and linear core magnetization effects.

The figure shows the equivalent circuit diagram for the wye-delta11 transformer.

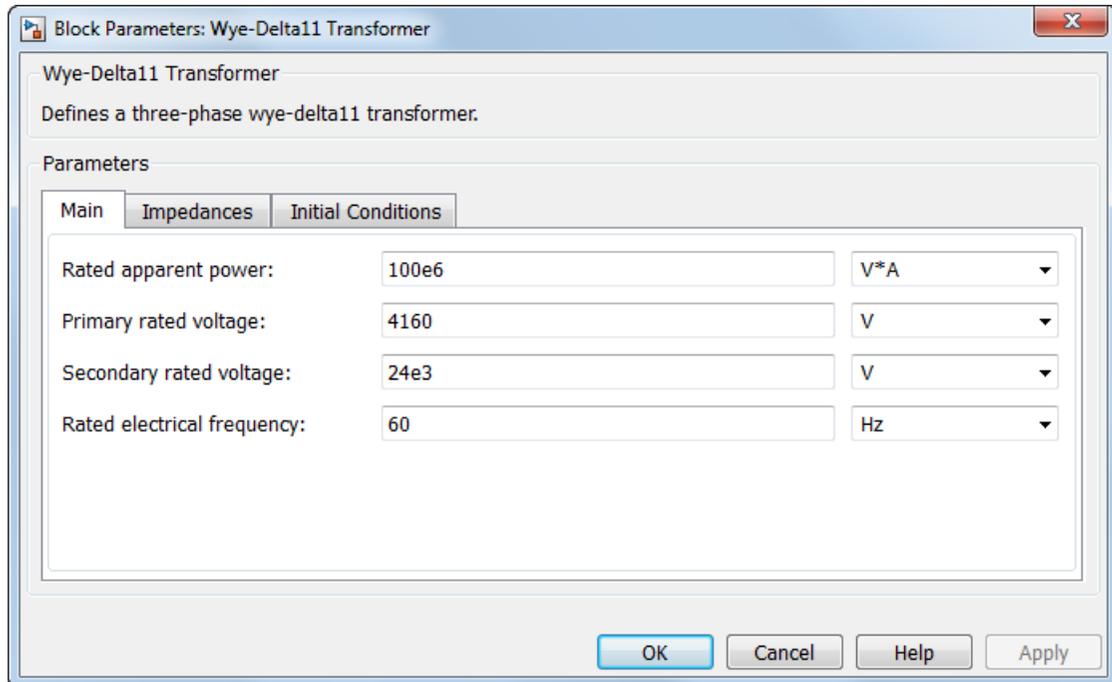
Wye-Delta 11 Transformer



- $w1_a$ is the primary winding connected between the a-phase and the primary neutral point.
- $w1_b$ is the primary winding connected between the b-phase and the primary neutral point.
- $w1_c$ is the primary winding connected between the c-phase and the primary neutral point.
- $w2_a$ is the secondary winding connected between the a-phase and the c-phase.
- $w2_b$ is the secondary winding connected between the b-phase and the a-phase.
- $w2_c$ is the secondary winding connected between the c-phase and the b-phase.

Wye-Delta11 Transformer

Dialog Box and Parameters



- “Main Tab” on page 1-306
- “Impedances Tab” on page 1-307
- “Initial Conditions Tab” on page 1-308

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Secondary rated voltage

RMS line voltage applied to the secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Secondary leakage resistance (pu)

Power loss in the secondary winding. The default value is 0.01.

Secondary leakage reactance (pu)

Magnetic flux loss in the secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Wye-Delta11 Transformer

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial secondary currents

Current through the secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

- ~1 Expandable three-phase port for primary winding
- ~2 Expandable three-phase port for secondary winding
- n1 Electrical conserving port associated with the primary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Delta1-Wye Transformer

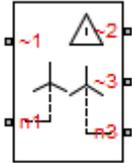
Purpose

Linear non-ideal wye-delta1-wye transformer with three-limb core

Library

Passive Devices / Transformers

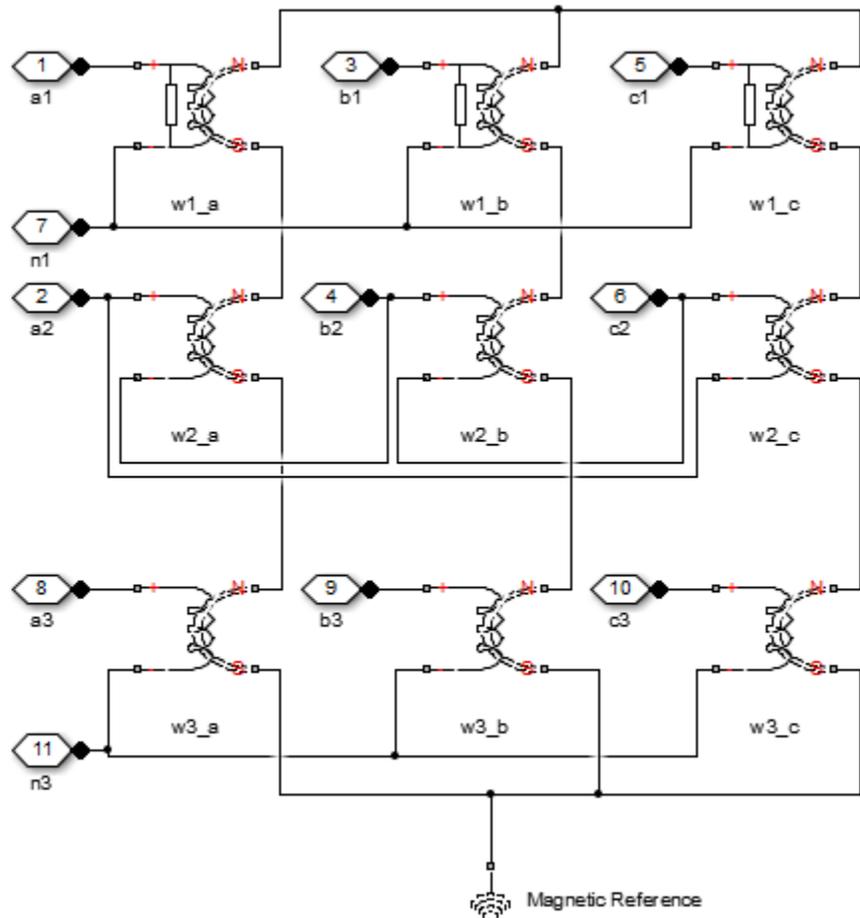
Description



The Wye-Delta1-Wye Transformer block models a linear non-ideal transformer with a three-limb core, in which the primary windings are configured in a wye connection, and there are delta secondary windings and wye secondary windings. The delta voltages lag the wye voltages by 30 degrees, hence the name 1 o'clock delta. It includes linear winding leakage and linear core magnetization effects.

The figure shows the equivalent circuit diagram for the wye-delta1-wye transformer.

Wye-Delta 1-Wye Transformer



- $w1_a$ is the primary winding connected between the a-phase and the primary neutral point.
- $w1_b$ is the primary winding connected between the b-phase and the primary neutral point.

Wye-Delta 1-Wye Transformer

- $w1_c$ is the primary winding connected between the c-phase and the primary neutral point.
- $w2_a$ is the secondary winding connected between the a-phase and the b-phase.
- $w2_b$ is the secondary winding connected between the b-phase and the c-phase.
- $w2_c$ is the secondary winding connected between the c-phase and the a-phase.
- $w3_a$ is the secondary winding connected between the a-phase and the secondary neutral point.
- $w3_b$ is the secondary winding connected between the b-phase and the secondary neutral point.
- $w3_c$ is the secondary winding connected between the c-phase and the secondary neutral point.

Wye-Delta1-Wye Transformer

Dialog Box and Parameters

Block Parameters: Wye-Delta1-Wye Transformer

Wye-Delta1-Wye Transformer
Defines a three-phase wye-delta1-wye transformer.

Parameters

Main Impedances Initial Conditions

Rated apparent power:	100e6	V*A
Primary rated voltage:	4160	V
Delta secondary rated voltage:	24e3	V
Wye secondary rated voltage:	24e3	V
Rated electrical frequency:	60	Hz

OK Cancel Help Apply

- “Main Tab” on page 1-313
- “Impedances Tab” on page 1-313
- “Initial Conditions Tab” on page 1-314

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Delta secondary rated voltage

RMS line voltage applied to the delta secondary winding under normal operating conditions. The default value is 24e3 V.

Wye secondary rated voltage

RMS line voltage applied to the wye secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Delta secondary leakage resistance (pu)

Power loss in the delta secondary winding. The default value is 0.01.

Delta secondary leakage reactance (pu)

Magnetic flux loss in the delta secondary winding. The default value is 0.001.

Wye-Delta 1-Wye Transformer

Wye secondary leakage resistance (pu)

Power loss in the wye secondary winding. The default value is 0.01.

Wye secondary leakage reactance (pu)

Magnetic flux loss in the wye secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial delta secondary currents

Current through the delta secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial wye secondary currents

Current through the wye secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

-1

Expandable three-phase port for primary winding

Wye-Delta 1-Wye Transformer

- 2 Expandable three-phase port for delta secondary winding
- 3 Expandable three-phase port for wye secondary winding
- n1 Electrical conserving port associated with the primary winding neutral point
- n3 Electrical conserving port associated with the wye secondary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

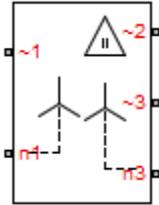
Wye-Delta 1 1-Wye Transformer

Purpose Linear non-ideal wye-delta 1 1-wye transformer with three-limb core

Library Passive Devices / Transformers

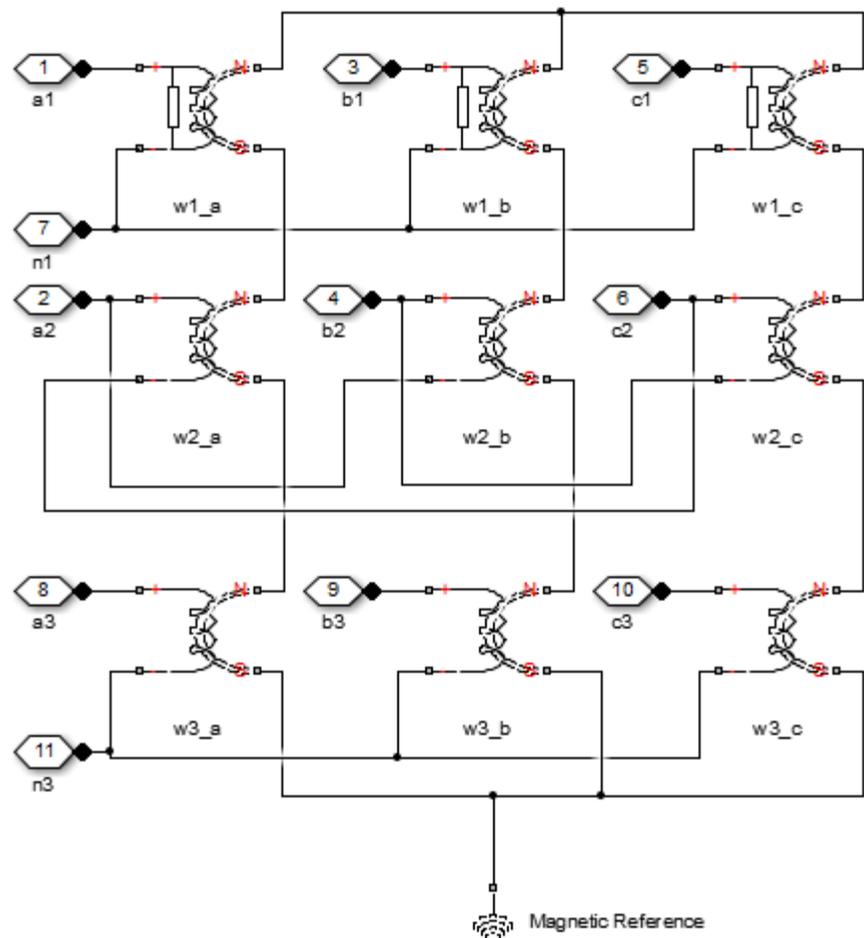
Wye-Delta11-Wye Transformer

Description



The Wye-Delta11-Wye Transformer block models a linear non-ideal transformer with a three-limb core, in which the primary windings are configured in a wye connection, and there are delta secondary windings and wye secondary windings. The delta voltages lead the wye voltages by 30 degrees, hence the name 11 o'clock delta. It includes linear winding leakage and linear core magnetization effects.

The figure shows the equivalent circuit diagram for the wye-delta11-wye transformer.



Wye-Delta 11-Wye Transformer

- $w1_a$ is the primary winding connected between the a-phase and the primary neutral point.
- $w1_b$ is the primary winding connected between the b-phase and the primary neutral point.
- $w1_c$ is the primary winding connected between the c-phase and the primary neutral point.
- $w2_a$ is the delta secondary winding connected between the a-phase and the c-phase.
- $w2_b$ is the delta secondary winding connected between the b-phase and the a-phase.
- $w2_c$ is the delta secondary winding connected between the c-phase and the b-phase.
- $w3_a$ is the wye secondary winding connected between the a-phase and the secondary neutral point.
- $w3_b$ is the wye secondary winding connected between the b-phase and the secondary neutral point.
- $w3_c$ is the wye secondary winding connected between the c-phase and the secondary neutral point.

Wye-Delta11-Wye Transformer

Dialog Box and Parameters

Block Parameters: Wye-Delta11-Wye Transformer

Wye-Delta11-Wye Transformer
Defines a three-phase wye-delta11-wye transformer.

Parameters

Main Impedances Initial Conditions

Rated apparent power:	100e6	V*A
Primary rated voltage:	4160	V
Delta secondary rated voltage:	24e3	V
Wye secondary rated voltage:	24e3	V
Rated electrical frequency:	60	Hz

OK Cancel Help Apply

- “Main Tab” on page 1-320
- “Impedances Tab” on page 1-320
- “Initial Conditions Tab” on page 1-321

Wye-Delta 11-Wye Transformer

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Delta secondary rated voltage

RMS line voltage applied to the delta secondary winding under normal operating conditions. The default value is 24e3 V.

Wye secondary rated voltage

RMS line voltage applied to the wye secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”.

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Delta secondary leakage resistance (pu)

Power loss in the delta secondary winding. The default value is 0.01.

Delta secondary leakage reactance (pu)

Magnetic flux loss in the delta secondary winding. The default value is 0.001.

Wye-Delta 11-Wye Transformer

Wye secondary leakage resistance (pu)

Power loss in the wye secondary winding. The default value is 0.01.

Wye secondary leakage reactance (pu)

Magnetic flux loss in the wye secondary winding. The default value is 0.001.

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial delta secondary currents

Current through the delta secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial wye secondary currents

Current through the wye secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

-1

Expandable three-phase port for primary winding

Wye-Delta 1 1-Wye Transformer

- 2 Expandable three-phase port for delta secondary winding
- 3 Expandable three-phase port for wye secondary winding
- n1 Electrical conserving port associated with the primary winding neutral point
- n3 Electrical conserving port associated with the wye secondary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Wye Transformer

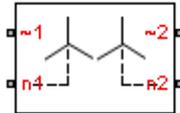
Purpose

Linear non-ideal wye-wye transformer with three-limb core

Library

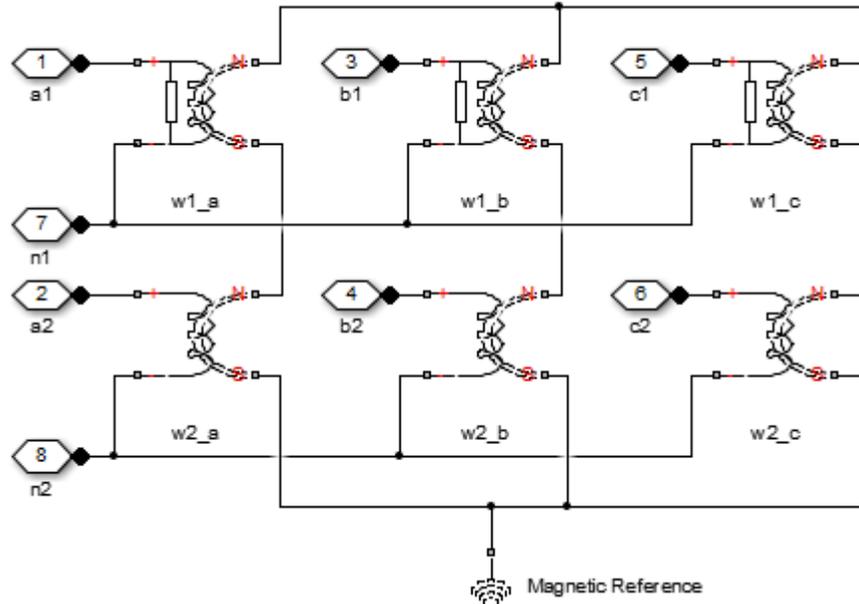
Passive Devices / Transformers

Description



The Wye-Wye Transformer block models a linear non-ideal transformer with a three-limb core, in which both the primary and the secondary windings are configured in a wye connection. It includes linear winding leakage and linear core magnetization effects.

The figure shows the equivalent circuit diagram for the wye-wye transformer.

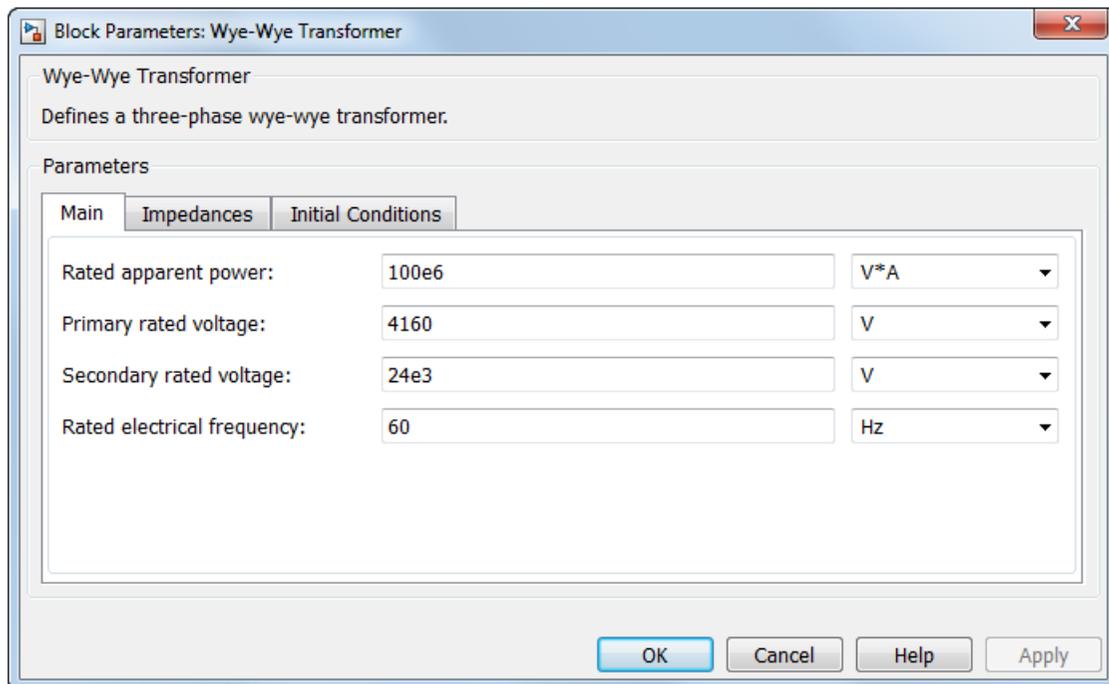


- $w1_a$ is the primary winding connected between the a-phase and the primary neutral point.
- $w1_b$ is the primary winding connected between the b-phase and the primary neutral point.

Wye-Wye Transformer

- $w1_c$ is the primary winding connected between the c-phase and the primary neutral point.
- $w2_a$ is the secondary winding connected between the a-phase and the secondary neutral point.
- $w2_b$ is the secondary winding connected between the b-phase and the secondary neutral point.
- $w2_c$ is the secondary winding connected between the c-phase and the secondary neutral point.

Dialog Box and Parameters



- “Main Tab” on page 1-325
- “Impedances Tab” on page 1-325
- “Initial Conditions Tab” on page 1-326

Main Tab

Rated apparent power

Apparent power flowing through the transformer when operating at rated capacity. The default value is 100e6 VA.

Primary rated voltage

RMS line voltage applied to the primary winding under normal operating conditions. The default value is 4160 V.

Secondary rated voltage

RMS line voltage applied to the secondary winding under normal operating conditions. The default value is 24e3 V.

Rated electrical frequency

Rated or nominal frequency of the AC network to which the transformer is connected. The default value is 60 Hz.

Impedances Tab

Parameters in this tab are expressed in per unit (pu). For more information, see “Per-Unit System of Units”

Primary leakage resistance (pu)

Power loss in the primary winding. The default value is 0.01.

Primary leakage reactance (pu)

Magnetic flux loss in the primary winding. The default value is 0.001.

Secondary leakage resistance (pu)

Power loss in the secondary winding. The default value is 0.01.

Secondary leakage reactance (pu)

Magnetic flux loss in the secondary winding. The default value is 0.001.

Wye-Wye Transformer

Shunt magnetizing resistance (pu)

Magnetic losses in transformer core. The default value is 500.

Shunt magnetizing reactance (pu)

Magnetic effects of the transformer core when operating in its linear region. The default value is 500.

Initial Conditions Tab

Initial primary currents

Current through the primary leakage inductors at time zero. The default value is [0 0 0] A.

Initial secondary currents

Current through the secondary leakage inductors at time zero. The default value is [0 0 0] A.

Initial magnetizing currents

Current through the shunt magnetization inductors at time zero. The default value is [0 0 0] A.

Initial fluxes

Magnetic fluxes in the limbs of the core at time zero. The default value is [0 0 0] Wb.

Ports

The block has the following ports:

- ~1 Expandable three-phase port for primary winding
- ~2 Expandable three-phase port for secondary winding
- n1 Electrical conserving port associated with the primary winding neutral point
- n2 Electrical conserving port associated with the secondary winding neutral point

Related Examples

- “Expand and Collapse Three-Phase Ports on a Block”

Wye-Wye Transformer

Functions — Alphabetical List

pe_calculateThdPercent

Purpose Compute the total harmonic distortion (THD) percentage

Syntax `[thdPercent] = pe_calculateThdPercent(harmonicOrder, harmonicMagnitude)`

Description `[thdPercent] = pe_calculateThdPercent(harmonicOrder, harmonicMagnitude)` calculates the total harmonic distortion (THD) percentage using these equations:

$$M = \frac{\text{harmonic magnitude}}{\sqrt{2}},$$

and

$$\%THD = 100 \frac{\sqrt{\sum_{i=2}^n M_i^2}}{M_1},$$

where:

- M_i is the root mean square (RMS) value of the harmonic magnitude corresponding to the i^{th} harmonic order.
- M is V_{RMS} or I_{RMS} as required.

You can use the `pe_getHarmonics` function to obtain the vectors of harmonic order and harmonic magnitude for a `simscape.logging.Node`.

Input Arguments

harmonicOrder - Harmonic orders

vector

Harmonic orders from 0 up to and including number of harmonics, specified as a vector.

Example: `[1;5;7;11;13]`

Data Types

`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

harmonicMagnitude - Harmonic magnitudes

vector

Harmonic magnitudes from the 0th harmonic up to and including the number of harmonics included in the analysis, specified as a vector.

Example:

```
[1.1756e+03;0.0437e+03;0.0221e+03;0.0173e+03;0.0127e+03]
```

Data Types

```
single | double | int8 | int16 | int32 | int64 | uint8 |  
uint16 | uint32 | uint64
```

Examples

Calculate THD percent

Calculate the THD from harmonic orders

[1;5;7;11;13] and harmonic magnitudes

[1.1756e+03;0.0437e+03;0.0221e+03;0.0173e+03;0.0127e+03].

```
harmonicOrder = [1;5;7;11;13];
```

```
harmonicMagnitude = [1.1756e+03;0.0437e+03;0.0221e+03;0.0173e+03;0.0127e+03];
```

```
thdPercent = pe_calculateThdPercent( harmonicOrder, harmonicMagnitude )
```

```
thdPercent =
```

```
4.5480
```

See Also

[pe_getHarmonics](#) | [pe_plotHarmonics](#)

Related Examples

- [Harmonic Analysis of a Three-Phase Rectifier](#)

pe_getHarmonics

Purpose Return harmonic orders, magnitudes, and fundamental frequency

Syntax

```
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] = pe_getHarmonics(loggingNode)  
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] =  
pe_getHarmonics(loggingNode,valueIdx)  
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] = pe_getHarmonics(loggingNode,valueIdx,  
    tOfInterest)  
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] = pe_getHarmonics(loggingNode,valueIdx,  
    tOfInterest,nPeriodOfInterest)  
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] = pe_getHarmonics(loggingNode,valueIdx,  
    tOfInterest,nPeriodOfInterest,offsetOfInterest)  
[harmonicOrder,harmonicMagnitude,  
    fundamentalFrequency] = pe_getHarmonics(loggingNode,valueIdx,  
    tOfInterest,nPeriodOfInterest,offsetOfInterest,nHarmonic)
```

Description [harmonicOrder,harmonicMagnitude, fundamentalFrequency] = pe_getHarmonics(loggingNode) calculates the harmonic orders, magnitudes, and fundamental frequency of a simscape.logging.Node of an AC or periodic variable.

The function finds the points in the i^{th} signal (valueIdx) where the Simscape log crosses a threshold (offsetOfInterest). It uses the crossing points to find the required number of periods (nPeriodOfInterest) preceding the specified time (tOfInterest). Then it inputs the down-selected data to the Goertzel algorithm, which calculates the harmonic magnitudes up to and including the required number of harmonics (nHarmonic).

Note This function uses threshold crossing points to determine the fundamental frequency of the data. If your input data is noisy or crosses the threshold more frequently than half of the fundamental period, filter it before you use this function to analyze it.

You enter the input arguments in a specific order. The Simscape logging node input argument is required. All other input arguments are optional and have default values. You enter [] to use the default value for an optional input argument if you are going to specify a value for a subsequent optional input argument.

You can use the `pe_plotHarmonics` function to obtain a bar chart from the same input arguments. You can use the outputs of this function as inputs to the `pe_calculateThdPercent` function to calculate the total harmonic distortion (THD) percentage.

[harmonicOrder,harmonicMagnitude, fundamentalFrequency] = `pe_getHarmonics`(loggingNode,valueIdx) uses the index into value data.

[harmonicOrder,harmonicMagnitude, fundamentalFrequency] = `pe_getHarmonics`(loggingNode,valueIdx, tOfInterest) uses the simulation time.

[harmonicOrder,harmonicMagnitude, fundamentalFrequency] = `pe_getHarmonics`(loggingNode,valueIdx, tOfInterest,nPeriodOfInterest) uses the number of periods of fundamental frequency.

[harmonicOrder,harmonicMagnitude, fundamentalFrequency] = `pe_getHarmonics`(loggingNode,valueIdx, tOfInterest,nPeriodOfInterest,offsetOfInterest) uses the DC offset.

[harmonicOrder,harmonicMagnitude, fundamentalFrequency] = `pe_getHarmonics`(loggingNode,valueIdx, tOfInterest,nPeriodOfInterest,offsetOfInterest,nHarmonic) uses the number of harmonics.

Input Arguments

loggingNode - Simscape logging node

1-by-1 `simscape.logging.Node`

Simscape logging node, specified as a 1-by-1 `simscape.logging.Node`. You create a `simscape.logging.Node` by running a simulation with Simscape logging enabled. See “How to Log Simulation Data” to learn how to enable data logging.

Example: `simlog.Load.V`

The Simscape logging node `simlog.Load.V` contains data from a three-phase voltage.

valueIdx - Index into value data

1 (default) | scalar

Index into value data, specified as a scalar. Specifies the i^{th} variable of interest in the Simscape log.

Example: 2

Specify the b-phase, which is the second signal from a three-phase voltage.

Example: []

Use [] to specify the default value of 1. The a-phase, which is the first signal from a three-phase voltage, is the default signal of interest.

Data Types

`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

tOfInterest - Simulation time

final time in Simscape log (default) | scalar

Simulation time of interest for harmonic analysis, specified as a scalar.

Example: 2.3

Specify a 2.3s simulation time.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

nPeriodOfInterest - Number of periods

12 (default) | scalar

Number of periods of fundamental frequency to be included in harmonic analysis, specified as a scalar.

Example: 10

Specify 10 periods of the signal.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

offsetOfInterest - DC offset

0 (default) | scalar

DC offset in the input signal, specified as a scalar. The function uses this value to find the periods of interest.

Example: 1

Specify a bias of 1V for the signal.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

nHarmonic - Number of harmonics

30 (default) | scalar

Number of harmonics to include in analysis, specified as a scalar.

Example: 15

Specify that the number of harmonics to be analyzed is 15.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

Output Arguments

harmonicOrder - Harmonic order

vector

Harmonic orders from 0 up to and including the number of harmonics used in the analysis, returned as a vector.

harmonicMagnitude - Harmonic magnitude

vector

Harmonic magnitudes from the 0th harmonic up to and including the number of harmonics used in the analysis, returned as a vector.

fundamentalFrequency - Fundamental frequency

scalar

Fundamental frequency over the range of the down-selected input data, returned as a scalar.

Examples

Analyze using default values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the default signal, which is the first, or a-phase, signal at the final simulation time. The function will use the default values of 12 for the number of periods of the signal, 0V for the signal bias, and 30 for the number of harmonics.

```
pe_getHarmonics(simlog.Load.V)
```

Analyze using specified values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the second, or b-phase, signal at a simulation time of 2.3s. The function will use 10 periods of the signal, which has a bias of 1V. The function will analyze 15 harmonics.

```
pe_getHarmonics(simlog.Load.V,2,2.3,10,1,15)
```

Analyze using default and specified values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the first, or a-phase, signal at a simulation time of 2.3s. The function will use 12 periods of the signal, which has a bias of 1V. The function will analyze the default number, 30, of harmonics.

```
pe_getHarmonics(simlog.Load.V,[],2.3,[],1)
```

See Also

[pe_calculateThdPercent](#) | [pe_plotHarmonics](#) | [simscape.logging.Node](#)

Related Examples

- Harmonic Analysis of a Three-Phase Rectifier
- “Log and Plot Simulation Data”

pe_plotHarmonics

Purpose

Plot percentage of fundamental magnitude versus harmonic order

Syntax

```
pe_plotHarmonics(loggingNode)
pe_plotHarmonics(loggingNode,valueIdx)
pe_plotHarmonics(loggingNode,valueIdx,tOfInterest)
pe_plotHarmonics(loggingNode,valueIdx,tOfInterest,nPeriodOfInterest)
pe_plotHarmonics(loggingNode,valueIdx,tOfInterest,nPeriodOfInterest,
    offsetOfInterest)
pe_plotHarmonics(loggingNode,valueIdx,tOfInterest,nPeriodOfInterest,
    offsetOfInterest,nHarmonic)
```

Description

`pe_plotHarmonics(loggingNode)` plots a bar chart of percentage of fundamental magnitude versus harmonic order of the `simscape.logging.Node` of an AC or periodic variable. The title of the bar chart includes the fundamental frequency, fundamental peak value, and total harmonic distortion (THD) percentage.

You enter the input arguments in a specific order. The Simscape logging node input argument is required. All other input arguments are optional and have default values. You enter `[]` to use the default value for an optional input argument if you are going to specify a value for a subsequent optional input argument.

The `pe_plotHarmonics` function uses the `pe_getHarmonics` function to:

- Find the points in the i^{th} signal (`valueIdx`) where the Simscape log crosses a threshold (`offsetOfInterest`).
- Use the crossing points to find the required number of periods (`nPeriodOfInterest`) preceding the specified time (`tOfInterest`).
- Calculate the harmonic magnitudes, up to and including the required number of harmonics (`nHarmonic`).
- Input the down-selected data to the Goertzel algorithm, which calculates the harmonic magnitudes up to and including the required number of harmonics (`nHarmonic`).

Note The `pe_getHarmonics` function uses threshold crossing points to determine the fundamental frequency of the data. If your input data is noisy or crosses the threshold more frequently than half of the fundamental period, filter it before you use the `pe_plotHarmonics` function to plot it.

The `pe_plotHarmonics` function then inputs the harmonic orders and harmonic magnitudes to the `pe_calculateThdPercent` function to calculate the THD.

`pe_plotHarmonics(loggingNode, valueIdx)` uses the index into value data.

`pe_plotHarmonics(loggingNode, valueIdx, tOfInterest)` uses the simulation time.

`pe_plotHarmonics(loggingNode, valueIdx, tOfInterest, nPeriodOfInterest)` uses the number of periods of fundamental frequency.

`pe_plotHarmonics(loggingNode, valueIdx, tOfInterest, nPeriodOfInterest, offsetOfInterest)` uses the DC offset.

`pe_plotHarmonics(loggingNode, valueIdx, tOfInterest, nPeriodOfInterest, offsetOfInterest, nHarmonic)` uses the number of harmonics.

Input Arguments

loggingNode - Simscape logging node

1-by-1 `simscape.logging.Node`

Simscape logging node, specified as a 1-by-1 `simscape.logging.Node`. You create a `simscape.logging.Node` by running a simulation with Simscape logging enabled. See “How to Log Simulation Data” to learn how to enable data logging,

Example: `simlog.Load.V`

The Simscape logging node `simlog.Load.V` contains data from a three-phase voltage.

valueIdx - Index into value data

pe_plotHarmonics

1 (default) | scalar

Index into value data, specified as a scalar. Specifies the i^{th} variable of interest in the Simscape log.

Example: 2

Specify the b-phase, which is the second signal from a three-phase voltage.

Example: []

Use [] to specify the default value of 1. The a-phase, which is the first signal from a three-phase voltage, is the default signal of interest.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

tOfInterest - Simulation time

final time in Simscape log (default) | scalar

Simulation time of interest for harmonic analysis, specified as a scalar.

Example: 2.3

Specify a 2.3s simulation time.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

nPeriodOfInterest - Number of periods

12 (default) | scalar

Number of periods of fundamental frequency to be included in harmonic analysis, specified as a scalar.

Example: 10

Specify 10 periods of the signal.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

offsetOfInterest - DC offset

0 (default) | scalar

DC offset in the input signal, specified as a scalar. The function uses this value to find the periods of interest.

Example: 1

Specify a bias of 1V for the signal.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

nHarmonic - Number of harmonics

30 (default) | scalar

Number of harmonics to include in analysis, specified as a scalar.

Example: 15

Specify that the number of harmonics to be analyzed is 15.

Data Types

single | double | int8 | int16 | int32 | int64 | uint8 |
uint16 | uint32 | uint64

Examples

Plot using default values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the default signal, which is the first, or a-phase, signal at the final simulation time. The function will use the default values of 12 for the number of periods of the signal, 0V for the signal bias, and 30 for the number of harmonics.

```
pe_plotHarmonics(simlog.Load.V)
```

Plot using specified values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the second, or b-phase, signal at a simulation time of 2.3s. The function will use 10 periods of the signal, which has a bias of 1V. The function will analyze 15 harmonics.

```
pe_plotHarmonics(simlog.Load.V,2,2.3,10,1,15)
```

Plot using default and specified values

This set of function arguments uses the Simscape logging node `simlog.Load.V`, which contains data from a three-phase voltage. The function will analyze the first, or a-phase, signal at a simulation time of 2.3s. The function will use the default number (12) of periods of the signal, which has a bias of 1V. The function will analyze the default number (30) of harmonics.

```
pe_plotHarmonics(simlog.Load.V,[],2.3,[],1)
```

See Also

[pe_calculateThdPercent](#) | [pe_getHarmonics](#) | [simlog.LoggingNode](#)

Related Examples

- [Harmonic Analysis of a Three-Phase Rectifier](#)
- [“Log and Plot Simulation Data”](#)

B

Susceptance.

C

Capacitance.

composite three-phase port

Three-phase electrical conserving port, i.e., a port that represents three electrical conserving ports with a single connection. You can use composite three-phase ports to build models corresponding to single-line diagrams of three-phase electrical systems. Instead of explicitly connecting each phase of the three-phase system between blocks, you connect all three phases using a single port.

delta connection

Three-phase winding configuration. Each of the three windings is connected between phases. Physically, the connection resembles the Greek capital letter Δ . For a delta connection, phase shifts can be specified in terms of the hours of a clock. An 11 o'clock delta connection represents a 30 degree phase advance. A 1 o'clock delta connection represents a 30 degree phase delay.

expanded three-phase port

Three separate electrical conserving ports that represent the individual phases of a three-phase system. You individually connect each phase of the three-phase system between blocks.

F_{Rated}

Rated electrical frequency of three-phase machine.

G

Conductance.

i

Instantaneous current.

I

RMS current.

L

Inductance.

line voltage

RMS value of the voltage measured between phases. In a balanced three-phase system with no harmonics, peak line voltage equals peak phase voltage multiplied by $\sqrt{3}$. The RMS value equals peak line voltage divided by $\sqrt{2}$. Standard abbreviations are V_{ab} , V_{ac} , V_{bc} , etc. Line voltage is also known as rated voltage, rated RMS, name plate voltage, line-line voltage, and phase-phase voltage.

nPolePairs

Number of pole pairs for three-phase machine.

phase voltage

RMS value of the voltage measured between a phase and reference point. The reference point is usually a neutral or ground point. In a balanced three-phase system with no harmonics, peak phase voltage is equal to peak line voltage divided by $\sqrt{3}$. The RMS value equals peak phase voltage divided by $\sqrt{2}$. Standard abbreviations are V_a , V_b , and V_c .

P_{PerPhase}

Real power per phase.

psi

Instantaneous peak magnetic flux linkage.

Psi

RMS magnetic flux linkage.

Q_{PerPhase}

Reactive power per phase.

R

Resistance.

S_{Rated} Rated apparent power.

S_{PerPhase} Apparent power per phase.

torque Torque of three-phase machine.

v Instantaneous voltage.

V RMS voltage.

Va, Vb, Vc Phase voltages.

Vab, Vac, Vbc,... Line voltages.

V_{Rated} Rated voltage of three-phase machine.

Electrical Electrical angular speed of three-phase machine.

Mechanical Mechanical angular speed of three-phase machine.

winding voltage Voltage measured between both ends of a winding. For a wye connection, winding voltage equals phase voltage. For a delta connection, winding voltage equals line voltage.

wye connection Three-phase winding configuration. Each of the three windings is connected between a phase and neutral point. Physically, the connection resembles the letter Y. A wye connection is also referred to as a star connection, or Y connection.

X

Reactance.

Y

Admittance.

z

Impedance.