Ansys

2025/R2

POWERING INNOVATION THAT DRIVES HUMAN ADVANCEMENT

Twin Builder® Components: Power System

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1 - Power System Library

This library includes components commonly used in power system design and simulations. In these models, parasitics are neglected, and the used power semiconductor models display static behavior (their v-i characteristic is calculated by an equivalent line).

Components in Power System library can be divided into the following categories:

- Power Distribution
- Power Load
- Power Source
- Power Storage

Power Distribution

Power Distribution components are divided into the following categories:

- Cable
- Connector
- Fuse
- Power Conversion
- Relay
- Wire

Cables

- EP Line Model - Single Phase (EPLine1)
- Three-Phase Line Model (EPLine3)
- EPLine - Coaxial cable with isolated Shield (EPLineCx)

EP Line Model – Single-Phase

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

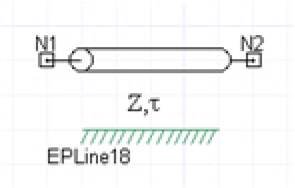

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
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- Example
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Description

The Single-Phase EP Line model represents a perfectly-transposed overhead line with distributed inductance and capacitance parameters. It can be used to represent some underground cables. Losses are included with constant series resistances. The model is more efficient, more accurate, and more convenient to use than a cascade of RLC sections. The main application is for electric power transmission and distribution lines.

Input parameters include surge impedance, series resistance per unit length, traveling wave velocity, and line length. The line travel time is length/velocity, and transients entering one end do not appear at the other end until that travel time has elapsed. There are no internal nodes created in the model to represent cascaded RLC pi sections, which limits the component count and simulated system size. This also prevents artificial oscillations within RLC pi sections.

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Assumptions and Limitations

- Parameters are not frequency-dependent.
- Earth return is assumed.

- Very lossy lines, in which the total series resistance approaches the magnitude of the line surge impedance, should be represented in segments.

Line models limit the maximum simulation time step to the travel time of the line regardless of the input simulation parameters. For a 10 km overhead line, this would be approximately 33.3 us. The maximum time step can be estimated from the shortest line length divided by the speed of light. If the maximum time step becomes too short for the application, this indicates that the line should be modeled with series RL components, ignoring the shunt capacitance.

The single-phase line model exposes two conservative nodes, N1 and N2. The voltage references are from N1 and N2 to ground. The current reference arrows enter the line at each end. For example, if N1 is considered the source end, then the current entering node N1 (I1) may be considered the source current. Then the current at N2 (I2) has the opposite polarity to the load current.

Parameterization

For a single-phase overhead line, Z typically ranges from 300 to 500. The velocity, V, would be 95% to 100% of the speed of light, which is 3e8 m/s. For an underground cable, Z typically ranges from 15 to 60 ohms, and V could be from 20% to 50% of the speed of light. The conductor resistance is often given in ohms/km, ohms/mile, or ohms/1000 feet. This line model, adopted ohms/meter as the resistance unit.

R times L should be less than or equal to 10% of Z; likewise for the line and ground modes in the three-phase model. If not, the line should be segmented.

During iterations at a given time step, the model presents a constant current source and a constant resistance matrix to the external system. There are no nonlinear effects in the model. However, the model may reduce the time step when a high-frequency transient arrives at the far end of the line.

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Mathematical Description

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Netlist Syntax

UMODEL EPLine1 ?InstanceName(@InstanceName):(@(Refbase)@(ID)) N1:= %0, N2:= %1 (Z:= @Z, R:= @R, V:= @V, L:= @L, U0:= @U0) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
N1	Node 1	electrical
N2	Node 2	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
Z	Characteristic Impedance	real	0.4 [Ohm]
R	Series Resistance	real	0 [Ohm/m]
V	Wave Velocity	real	0.3G [Ohm/m]
L	Line length	real	10k [m]
U0	Initial Voltage	real	0 [V]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
I1	Node Current 1 [A]	Output	real
V1	Node Voltage 1 [V]	Output	real
I2	Node Current 2 [A]	Output	real
V2	Node Voltage 2 [V]	Output	real

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Example

This example illustrates basic traveling wave behaviors. The voltage drop across the line segments and reflection effects can be observed. A cascade of 3 EP Line models are used. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

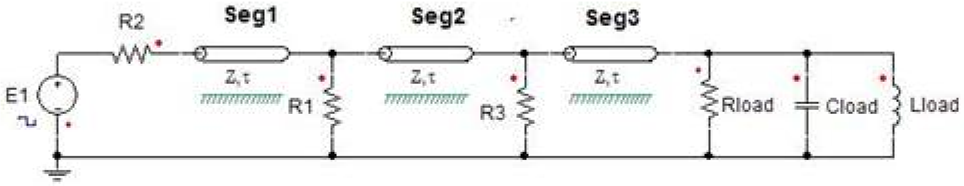

Figure 2. Application example of the Single-Phase EP Line model

Table 4. System Parameters

Component	Parameter	Value [unit]
Voltage Source (Pulse) E1	Amplitude	10k [V]
	Frequency	50 [Hz]
	Delay	1m [s]
	Phase	0 [degree]
	Offset	0 [V]
Resistor R1	R	Rshunt
Resistor R2	R	20 [Ohm]
Resistor R3	R	Rshunt
EP Line – Single Phase Seg1	Z	Zline
	R	0 [Ohm/m]
	V	0.3G [Ohm/m]
	L	300k [m]
	U0	0 [V]
EP Line – Single Phase Seg2	Z	Zline
	R	0 [Ohm/m]
	V	0.3G [Ohm/m]
	L	300k [m]
	U0	0 [V]
EP Line – Single Phase Seg3	Z	Zline
	R	0 [Ohm/m]
	V	0.3G [Ohm/m]
	L	300k [m]
	U0	0 [V]
Resistor R2	R	20 [Ohm]
Resistor Rload	R	400 [Ohm]
Inductor Lload	L	200m [H]
	i0	0 [A]
Capacitor Cload	C	0.1u [F]
	U0	0 [V]
Initial Values FML_INIT1		Zline:=400
		Rshunt:=1k

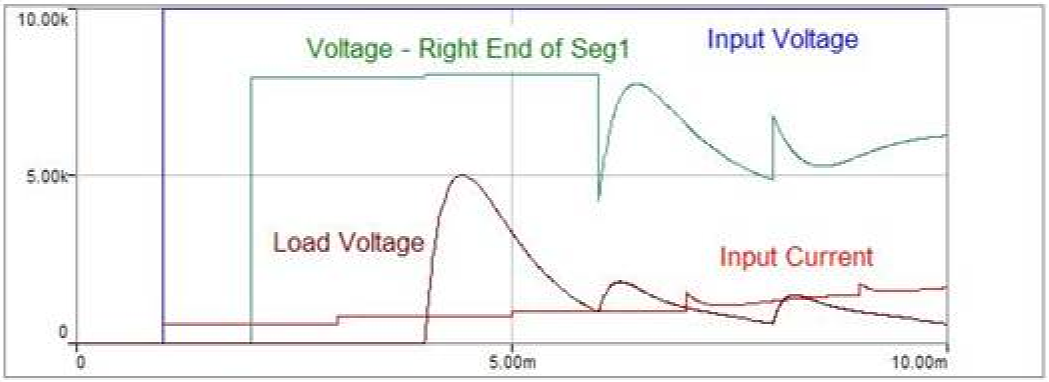

Figure 3. Simulation results

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References

[1] H.W. Dommel and W. S. Meyer: *Computation of Electromagnetic Transients*, Proc. IEEE, vol. 62, pp. 983-993, July 1974.

[2] Electromagnetic Transients Program Reference Manual (EMTP Theory Book), Bonneville Power Administration, August 1986.

EP Line Model – Three-Phase

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

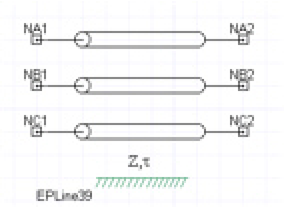

Figure 1. Component symbol

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Description

The three-phase EP Line model represents a perfectly-transposed overhead line with distributed inductance and capacitance parameters. Losses are included with constant series resistances. This model is more efficient, more accurate, and more convenient to use than a cascade of RLC sections. The main application is for electric power transmission and distribution lines.

Input parameters include surge impedance, series resistance per unit length, traveling wave velocity, and line length. In the three-phase model, the surge impedance, resistance, and wave velocity are input separately for the ground mode (zero sequence) and the line mode (positive sequence). The line travel time is length/velocity, and transients entering one end do not appear at the other end until that travel time has elapsed. There are no internal nodes created in the model to represent cascaded RLC pi sections, which limits the component count and simulated system size and also prevents artificial oscillations within RLC pi sections.

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Assumptions and Limitations

- Parameters are not frequency-dependent.
- The three-phase model is perfectly transposed.

- Earth return is assumed.

- Very lossy lines, in which the total series resistance approaches the magnitude of the line surge impedance, should be represented in segments.

Furthermore, the use of line models limits the maximum simulation time step to the travel time of the line regardless of the input simulation parameters. For a 10 km overhead line, this would be approximately 33.3 us. The maximum time step can be estimated from the shortest line length divided by the speed of light. If the maximum time step becomes too short for the application, this indicates that the line should be modeled with series RL components, ignoring the shunt capacitance.

The three-phase line model exposes six conservative nodes. At one end, the three-phase nodes are NA1, NB1, and NC1. At the other end, the three-phase nodes are NA2, NB2, and NC2. Voltage and current references are similar to the single-phase model; that is, positive currents enter each node, and the voltages are with respect to ground. Each model decouples the source-end network from the load-end network. The source-end and load-end networks each require a path to ground.

There should be no direct lumped branch connections between ends of the line (for example, between NA1 and NA2 in the three-phase case). While the simulation could run this way, a different modeling approach is required. The first option would be to replace the line with lumped components. The second option would be to include another distributed-parameter line model in the parallel path connecting NA1 and NA2.

The series resistance, if present, is distributed at each end of the line (R/4) and in the middle (R/2). To accomplish this, the traveling wave equations are modified, rather than creating internal nodes.

For three-phase lines, a modal transformation matrix, similar to the αβ□transformation matrix, interfaces the three-phase nodes to the wave propagation modes. Internally, the model includes one single-phase line to represent the ground mode and two more identical single-phase lines to represent the line modes.

Parameterization

For a three-phase overhead line, the line-mode Z typically ranges from 250 to 450. The lower values in this range would be for higher-voltage lines, particularly those with bundled sub-conductors. The line-mode velocity would be 95% to 100% of the speed of light. The ground-mode Z should be higher than the line-mode Z, and it typically ranges from 600 to 1100 ohms. The lower values in this range correspond to the higher-voltage lines. The ground-mode velocity is typically two-thirds the speed of light. The conductor resistance may be used for the line-mode resistance. On the other hand, the ground-mode resistance includes the effects of earth return, and it may be several times higher than the line-mode resistance.

Sometimes for a three-phase line, the available data will include the following:

- Positive-sequence resistance

- Positive-sequence reactance

- Zero-sequence resistance

- Zero-sequence reactance
- Length of the line

To use this data, do the following:

1. First convert the line length to meters.
2. Then divide the zero-sequence resistance by length and the positive-sequence resistance by length for input as R0 and R1, respectively. Assume that V0 is 2e8 and V1 is 3e8. The values of Z0 and Z1 may then be obtained from the sequence reactances.

The surge impedance, velocity, series inductance per unit length, and shunt capacitance per unit length are all related as follows:

$$Z = \sqrt{\frac{L'}{C'}} \qquad V = \frac{1}{\sqrt{L' \cdot C'}}$$

In this case, V is assumed from typical values and L' is obtained from the sequence reactance:

$$L' = \frac{X}{2\pi f d} \qquad Z = L' \cdot V$$

where X is the zero-sequence or positive-sequence reactance in ohms, f is the nominal frequency in Hz, and d is the line length in meters. V is either 2e8 or 3e8. X is often given in ohms per km or ohms per mile, in which case d becomes 1000 or 1609, respectively.

During Jacobi matrix iterations at a given time step, the model presents a constant current source and constant resistance matrix to the external system. There are no nonlinear effects in the model. However, the model may reduce the time step when a high-frequency transient arrives at the far end of the line.

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Mathematical Description

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Netlist Syntax

UMODEL EPLine3 ?InstanceName(@InstanceName):(@(Refbase)@(ID)) NA1:= %0, NB1:= %1, NC1:= %2, NA2:= %3, NB2:= %4, NC2:= %5 (Z0:= @Z0, R0:= @R0, V0:= @V0, Z1:= @Z1, R1:= @R1, V1:= @V1, L:= @L, U0A:= @U0A, U0B:= @U0B, U0C:= @U0C) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
NA1/NB1/NC1	Bus 1 Phase A/B/C	electrical
NA2/NB1/NC2	Bus 2 Phase A/B/C	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
Z0	Ground-Mode Characteristic Impedance	real	0.65k [Ohm]
R0	Ground-Mode Series Resistance	real	0 [Ohm/m]
V0	Ground-Mode Wave Velocity	real	0.2G [V]
Z1	Line-Mode Characteristic Impedance	real	0.3k [Ohm]
R1	Line-Mode Series Resistance	real	0 [Ohm]
V1	Line-Mode Wave Velocity	real	0.3G [m/s]
L	Line Length	real	10k [m]
U0A	Initial Voltage Phase A	real	0 [V]
U0B	Initial Voltage Phase B	real	0 [V]
U0C	Initial Voltage Phase C	real	0 [V]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Nature/Data Type
IA1/IB1/IC1	Phase A/B/C Current Bus 1 [A]	Output	real
VA1/VB1/VC1	Phase A/B/C Voltage Bus 1 [V]	Output	real
IA2/IB2/IC2	Phase A/B/C Current Bus 2 [A]	Output	real
VA2/VB2/VC2	Phase A/B/C Voltage Bus 2 [V]	Output	real

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Example

In this example, a three-phase switch is closed after an assumed fault. Since there is a charge left on the line, the initial voltages are set to non-zero values. After the switches are closed, over-voltages due to oscillations occur. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

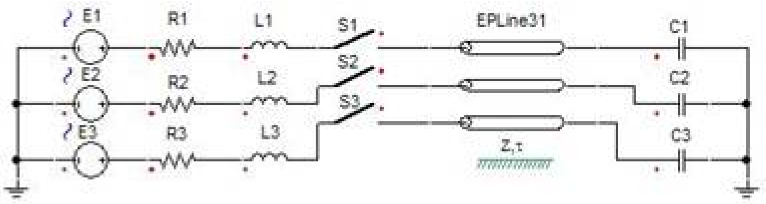

Figure 2. Application example of the Single-Phase EP Line model

Table 4. System Parameters

Component	Parameter	Value [unit]
Voltage Source (Sine) E1	Amplitude	1k [V]
	Frequency	50 [Hz]
	Delay	0 [s]
	Phase	0 [degree]
	Offset	0 [V]
Voltage Source (Sine) E2	Amplitude	1k [V]
	Frequency	50 [Hz]
	Delay	0 [s]
	Phase	120 [degree]
	Offset	0 [V]
Voltage Source (Sine) E3	Amplitude	1k [V]
	Frequency	50 [Hz]
	Delay	0 [s]
	Phase	240 [degree]
	Offset	0 [V]
Resistor R1	R	1 [Ohm]
Resistor R2	R	1 [Ohm]
Resistor R3	R	1 [Ohm]
Inductor L1	L	26.52m [H]
	i0	0 [A]

Inductor L2	L	26.52m [H]
	i0	0 [A]
Inductor L3	L	26.52m [H]
	i0	0 [A]
EP Line – Three Phase EPLine31	Z0	Zline
	R0	0.65k [Ohm]
	V0	0 [Ohm/m]
	Z1	0.2G [V]
	R1	0.3k [Ohm]
	V1	0 [Ohm]
	L	0.3G [m/s]
	U0A	1k [m]
	U0B	-0.5k [V]
	U0C	-0.8k [V]
Capacitor C1	C	1n [F]
	v0	1k [V]
Capacitor Cload	C	1n [F]
	U0	-0.5k [V]
Capacitor C1	C	1n [F]
	v0	-0.8k [V]

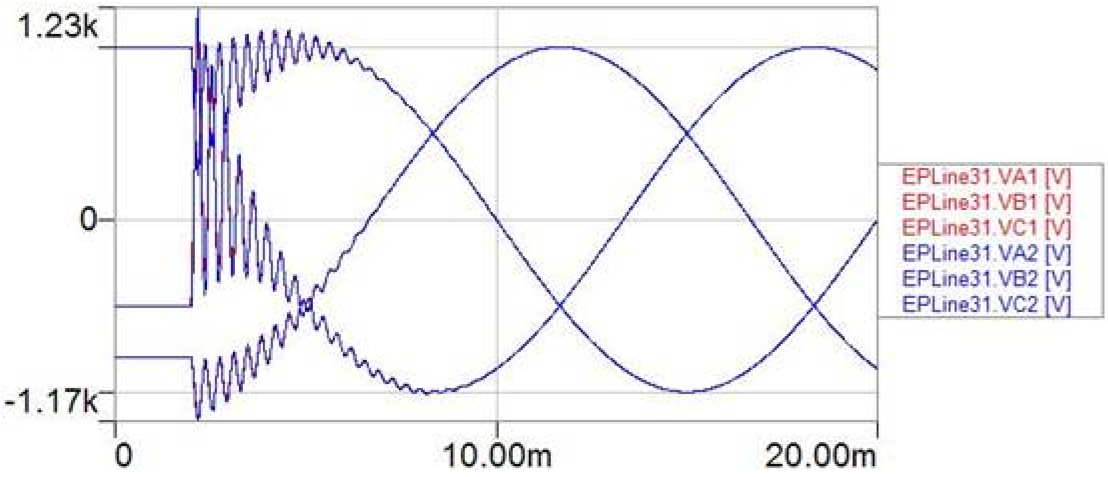

Figure 3. Simulation results

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References

[1] H.W. Dommel and W. S. Meyer: *Computation of Electromagnetic Transients*, Proc. IEEE, vol. 62, pp. 983-993, July 1974.

[2] Electromagnetic Transients Program Reference Manual (EMTP Theory Book), Bonneville Power Administration, August 1986.

EP Line – Coaxial Cable with Isolated Shield

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

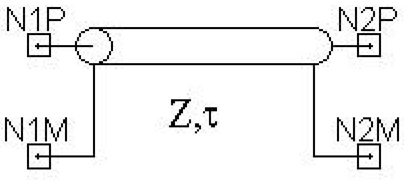

Figure 1. Component symbol

Description

The Coaxial Cable with Isolated Shield model is similar to the Single-Phase EP Line model with the exception that the cable shield is isolated from ground. The model exposes a pin at each end of the cable for connecting to the shield.

Input parameters include series resistance per unit length, traveling wave velocity, and cable length. The line travel time is length/velocity, and transients entering one end do not appear at the other end until that travel time has elapsed. There are no internal nodes created in the model to represent cascaded RLC pi sections, which limits the component count and simulated system size. This also prevents artificial oscillations within RLC pi sections.

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Assumptions and Limitations

- Parameters are not frequency-dependent.
- Z1 is the line mode characteristic impedance, given by Z1 = Z/(2.0 + 1.0e-6) which needs to be within a range of 5.0 to 2000.0.

- Very lossy lines, in which the total series resistance approaches the magnitude of the line surge impedance, should be represented in segments.

Line models limit the maximum simulation time step to the travel time of the line regardless of the input simulation parameters. The maximum time step can be estimated from the shortest line length divided by the speed of light. If the maximum time step becomes too short for the application, this indicates that the line should be modeled with series RL components, ignoring the shunt capacitance.

The Coaxial Line with Isolated Shield model exposes four conservative nodes, N1P and N2P represent the center conductor (conductor P) connections while N1M and N2M are the shield (conductor M) connections. The voltage references are from N1P and N2P to ground. The current reference arrows enter the line at each end. For example, if N1P is considered the source end, then the current entering node N1P (I1) may be considered the source current. Then the current at N2P (I2) has the opposite polarity to the load current.

For more information See EP Line Model – Single-Phase.

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Mathematical Description

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Netlist Syntax

UMODEL EPLineCx ?InstanceName(@InstanceName):(@(Refbase)@(ID)) N1P:= %0, N1M:= %1, N2P:= %2, N2M:= %3 (Z:= @Z, R:= @R, V:= @V, L:= @L, U0P:= @U0P, U0M:= @U0M) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
N1P	Node 1	electrical
N2P	Node 2	electrical
N1M	Shield Node 1	electrical
N2M	Shield Node 2	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

Z	Characteristic Impedance	real	50 [Ohm]
R	Series Resistance	real	0 [Ohm/m]
V	Wave Velocity	real	1.5e8 [m/sec]
L	Line length	real	100 [m]
U0P	Initial Voltage, Conductor P	real	0 [V]
U0M	Initial Voltage, Conductor M	real	0 [V]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
I1P	Current into Port 1+ [A]	Output	real
V1P	Voltage to Ground at Port 1+ [V]	Output	real
I2P	Current into Port 2+ [A]	Output	real
V2P	Voltage to Ground at Port 2+ [V]	Output	real
I1M	Current into Port 1- [A]	Output	real
V1M	Voltage to Ground at Port 1- [V]	Output	real
I2M	Current into Port 2- [A]	Output	real
V2M	Voltage to Ground at Port 2- [V]	Output	real

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Example

This example illustrates basic behavior of a coaxial line. The shield is grounded spearately on each side of the line. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

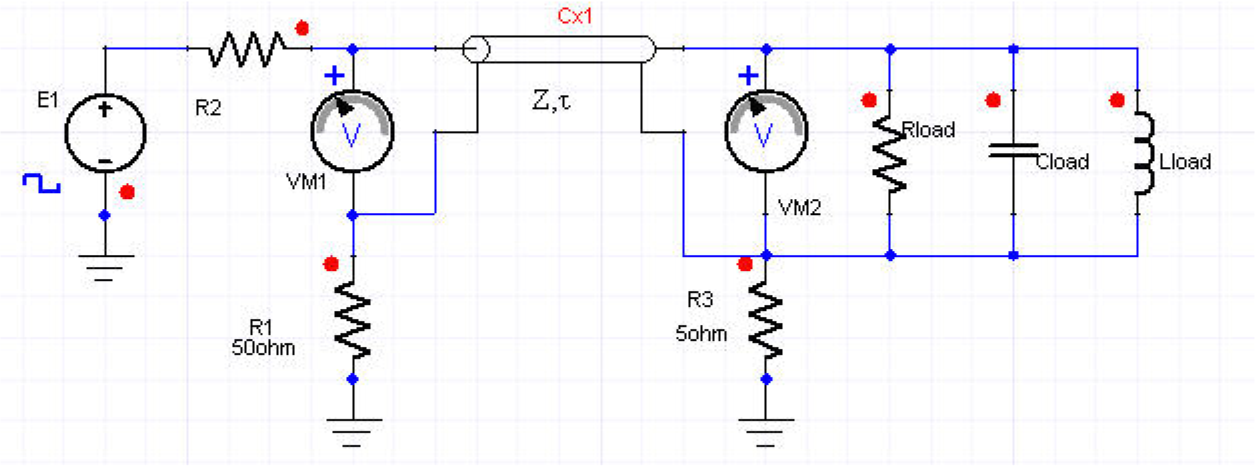

Figure 2. Application example of the Coaxial Line with Isolated Shield model

Table 4. System Parameters

Component	Parameter	Value [unit]
Voltage Source (Pulse) E1	Amplitude	10k [V]
	Frequency	5 [Hz]
	Delay	1e-6 [s]
	Phase	0 [degree]
	Offset	0 [V]
Resistor R1	R	50 [Ohm]
Resistor R2	R	20 [Ohm]
Resistor R3	R	5 [Ohm]
Resistor Rload	R	400 [Ohm]
Coaxial Cable Cx1	Z	50 [Ohm]
	R	0 [Ohm/m]
	V	1.5e8 [m/sec]
	L	100 [m]
	U0P	0 [V]
	U0M	0 [V]
Inductor Lload	L	0.2 [H]
	i0	0 [A]
Capacitor Cload	C	0.1u [F]
	U0	0 [V]

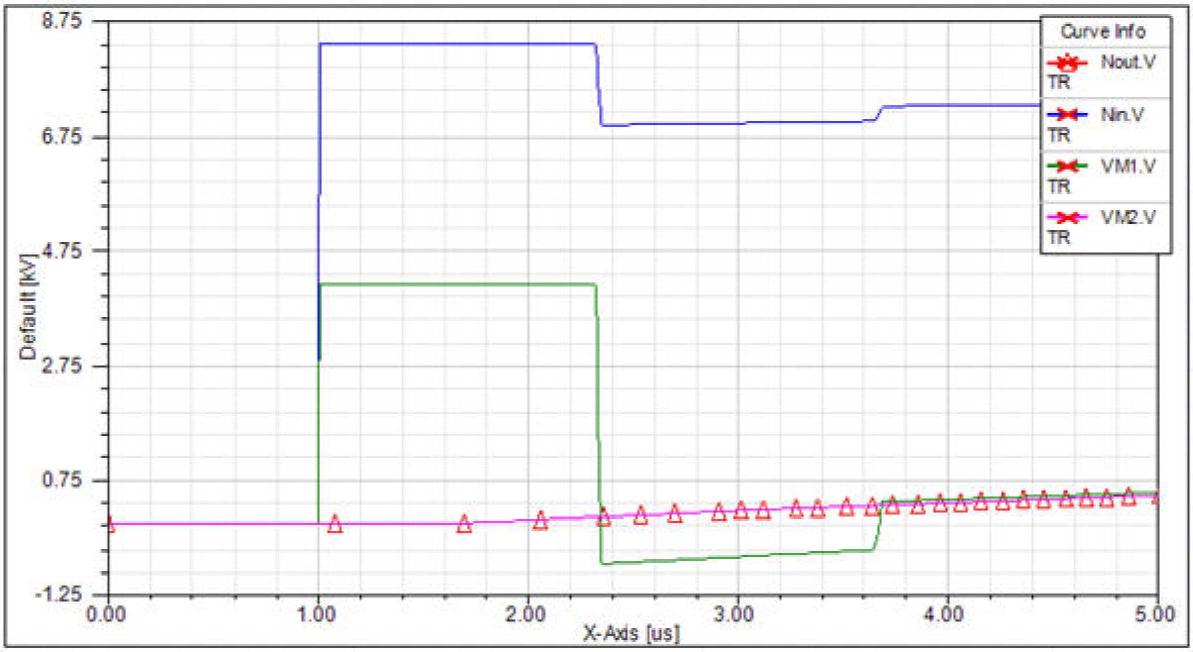

Figure 3. Simulation results

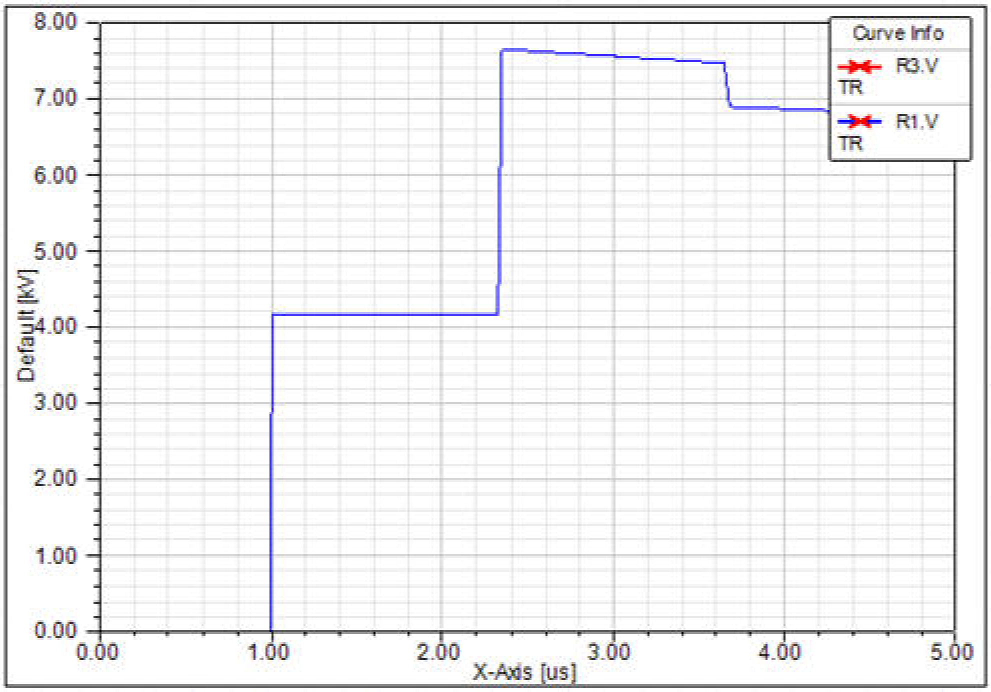

Figure 4. Simulation results

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References

[1] H.W. Dommel and W. S. Meyer: *Computation of Electromagnetic Transients*, Proc. IEEE, vol. 62, pp. 983-993, July 1974.

[2] Electromagnetic Transients Program Reference Manual (EMTP Theory Book), Bonneville Power Administration, August 1986.

Connectors

- Eyelet terminal (elt)
- Inline terminal Pair (itp)

ELT (Eyelet Terminal)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

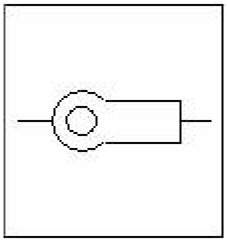

Figure 1. Component symbol

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Description

The ELT model uses a temperature-dependent resistance to represent the electrical properties. The value of the resistance is calculated from the nominal resistance at reference temperature, the instantaneous temperature of the connector, and the temperature coefficient.

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Assumptions and Limitations

The model does not represent self-heating.

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Mathematical Description

Resistance value:

$$R_{val} = R_U \cdot (1 + \alpha \cdot (T - T_{ref}))$$

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Netlist Syntax

MODEL elt ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0:= @r0, alpha:= @alpha, temperature:= @temperature, tref:= @tref) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	1m [Ohm]
alpha	Temperature Coefficient	real	3.93m [1/K]
temperature	Contact Temperature	real	THETA [^{o}C]
tref	Reference Temperature	real	20 [^{o}C]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Connector Voltage [V]	Output	real
i	Connector Current [A]	Output	real
rval	Connector Resistance [Ohm]	Output	real

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Example

In this example, a Battery battery1 is connect to a Lamp Lamp1 through 2 Eyelet Terminals, ELT1 and ELT2, and a Wire wire1. Different connector temperatures at ELT1 and ELT2 lead to different voltage drops. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

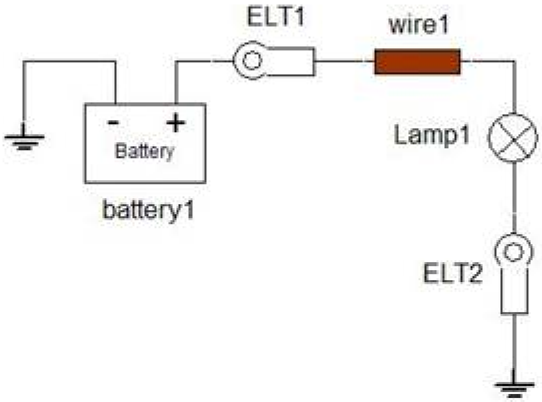

Figure 2. Application example of the Eyelet Terminal model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	12 [V]
	rin	10m [Ohm]
Eyelet Terminal ELT1	r0	1m [Ohm]
	alpha	3.93m [1/K]
	temperature	THETA [^{o}C]
	tref	20 [^{o}C]
Eyelet Terminal ELT2	r0	1m [Ohm]
	alpha	3.93m [1/K]
	temperature	THETA+20 [^{o}C]
	tref	20 [^{o}C]
Thermal Wire wire1 (Level 1)	r	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^{o}C]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^{o}C]
	timelt	150 [^{o}C]

Lamp (advanced model) lamp1	tnom	20 [^{o}C]
	pnom	55 [W]
	ct	2.5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_share	50m
	ton	1.8k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]

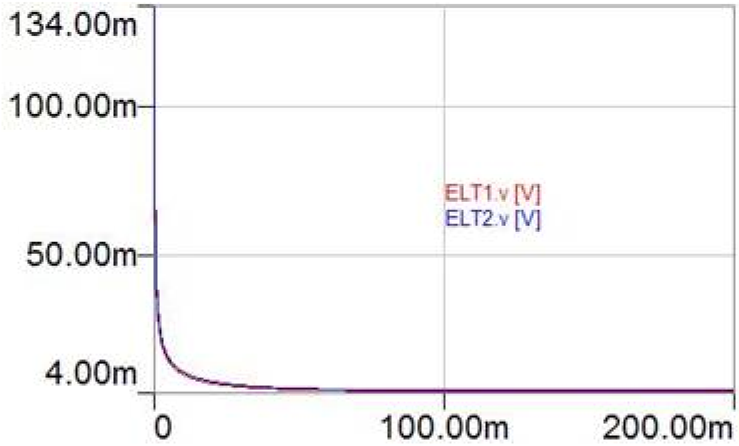

Figure 3. Simulation results

Top

References

ITP (Inline Terminal Pair)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

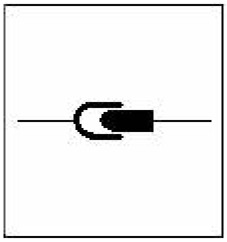

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The ITP model uses a temperature-dependent resistance to represent the electrical properties. The value of the resistance is calculated from the nominal resistance at reference temperature, the instantaneous temperature of the connector, and the temperature coefficient.

Top

Assumptions and Limitations

The model does not represent self-heating.

Top

Mathematical Description

Resistance value:

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref}))$$

Top

Netlist Syntax

MODEL itp ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0:= @r0, alpha:= @alpha, tref:= @tref, temperature:= @temperature) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	1m [Ohms]
alpha	Temperature Coefficient	real	2.93 [1/K]
temperature	Contact Temperature	real	THETA [^{o}C]
tref	Reference Temperature	real	23 [^{o}C]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Connector Voltage [V]	Output	real
i	Connector Current [A]	Output	real
rval	Connector Resistance [Ohm]	Output	real

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Example

In this example, a Battery battery1 is connect to a Lamp Lamp1 through 2 Inline Terminal Pair, ITP1 and ITP2, and a Wire wire1. Different connector temperatures at ITP1 and ITP2 lead to different voltage drops. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

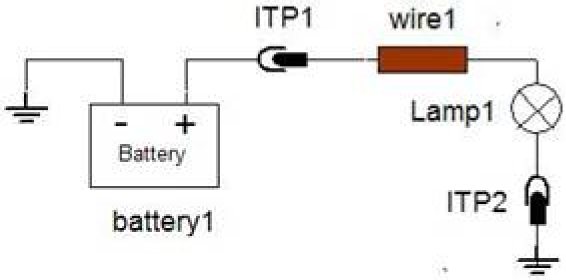

Figure 2. Application example of the Inline Terminal Pair model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	12 [V]
	rin	10m [Ohm]
Inline Terminal Pair ITP1	r0	1m [Ohm]
	alpha	3.93m [1/K]
	temperature	THETA [^{o}C]
	tref	20 [^{o}C]
Inline Terminal Pair ITP2	r0	1m [Ohm]
	alpha	3.93m [1/K]
	temperature	THETA+20 [^{o}C]
	tref	20 [^{o}C]

Thermal Wire wire1 (Level 1)	r	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	lval	10n [H/m]
	i0	45 [A]
	tamb	20 [^{o}C]
	tinit	20 [^{o}C]
	tref	20 [^{o}C]
	enable_break	0
	tdoff	1 [s]
	roff	1G [Ohm]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	spgc	9k [kg/m^3]
	shcc	0.38k [J/(K kg)]
	kc	0.401k [W/(K m)]
	tcmelt	1084 [^{o}C]
	spgi	1.3k [kg/m^3]
	shci	1.5k [J/(K kg)]
	timelt	150 [^{o}C]
	ki	0.16 [W/(k m)]
Lamp (advanced model) lamp1	tnom	20 [^{o}C]
	pnom	55 [W]
	ct	2.5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_share	50m
	ton	1.8k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]

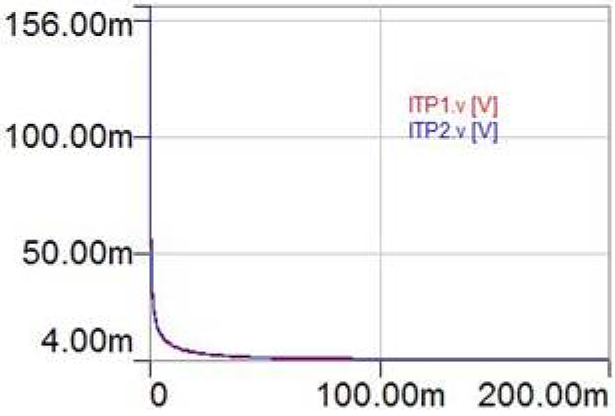

Figure 3. Simulation results

Top

References

Fuse

The fuse models provide basic behavioral representations of fuses (thermal and electric properties including self-heating effects) with different simulation depths. The models contain built-in destruction detection with animation. If the fuse temperature exceeds a defined limit for a certain time, the fuse changes its resistance.

- Advanced Dynamic Fuse Model (fuse)
- Dynamic Model of a Double-Element Fuse (fuse_de)
- Dynamic Model of a Single Element Fuse (fuse_se)
- Dynamic Model of a PPTC Fuse with Three-Stage Thermal Network (pptc)
- Dynamic Model of a PPTC Fuse with Two-Stage Thermal Network (pptc_2rc)

Fuse – Advanced

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

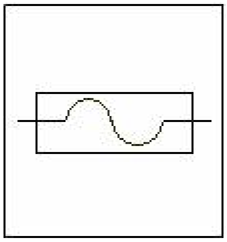

Figure 1. Component symbol

- Description
- Assumptions and Limitations
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- Netlist Syntax
- Conservative Pins
- Parameters
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Description

The model represents a fuse that uses a resistance to represent electrical fuse properties. The instantaneous resistance, R_{val}, is calculated from the nominal resistance, R_0, at reference temperature, T_{ref}, the fuse temperature, T, and the temperature coefficient, α. The fuse temperature is calculated within the internal thermal network, which consists of three RC combinations. Using one more RC combination (than the model *Fuse - Single Element*) allows a better adaptation of the fuse characteristic, but may increase the simulation time -- especially if more fuses are simulated. The thermal network is fed by the losses calculated within the internal electrical network of the model.

The model contains built-in destruction detection with animation. If the fuse temperature exceeds a defined limit tmax, the destruction of the fuse can be modeled. If the parameter enable_break is set to '1', the fuse resistance increases up to the value specified by R_{off}. The slope of the resistance change is set by tdoff.

The fuse destruction is displayed at the output ok. If the fuse temperature has exceeded the maximum value allowed, ok is permanently set to zero. The property is independent of enable_break. Using this behavior, you can include tolerances of fuse parameters. The destruction of other components, which would happen shortly after breaking the wire, can be seen.

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Assumptions and Limitations

The minimum time step of the simulator must be set according to the time constant of the thermal network. Usually, the default value, HMIN=10s, can be used.

Top

Mathematical Description

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref})) \qquad temperature \geq tmax \wedge t \geq tdoff \Rightarrow R_{val} \rightarrow R_{off}$$

Top

Netlist Syntax

MODEL fuse ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0:= @r0, alpha:= @alpha, rt1:= @rt1, rt2:= @rt2, rt3:= @rt3, ct1:= @ct1, ct2:= @ct2, ct3:= @ct3, tmax:= @tmax, enable_break:= @enable_break, tdoff:= @tdoff, tamb:= @tamb, tref:= @tref, roff:= @roff) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	2m [Ohm]
alpha	Temperature Coefficient	real	3.93 [1/K]
tref	Reference Temperature	real	20 [^{o}C]
roff	Resistance after Blowing	real	1G [Ohm]
tamb	Ambient Temperature	real	20 [^{o}C]
rt1	Thermal Resistance 1	real	33 [K/W]
rt2	Thermal Resistance 2	real	30 [K/W]

rt3	Thermal Resistance 3	real	1k [K/W]
ct1	Thermal Capacitance 1	real	10m [Ws/K]
ct2	Thermal Capacitance 2	real	1.5 [Ws/K]
ct3	Thermal Capacitance 3	real	0.125k [Ws/K]
enable_ break	Flag Enable Circuit Break, 1=on	real	0
tmax	Maximum Temperature	real	400 [ºC]
tdoff	Blowing Delay	real	0.1 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Fuse Voltage [V]	Output	real
i	Fuse Current [A]	Output	real
temperature	Fuse Temperature [ºC]	Output	real
rval	Fuse Resistance [Ohm]	Output	real
state	Fuse State	Output	real
breaktime	Blowing Time [s]	Output	real

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Example

In this example, the fuse blows when the dc machine DCM1 is switched on. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

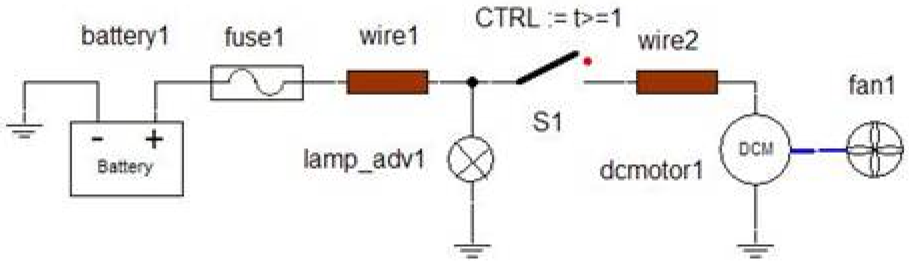

Figure 2. Application example of the Advanced Fuse model

Table 4. System Parameters

Component	Parameter	Value [unit]

Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Fuse1	r0	2m [Ohm]
	alpha	3.93 [1/K]
	tref	20 [ºC]
	roff	1G [Ohm]
	tamb	20 [ºC]
	rt1	33 [K/W]
	rt2	30 [K/W]
	rt3	1k [K/W]
	ct1	10m [Ws/K]
	ct2	1.5 [Ws/K]
	ct3	0.125k [Ws/K]
	enable_break	1
	tmax	400 [ºC]
	tdoff	0.1 [s]
wire1/wire2 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [ºC]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [ºC]
	timelt	150 [ºC]

Lamp (advanced model) lamp_ adv1	tnom	20 [^{o}C]
	pnom	20 [W]
	ct	5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_ share	50m
	ton	1.4k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]
DC Machine DCM1	ra	10m [Ohm]
	la	1m [H]
	ke	100m
	j	200m [kg m^2]
	cf	1m [Nms/rad]
	N0	0 rpm
Fan1	cf	0 [Nms/rad]
	windage	0.001 [Nms^2/rad^2]

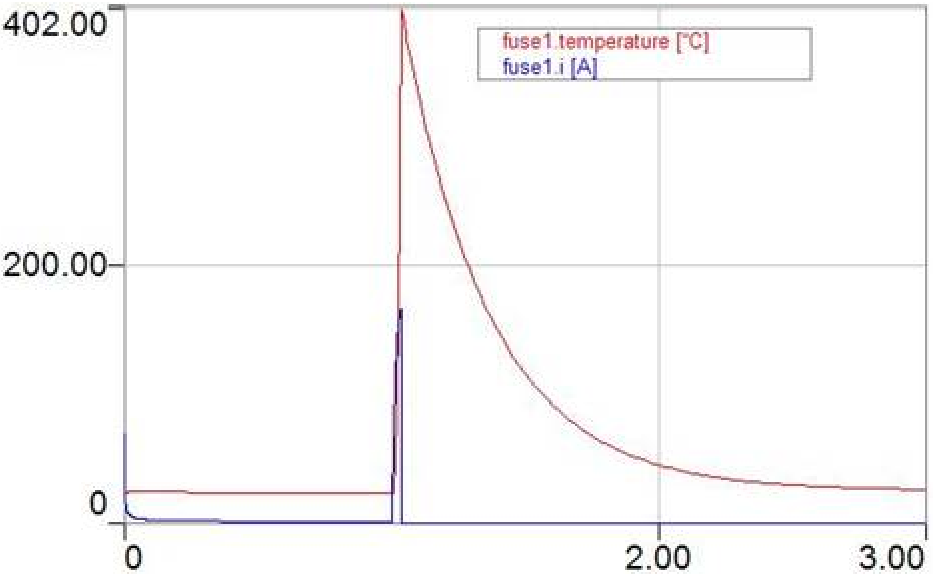

Figure 3. Simulation results

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References

Fuse Double Element

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

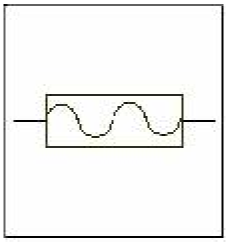

Figure 1. Component symbol

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- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a serial connection of two single fuses and uses a resistance to represent electrical fuse properties. Two different fuse characteristics are combined within one component. The instantaneous resistance, R_{val}, is calculated from the nominal resistance, R_0, at reference temperature, T_{ref}, the fuse temperature, T, and the temperature coefficient, α.

The fuse temperature is calculated within the internal thermal network, which consists of two RC combinations. The thermal network is fed by the losses calculated within the internal electrical network.

The model has built-in destruction detection with animation. If the fuse temperature exceeds one of the defined limits, tmax_a or tmax_b, for a certain time, tdoff_a or tdoff_b, the fuse resistance changes as defined by R_{off}.

Top

Assumptions and Limitations

The minimum time step of the simulator must be set according to the time constant of the thermal network. Usually, the default value, HMIN=10s, can be used.

Top

Mathematical Description

The instantaneous resistance, R_{val} is calculated as follows

$$R_{val} = R_0 \cdot \left(1 + \alpha \cdot \left(T - T_{ref}\right)\right) \qquad temperature \geq tmax \wedge t \geq tdoff \Rightarrow R_{val} \rightarrow R_{off}$$

where R_0 isthe nominal resistance, T_{ref} the eference temperature, T the fuse temperature, and α the temperature coefficient.

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Netlist Syntax

MODEL fuse_de ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0a:= @r0a, alpha_a:= @alpha_a, rta1:= @rta1, rta2:= @rta2, cta1:= @cta1, cta2:= @cta2, tmax_a:= @tmax_a, tamb:= @tamb, tref:= @tref, roff:= @roff, tdoff_a:= @tdoff_a, rtb1:= @rtb1, rtb2:= @rtb2, r0b:= @r0b, alpha_b:= @alpha_b, ctb1:= @ctb1, ctb2:= @ctb2, tmax_b:= @tmax_b, tdoff_b:= @tdoff_b) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0a	Resistance at Reference Temperature - Fuse 1	real	1.9 [Ohm]
alpha_a	Temperature Coefficient - Fuse 1	real	3.93 [1/K]
rta1	Thermal Resistance 1 - Fuse 1	real	40 [K/W]
rta2	Thermal Resistance 2 - Fuse 1	real	30 [K/W]
cta1	Thermal Capacitance 1 - Fuse 1	real	10m [Ws/K]
cta2	Thermal Capacitance 2 - Fuse 1	real	1.5 [Ws/K]
tmax_a	Maximum Temperature - Fuse 1	real	400 [^{o}C]
tamb	Ambient Temperature	real	20 [^{o}C]

tref	Reference Temperature	real	20 [^{o}C]
tdoff_a	Delay On -> Off - Fuse 1	real	0 [s]
rtb1	Thermal Resistance1 – Fuse 2	real	30 [K/W]
rtb2	Thermal Resistance2 – Fuse 2	real	20 [K/W]
r0b	Resistance at Reference Temperature - Fuse 2	real	3m [Ohm]
alpha_b	Temperature Coefficient - Fuse 2	real	3.93m [1/K]
ctb1	Thermal Capacitance 1 - Fuse 2	real	7m [Ws/K]
ctb2	Thermal Capacitance 2 - Fuse 2	real	1 [Ws/K]
tmax_b	Maximum Temperature - Fuse 2	real	450 [^{o}C]
tdoff_b	Delay On -> Off - Fuse 2	real	0 s
roff	Resistance after Blowing	real	1G [ohms]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Fuse Voltage [V]	Output	real
i	Fuse Current [A]	Output	real
temperature_a	Fuse temperature – Fuse 1 [^{o}C]	Output	real
temperature_b	Fuse temperature – Fuse 2 [^{o}C]	Output	real
rval	Fuse Resistance [Ohm]	Output	real
state_a	State – Fuse 1	Output	real
state_b	State – Fuse 2	Output	real

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Example

In this example, the double-element fuse Fuse_de1 has two part: fuse 1 has shorter time constant and higher current rating, while fuse 2 has longer time constant while lower current rating. If either fuse reaches the defined limits, the resistance of Fuse_de1 changes to $R_{off.}$ The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

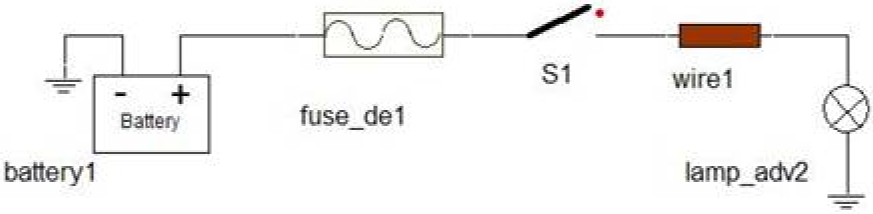

Figure 2. Application example of the Double-Element Fuse

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Fuse1	r0a	15m [Ohm]
	alpha_a	3.93 [1/K]
	rta1	30 [K/W]
	rta2	10 [K/W]
	cta1	2m [Ws/K]
	cta2	500m [Ws/K]
	tmax_a	400 [ºC]
	tamb	20 [ºC]
	tref	20 [ºC]
	tdoff_a	0 [s]
	rtb1	50 [K/W]
	rtb2	20 [K/W]
	r0b	25m [Ohm]
	alpha_b	3.93m [1/K]
	ctb1	20m [Ws/K]
	ctb2	5 [Ws/K]
	tmax_b	450 [ºC]
	tdoff_b	0 [s]
	roff	1G [ohms]

wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	lval	10n [H/m]
	i0	45 [A]
	tamb	20 [^{o}C]
	tinit	20 [^{o}C]
	tref	20 [^{o}C]
	enable_break	0
	tdoff	1 [s]
	roff	1G [Ohm]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	spgc	9k [kg/m^3]
	shcc	0.38k [J/(K kg)]
	kc	0.401k [W/(K m)]
	tcmelt	1084 [^{o}C]
	spgi	1.3k [kg/m^3]
	shci	1.5k [J/(K kg)]
	timelt	150 [^{o}C]
	ki	0.16 [W/(k m)]
Lamp (advanced model) lamp_ adv2	tnom	20 [^{o}C]
	pnom	20 [W]
	ct	5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_ share	50m
	ton	1.4k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]

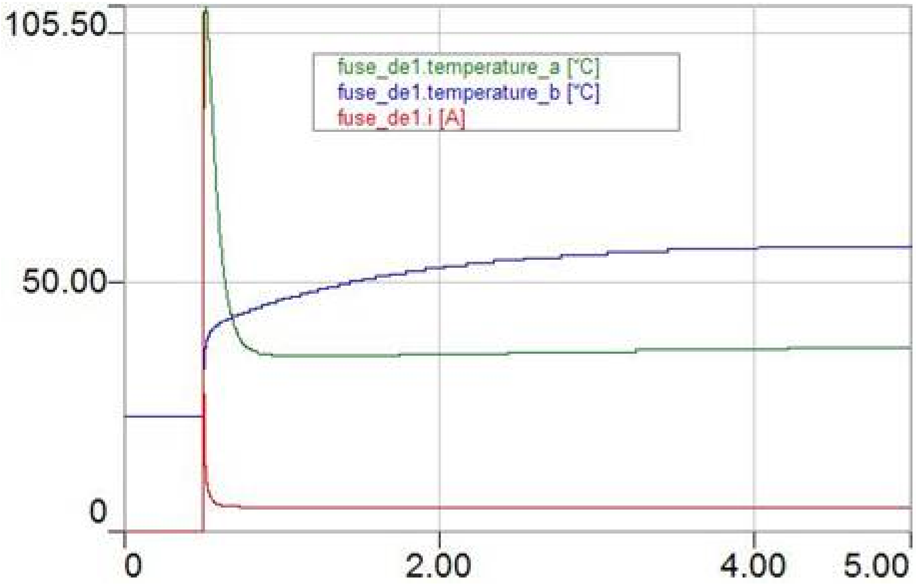

Figure 3. Simulation results

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References

Fuse – Single Element

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

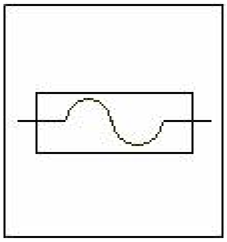

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a fuse, using a resistance to represent electrical fuse properties. The instantaneous resistance, R_{val}, is calculated from the nominal resistance, R_0, at reference temperature, T_{ref}, the fuse temperature, T, and the temperature coefficient, α.

The fuse temperature is calculated within the internal thermal network, which consists of two RC combinations. The thermal network is fed by the losses calculated within the internal electrical network of the model.

The model has built-in destruction detection with animation. If the fuse temperature exceeds a defined limit, tmax, for a certain time, tdoff, the fuse changes its resistance as defined by the value of R_{off}.

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Assumptions and Limitations

The minimum time step of the simulator must be set according to the time constant of the thermal network. Usually, the default value, HMIN=10s, can be used.

Top

Mathematical Description

The instantaneous resistance, R_{val} is calculated as follows

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref})) \qquad \text{temperature} \geq \text{tmax} \wedge t \geq \text{tdoff} \Rightarrow R_{val} \rightarrow R_{off}$$

where R_0 isthe nominal resistance, T_{ref} the eference temperature, T the fuse temperature, and α the temperature coefficient.

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Netlist Syntax

UMODEL EPLineCx ?InstanceName(@InstanceName):(@(Refbase)@(ID)) N1P:= %0, N1M:= %1, N2P:= %2, N2M:= %3 (Z:= @Z, R:= @R, V:= @V, L:= @L, U0P:= @U0P, U0M:= @U0M) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	1.9m [Ohm]
alpha	Temperature Coefficient	real	3.93m [1/K]
tref	Reference Temperature	real	20 [^{o}C]
roff	Resistance after Blowing	real	1G [Ohm]
tamb	Ambient Temperature	real	20 [^{o}C]
rt1	Thermal Resistance 1	real	33 [K/W]
rt2	Thermal Resistance 2	real	30 [K/W]
ct1	Thermal Capacitance 1	real	10m [Ws/K]
ct2	Thermal Capacitance 2	real	1.5 [Ws/K]
tmax	Maximum Temperature	real	0.4k [^{o}C]

tdoff	Blowing Delay	real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Fuse Voltage [V]	Output	real
i	Fuse Current [A]	Output	real
temperature	Fuse Temperature [ºC]	Output	real
rval	Fuse Resistance [Ohm]	Output	real
state	Fuse State	Output	real
breaktime	Blowing Time [s]	Output	real

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Example

In this example, the fuse blows when the dc machine DCM1 is switched on. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

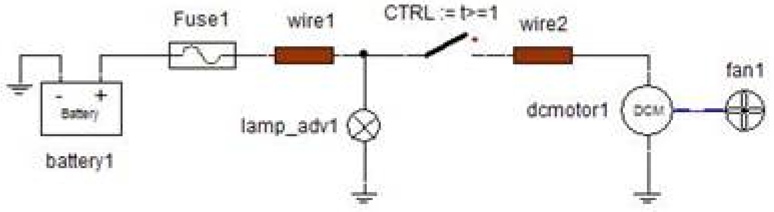

Figure 2. Application example of the Single-Element Fuse

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]

Fuse1	r0	1.9m [Ohm]
	alpha	3.93m [1/K]
	tref	20 [°C]
	roff	1G [Ohm]
	tamb	20 [°C]
	rt1	33 [K/W]
	rt2	30 [K/W]
	ct1	10m [Ws/K]
	ct2	1.5 [Ws/K]
	tmax	0.4k [°C]
	tdoff	0 [s]
wire1/wire2 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	lval	10n [H/m]
	i0	45 [A]
	tamb	20 [°C]
	tinit	20 [°C]
	tref	20 [°C]
	enable_break	0
	tdoff	1 [s]
	roff	1G [Ohm]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	spgc	9k [kg/m^3]
	shcc	0.38k [J/(K kg)]
	kc	0.401k [W/(K m)]
	tcmelt	1084 [°C]
	spgi	1.3k [kg/m^3]
	shci	1.5k [J/(K kg)]
	timelt	150 [°C]
	ki	0.16 [W/(k m)]

Lamp (advanced model) lamp_adv1	tnom	20 [^{o}C]
	pnom	20 [W]
	ct	5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_share	50m
	ton	1.4k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]
DC Machine DCM1	ra	10m [Ohm]
	la	1m [H]
	ke	100m
	j	200m [kg m^{2}]
	cf	1m [Nms/rad]
	N0	0 rpm
Fan1	cf	0 [Nms/rad]
	windage	0.001 [Nms^{2}/rad^{2}]

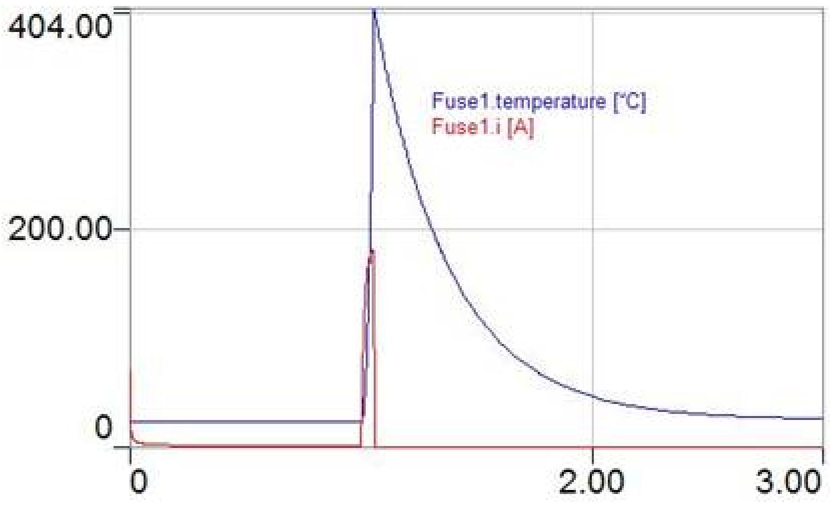

Figure 3. Simulation results

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References

PPTC (Three RC Combinations)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

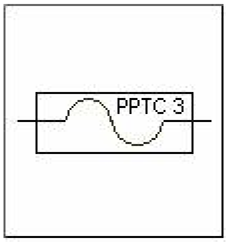

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a PPTC (Polymer Positive Temperature Coefficient) fuse with reset function. Because of its highly nonlinear behavior, the resistance increases considerably with increasing temperature. In case of an over-temperature, the PPTC fuse increases its resistance considerably, which reduces the current of the circuit. After the over-current disappears, the fuse cools off again, and the fuse resistance returns to the nominal value.

The PPTC fuse model uses a resistance to represent the electrical fuse properties. The instantaneous resistance, R_{val}, is calculated from the nominal resistance, R_0, at reference temperature, T_{ref}, the fuse temperature, T, and a look-up table (char) that contains the curve of the resistance change over the temperature. The characteristic file contains relative resistance values (R_{val} / R_0) for a specific temperature. The same characteristic file can be used for several fuses with different ratings but the same general behavior.

The fuse temperature is calculated within the internal thermal network, which consists of three RC combinations. Using one more RC combination (than the model *PPTC - Two RC combinations*) allows the fuse characteristic to better adapt, but the simulation time may increase -- especially if a greater number of fuses are simulated. The thermal network is fed by the losses calculated within the model's internal electrical network.

The model contains built-in destruction detection with animation. If the fuse temperature exceeds a defined limit (tmax), the destruction of the fuse can be modeled. The slope of the resistance change can be set with the time tdoff. The PPTC fuse usually does not go into the destruction state. However, if the current through the fuse is driven by a current source, very high losses may occur inside the fuse. The destruction of the fuse is displayed at the output ok. If the fuse temperature has exceeded the maximum value allowed, ok is permanently set to zero.

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Assumptions and Limitations

The minimum time step of the simulator must be set according to the time constant of the thermal network. Usually, the default value, HMIN=10s, can be used.

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Mathematical Description

Figure 2 shows an example of relative resistance values (Rval / R0) changes with the temperature.

Figure 2. The curve of the relative resistance changes over the temperature

Top

Netlist Syntax

MODEL pptc ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0:= @r0, rt1:= @rt1, rt2:= @rt2, rt3:= @rt3, ct1:= @ct1, ct2:= @ct2, ct3:= @ct3, tmax:= @tmax, tdoff:= @tdoff, tamb:= @tamb, roff:= @roff, char:= @char) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	1.9m [Ohm]
char	Characteristic - Relative Resistance	file	-
roff	Resistance after Blowing	real	1G [Ohm]
tamb	Ambient Temperature	real	20 [^{o}C]
rt1	Thermal Resistance 1	real	33 [K/W]
rt2	Thermal Resistance 2	real	30 [K/W]
rt3	Thermal Resistance 3	real	1k [K/W]
ct1	Thermal Capacitance 1	real	10m [Ws/K]
ct2	Thermal Capacitance 2	real	1.5 [Ws/K]
ct3	Thermal Capacitance 3	real	0.125k [Ws/K]
tmax	Maximum Temperature	real	400 [^{o}C]
tdoff	Blowing Delay	real	0.1 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Fuse Voltage [V]	Output	real
i	Fuse Current [A]	Output	real
temperature	Fuse Temperature [^{o}C]	Output	real
rval	Fuse Resistance [Ohm]	Output	real
ok	Fuse State	Output	real
breaktime	Blowing Time [s]	Output	real

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Example

In this example, the switch S2 shortens the load when time t is between 2 and 3s. The fuse pptc 1 protects the circuit as long as S2 is shorted.After cooling down pptc1 allows the current flow again.

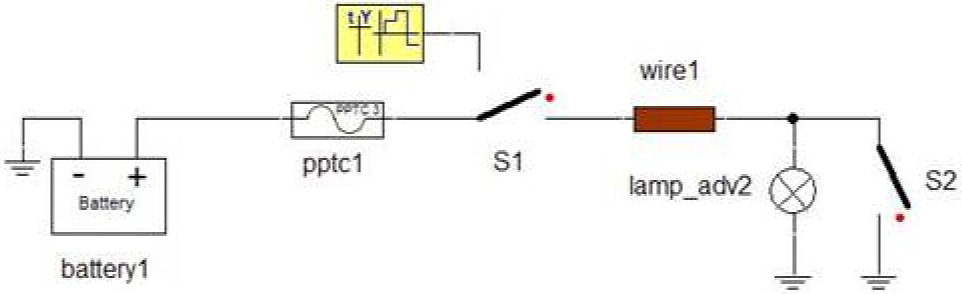

Figure 3. Application example of the fuse with three rc combinations

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Fusewith three rc combinations pptc1	r0	5m [Ohm]
	char	pptc.mdx
	roff	1G [Ohm]
	tamb	20 [^oC]
	rt1	33 [K/W]
	rt2	30 [K/W]
	rt3	1k [K/W]
	ct1	10m [Ws/K]
	ct2	1.5 [Ws/K]
	ct3	0.125k [Ws/K]
	tmax	400 [^oC]
	tdoff	0.1 [s]
wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^oC]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^oC]
	timelt	150 [^oC]

Lamp (advanced model) lamp_adv1	tnom	20 [°C]
	pnom	20 [W]
	ct	5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [°C]
	tmax	2.2k [°C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_ share	50m
	ton	1.4k [°C]
	roff	1G [Ohm]
	tdoff	10m [s]

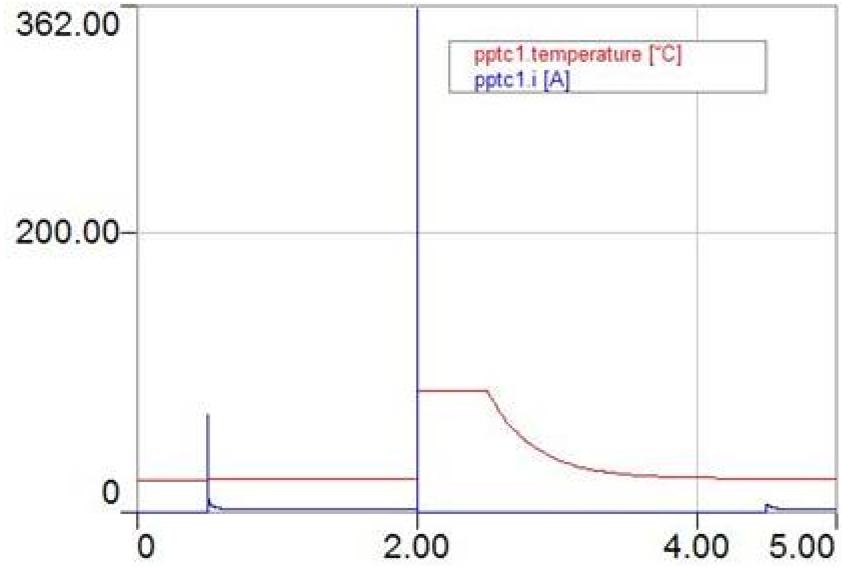

Figure 4. Simulation results

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References

PPTC (Two RC Combinations)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

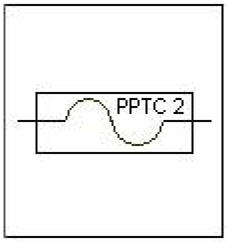

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a PPTC (Polymer Positive Temperature Coefficient) fuse with reset function. Because of its highly nonlinear behavior, the resistance increases considerably with increasing temperature. In the case of an over-temperature, the PPTC fuse resistance increases considerably, which reduces the current. After the over-current cools off, the fuse resistance returns to the nominal value.

The PPTC fuse model uses a resistance to represent the electrical fuse properties. The instantaneous resistance, R_{val}, is calculated from the nominal resistance, R_0, at reference temperature, T_{ref}, the fuse temperature, T, and a look-up table (char) that contains the curve of the resistance change over the temperature. The characteristic file contains relative resistance values (R_{val} / R_0) for specific temperatures. The same characteristic file can be used for several fuses with different ratings but with the same general behavior.

The fuse temperature is calculated within the internal thermal network, which consists of two RC combinations. The thermal network is fed by the losses calculated within the model's internal electrical network.

The model contains built-in destruction detection with animation. If the fuse temperature exceeds a defined limit tmax, the destruction of the fuse can be modeled. The slope of the resistance change can be set with the time tdoff. The PPTC fuse typically does not go into the destruction state. However, if the current through the fuse is driven by a current source, very high losses may occur inside the fuse. The destruction of the fuse is displayed at the output ok. If the fuse temperature has exceeded the maximum value allowed, ok is permanently set to zero.

Top

Assumptions and Limitations

The minimum time step of the simulator must be set according to the time constant of the thermal network. Usually, the default value, HMIN=10s, can be used.

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Mathematical Description

Figure 2 shows an example of relative resistance values (Rval / R0) changes with the temperature.

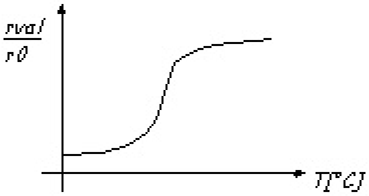

Figure 2. The curve of the relative resistance changes over the temperature

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Netlist Syntax

MODEL pptc_2rc ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (r0:= @r0, rt1:= @rt1, rt2:= @rt2, ct1:= @ct1, ct2:= @ct2, tmax:= @tmax, tdoff:= @tdoff, tamb:= @tamb, roff:= @roff, char:= @char) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data	Default Value

		Type	[Unit]
r0	Resistance at Reference Temperature	real	1.9m [Ohm]
char	Characteristic - Relative Resistance	file	
roff	Resistance after Blowing	real	1G [Ohm]
tamb	Ambient Temperature	real	20 [^{o}C]
rt1	Thermal Resistance 1	real	33 [K/W]
rt2	Thermal Resistance 2	real	30 [K/W]
ct1	Thermal Capacitance 1	real	10m [Ws/K]
ct2	Thermal Capacitance 2	real	1.5 [Ws/K]
tmax	Maximum Temperature	real	400 [^{o}C]
tdoff	Blowing Delay	real	0.1 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Fuse Voltage [V]	Output	real
i	Fuse Current [A]	Output	real
temperature	Fuse Temperature [^{o}C]	Output	real
rval	Fuse Resistance [Ohm]	Output	real
ok	Fuse State	Output	real
breaktime	Blowing Time [s]	Output	real

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Example

In this example, the switch S2 shortens the load when time t is between 2 and 3s. Fuse1 protects the circuit as long as S2 is shorted. After cooling down fuse1 allows the current flow again.

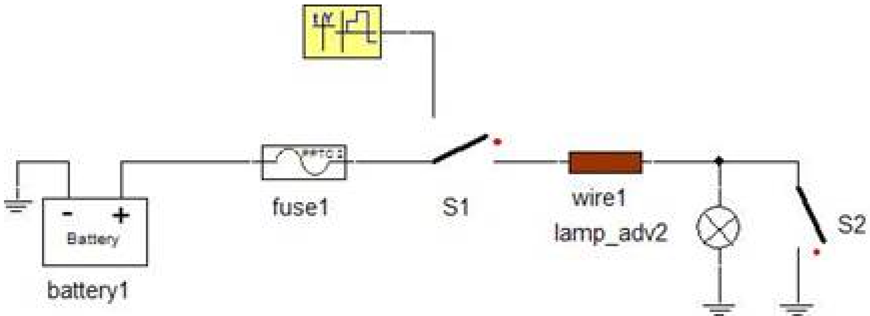

Figure 3. Application example of the fuse with three rc combinations

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Fuse with two rc combinations fuse1	r0	1.9m [Ohm]
	char	pptc.mdx
	roff	1G [Ohm]
	tamb	20 [^oC]
	rt1	33 [K/W]
	rt2	30 [K/W]
	ct1	10m [Ws/K]
	ct2	1.5 [Ws/K]
	tmax	400 [^oC]
	tdoff	0.1 [s]
wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^oC]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^oC]
	timelt	150 [^oC]

Lamp (advanced model) lamp_adv1	tnom	20 [^{o}C]
	pnom	20 [W]
	ct	5m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	tmax	2.2k [^{o}C]
	Enable_break	1
	vnom	12 [V]
	Conductivity_share	50m
	ton	1.4k [^{o}C]
	roff	1G [Ohm]
	tdoff	10m [s]

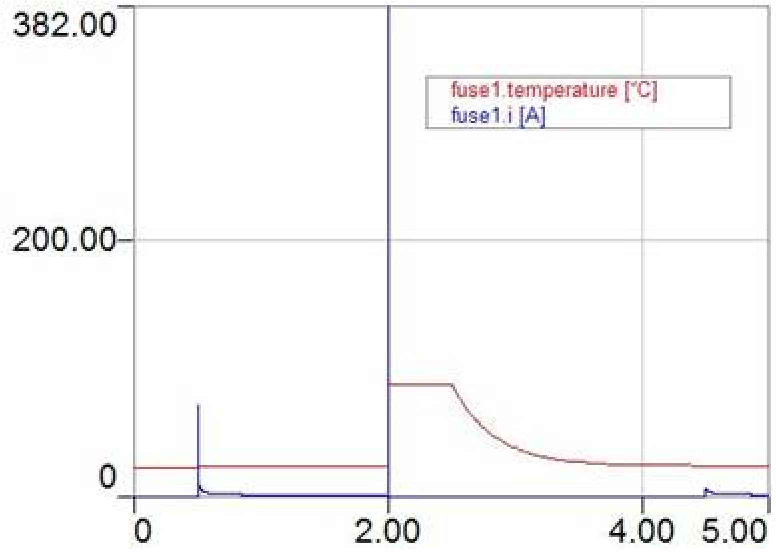

Figure 4. Simulation results

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References

Power Conversion

Power Conversion components are divided into the following categories:

- Control Algorithm
- Converter
- Inverter
- PWM

Control Algorithms

- Deadtime Generator for Mutual Locking of Half Bridge Valves (DEADTIME)
- Controller Macro for B6C2L as Direct Converter or Reversible Converter with Current Control (DUR_IREG)
- Controller Macro for B6C2L as Direct Converter with Trapezoidal Control Algorithm (DUR_TRAPEZ)
- Four Quadrant Current Control Algorithm (FOUR_QC_IBAND)
- Four Quadrant Natural Sampling Algorithm (FOUR_QC_NSAMP)
- Three-Level Single-Phase Natural Sampling (THREE_LVL_1P_H_NSAMP)
- Three-Level Single-Phase Control Algorithm (THREE_LVL_1P_H_VBC)
- Three-Level Three-Phase Natural Sampling Algorithm (THREE_LVL_3P_NSAMP)
- Three-Level Three-Phase Control Algorithm (THREE_LVL_3P_VBC)
- Two Level Natural Sampling Control Algorithm (TWO_LVL_NSAMP)
- Two Level Square Wave Control Algorithm (TWO_LVL_SQW)

Dead Time Generator

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

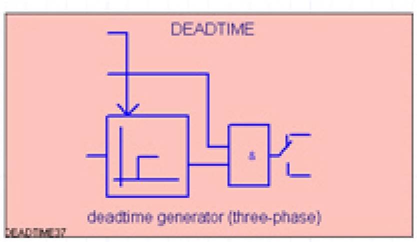

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

To prevent a shortcut of an inverter half bridge, this Dead Time Generator model provides a logic-generating delay before firing the opposite valve. This is necessary if simulating the switching behavior, for example, the tail current of an IGBT..

The default value of t_dead (5µs) is typical for IGBTs. If the control algorithms 2L_NSAMP or 2L_SQW are used, the gate control signals G_X1 (return values of the control algorithm) have to be assigned to the state signals Z_X (x = R, S, or T).

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Assumptions and Limitations

Top

Mathematical Description

Top

Netlist Syntax

MODEL DEADTIME ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (T_DEAD:= @T_DEAD, ENABLE:= @ENABLE, Z_R:= @Z_R, Z_S:= @Z_S, Z_T:= @Z_T, G_R1:= @G_R1, G_R2:= @G_R2, G_S1:= @G_S1, G_S2:= @G_S2, G_T1:= @G_T1, G_T2:= @G_T2) SRC: DB (Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
T_DEAD	Dead time	real	5u [s]
ENABLE	Enable Output	real	1

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
Z_R	Control Signal Phase R	Input	real
Z_S	Control Signal Phase S	Input	real
Z_T	Control Signal Phase T	Input	real
G_R1	Control Signal Upper Transistor Phase R	Input/Output	real
G_R2	Control Signal Lower Transistor Phase R	Input/Output	real
G_S1	Control Signal Upper Transistor Phase S	Input/Output	real
G_S2	Control Signal Lower Transistor Phase S	Input/Output	real
G_T1	Control Signal Upper Transistor Phase T	Input/Output	real
G_T2	Control Signal Lower Transistor Phase T	Input/Output	real

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Example

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References

Current Control for Direct Converter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

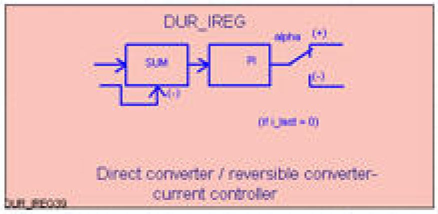

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a PI controller to use with the B6C2L bridge connection to model a direct converter. Depending on the sign of the desired value of I_NOM, variable ALPHA is assigned to either converter 1 or converter 2. It is also possible to simulate a DC reversing drive.

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Assumptions and Limitations

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Mathematical Description

Top

Netlist Syntax

MODEL DUR_IREG ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (I_NOM:= @I_NOM, I_LOAD:= @I_LOAD, KP:= @KP, KI:= @KI, TA:= @TA, ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2) SRC: DB(Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
I_NOM	Reference Value Load Current	real	Inom* [A]
I_LOAD	Actual Value Load Current	real	Iload* [A]
KP	Proportional Gain	real	0.1
KI	Integral Gain	real	5
TA	Controller Sample Time	real	1m [s]

* These parameters must be predefined variables.

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Nature/Data Type
ALPHA1	Delay Angle Converter 1 [degree]	Input/Output	real
ALPHA2	Delay Angle Converter 2 [degree]	Input/Output	real

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Example

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References

Trapezoidal Control for Direct Converter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

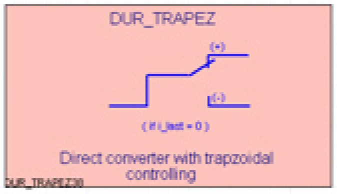

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a control algorithm to generate a trapezoidal secondary voltage according to the frequency ratio. Both converters are controlled using a fixed value of the delay angle. Load current must be zero to be able to control the opposite converter.

The duration of the first half wave of the secondary voltage v2 must be longer than T2/2 and depends on the value of the load inductance (the fall time of the load current). This is caused by the synchronization of the control to the load current (first zero crossing).

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Assumptions and Limitations

Top

Mathematical Description

Top

Netlist Syntax

MODEL DUR_TRAPEZ ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (F1:= @F1, F1ZUF2:= @F1ZUF2, PHI_U2:= @PHI_U2, ALPHA:= @ALPHA, I_LOAD:= @I_LOAD,

ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2) SRC: DB(Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
F1	Frequency of Input Voltage	real	50 [Hz]
F1ZUF2	Frequency Ratio (Input to Output Frequency)	real	3
PHI_U2	Phase Shift of Output Voltage	real	0 [degree]
ALPHA	Reference Value of Ratio ALPHA1 / ALPHA2	real	0
I_LOAD	Value of Load Current	real	r_load.I* [A]

* This parameter must be predefined variables.

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
ALPHA1	Delay Angle Converter 1 [degree]	Input/Output	real
ALPHA2	Delay Angle Converter 2 [degree]	Input/Output	real

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Example

Top

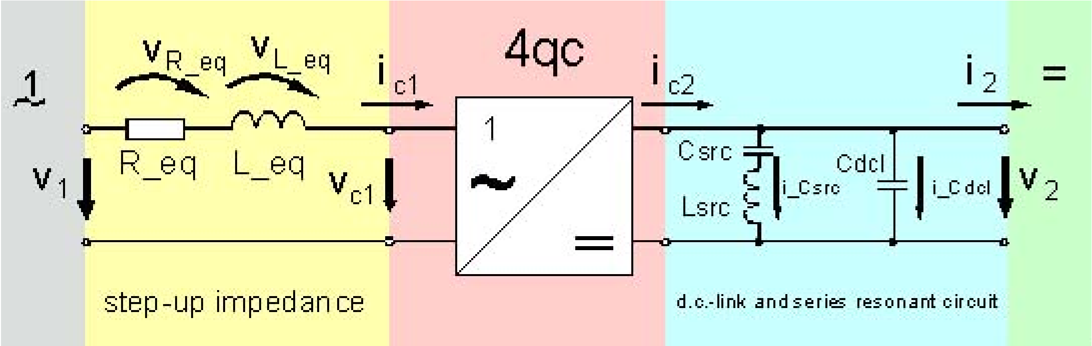
References

4QC definition of Variables and System of Equations

Variable definition and the system of equations are valid for the following control algorithms:

- Four Quadrant Current Control (FOUR_QC_IBAND)
- Four Quadrant Natural Sampling (FOUR_QC_NSAMP)

Definition of variables



Voltage equation

$$v_{c1} = v_1 - v_{R\_eq} - v_{L\_eq}$$

$$v_{c1} = V_{1\_ampl} \cdot \sin(\omega t) - \omega \cdot L\_eq \cdot I_{c1\_ampl} \cdot \cos(\omega t + phi\_ic1)$$

$$-R\_eq \cdot I_{c1\_ampl} \cdot \sin(\omega t + phi\_ic1)$$

v1 - system (supply) voltage

vc1 - converter input voltage

ic1 - converter input current

Index_ampl - amplitude of indexed quantity

$$v_{c1} = V_{c1\_ampl} \cdot \sin(\omega t - \psi)$$

Standardized - used as sinusoidal reference function of natural sampling

Power equilibrium

$$p_{c1} = p_{c2} \qquad p_{c1} = v_{c1} \cdot i_{c1} \qquad p_{c2} = v_{c2} \cdot i_{c2}$$

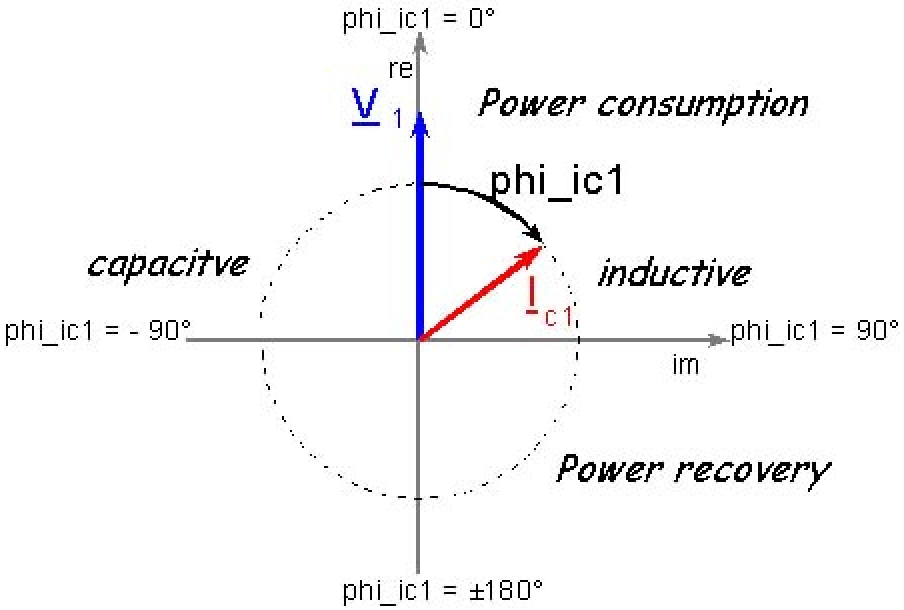
$$I_{c1\_ampl} = \frac{1}{2 \cdot R\_eq} \cdot \Big[V_{1\_ampl} \cdot \cos(phi\_ic1) - \sqrt{(V_{1\_ampl})^2 \cdot (\cos(phi\_ic1))^2 - 8 \cdot P2 \cdot R\_}$$

$$i_{c1\_soll} = I_{c1\_ampl} \cdot \sin(\omega t + phi\_ic1)$$

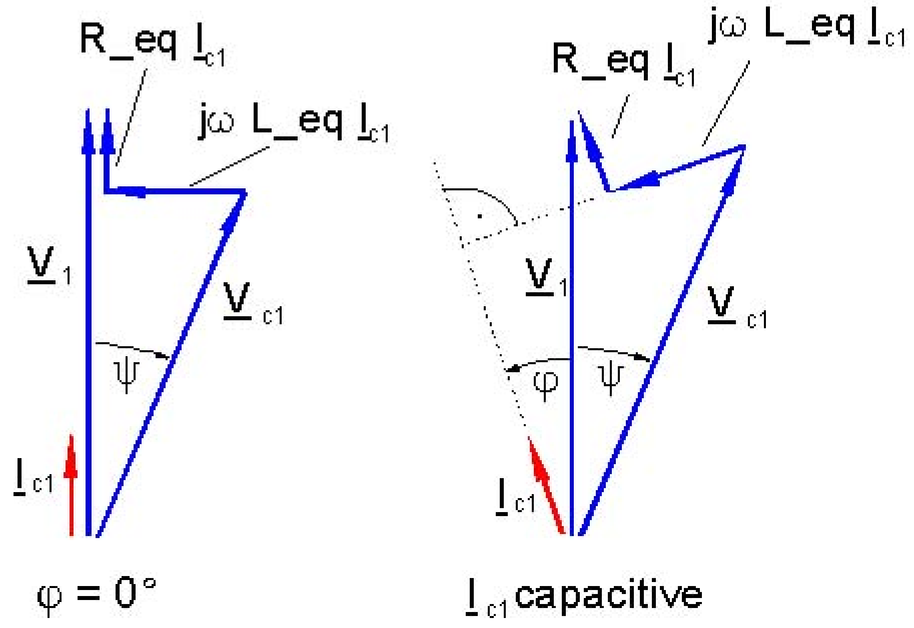
P2 - average of power output

$\omega = 2\pi \cdot F1$

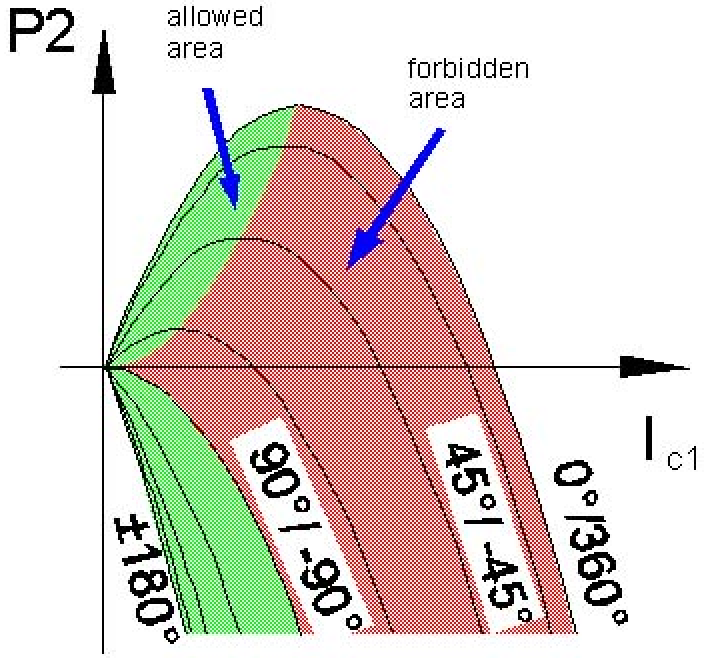
Definition of quadrants



Phase diagrams (examples)



Dependence of the 4qc power output from the input current and its phase angle



Four Quadrant Current Control

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

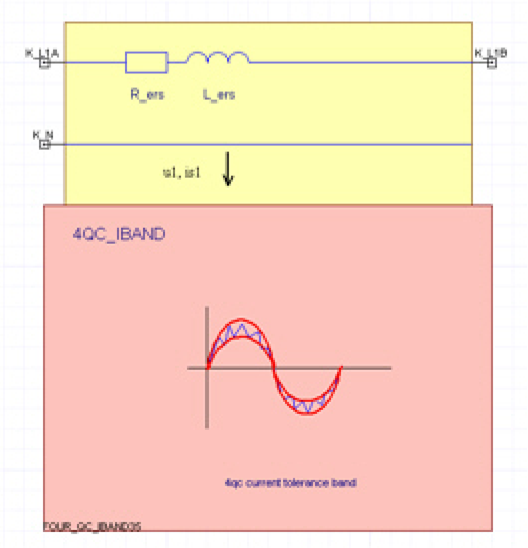


Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a control algorithm of a four-quadrant converter connected to a single-phase AC network based on a step-up method. A nearly sinusoidal current is forced, and the harmonic content depends on the width of the tolerance band. Because the control algorithm needs step-up impedance variables, those components are assigned to this model.

See also Definition of Variables and System of Equations

Top

Assumptions and Limitations

Top

Mathematical Description

The control algorithm calculates the value of the converter input current reference ic1_soll. The points of commutation are determined in the following way:

ic1 ^{3} ic1_soll + delta_i (upper limit of tolerance band)

ic1 ≤ ic1_soll - delta_i (lower limit of tolerance band)

The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is £ 0, the valve is turned off.

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Netlist Syntax

MODEL FOUR_QC_IBAND ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_L1A:= %0, K_L1B:= %1, K_N:= %2 (R_ERS:= @R_ERS, L_ERS:= @L_ERS, U1_AMPL:= @U1_AMPL, FREQUENCY:= @FREQUENCY, PHI_IC1:= @PHI_IC1, DELTA_I:= @DELTA_I, P2:= @P2, GATE1:= @GATE1, GATE2:= @GATE2, GATE3:= @GATE3, GATE4:= @GATE4) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Single-Phase Two Level Inverter

Top

Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_L1A	Terminal 1	electrical
K_L1B	Terminal 2	electrical
K_N	Terminal 3	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
R_ERS	Resistance	real	20m [Ohm]

L_ERS	Inductance	real	5m [H]
U1_AMPL	Amplitude AC Voltage	real	2.0223k [V]
FREQUENCY	Frequency Input Voltage	real	16.67 [Hz]
PHI_IC1	Reference Value Phase Shift Line Current	real	0 [degree]
DELTA_I	Current Tolerance Band	real	0.1k [A]
P2	Reference Value DC Power	real	p2* [W]

* This parameter must be predefined variables.

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
GATE1	Control Signal Upper Transistor Phase 1	Input/Output	real
GATE2	Control Signal Lower Transistor Phase 1	Input/Output	real
GATE3	Control Signal Upper Transistor Phase 2	Input/Output	real
GATE4	Control Signal Lower Transistor Phase 2	Input/Output	real

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Example

In this example, a sinusoidal voltage source ET1 is applied to a Single-Phase Two Level Inverter _2LH_GTOS1 through a Four-Quadrant Current Controller FOUR_QS_IBAND. The output of the inverter is connected to a first-order RC load. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

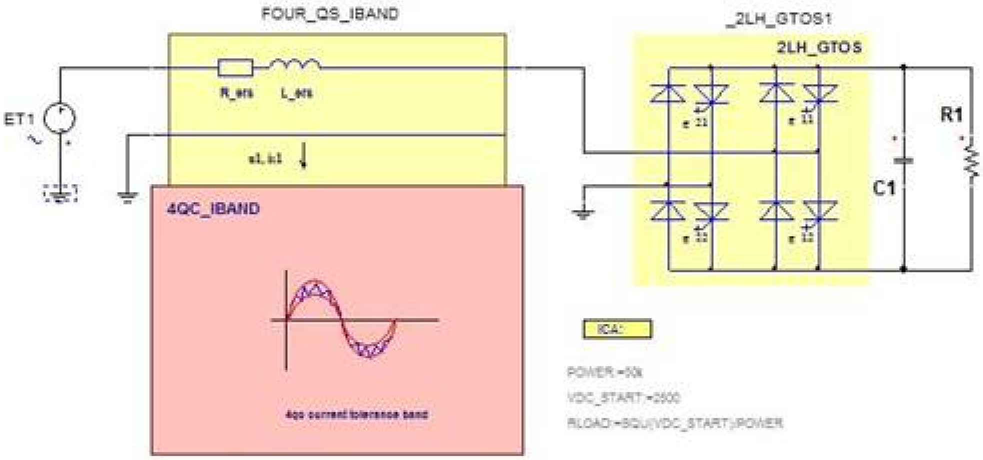

Figure 2. Application example of the Single-Phase Two Level Inverter model

Table 4. System Parameters

Component	Parameter	Value [unit]
Voltage Source (Sinusoidal) ET1	AMPL	2000 [V]
	FREQ	1/0.06 [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]
Single-Phase Two Level Inverter 2L3_GTOS1	G_11	G_11
	G_12	G_12
	G_21	G_21
	G_22	G_22
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]

Four-Quadrant Current Control FOUR_QS_IBAND	R_ERS	20m [Ohm]
	L_ERS	100m [H]
	U1_AMPL	2000 [V]
	FREQUENCY	16.67 [Hz]
	PHI_IC1	0 [degree]
	DELTA_1	1 [A]
	P2	POWER*
Resistor R1	R	RLOAD*
Capacitor C1	C	500m [F]
	V0	VDC_START*
Initial Values FML_INIT1	POWER	500k
	VDC_START	2500
	RLOAD	SQU(VDC_START)/POWER

* These parameters are defined by the Initial Value Block FML_INIT1.

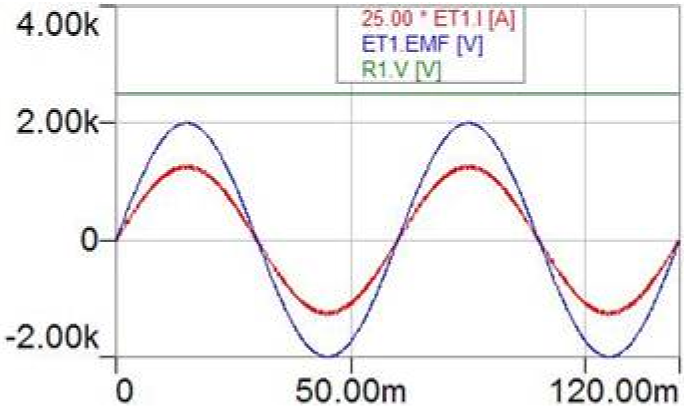

Figure 3. Simulation results-voltage and current of ET1 (ET1.EMF and ET1.I) and output voltage of the inverter (R1.V)

Top

References

Four Quadrant Natural Sampling

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

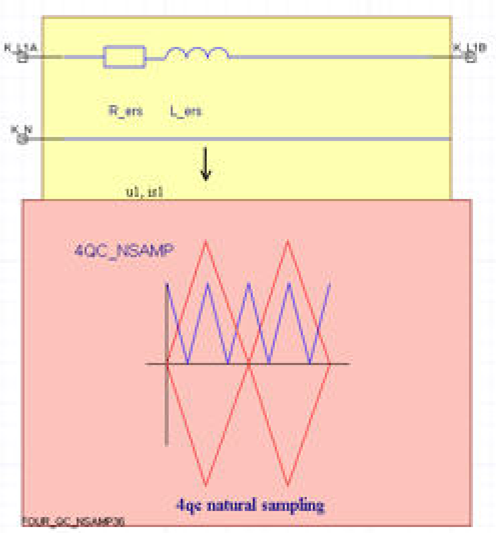

Figure 1. Component symbol

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- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a control algorithm of a four-quadrant converter connected to a single-phase AC network based on a step-up method. A nearly sinusoidal current is forced, and the harmonic content depends on the number of pulses (the frequency of the triangular function). Because the control algorithm needs step-up impedance variables, those components are assigned to this model.

See also Definition of Variables and System of Equations

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Assumptions and Limitations

Top

Mathematical Description

The number of pulses is related to a half-wave of the (input) AC voltage. The value range of the number of pulses depends on F1. For F1 = 16 2/3 Hz is (3 <= pulsnum <= 3)}. This corresponds to a maximum frequency of the triangular reference function of 2 * f1 * PULSNUM = 1100 Hz (useful for the application of GTOs).

The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is ≤ 0, the valve is turned off.

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Netlist Syntax

MODEL FOUR_QC_NSAMP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_L1A:= %0, K_L1B:= %1, K_N:= %2 (R_ERS:= @R_ERS, L_ERS:= @L_ERS, U1_AMPL:= @U1_AMPL, FREQUENCY:= @FREQUENCY, PHI_IC1:= @PHI_IC1, PULSE:= @PULSE, U2:= @U2, P2:= @P2, GATE1:= @GATE1, GATE2:= @GATE2, GATE3:= @GATE3, GATE4:= @GATE4) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Single-Phase Two Level Inverter

Top

Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_L1A	Terminal 1	electrical
K_L1B	Terminal 2	electrical
K_N	Terminal 3	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
R_ERS	Resistance	real	20m [Ohm]
L_ERS	Inductance	real	5m [H]

U1_AMPL	Amplitude AC Voltage	real	2.0223k [V]
FREQUENCY	Frequency Input Voltage	real	16.67 [Hz]
PHI_IC1	Reference Value Phase Shift Line Current	real	0 [degree]
PULSE	Number of Pulses	real	11
U2	Reference Value DC Voltage	real	2.8k [V]
P2	Reference Value DC Power	real	p2* [W]

* This parameter must be predefined variables.

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
GATE1	Control Signal Upper Transistor Phase 1	Input/Output	real
GATE2	Control Signal Lower Transistor Phase 1	Input/Output	real
GATE3	Control Signal Upper Transistor Phase 2	Input/Output	real
GATE4	Control Signal Lower Transistor Phase 2	Input/Output	real

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Example

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References

Three-Level Single-Phase NS

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

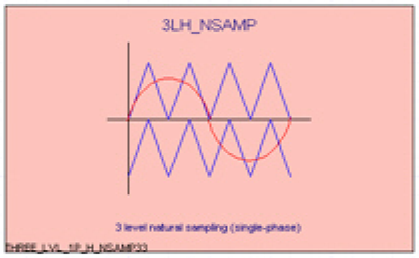

Figure 1. Component symbol

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Description

The Three-Level Single-Phase NS (which stands for Natural Sampling) model describes a control algorithm for voltage source pulse inverters, based on a comparison of a sinusoidal reference function with two triangular reference functions (ranges of values: {0 <= triangle1 <= 1} and {-1 <= triangle2 <= 0}). All functions have variable frequencies. The gate control signals are derived from the points of intersection of the sinusoidal and triangular functions. The derived control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is £ 0, the valve is turned off.

The following definitions apply to the input parameters:

$$\mathrm{MODERATE} = \frac{\mathrm{AMPL\_RECT}}{\mathrm{AMPL\_TRIAN}} \qquad f_{trian} = \mathrm{PULSNUM} \cdot \mathrm{F1}$$

The frequency F1 of the sinusoidal reference functions corresponds to the frequency of the fundamental of the generated inverter output voltage. If the rate of modulation is greater than 1, there are no points of intersection (voltage block control).

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL THREE_LVL_1P_H_NSAMP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, MODRATE:= @MODRATE, PULSNUM:= @PULSNUM, G_11:= @G_11, G_12:= @G_12, G_13:= @G_13, G_14:= @G_14, G_21:= @G_21, G_22:= @G_22, G_23:= @G_23, G_24:= @G_24) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Single-Phase Three-Level Inverter

Top

Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
MODRATE	Modulation Rate	real	0.9
PULSNUM	Number of Pulses	real	15

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_11	Control Signal Transistor 1 Phase 1	Input/Output	real
G_12	Control Signal Transistor 2 Phase 1	Input/Output	real
G_13	Control Signal Transistor 3 Phase 1	Input/Output	real
G_14	Control Signal Transistor 4 Phase 1	Input/Output	real
G_21	Control Signal Transistor 1 Phase 2	Input/Output	real
G_22	Control Signal Transistor 2 Phase 2	Input/Output	real

G_23	Control Signal Transistor 3 Phase 2	Input/Output	real
G_24	Control Signal Transistor 4 Phase 2	Input/Output	real

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Example

In this example, a DC voltage source E1 is applied to a first-order RL Load through a Single-Phase Three-Level Inverter _3LH_GTOS1. The control signals for the inverter are decided by a Three-Level Single Phase NS control block _3LH_NSAMP1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

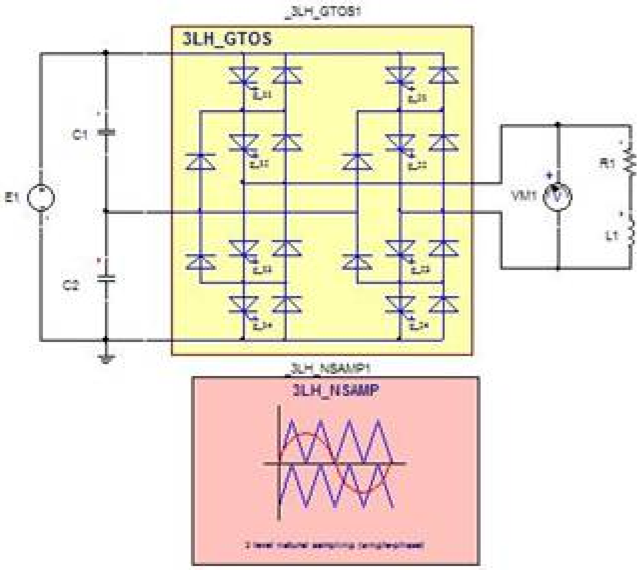

Figure 2. Application example of the Three-Level Single Phase NS model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	2.8k [V]

Three Level Single-Phase Inverter _3LH_ GTOS1	G_11	G_11
	G_12	G_12
	G_13	G_13
	G_14	G_14
	G_21	G_21
	G_22	G_22
	G_23	G_23
	G_24	G_24
	G_11	G_11
	G_12	G_12
	G_13	G_13
	G_14	G_14
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three-Level Single Phase NS _3LH_ NSAMP1	FREQUENCY	50 [Hz]
	MODRATE	0.9
	PULSNUM	15
Resistor R1	R	3 [Ohm]
Inductor L1	L	2m [H]
	I0	0 [A]

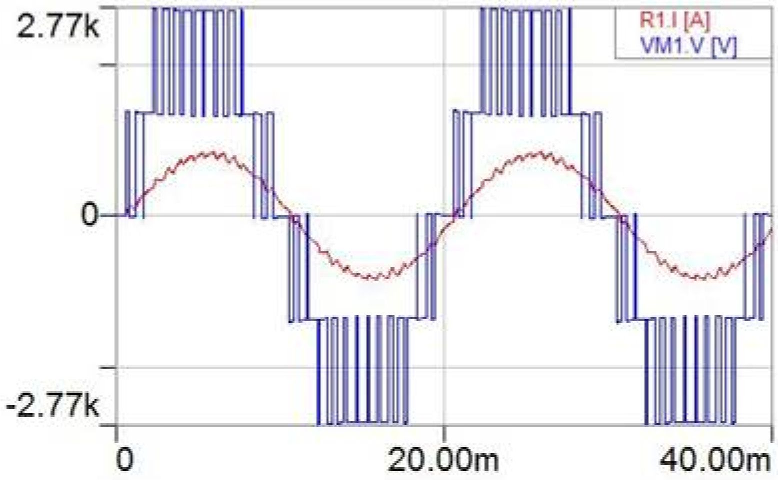

Figure 3. Simulation results

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References

Three-Level Single-Phase

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

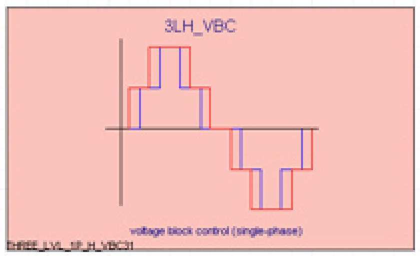

Figure 1. Component symbol

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Description

This model describes a voltage block control of a single-phase three-level inverter. Changing the parameters ALPHA and BETA influences the RMS value of the output voltage. ALPHA and BETA have a sensible shift range of 0º£ alpha/beta < 60 degrees (electrical). The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is £ 0, the valve is turned off.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL THREE_LVL_1P_H_VBC ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, ALPHA:= @ALPHA, BETA:= @BETA, G_11:= @G_11, G_12:= @G_12, G_13:= @G_13, G_14:= @G_14, G_21:= @G_21, G_22:= @G_22, G_23:= @G_23, G_24:= @G_24) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Single-Phase Three-Level Inverter

Top

Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
ALPHA	Angle at Positive Edge	real	30 [degree]
BETA	Angle at Negative Edge	real	30 [degree]

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_11	Control Signal Transistor 1 Phase 1	Input/Output	real
G_12	Control Signal Transistor 2 Phase 1	Input/Output	real
G_13	Control Signal Transistor 3 Phase 1	Input/Output	real
G_14	Control Signal Transistor 4 Phase 1	Input/Output	real
G_21	Control Signal Transistor 1 Phase 2	Input/Output	real
G_22	Control Signal Transistor 2 Phase 2	Input/Output	real
G_23	Control Signal Transistor 3 Phase 2	Input/Output	real
G_24	Control Signal Transistor 4 Phase 2	Input/Output	real

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Example

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References

Three-Level Three-Phase NS

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

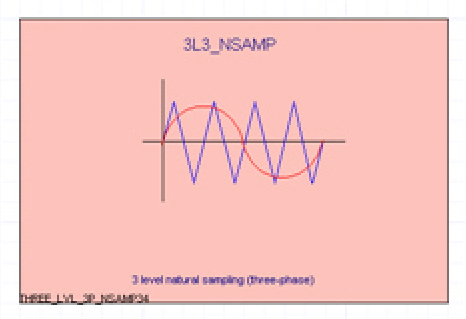

Figure 1. Component symbol

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Description

The Three-Level Three-Phase NS (which stands for Natural Sampling) model describes a control algorithm for voltage source pulse inverters, based on a comparison of three sinusoidal reference functions (equivalent to a three-phase system) with a triangular reference function. All functions have variable frequencies. The gate control signals are derived from the points of intersection of the sinusoidal and triangular functions. The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is £ 0, the valve is turned off.

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Assumptions and Limitations

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Mathematical Description

The following definitions apply to the input parameters:

The frequency F1of the sinusoidal reference functions corresponds to the frequency of the fundamental of the generated inverter output voltage. If the rate of modulation is greater than 1, there are no points of intersection (voltage block control). To model a soft-start of an induction machine, MODRATE can be assigned to the value of a time function.

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Netlist Syntax

MODEL THREE_LVL_3P_NSAMP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, MODRATE:= @MODRATE, PULSNUM:= @PULSNUM, G_R1:= @G_R1, G_R2:= @G_R2, G_R3:= @G_R3, G_R4:= @G_R4, G_S1:= @G_S1, G_S2:= @G_S2, G_S3:= @G_S3, G_S4:= @G_S4, G_T1:= @G_T1, G_T2:= @G_T2, G_T3:= @G_T3, G_T4:= @G_T4) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Three-Phase Three-Level Inverter

Top

Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
MODRATE	Modulation Rate	real	1
PULSNUM	Number of Pulses	real	15

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_R1	Control Signal Transistor 1 Phase R	Input/Output	real
G_R2	Control Signal Transistor 2 Phase R	Input/Output	real
G_R3	Control Signal Transistor 3 Phase R	Input/Output	real
G_R4	Control Signal Transistor 4 Phase R	Input/Output	real
G_S1	Control Signal Transistor 1 Phase S	Input/Output	real
G_S2	Control Signal Transistor 2 Phase S	Input/Output	real

G_S3	Control Signal Transistor 3 Phase S	Input/Output	real
G_S4	Control Signal Transistor 4 Phase S	Input/Output	real
G_T1	Control Signal Transistor 1 Phase T	Input/Output	real
G_T2	Control Signal Transistor 2 Phase T	Input/Output	real
G_T3	Control Signal Transistor 3 Phase T	Input/Output	real
G_T4	Control Signal Transistor 4 Phase T	Input/Output	real

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Example

In this example, a DC voltage source E1 is applied to a Three-Phase Three-Phase RL Load RL31 through a Three-Phase Three-Level Inverter _3L3_GTOS1. The control signals for the inverter are decided by a Three-Level Three Phase NS control block _3L3_NSAMP1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

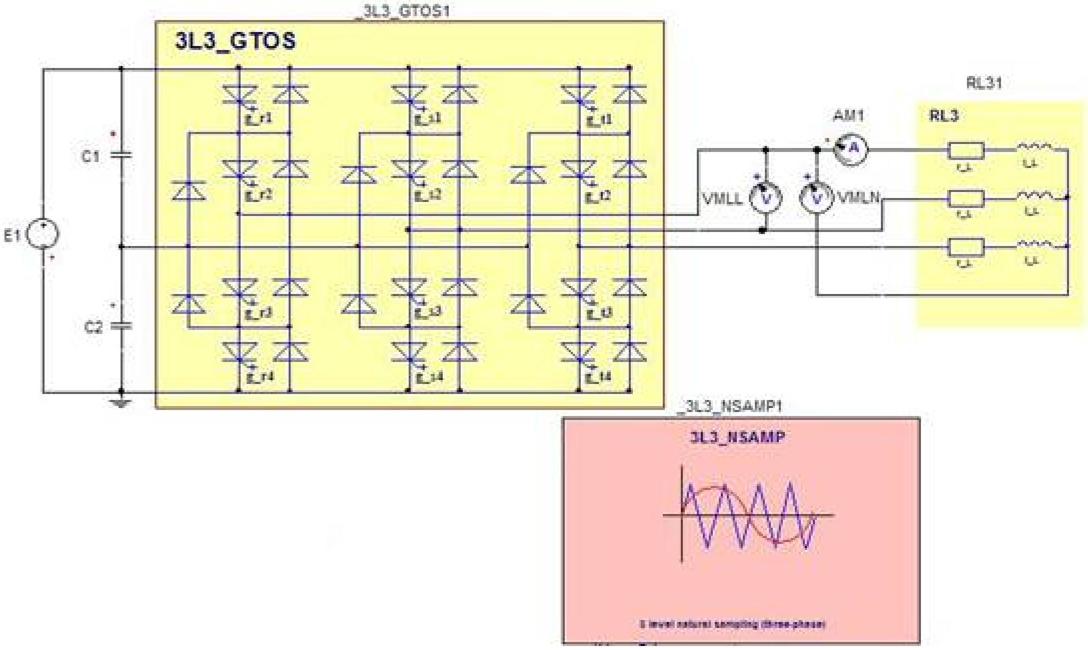

Figure 2. Application example of the Three-Level Three-Phase NS model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	2.8k [V]

Three-Phase Three Level Inverter 3L3_ GTOS1	G_R1	G_R1
	G_R2	G_R2
	G_R3	G_R3
	G_R4	G_S4
	G_S1	G_S1
	G_S2	G_S2
	G_S3	G_S3
	G_S4	G_S4
	G_T1	G_T1
	G_T2	G_T2
	G_T3	G_T3
	G_T4	G_T4
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three-Level Three Phase _3L3_ NSAMP1	FREQUENCY	40 [Hz]
	MODRATE	0.75
	PULSNUM	11
Three-Phase RL Load RL31	R_L	3 [Ohm]
	L_L	2m [H]

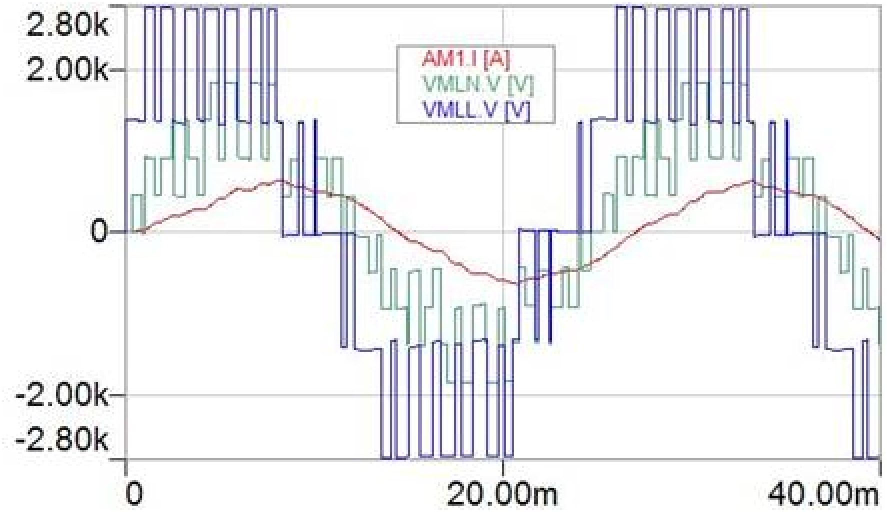

Figure 3. Simulation results

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References

Three-Level Three-Phase

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

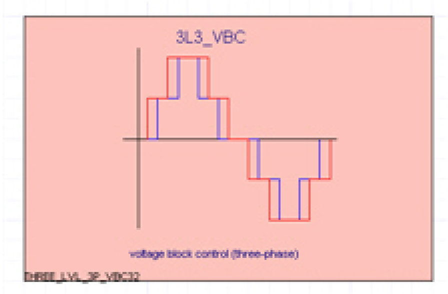

Figure 1. Component symbol

- Description
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- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a voltage block control of a three-phase three-level inverter. Changing the parameter ALPHA influences the RMS value of the output voltage. ALPHA has a sensible shift range 0º£ alpha/beta < 90 degrees (electrical). The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is £ 0, the valve is turned off.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL THREE_LVL_3P_VBC ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, ALPHA:= @ALPHA, G_R1:= @G_R1, G_R2:= @G_R2, G_R3:= @G_R3, G_R4:= @G_R4, G_S1:= @G_S1, G_S2:= @G_S2, G_S3:= @G_S3, G_S4:= @G_S4, G_T1:= @G_T1, G_T2:= @G_T2, G_T3:= @G_T3, G_T4:= @G_T4) SRC: DB(Lib:-:=@ModelLibraryName) ;

Possible circuit topologies:

See also Three-Phase Three-Level Inverter

Top

Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
ALPHA	Angle at Positive Edge	real	30 [degree]

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_R1	Control Signal Transistor 1 Phase R	Input/Output	real
G_R2	Control Signal Transistor 2 Phase R	Input/Output	real
G_R3	Control Signal Transistor 3 Phase R	Input/Output	real
G_R4	Control Signal Transistor 4 Phase R	Input/Output	real
G_S1	Control Signal Transistor 1 Phase S	Input/Output	real
G_S2	Control Signal Transistor 2 Phase S	Input/Output	real
G_S3	Control Signal Transistor 3 Phase S	Input/Output	real
G_S4	Control Signal Transistor 4 Phase S	Input/Output	real
G_T1	Control Signal Transistor 1 Phase T	Input/Output	real
G_T2	Control Signal Transistor 2	Input/Output	real

	Phase T		
G_T3	Control Signal Transistor 3 Phase T	Input/Output	real
G_T4	Control Signal Transistor 4 Phase T	Input/Output	real

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Example

In this example, a DC voltage source E1 is applied to a Three-Phase Three-Phase RL Load RL31 through a Three-Phase Three-Level Inverter _3L3_GTOS1. The control signals for the inverter are decided by a Three-Level Three Phase control block _3L3_VBC1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

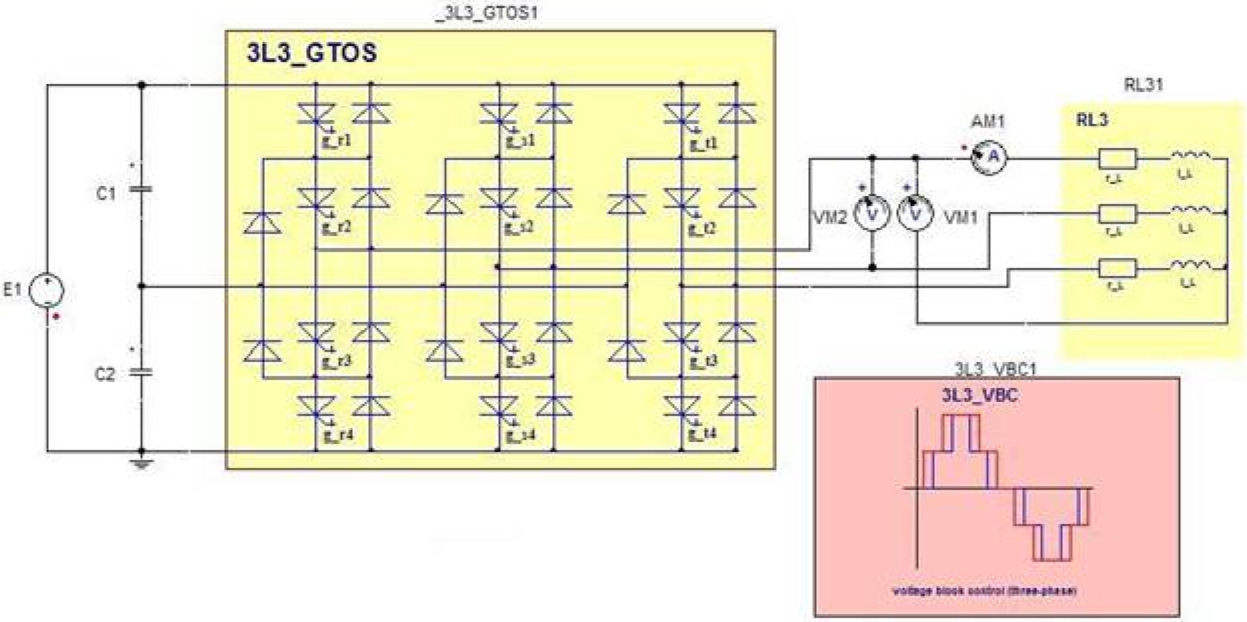

Figure 2. Application example of the Three-Level Three-Phase model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	2.8k [V]

Three-Phase Three Level Inverter 3L3_ GTOS1	G_R1	G_R1
	G_R2	G_R2
	G_R3	G_R3
	G_R4	G_S4
	G_S1	G_S1
	G_S2	G_S2
	G_S3	G_S3
	G_S4	G_S4
	G_T1	G_T1
	G_T2	G_T2
	G_T3	G_T3
	G_T4	G_T4
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three-Level Three Phase _3L3_VBC1	FREQUENCY	50 [Hz]
	ALPHA	60 [degree]
Three-Phase RL Load RL31	R_L	3 [Ohm]
	L_L	2m [H]

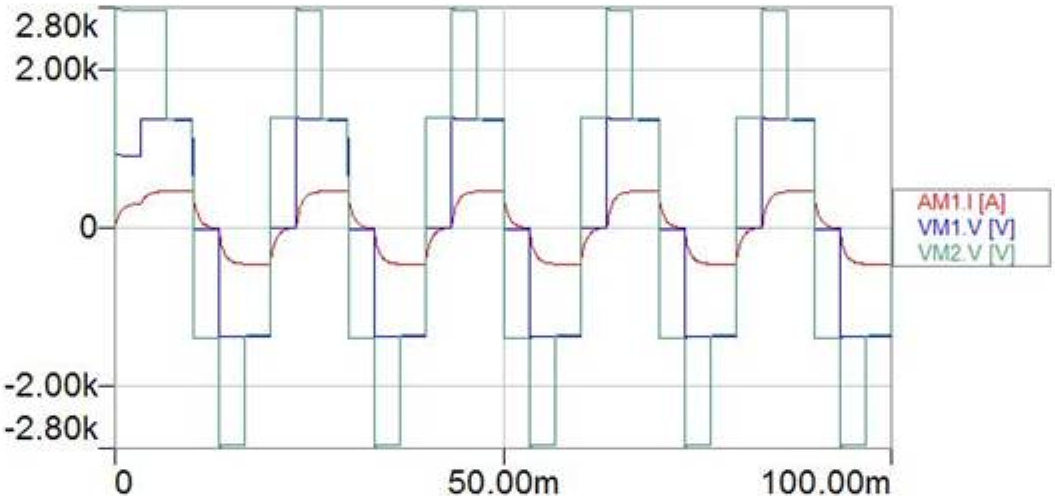

Figure 3. Simulation results

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References

Two Level Natural Sampling

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

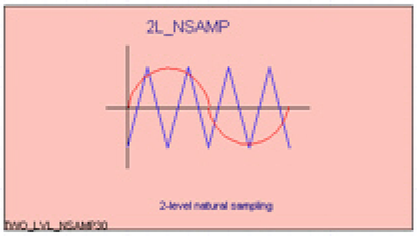

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a control algorithm for voltage source pulse inverters, based on a comparison of three sinusoidal reference functions (equivalent to a three-phase system) with a triangular reference function. All functions have variable frequencies. The gate control signals are derived from the points of intersection of the sinusoidal and triangular functions. The provided control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is ≤ 0, the valve is turned off.

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Assumptions and Limitations

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Mathematical Description

The following definitions apply to the input parameters:

$$\mathrm{MODRATE} = \frac{\mathrm{AMPL\_RECT}}{\mathrm{AMPL\_TRIAN}} \qquad f_{\mathrm{trian}} = \mathrm{PULSNUM} \cdot \mathrm{F1}$$

The frequency F1 of the sinusoidal reference functions corresponds to the frequency of the fundamental of the generated inverter output voltage. If the rate of modulation is greater than 1, there are no points of intersection (voltage block control). To model a soft-start of an induction machine, MODRATE can be assigned to the value of a time function.

If the macro is being used together with a single-phase circuit (2LH_GTOS), the gate control signals of one phase (preferably phase R) can be assigned to the valve diagonals (g_11 = g_22 = g_r1 and g_21 = g_12 = g_r2).

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Netlist Syntax

MODEL TWO_LVL_NSAMP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, MODRATE:= @MODRATE, PULSNUM:= @PULSNUM, G_R1:= @G_R1, G_R2:= @G_R2, G_S1:= @G_S1, G_S2:= @G_S2, G_T1:= @G_T1, G_T2:= @G_T2) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Two Level Inverter Equivalent Circuit

See also Three-Phase Two Level Inverter

See also Single-Phase Two Level Inverter

Top

Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
MODRATE	Modulation Rate	real	1
PULSNUM	Number of Pulses	real	15

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_R1	Control Signal Upper Transistor Phase R	Input/Output	real
G_R2	Control Signal Lower Transistor Phase R	Input/Output	real
G_S1	Control Signal Upper Transistor Phase S	Input/Output	real

G_S2	Control Signal Lower Transistor Phase S	Input/Output	real
G_T1	Control Signal Upper Transistor Phase T	Input/Output	real
G_T2	Control Signal Lower Transistor Phase T	Input/Output	real

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Example

In this example, a DC voltage source E1 is applied to a Three-Phase RL Load RL31 through a Three-Phase Two-Level Inverter _2L3_GTOS1. The control signals for the inverter are decided by a Two-Level Square Wave control block _2L_NSAMP1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

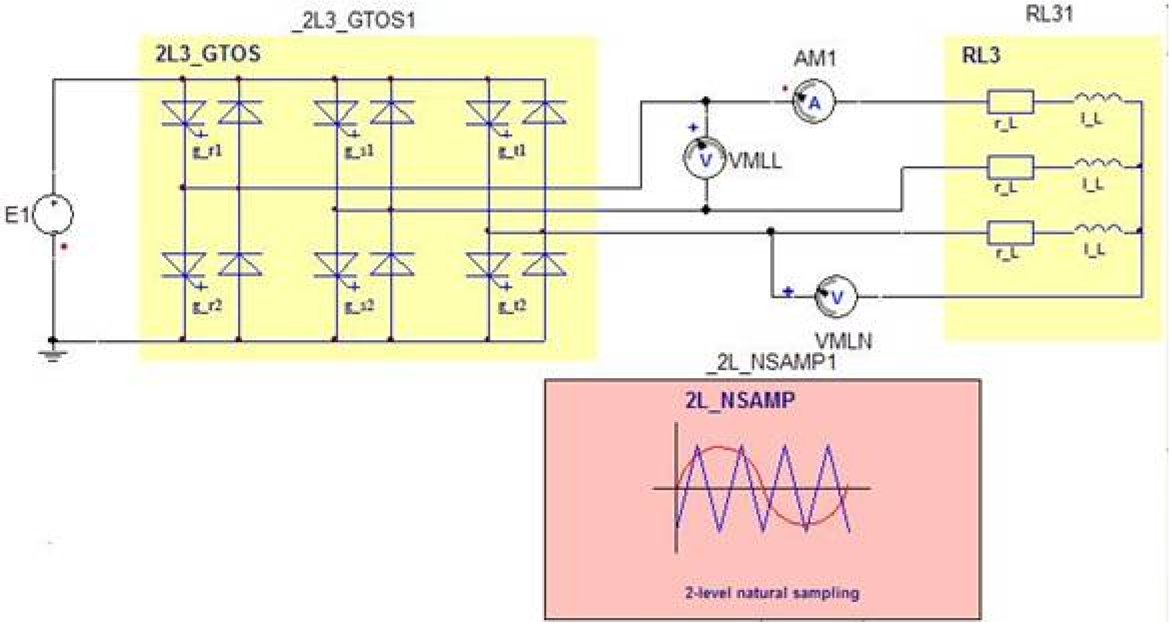

Figure 2. Application example of the Two Level Square Wave model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	500 [V]

Two Level Three-Phase Inverter _2L3_ GTOS1	G_R1	g_r1
	G_R2	g_r2
	G_S1	g_s1
	G_S2	g_s2
	G_T1	g_t1
	G_T2	g_t2
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Two Level Natural Wave _2L_NSAMP1	FREQUENCY	50 [Hz]
	MODRATE	0.75
	PULSNUM	20
Three-Phase RL Load RL31	R	1 [Ohm]
	L	2m [H]

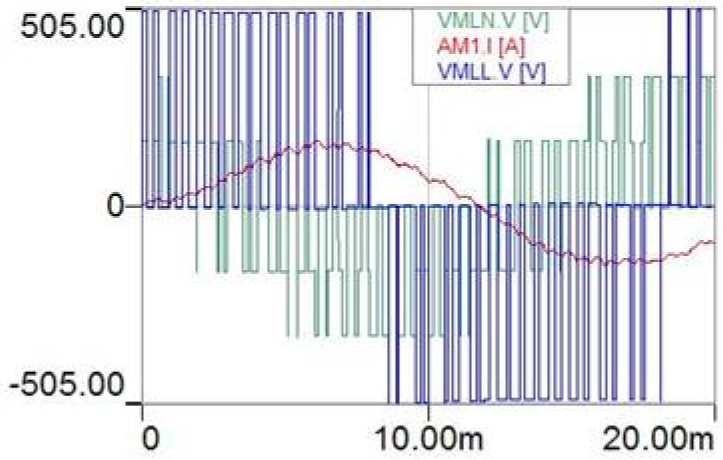

Figure 3. Simulation results

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References

Two Level Square Wave

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

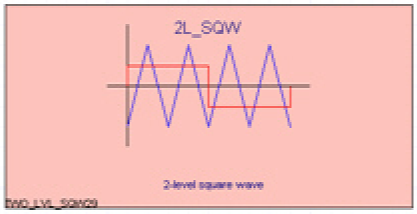

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a control algorithm for voltage source pulse inverters, based on a comparison of three rectangular reference functions (equivalent to a three-phase system) with a triangular reference function. All functions have variable frequencies. The gate control signals are derived from the intersection points of the rectangular and triangular functions. The output control signals can be used to control static semiconductors (switches). If the control signal value is > 0, the valve is turned on. If the control signal value is ≤ 0, the valve is turned off.

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Assumptions and Limitations

Top

Mathematical Description

The frequency F1 of the rectangular reference functions corresponds to the frequency of the fundamental of the generated inverter output voltage. If the rate of modulation is greater than 1, there are no points of intersection (voltage block control). To model a soft-start of an induction machine, MODRATE can be assigned to the value of a time function.

If the model is being used together with a single-phase circuit (2LH_GTOS), the gate control signals of one phase (preferably phase R) can be assigned to the valve diagonals (g_11 = g_22 = g_r1 and g_21 = g_12 = g_r2).

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Netlist Syntax

MODEL TWO_LVL_SQW ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (FREQUENCY:= @FREQUENCY, MODRATE:= @MODRATE, PULSNUM:= @PULSNUM, G_R1:= @G_R1, G_R2:= @G_R2, G_S1:= @G_S1, G_S2:= @G_S2, G_T1:= @G_T1, G_T2:= @G_T2) SRC: DB(Lib:=@ModelLibraryName) ;

Possible circuit topologies:

See also Two Level Inverter Equivalent Circuit

See also Three-Phase Two Level Inverter

See also Single-Phase Two Level Inverter

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Frequency AC Voltage	real	50 [Hz]
MODRATE	Modulation Rate	real	1
PULSNUM	Number of Pulses	real	15

Top

Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
G_R1	Control Signal Upper Transistor Phase R	Input/Output	real
G_R2	Control Signal Lower Transistor Phase R	Input/Output	real
G_S1	Control Signal Upper Transistor Phase S	Input/Output	real
G_S2	Control Signal Lower Transistor Phase S	Input/Output	real
G_T1	Control Signal Upper Transistor Phase T	Input/Output	real

G_T2	Control Signal Lower Transistor Phase T	Input/Output	real

Top

Example

In this example, a DC voltage source E1 is applied to a Three-Phase RL Load RL31 through a Three-Phase Two-Level Inverter _2L3_GTOS1. The control signals for the inverter are decided by a Two-Level Square Wave control block TWO_LVL_SQW1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

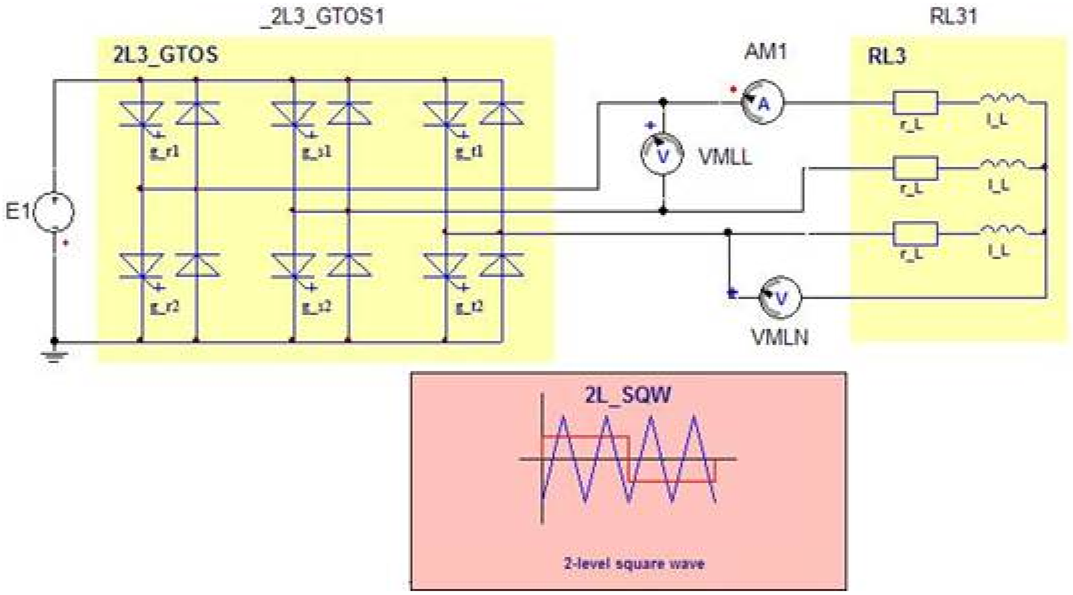

Figure 2. Application example of the Two Level Square Wave model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	500 [V]

Two Level Three-Phase Inverter _2L3_ GTOS1	G_R1	g_r1
	G_R2	g_r2
	G_S1	g_s1
	G_S2	g_s2
	G_T1	g_t1
	G_T2	g_t2
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Two Level Squar Wave TWO_LVL_ SQW1	FREQUENCY	50 [Hz]
	MODRATE	0.5
	PULSNUM	15
Three-Phase RL Load RL31	R	1 [Ohm]
	L	2m [H]

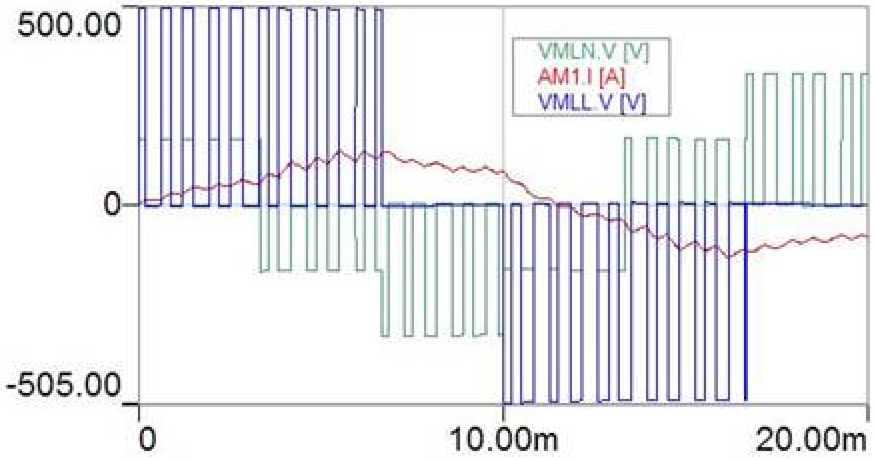

Figure 3. Simulation results

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References

Converter

- Fully-controlled 12-pulse Bridge Connection with static Models for Thyristors - Two B6C Bridges in Parallel (B12CP)
- Fully-controlled 12-pulse Bridge Connection with static Models for Thyristors - Cascade Two B6C Bridges (B12CS)
- Uncontrolled 12-pulse Bridge Connection with static Models for Diodes - Cascade Two B6U Bridges (B12U)
- Fully-controlled 18-pulse Bridge Connection with static Models for Thyristors - Cascade Three B6C Bridges (B18)
- Fully-controlled 24-pulse Bridge Connection with static Models for Thyristors (B24)
- Fully-controlled 2-pulse Bridge Connection with static Models for Thyristors (B2C)
- Symmetrical half-controlled 2-pulse Bridge Connection with static Models for Diodes and Thyristors (B2HK)
- Asymmetrical half-controlled 2-pulse Bridge Connection with static Models for Diodes and Thyristors (B2HZ)
- Uncontrolled 2-pulse Bridge Connection with static Models for Diodes (B2U)
- Fully-controlled 6-pulse Bridge Connection with static Models for Thyristors (B6C)
- B6C with Additional Inputs for Signal Generation and Pulse Enable (B6C_E)
- Inverse-parallel Connection of two B6C-Bridges for Implementation of reversible Converters and direct Converters (B6C2L)
- Uncontrolled 6-pulse Bridge Connection with static Models for Diodes (B6U)
- Deadtime Generator for Mutual Locking of Half Bridge Valves (DEADTIME)
- Controller Macro for B6C2L as Direct Converter or Reversible Converter with Current Control (DUR_IREG)
- Power Controller with static Models for Thyristors (W1C)
- 3-Phase A.C. Power Controller with static Models for Thyristors - Three W1C in parallel (W3C_3A)

B12 Thyristor Bridge Parallel Connection (B12CP)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

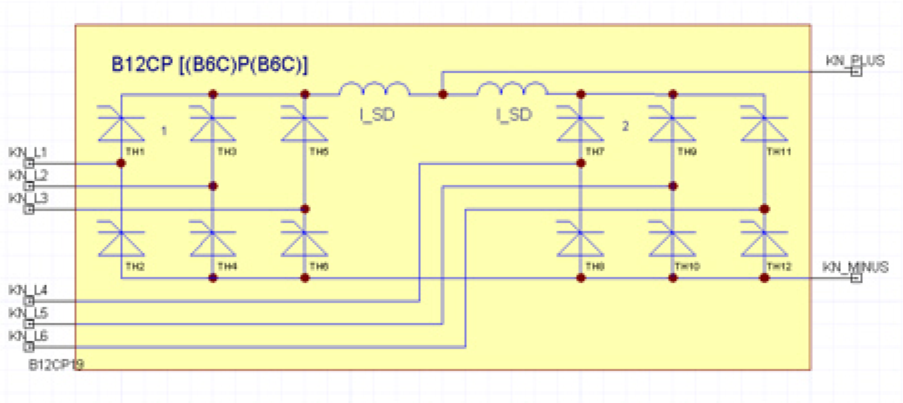

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model consists of two B6C bridges connected in parallel via two balance coils. To model a phase shift of 30 degrees (electrical), the AC terminals of this macro have to be connected to a transformer with two secondary winding connections (star/delta).

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL B12CP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_L4:= %3, KN_L5:= %4, KN_L6:= %5, KN_PLUS:= %6, KN_MINUS:= %7 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, L_SD:= @L_SD, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3 Converter 1	electrical
KN_L4/KN_L5/KN_L6	AC Terminal Line 1/2/3 Converter 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [deg]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
L_SD	Inductivity of One Smoothing Inductance	real	0.1u [H]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type

V_TH1	Diode Voltage [V]	Output	real
I_TH1	Diode Current [A]	Output	real
V_TH2	Diode Voltage [V]	Output	real
I_TH2	Diode Current [A]	Output	real
V_TH3	Diode Voltage [V]	Output	real
I_TH3	Diode Current [A]	Output	real
V_TH4	Diode Voltage [V]	Output	real
I_TH4	Diode Current [A]	Output	real
V_TH5	Diode Voltage [V]	Output	real
I_TH5	Diode Current [A]	Output	real
V_TH6	Diode Voltage [V]	Output	real
I_TH6	Diode Current [A]	Output	real
V_TH7	Diode Voltage [V]	Output	real
I_TH7	Diode Current [A]	Output	real
V_TH8	Diode Voltage [V]	Output	real
I_TH8	Diode Current [A]	Output	real
V_TH9	Diode Voltage [V]	Output	real
I_TH9	Diode Current [A]	Output	real
V_TH10	Diode Voltage [V]	Output	real
I_TH10	Diode Current [A]	Output	real
V_TH11	Diode Voltage [V]	Output	real
I_TH11	Diode Current [A]	Output	real
V_TH12	Diode Voltage [V]	Output	real
I_TH12	Diode Current [A]	Output	real

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Example

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References

B12 Thyristor Bridge Cascade (B12CS)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

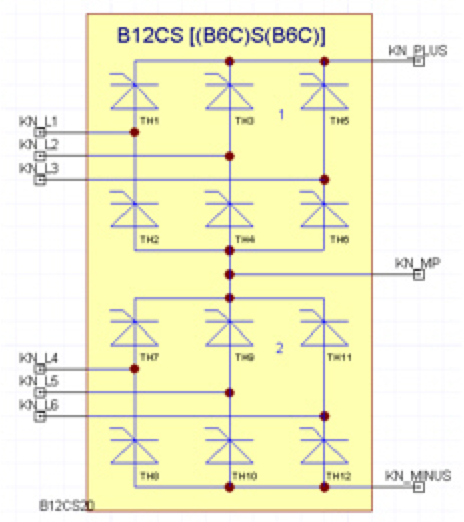

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model consists of two B6C bridges connected in series. To model a phase shift of 30 degrees (electrical), the AC terminals of this macro have to be connected to a transformer with two secondary winding connections (star/delta). The terminal KN_MP is put outside for measurement purposes.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL B12CS ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_L4:= %3, KN_L5:= %4, KN_L6:= %5, KN_PLUS:= %6, KN_MP:= %7, KN_MINUS:= %8 (ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3 Converter 1	electrical
KN_L4/KN_L5/KN_L6	AC Terminal Line 1/2/3 Converter 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA1	Delay Angle Converter 1	real	30 [deg]
ALPHA2	Delay Angle Converter 2	real	30 [deg]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real
V_TH3	Thyristor Voltage [V]	Output	real
I_TH3	Thyristor Current [A]	Output	real
V_TH4	Thyristor Voltage [V]	Output	real
I_TH4	Thyristor Current [A]	Output	real
V_TH5	Thyristor Voltage [V]	Output	real
I_TH5	Thyristor Current [A]	Output	real
V_TH6	Thyristor Voltage [V]	Output	real
I_TH6	Thyristor Current [A]	Output	real
V_TH7	Thyristor Voltage [V]	Output	real
I_TH7	Thyristor Current [A]	Output	real
V_TH8	Thyristor Voltage [V]	Output	real
I_TH8	Thyristor Current [A]	Output	real
V_TH9	Thyristor Voltage [V]	Output	real
I_TH9	Thyristor Current [A]	Output	real
V_TH10	Thyristor Voltage [V]	Output	real
I_TH10	Thyristor Current [A]	Output	real
V_TH11	Thyristor Voltage [V]	Output	real
I_TH11	Thyristor Current [A]	Output	real
V_TH12	Thyristor Voltage [V]	Output	real
I_TH12	Thyristor Current [A]	Output	real

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Example

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References

B12 Diode Bridge (B12U)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

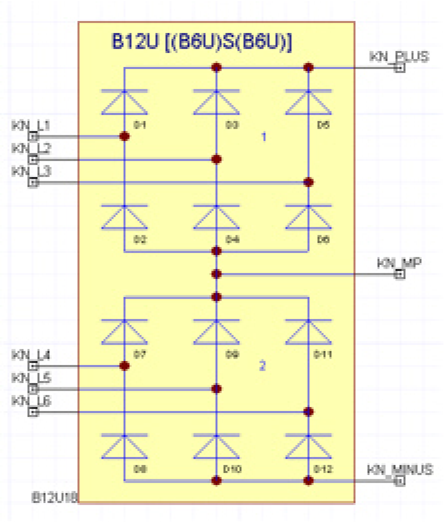

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a two-level three-phase diode bridge topology consisting of the power electronic devices. The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

To model a phase shift of 30 degree (electrical), the AC terminals of the model have to be connected to a transformer with two secondary winding connections (star/delta). The terminal KN_ MP is being put outside for measurement purposes.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL B12U ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_L4:= %3, KN_L5:= %4, KN_L6:= %5, KN_PLUS:= %6, KN_MP:= %7, KN_MINUS:= %8 (VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3 Converter 1	electrical
KN_L4/KN_L5/KN_L6	AC Terminal Line 1/2/3 Converter 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MP	DC Terminal (Center Point)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1 Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_D1	Diode Voltage [V]	Output	real
I_D1	Diode Current [A]	Output	real
V_D2	Diode Voltage [V]	Output	real
I_D2	Diode Current [A]	Output	real
V_D3	Diode Voltage [V]	Output	real
I_D3	Diode Current [A]	Output	real
V_D4	Diode Voltage [V]	Output	real
I_D4	Diode Current [A]	Output	real
V_D5	Diode Voltage [V]	Output	real
I_D5	Diode Current [A]	Output	real
V_D6	Diode Voltage [V]	Output	real
I_D6	Diode Current [A]	Output	real
V_D7	Diode Voltage [V]	Output	real
I_D7	Diode Current [A]	Output	real
V_D8	Diode Voltage [V]	Output	real
I_D8	Diode Current [A]	Output	real
V_D9	Diode Voltage [V]	Output	real
I_D9	Diode Current [A]	Output	real
V_D10	Diode Voltage [V]	Output	real
I_D10	Diode Current [A]	Output	real
V_D11	Diode Voltage [V]	Output	real
I_D11	Diode Current [A]	Output	real
V_D12	Diode Voltage [V]	Output	real
I_D12	Diode Current [A]	Output	real

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Example

In this example, two Three-Phase Power Supply _3PHAS_Z1 and _3PHAS_Z1 are connected to a resistive load through a B12 Diode Bridge B12U1. The phase shift between _3PHAS_Z1 AND _3PHAS_Z2 is 60 degrees. The schematic of the system is shown in Figure 3, system parameters are listed in Table 4, and the simulation results are shown in Figure 4.

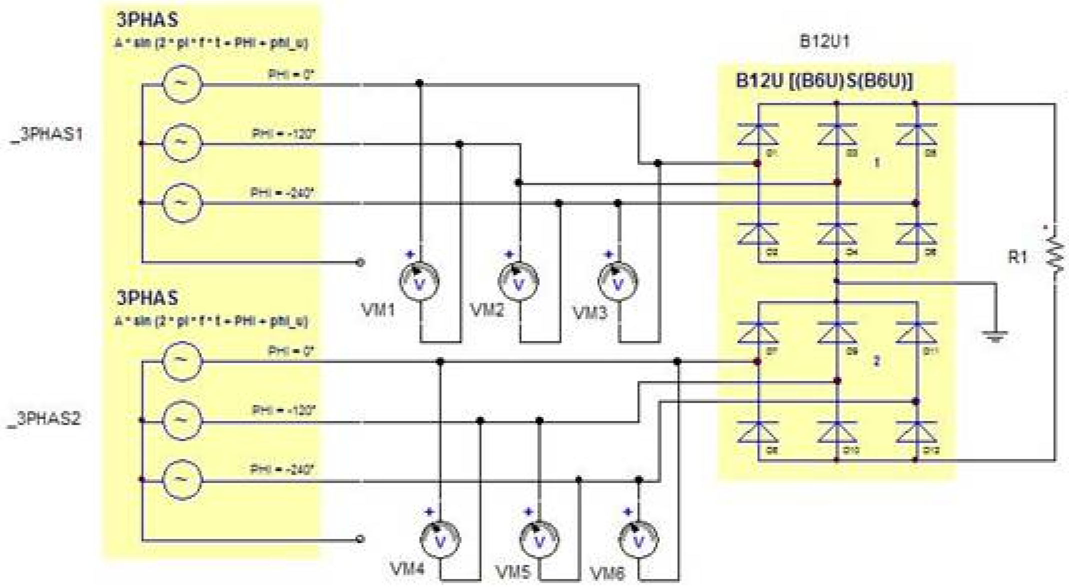

Figure 2. Application example of the B12 Diode Bridge – Inverse Parallel Connection model

Table 4. System Parameters

Component	Parameter	Value [unit]
Ideal Three-Phase Power Supply _ 3PHAS1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
Ideal Three-Phase Power Supply _ 3PHAS2	AMPLITUDE	0.311k [V]
	FREQUENCY	50 [Hz]
	PHI_U	60 [deg]
B12 Diode Bridge B12U1	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1 Meg [Ohm]
Resistor R1	R	1 [Ohm]

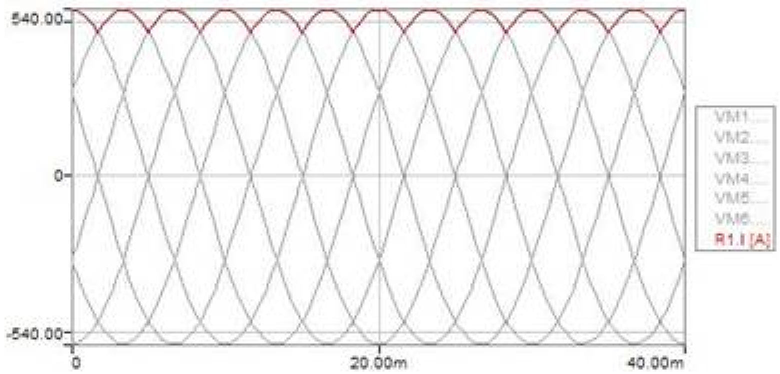

Figure 3. Simulation results

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References

B18 Thyristor Bridge Parallel Connection (B18)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

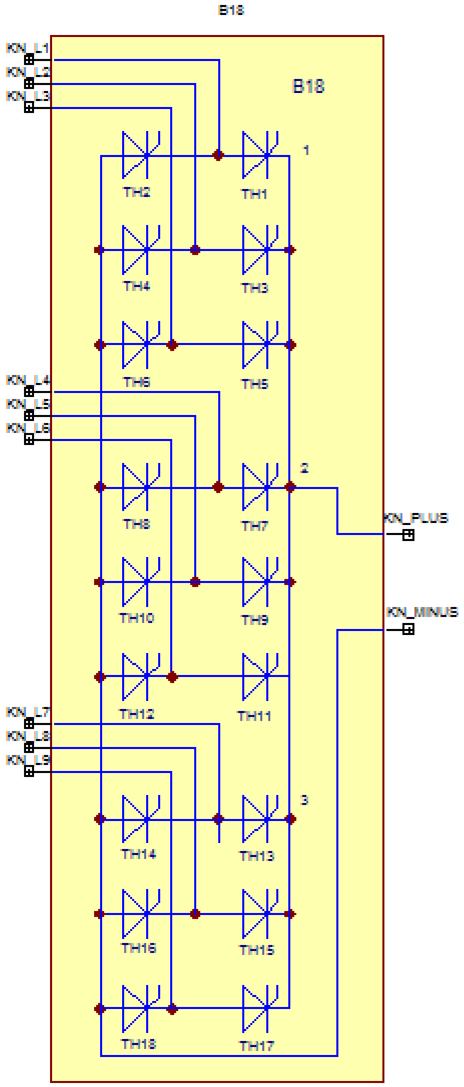

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins

- Parameters
- Input/Output Quantities
- Example
- References

Description

This model consists of three B6C bridges connected in parallel. The rectifier inputs must have a phase shift of 20 degrees (electrical).

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL B12CP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_L4:= %3, KN_L5:= %4, KN_L6:= %5, KN_L7:= %6, KN_L8:= %7, KN_L9:= %8, KN_PLUS:= %9, KN_MINUS:= %10 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3 Converter 1	electrical
KN_L4/KN_L5/KN_L6	AC Terminal Line 1/2/3 Converter 2	electrical
KN_L7/KN_L8/KN_L9	AC Terminal Line 1/2/3 Converter 3	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [deg]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Diode Voltage [V]	Output	real
I_TH1	Diode Current [A]	Output	real
V_TH2	Diode Voltage [V]	Output	real
I_TH2	Diode Current [A]	Output	real
V_TH3	Diode Voltage [V]	Output	real
I_TH3	Diode Current [A]	Output	real
V_TH4	Diode Voltage [V]	Output	real
I_TH4	Diode Current [A]	Output	real
V_TH5	Diode Voltage [V]	Output	real
I_TH5	Diode Current [A]	Output	real
V_TH6	Diode Voltage [V]	Output	real
I_TH6	Diode Current [A]	Output	real
V_TH7	Diode Voltage [V]	Output	real
I_TH7	Diode Current [A]	Output	real
V_TH8	Diode Voltage [V]	Output	real
I_TH8	Diode Current [A]	Output	real

V_TH9	Diode Voltage [V]	Output	real
I_TH9	Diode Current [A]	Output	real
V_TH10	Diode Voltage [V]	Output	real
I_TH10	Diode Current [A]	Output	real
V_TH11	Diode Voltage [V]	Output	real
I_TH11	Diode Current [A]	Output	real
V_TH12	Diode Voltage [V]	Output	real
I_TH12	Diode Current [A]	Output	real
V_TH13	Diode Voltage [V]	Output	real
I_TH13	Diode Current [A]	Output	real
V_TH14	Diode Voltage [V]	Output	real
I_TH14	Diode Current [A]	Output	real
V_TH15	Diode Voltage [V]	Output	real
I_TH15	Diode Current [A]	Output	real
V_TH16	Diode Voltage [V]	Output	real
I_TH16	Diode Current [A]	Output	real
V_TH17	Diode Voltage [V]	Output	real
I_TH17	Diode Current [A]	Output	real
V_TH18	Diode Voltage [V]	Output	real
I_TH18	Diode Current [A]	Output	real

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Example

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References

B24 Thyristor Bridge (B24)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

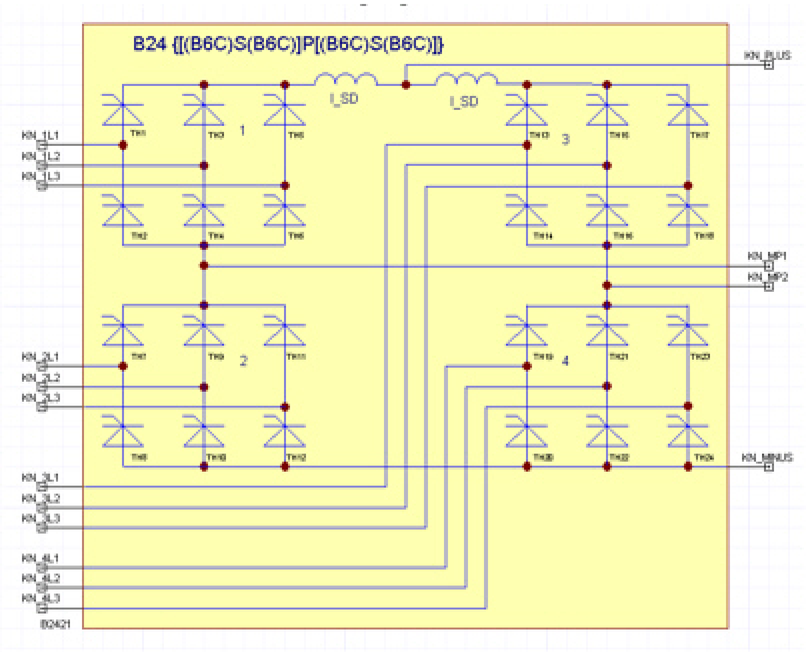

Figure 1. Component symbol

- [Description]
- [Assumptions and Limitations]
- [Mathematical Description]
- [Netlist Syntax]
- [Conservative Pins]
- [Parameters]
- [Input/Output Quantities]
- [Example]
- [References]

Description

This model consists of two B12CS bridges connected in parallel via two balance coils. The AC terminals of this macro have to be connected to a supply system with four secondary winding connections with a phase shift of 15 degrees (electrical). The terminal KN_MP is put outside for measurement purposes.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL B24 ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_1L1:= %0, KN_1L2:= %1, KN_1L3:= %2, KN_2L1:= %3, KN_2L2:= %4, KN_2L3:= %5, KN_3L1:= %6, KN_3L2:= %7, KN_3L3:= %8, KN_4L1:= %9, KN_4L2:= %10, KN_4L3:= %11, KN_PLUS:= %12, KN_MINUS:= %13, KN_MP1:= %14, KN_MP2:= %15 (ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2, ALPHA3:= @ALPHA3, ALPHA4:= @ALPHA4, FREQUENCY:= @FREQUENCY, L_SD:= @L_SD, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN1_L1/KN1_L2/KN1_L3	AC Terminal Line 1/2/3 Converter 1	electrical
KN2_L1/KN2_L2/KN2_L3	AC Terminal Line 1/2/3 Converter 2	electrical
KN3_L1/KN3_L2/KN3_L3	AC Terminal Line 1/2/3 Converter 3	electrical
KN4_L1/KN4_L2/KN4_L3	AC Terminal Line 1/2/3 Converter 4	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical
KN_MP1	DC Terminal (Center Point 1)	electrical
KN_MP2	DC Terminal (Center Point 2)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA1	Delay Angle Converter 1	real	30 [deg]

ALPHA2	Delay Angle Converter 2	real	30 [deg]
ALPHA3	Delay Angle Converter 3	real	30 [deg]
ALPHA4	Delay Angle Converter 4	real	30 [deg]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
L_SD	Inductivity of One Smoothing Inductance	real	0.1u [H]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real
V_TH3	Thyristor Voltage [V]	Output	real
I_TH3	Thyristor Current [A]	Output	real
V_TH4	Thyristor Voltage [V]	Output	real
I_TH4	Thyristor Current [A]	Output	real
V_TH5	Thyristor Voltage [V]	Output	real
I_TH5	Thyristor Current [A]	Output	real
V_TH6	Thyristor Voltage [V]	Output	real
I_TH6	Thyristor Current [A]	Output	real
V_TH7	Thyristor Voltage [V]	Output	real
I_TH7	Thyristor Current [A]	Output	real
V_TH8	Thyristor Voltage [V]	Output	real
I_TH8	Thyristor Current [A]	Output	real

V_TH9	Thyristor Voltage [V]	Output	real
I_TH9	Thyristor Current [A]	Output	real
V_TH10	Thyristor Voltage [V]	Output	real
I_TH10	Thyristor Current [A]	Output	real
V_TH11	Thyristor Voltage [V]	Output	real
I_TH11	Thyristor Current [A]	Output	real
V_TH12	Thyristor Voltage [V]	Output	real
I_TH12	Thyristor Current [A]	Output	real
V_TH13	Thyristor Voltage [V]	Output	real
I_TH13	Thyristor Current [A]	Output	real
V_TH14	Thyristor Voltage [V]	Output	real
I_TH14	Thyristor Current [A]	Output	real
V_TH15	Thyristor Voltage [V]	Output	real
I_TH15	Thyristor Current [A]	Output	real
V_TH16	Thyristor Voltage [V]	Output	real
I_TH16	Thyristor Current [A]	Output	real
V_TH17	Thyristor Voltage [V]	Output	real
I_TH17	Thyristor Current [A]	Output	real
V_TH18	Thyristor Voltage [V]	Output	real
I_TH18	Thyristor Current [A]	Output	real
V_TH19	Thyristor Voltage [V]	Output	real
I_TH19	Thyristor Current [A]	Output	real
V_TH20	Thyristor Voltage [V]	Output	real
I_TH20	Thyristor Current [A]	Output	real
V_TH21	Thyristor Voltage [V]	Output	real
I_TH21	Thyristor Current [A]	Output	real
V_TH22	Thyristor Voltage [V]	Output	real
I_TH22	Thyristor Current [A]	Output	real
V_TH23	Thyristor Voltage [V]	Output	real
I_TH23	Thyristor Current [A]	Output	real

V_TH24	Thyristor Voltage [V]	Output	real
I_TH24	Thyristor Current [A]	Output	real

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Example

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References

B2 Fully Controlled (B2C)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

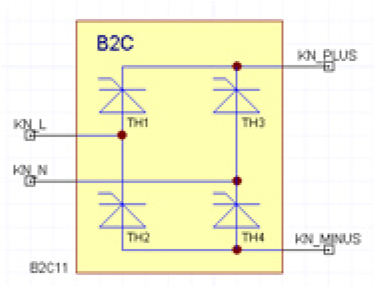

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model provides a single-phase converter topology consisting of power electronic devices and the firing-circuit module (delay angle generator). The used power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0^{o}, 179^{o}] (electrical). The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), then a variable identifier must be assigned. The phase relation can be chosen freely (zero crossing detection). The control is inactive until the first zero crossing of the AC line voltage.

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Netlist Syntax

MODEL B2C ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1, KN_PLUS:= %2, KN_MINUS:= %3 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_N	AC Terminal 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [deg]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Thyristor Voltage [V]	Output	real

I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real
V_TH3	Thyristor Voltage [V]	Output	real
I_TH3	Thyristor Current [A]	Output	real
V_TH4	Thyristor Voltage [V]	Output	real
I_TH4	Thyristor Current [A]	Output	real

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Example

In this example, a Single-Phase Power Supply SINGLE_PHASE_Z1 is connected to a first-order RL load through a thyristor bridge B2C1. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

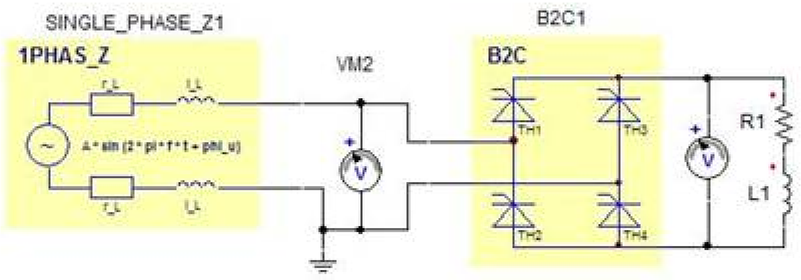

Figure 2. Application example of the B2 Fully Controlled model

Table 4. System Parameters

Component	Parameter	Value [unit]
Single-Phase Power Supply Single_Phase_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
B2 Fully Controlled B2C1	ALPHA	10 [degree]
	FREQUENCY	50 [Hz]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1Meg [Ohm]

Resistor R1	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	0 [A]

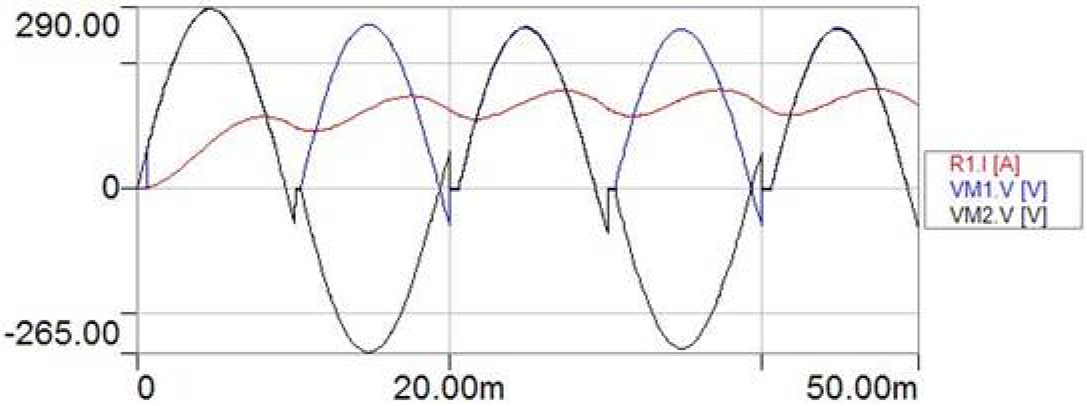

Figure 3. Simulation results

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References

B2 Half-Controlled, Symmetrical (B2HK)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

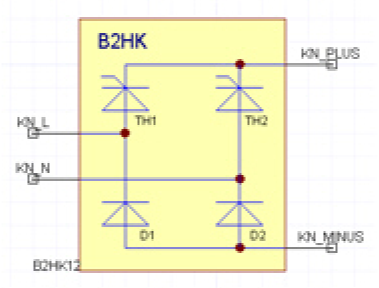

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a half bridge topology consisting of power electronic devices and the firing-circuit module (delay angle generator). The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0º, 179º] (electrical). The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), a variable identifier must be assigned. The phase relation can be chosen freely (zero crossing detection). The control becomes inactive until the first zero cro2ssing of the AC line voltage.

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Netlist Syntax

MODEL B2HK ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1, KN_PLUS:= %2, KN_MINUS:= %3 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_THY:= @VF_THY, RB_THY:= @RB_THY, RR_THY:= @RR_THY) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_N	AC Terminal 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Description [Unit]
ALPHA	Delay Angle	real	30 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF_DIODE	Forward Voltage of Diodes	real	0.8 [V]
RB_DIODE	Bulk Resistance of Diodes	real	1m [Ohm]
RR_DIODE	Reverse Resistance of Diodes	real	0.1Meg [Ohm]
VF_THY	Forward Voltage of Thyristors	real	0.8 [V]
RB_THY	Bulk Resistance of Thyristors	real	1m [Ohm]
RR_THY	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_D1	Diode Voltage [V]	Output	real
I_D1	Diode Current [A]	Output	real
V_D2	Diode Voltage [V]	Output	real
I_D2	Diode Current [A]	Output	real
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real

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Example

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References

B2 Half-Controlled, Asymmetrical (B2HZ)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

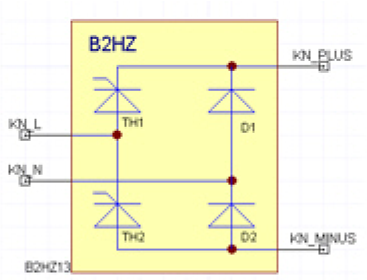

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a half-controlled converter topology consisting of the power electronic devices and the firing-circuit module (delay angle generator). The used power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0^{o}, 179^{o}] (electrical). The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), a variable identifier must be assigned. The phase relation of the AC line voltage can be chosen freely (zero crossing detection). The control becomes inactive until the first zero crossing of the AC line voltage.

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Netlist Syntax

MODEL B2HZ ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1, KN_PLUS:= %2, KN_MINUS:= %3 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_THY:= @VF_THY, RB_THY:= @RB_THY, RR_THY:= @RR_THY) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_N	AC Terminal 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF_DIODE	Forward Voltage of Diodes	real	0.8 [V]
RB_DIODE	Bulk Resistance of Diodes	real	1m [Ohm]
RR_DIODE	Reverse Resistance of Diodes	real	0.1Meg [Ohm]
VF_THY	Forward Voltage of Thyristors	real	0.8 [V]
RB_THY	Bulk Resistance of Thyristors	real	1m [Ohm]
RR_THY	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_D1	Diode Voltage [V]	Output	real
I_D1	Diode Current [A]	Output	real
V_D2	Diode Voltage [V]	Output	real
I_D2	Diode Current [A]	Output	real
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real

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Example

In this example, a Single-Phase Power Supply SINGLE_PHASE_Z1 is connected to a first-order RL load through a half-controlled converter bridge B2Z1. The schematic of the system is shown in Figure 2, parameters of the system are listed in Table 4, and the simulation results are shown in Figure 3.

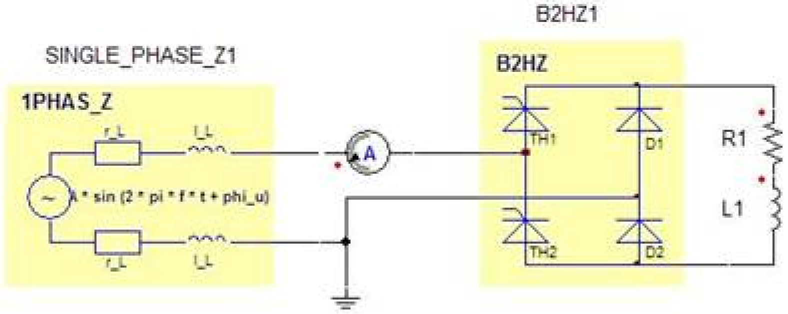

Figure 2. Application example of the B2 Half-Controlled Symmetrical model

Table 4. System Parameters

Component	Parameter	Value [unit]

Single-Phase Power Supply Single_Phase_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
B2 Half-Controlled Symmetrical B2Z1	ALPHA	10 [degree]
	FREQUENCY	50 [Hz]
	VF_DIODE	0.8 [V]
	RB_DIODE	1m [Ohm]
	RR_DIODE	0.1Meg [Ohm]
	VF_THY	0.8 [V]
	RB_THY	1m [Ohm]
	RR_THY	0.1Meg [Ohm]
Resistor R1	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	125 [A]

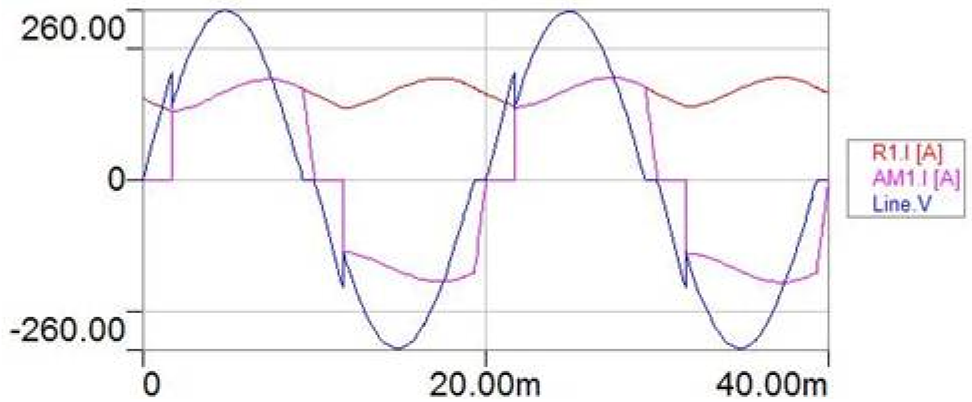

Figure 3. Simulation results

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References

B2 Diode Bridge (B2U)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

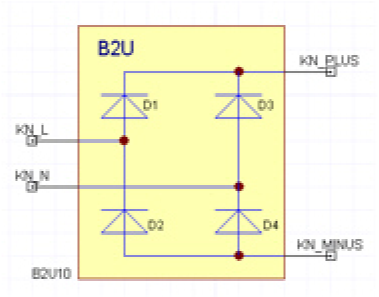

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This model describes a single-phase diode bridge topology consisting of power electronic devices. The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Mathematical Description

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Netlist Syntax

MODEL B2U ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1, KN_PLUS:= %2, KN_MINUS:= %3 (VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_N	AC Terminal 2	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
VF	Forward Voltage of Diodes	real	0.8 [V]
RB	Bulk Resistance of Diodes	real	1m [Ohm]
RR	Reverse Resistance of Diodes	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_D1	Diode Voltage [V]	Output	real
I_D1	Diode Current [A]	Output	real
V_D2	Diode Voltage [V]	Output	real
I_D2	Diode Current [A]	Output	real
V_D3	Diode Voltage [V]	Output	real
I_D3	Diode Current [A]	Output	real

V_D4	Diode Voltage [V]	Output	real
I_D4	Diode Current [A]	Output	real

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Example

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References

B6C Thyristor Bridge (B6C)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

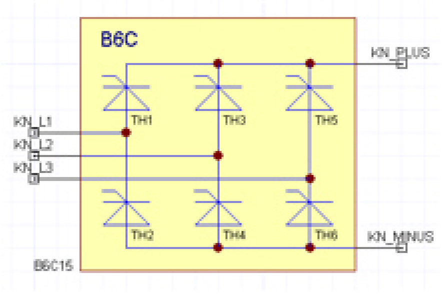

Figure 1. Component symbol

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Description

This model describes three-phase thryristor bridge topology consisting of power electronic devices and the firing-circuit module (delay angle generator). The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0°📪150°] (electrical). The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), a variable identifier must be assigned. The phase relation can be chosen freely (zero crossing detection). The control becomes inactive until the first zero crossing of the AC line voltage.

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Netlist Syntax

MODEL B6C ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_PLUS:= %3, KN_MINUS:= %4 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal 1/2/3	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	20 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF_DIODE	Forward Voltage of Thyristors	real	0.8 [V]
RB_DIODE	Bulk Resistance of Thyristors	real	1m [Ohm]
RR_DIODE	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Thyristor Voltage [V]	Output	real

I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real
V_TH3	Thyristor Voltage [V]	Output	real
I_TH3	Thyristor Current [A]	Output	real
V_TH4	Thyristor Voltage [V]	Output	real
I_TH4	Thyristor Current [A]	Output	real
V_TH5	Thyristor Voltage [V]	Output	real
I_TH5	Thyristor Current [A]	Output	real
V_TH6	Thyristor Voltage [V]	Output	real
I_TH6	Thyristor Current [A]	Output	real

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Example

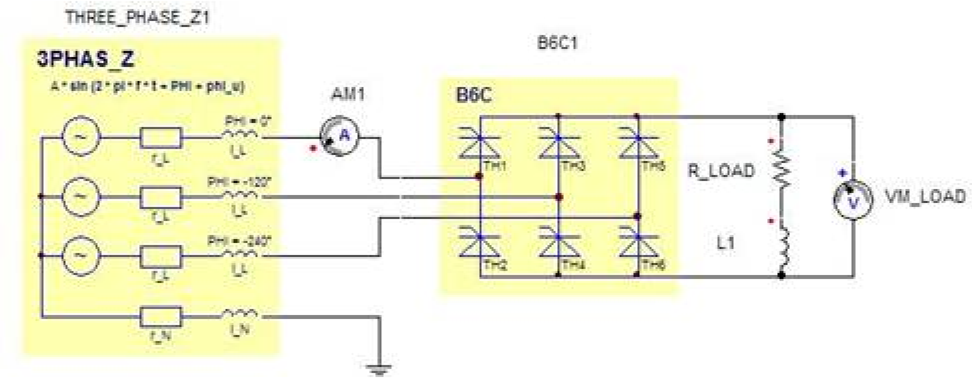

Figure 2. Application example of the B6 Thyristor Bridge model

Table 4. System Parameters

Component	Parameter	Value [unit]

Three-Phase Power Supply THREE_ PHASE_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	60 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
	R_N	0.16 [Ohm]
	L_N	0.1u [H]
B6 Thyristor Bridge B6C1	ALPHA	10 [degree]
	FREQUENCY	50 [Hz]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1Meg [Ohm]
Resistor R_Load	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	125 [A]

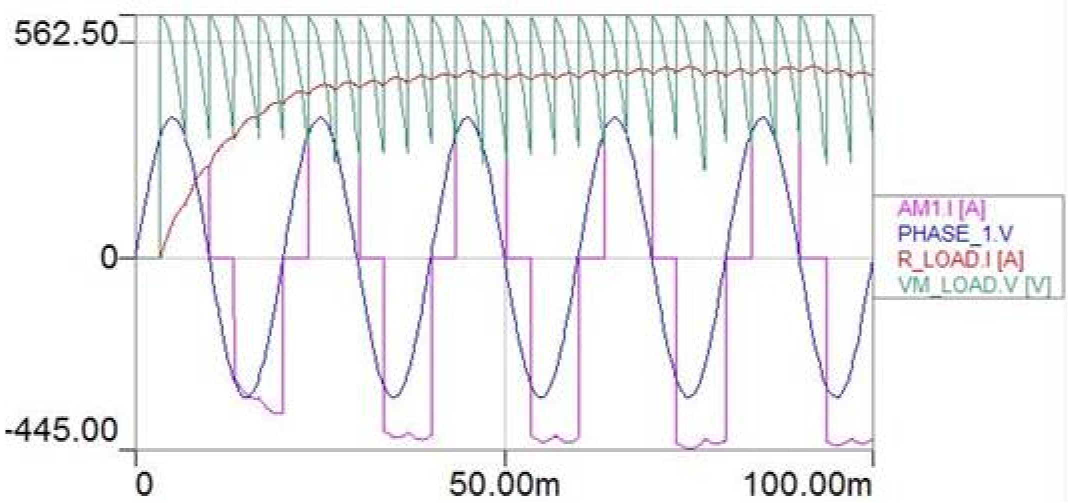

Figure 3. Simulation results

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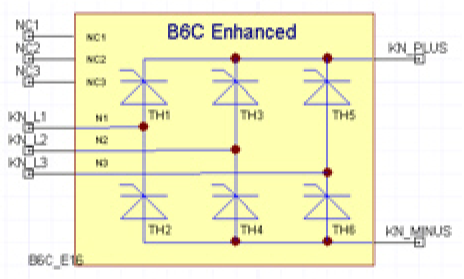
B6C Thyristor Bridge Enhanced

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2



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Description

The B6C thyristor bridge performs an AC rectification by six controlled switches. It provides a topology consisting of the power electronic devices and the firing-circuit module (delay angle generator). Each leg is connected to one of the phases of the three-phase voltage. The model uses system level switches for faster simulations. The characteristics of the switches (equivalent line) are defined by the forward voltage drop, bulk resistance, and reverse resistance.

Three additional conservative nodes are provided to input reference voltage signals. They can be connected either with the input power lines or with auxiliary voltage sources. The second option is suitable if the line voltages are disturbed and their deviation affects the proper function of the thyristor bridge.

An additional input signal (START) can be set to start the evaluation of the input voltages. If the parameter is set to **TRUE** ('1'), the angle calculation starts. After it is set to **TRUE**, the value of START has no influence on the model. Between the setting of START and the first switching of a thyristor, there is a delay time. This delay time is due to the time necessary for detecting the crossings of the input voltages and the direction of the three-phase system.

The parameter ENABLE can disable the control signals of the thyristors by setting the parameter to **FALSE**.

The length of the ON-signal applied to the thyristors can be set by TON. This value must be smaller than the time period divided by three. In the dialog box, you can define the frequency of the source and the firing angle of the controlled switches. Both can be time-dependent.

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Netlist Syntax

MODEL B6C_E ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_PLUS:= %3, KN_MINUS:= %4, NC1:= %5, NC2:= %6, NC3:= %7 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, ENABLE:= @ENABLE, START:= @START, TON:= @TON, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC side phase A/B/C terminal	electrical
KN_PLUS	DC side positive terminal	electrical
KN_MINUS	DC side negative terminal	electrical
NC1/NC2/NC3	Control input phase A/B/C	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
FREQUENCY	Line frequency	real	50 [Hz]
ALPHA	Firing angle of the switches	real	30 [degree]
VF	Forward voltage of thyristors	real	0.8 [V]
RB	Bulk resistance of thyristors	real	1m [Ohm]
RR	Reverse resistance of thyristors	real	0.1 Meg [Ohm]
TON	Pulse length	real	6m [S]
START	Start flag for angle calculation	real	1
ENABLE	Enable for thyristor control signals	real	1

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real
V_TH2	Thyristor Voltage [V]	Output	real
I_TH2	Thyristor Current [A]	Output	real
V_TH3	Thyristor Voltage [V]	Output	real
I_TH3	Thyristor Current [A]	Output	real
V_TH4	Thyristor Voltage [V]	Output	real
I_TH4	Thyristor Current [A]	Output	real
V_TH5	Thyristor Voltage [V]	Output	real
I_TH5	Thyristor Current [A]	Output	real
V_TH6	Thyristor Voltage [V]	Output	real
I_TH6	Thyristor Current [A]	Output	real

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Example

In this example, a twelve-pulse rectifier is simulated using the enhanced model of the six-pulse thyristor bridge. Two three-phase systems with a phase shift of 30^{o} are generated by a three-winding transformer. The thyristor bridges get undisturbed reference signals to avoid wrong switching due to the voltage drop across the parasitic. The schematic of the system is shown in Figure 3, system parameters are listed in Table 4, and the simulation results are shown in Figure 4.

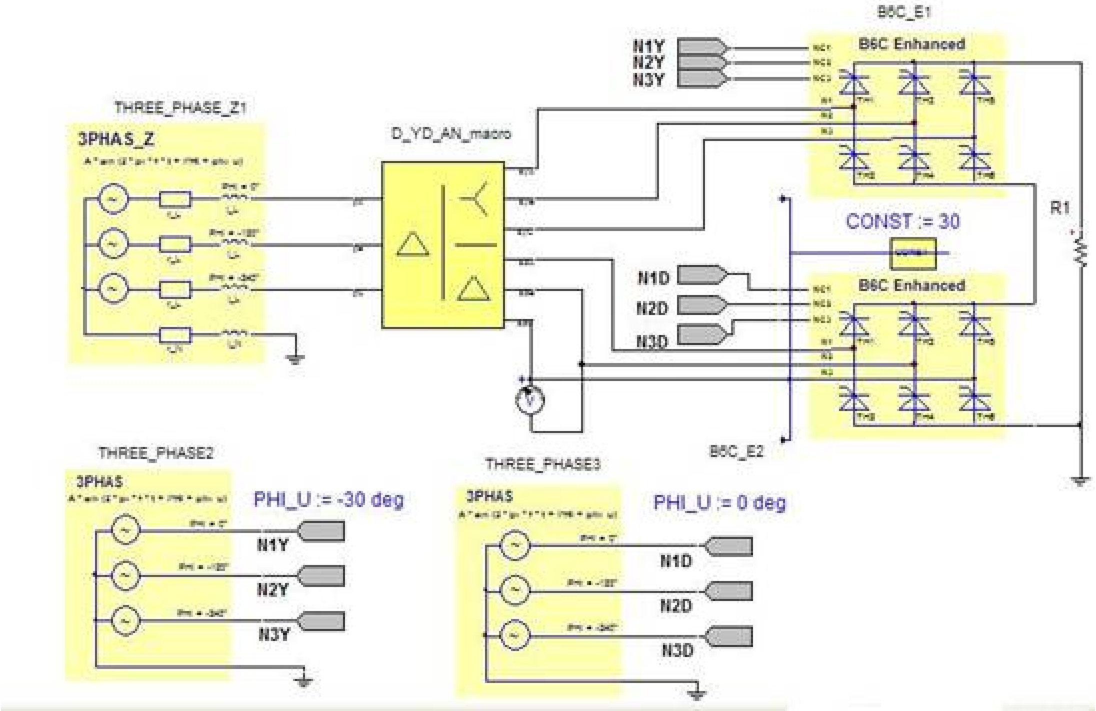

Figure 2. Application example of the Enhanced model of B6 Thyristor Bridge

Table 4. System Parameters

Component	Parameter	Value [unit]
Three-Phase Power Supply THREE_ PHASE_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	60 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
	R_N	0.16 [Ohm]
	L_N	0.1u [H]

B6 Thyristor Bridge Enhanced B6C_E1 /B6C_E2	FREQUENCY	60 [Hz]
	ALPHA	alpha.VAL
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1 Meg [Ohm]
	TON	5.5m [S]
	START	1
	ENABLE	1
Constant Value alpha	VAL	30
Ideal Three-Phase Power Supply THREE_PHASE2/ THREE_PHASE3	AMPLITUDE	1 [V]
	FREQUENCY	60 [Hz]
	PHI_U	0 [degree]
Resistor R_Load	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	125 [A]

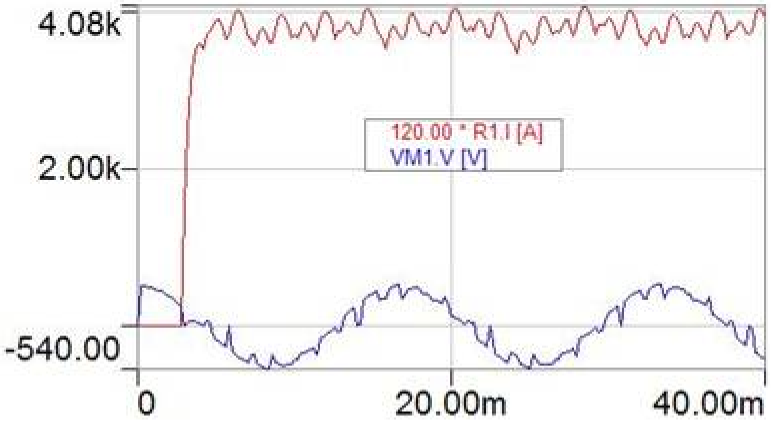

Figure 3. Simulation results

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References

B6 Bridges – Inverse Parallel Connection (B6C2L)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

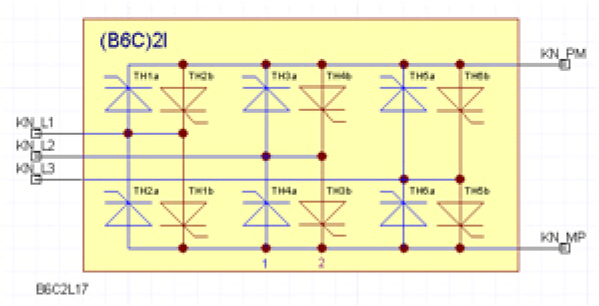

Figure 1. Component symbol

Description

This model describes a three-phase inverse-parallel connected thyristor bridge topology consisting of the power electronic devices and the firing-circuit module (delay angle generator). The used power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameters ALPHA1 and ALPHA2 have a sensible shift range of [0º📪150º] (electrical). To apply the circuit to a direct converter, a Trapezoidal voltage control (DUR_TRAPEZ) or a Direct converter current control (DUR_IREG) can be used.

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Netlist Syntax

MODEL B6C2L ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_PM:= %3, KN_MP:= %4 (ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal 1/2/3	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA1	Delay Angle of Inverter 1	real	30 [degree]
ALPHA2	Delay Angle of Inverter 2	real	30 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1 Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_TH1A	Thyristor Voltage [V]	Output	real
I_TH1A	Thyristor Current [A]	Output	real
V_TH2A	Thyristor Voltage [V]	Output	real
I_TH2A	Thyristor Current [A]	Output	real
V_TH3A	Thyristor Voltage [V]	Output	real
I_TH3A	Thyristor Current [A]	Output	real
V_TH4A	Thyristor Voltage [V]	Output	real
I_TH4A	Thyristor Current [A]	Output	real
V_TH5A	Thyristor Voltage [V]	Output	real
I_TH5A	Thyristor Current [A]	Output	real
V_TH6A	Thyristor Voltage [V]	Output	real
I_TH6A	Thyristor Current [A]	Output	real
V_TH1B	Thyristor Voltage [V]	Output	real
I_TH1B	Thyristor Current [A]	Output	real
V_TH2B	Thyristor Voltage [V]	Output	real
I_TH2B	Thyristor Current [A]	Output	real
V_TH3B	Thyristor Voltage [V]	Output	real
I_TH3B	Thyristor Current [A]	Output	real
V_TH4B	Thyristor Voltage [V]	Output	real
I_TH4B	Thyristor Current [A]	Output	real
V_TH5B	Thyristor Voltage [V]	Output	real
I_TH5B	Thyristor Current [A]	Output	real
V_TH6B	Thyristor Voltage [V]	Output	real
I_TH6B	Thyristor Current [A]	Output	real

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Example

In this example, a Three-Phase Power Supply _3PHAS_Z1 is connected to a first-order RL load through a Inverse Parallel-Connected Thyristor Bridge B6C2L1. The delay angles of the thyristors are controlled by a Current Control block DUR_IREG1. The schematic of the system is shown in Figure 3, system parameters are listed in Table 4, and the simulation results are shown in Figure 4.

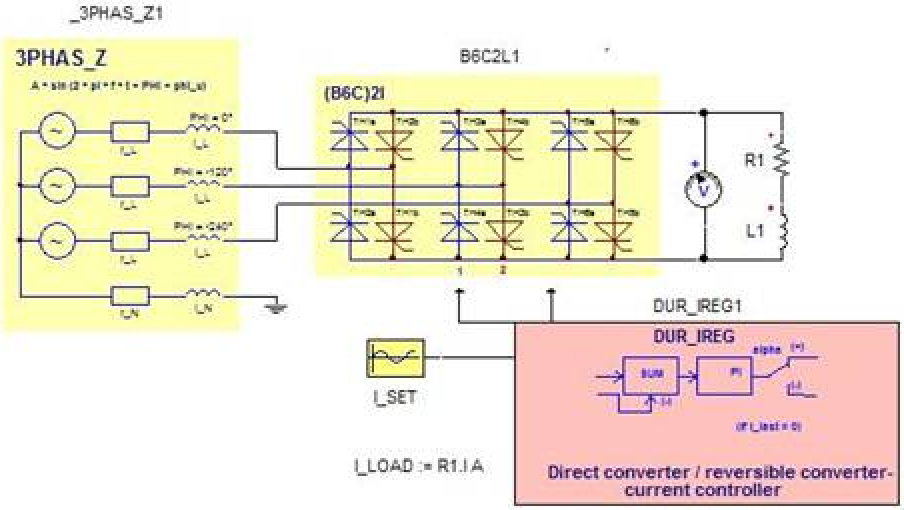

Figure 2. Application example of the B6 Thyristor Bridge – Inverse Parallel Connection model

Table 4. System Parameters

Component	Parameter	Value [unit]
Three-Phase Power Supply THREE_PHASE_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	60 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
	R_N	0.16 [Ohm]
	L_N	0.1u [H]
B6 Bridges Inverse Parallel Connection B6C2L1	ALPHA1	DUR_ IREG1.ALPHA1
	ALPHA2	DUR_ IREG1.ALPHA2
	FREQUENCY	0.8 [V]
	VF	60 [Hz]
	RB	1m [Ohm]
	RR	0.1 Meg [Ohm]

Sine Wave I_SET	AMPL	0.3k
	FREQ	16.667 [Hz]
	TDELAY	0 [s]
	PHASE	[degree]
	OFF	0
Ideal Three-Phase Power Supply THREE_PHASE2/ THREE_PHASE3	I_NOM	I_SET.VAL
	I_LOAD	R1.I
	KP	0.1
	KI	1
	TA	0.1M [s]
Resistor R1	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	0 [A]

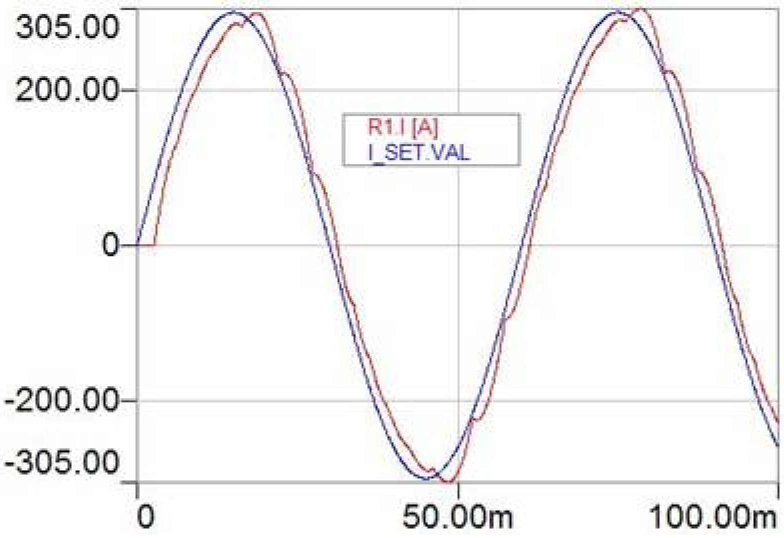

Figure 3. Simulation results – current reference (I_SET.VAL) and load current (R1.I)

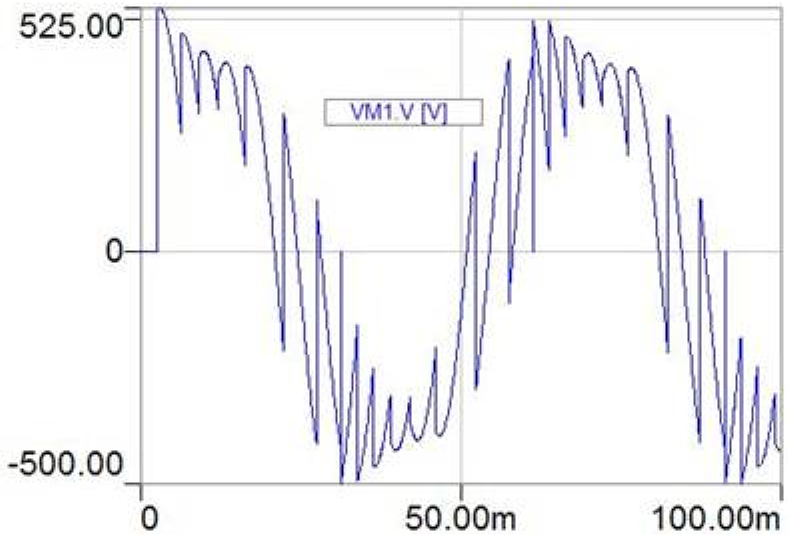

Figure 4. Simulation results – output voltage of the thyristor bridge B6C2L1

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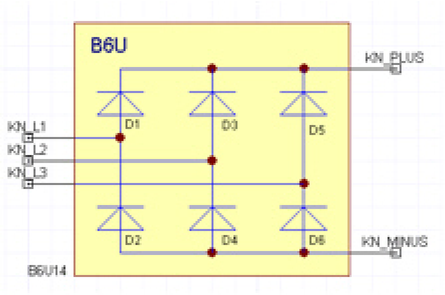
References

B6 Diode Bridge (B6U)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2



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Description

This model describes three-phase diode bridge topology consisting of power electronic devices. This model provides a topology consisting of the power electronic devices. The used power semi-conductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Netlist Syntax

MODEL B6U ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_PLUS:= %3, KN_MINUS:= %4 (VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal 1/2/3	electrical
KN_PLUS	DC Terminal (Plus)	electrical
KN_MINUS	DC Terminal (Minus)	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
VF_DIODE	Forward Voltage of Diodes	real	0.8 [V]
RB_DIODE	Bulk Resistance of Diodes	real	1m [Ohm]
RR_DIODE	Reverse Resistance of Diodes	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description (Unit)	Direction	Data Type
V_D1	Diode Voltage [V]	Output	real
I_D1	Diode Current [A]	Output	real
V_D2	Diode Voltage [V]	Output	real
I_D2	Diode Current [A]	Output	real
V_D3	Diode Voltage [V]	Output	real
I_D3	Diode Current [A]	Output	real

V_D4	Diode Voltage [V]	Output	real
I_D4	Diode Current [A]	Output	real
V_D5	Diode Voltage [V]	Output	real
I_D5	Diode Current [A]	Output	real
V_D6	Diode Voltage [V]	Output	real
I_D6	Diode Current [A]	Output	real

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Dead Time Generator

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

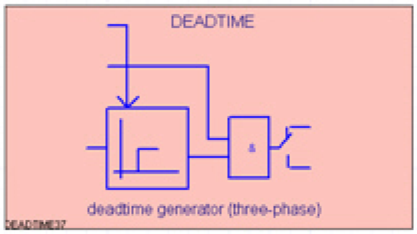

Figure 1. Component symbol

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Description

To prevent a shortcut of an inverter half bridge, this Dead Time Generator model provides a logic-generating delay before firing the opposite valve. This is necessary if simulating the switching behavior, for example, the tail current of an IGBT..

The default value of t_dead (5μs) is typical for IGBTs. If the control algorithms 2L_NSAMP or 2L_SQW are used, the gate control signals G_X1 (return values of the control algorithm) have to be assigned to the state signals Z_X (x = R, S, or T).

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Netlist Syntax

MODEL DEADTIME ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (T_DEAD:= @T_DEAD, ENABLE:= @ENABLE, Z_R:= @Z_R, Z_S:= @Z_S, Z_T:= @Z_T, G_R1:= @G_R1, G_R2:= @G_R2, G_S1:= @G_S1, G_S2:= @G_S2, G_T1:= @G_T1, G_T2:= @G_T2) SRC: DB (Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
T_DEAD	Dead time	real	5u [s]
ENABLE	Enable Output	real	1

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
Z_R	Control Signal Phase R	Input	real
Z_S	Control Signal Phase S	Input	real
Z_T	Control Signal Phase T	Input	real
G_R1	Control Signal Upper Transistor Phase R	Input/Output	real
G_R2	Control Signal Lower Transistor Phase R	Input/Output	real
G_S1	Control Signal Upper Transistor Phase S	Input/Output	real
G_S2	Control Signal Lower Transistor Phase S	Input/Output	real
G_T1	Control Signal Upper Transistor Phase T	Input/Output	real
G_T2	Control Signal Lower Transistor Phase T	Input/Output	real

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Current Control for Direct Converter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

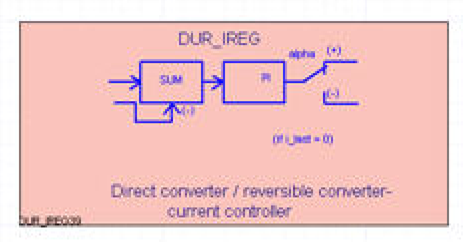

Figure 1. Component symbol

Description

This model describes a PI controller to use with the B6C2L bridge connection to model a direct converter. Depending on the sign of the desired value of I_NOM, variable ALPHA is assigned to either converter 1 or converter 2. It is also possible to simulate a DC reversing drive.

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Netlist Syntax

MODEL DUR_IREG ?InstanceName(@InstanceName):(@(Refbase)@(ID)) (I_NOM:= @I_NOM, I_LOAD:= @I_LOAD, KP:= @KP, KI:= @KI, TA:= @TA, ALPHA1:= @ALPHA1, ALPHA2:= @ALPHA2) SRC: DB(Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
I_NOM	Reference Value Load Current	real	Inom* [A]
I_LOAD	Actual Value Load Current	real	Iload* [A]
KP	Proportional Gain	real	0.1
KI	Integral Gain	real	5
TA	Controller Sample Time	real	1m [s]

* These parameters must be predefined variables.

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Nature/Data Type
ALPHA1	Delay Angle Converter 1 [degree]	Input/Output	real
ALPHA2	Delay Angle Converter 2 [degree]	Input/Output	real

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Single-Phase AC Chopper (W1C)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

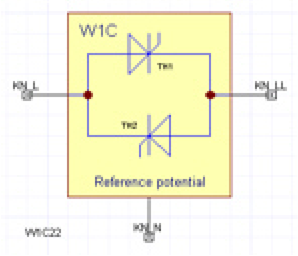

Figure 1. Component symbol

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Description

This model describes a Single-Phase AC Chopper topology consisting of power electronic devices and the firing-circuit module (delay angle generator). The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0°–179°] (electrical). The control ability is restricted to ALPHA > arctan(wL/R). The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), a variable identifier must be assigned. The phase relation of the AC line voltage can be chosen freely (zero crossing detection). The control becomes inactive until the first zero crossing of the AC line voltage.

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Netlist Syntax

MODEL W1C ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1, KN_LL:= %2 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_LL	AC Terminal 2	electrical
KN_N	Reference Terminal	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description	Direction	Nature/Data Type
V_TH1	Thyristor Voltage [V]	Output	real
I_TH1	Thyristor Current [A]	Output	real

I_TH2	Thyristor Current [A]	Output	real

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Example

In this example, a Single-Phase Power Supply _1PHAS_Z1 is connected to a first-order RL load through a Single Phase A.C. Chopper W1C1. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

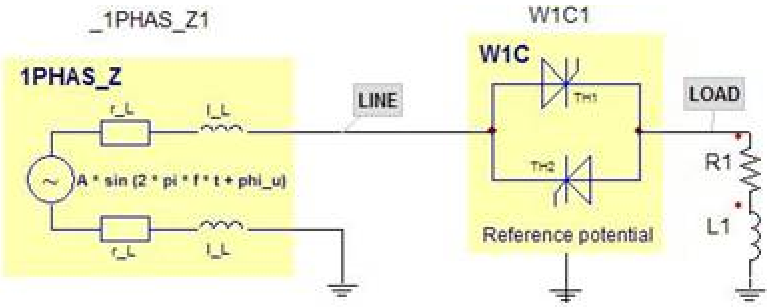

Figure 2. Application example of the Single-Phase Power Supply model

Table 4. System Parameters

Component	Parameter	Value [unit]
Single-Phase Power Supply _1PHAS_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
Single Phase A.C. Chopper W1C1	ALPHA	60 [degree]
	FREQUENCY	50 [Hz]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1Meg [Ohm]
Resistor R1	R	5 [Ohm]
Inductor L1	L	10m [H]
	i0	0 [A]

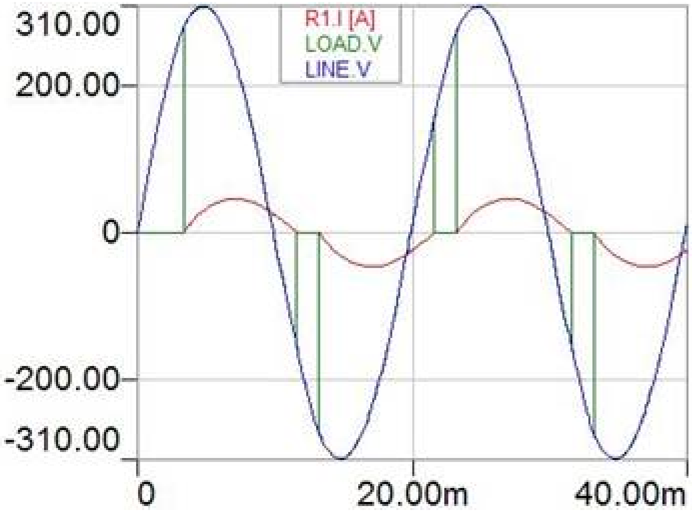

Figure 3. Simulation results

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References

Three-Phase AC Chopper (W3C_3A)

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

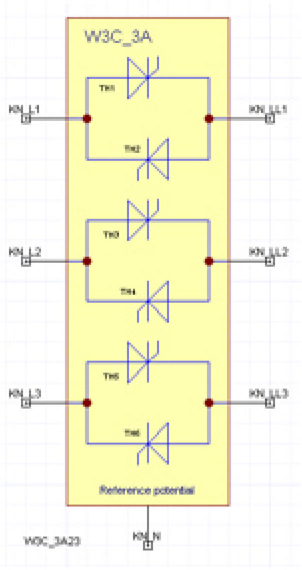

Figure 1. Component symbol

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- Input/Output Quantities
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Description

This model describes a Three-Phase AC Chopper topology consisting of the power electronic devices and the firing-circuit module (delay angle generator). The used power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

The parameter ALPHA has a sensible shift range of [0º📪179º] (electrical). The control ability is restricted to arctan(wL/R) < ALPHA < 2p/3. The parameter FREQUENCY specifies the frequency of the connected power system to convert ALPHA into a corresponding delay time. If ALPHA is a manipulated variable (of a primary control), a variable identifier must be assigned.

The phase relation of the AC line voltage can be chosen freely (zero crossing detection). The control becomes inactive until the first zero crossing of the AC line voltage.

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Netlist Syntax

MODEL W3C_3A ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_N:= %3, KN_LL1:= %4, KN_LL2:= %5, KN_LL3:= %6 (ALPHA:= @ALPHA, FREQUENCY:= @FREQUENCY, VF:= @VF, RB:= @RB, RR:= @RR) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3	electrical
KN_LL1/KN_LL2/KN_LL3	Load Terminal Line 1/2/3	electrical
KN_N	Reference Voltage	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ALPHA	Delay Angle	real	30 [degree]
FREQUENCY	Frequency of Input Voltage	real	50 [Hz]
VF	Forward Voltage of Thyristors	real	0.8 [V]
RB	Bulk Resistance of Thyristors	real	1m [Ohm]
RR	Reverse Resistance of Thyristors	real	0.1Meg [Ohm]

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Input/Output Quantities

Table 3

Name	Description	Direction	Nature/Data Type
I_TH1	Thyristor Current [A]	real	Output
I_TH2	Thyristor Current [A]	real	Output
I_TH3	Thyristor Current [A]	real	Output
I_TH4	Thyristor Current [A]	real	Output
I_TH5	Thyristor Current [A]	real	Output
I_TH6	Thyristor Current [A]	real	Output

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Example

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References

Inverter

- 1-Phase 3-Level H-Circuit (THREE_LVL_1P_H_GTO)
- 3-Phase 3-Level Voltage Inverter (THREE_LVL_3P_GTP)
- 1-Phase 2-Level H-Circuit (TWO_LVL_1P_H_GTO)
- Two Level Inverter Equivalent Circuit - Three Voltage Sources (TWO_LVL_3P_EQUIVAL)
- 3-Phase 2-Level Voltage Inverter (TWO_LVL_3P_GTO)

Single-Phase Three-Level Inverter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

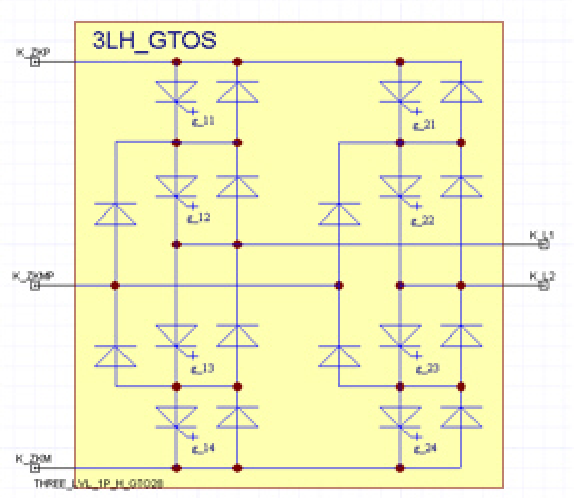

Figure 1. Component symbol

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Description

This model describes a single-phase three-level inverter topology consisting of power electronic devices. The used power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Netlist Syntax

MODEL THREE_LVL_1P_H_GTO ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_ZKP:= %0, K_ZKM:= %1, K_ZKMP:= %2, K_L1:= %3, K_L2:= %4 (G_11:= @G_11, G_12:= @G_12, G_13:= @G_13, G_14:= @G_14, G_21:= @G_21, G_22:= @G_22, G_23:= @G_23, G_24:= @G_24, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_GTO:= @VF_GTO, RB_GTO:= @RB_GTO, RR_GTO:= @RR_GTO) SRC: DB(Lib:=@ModelLibraryName) ;

Possible control algorithms:

See also Three-Level Single-Phase

See also Three-Level Single-Phase NS

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_ZKP	DC Terminal (Plus)	electrical
K_ZKM	DC Terminal (Center Point)	electrical
K_ZKMP	DC Terminal (Minus)	electrical
K_L1/K_L2	AC Terminal 1/2	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
G_11	Control Signal Transistor 1 Phase 1	real	G_11
G_12	Control Signal Transistor 2 Phase 1	real	G_12
G_13	Control Signal Transistor 3 Phase 1	real	G_13
G_14	Control Signal Transistor 4 Phase 1	real	G_14
G_21	Control Signal Transistor 1 Phase 2	real	G_21
G_22	Control Signal Transistor 2 Phase 2	real	G_22
G_23	Control Signal Transistor 3 Phase 2	real	G_23
G_24	Control Signal Transistor 4 Phase 2	real	G_24
VF_ DIODE	Forward Voltage of Diodes	real	0.85 [V]
RB_ DIODE	Bulk Resistance of Diodes	real	15m [Ohm]
RR_ DIODE	Reverse Resistance of Diodes	real	0.3Meg [Ohm]
VF_GTO	Forward Voltage of GTO Models	real	1.1 [V]
RB_GTO	Bulk Resistance of GTO Models	real	20m [Ohm]
RR_ GTO	Reverse Resistance of GTO Models	real	0.2 Meg [Ohm]

* These parameters must be predefined variables, e.g. the outputs from control algorithm blocks.

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Example

In this example, a DC voltage source E1 is applied to a first-order RL Load through a Single-Phase Three-Level Inverter _3LH_GTOS1. The control signals for the inverter are decided by a Three-Level Single Phase control block _3LH_NSAMP1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

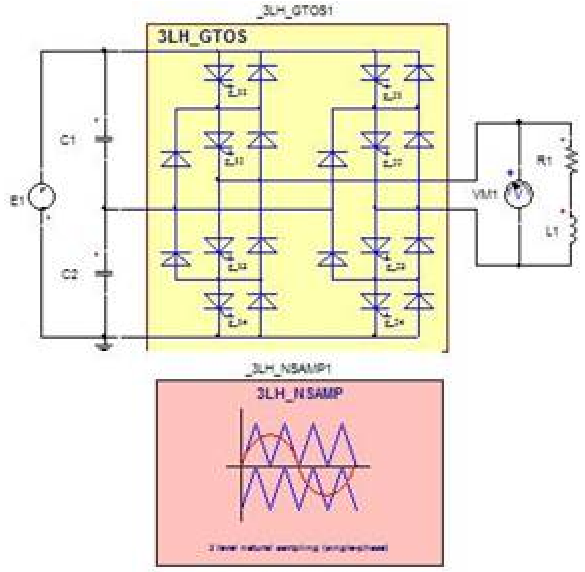

Figure 2. Application example of the Three Level Single-Phase Inverter model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	2.8k [V]

Three Level Single-Phase Inverter _3LH_ GTOS1	G_11	G_11
	G_12	G_12
	G_13	G_13
	G_14	G_14
	G_21	G_21
	G_22	G_22
	G_23	G_23
	G_24	G_24
	G_11	G_11
	G_12	G_12
	G_13	G_13
	G_14	G_14
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three-Level Single Phase NS _3LH_ NSAMP1	FREQUENCY	50 [Hz]
	MODRATE	0.9
	PULSNUM	15
Resistor R1	R	3 [Ohm]
Inductor L1	L	2m [H]
	I0	0 [A]

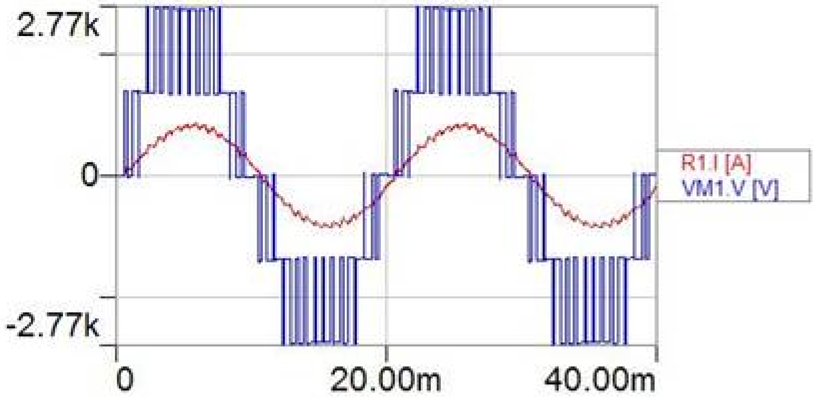

Figure 3. Simulation results

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References

Three-Phase Three-Level Inverter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

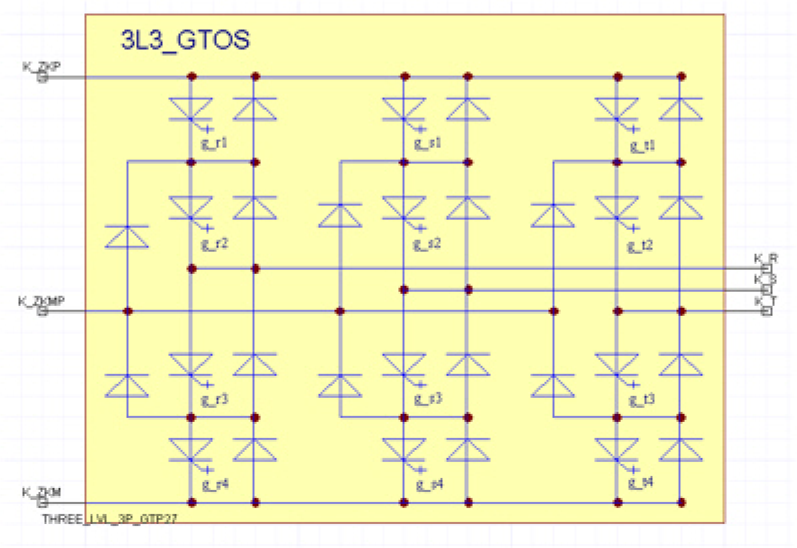

Figure 1. Component symbol

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Description

This model describes a three-phase three-level inverter topology consisting of power electronic devices. The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Netlist Syntax

MODEL THREE_LVL_3P_GTP ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_ZKP:= %0, K_ZKM:= %1, K_ZKMP:= %2, K_R:= %3, K_S:= %4, K_T:= %5 (G_R1:= @G_R1, G_R2:= @G_R2, G_R3:= @G_R3, G_R4:= @G_R4, G_S1:= @G_S1, G_S2:= @G_S2, G_S3:= @G_S3, G_S4:= @G_S4, G_T1:= @G_T1, G_T2:= @G_T2, G_T3:= @G_T3, G_T4:= @G_T4, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_GTO:= @VF_GTO, RB_GTO:= @RB_GTO, RR_GTO:= @RR_GTO) SRC: DB (Lib:=@ModelLibraryName) ;

Possible control algorithms:

See also Three-Level Three-Phase

See also Three-Level Three-Phase NS

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_ZKP	DC Terminal (Plus)	electrical
K_ZKM	DC Terminal (Center Point)	electrical
K_ZKMP	DC Terminal (Minus)	electrical
K_R/K_S/K_T	AC Terminal 1/2/3	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
G_R1	Control Signal Transistor 1 Phase R	real	G_R1*
G_R2	Control Signal Transistor 2 Phase R	real	G_R2*
G_R3	Control Signal Transistor 3 Phase R	real	G_R3*
G_R4	Control Signal Transistor 4 Phase R	real	G_R4*
G_S1	Control Signal Transistor 1 Phase S	real	G_S1*

G_S2	Control Signal Transistor 2 Phase S	real	G_S2*
G_S3	Control Signal Transistor 3 Phase S	real	G_S3*
G_S4	Control Signal Transistor 4 Phase S	real	G_S4*
G_T1	Control Signal Transistor 1 Phase T	real	G_T1*
G_T2	Control Signal Transistor 2 Phase T	real	G_T2*
G_T3	Control Signal Transistor 3 Phase T	real	G_T3*
G_T4	Control Signal Transistor 4 Phase T	real	G_T4*
VF_DIODE	Forward Voltage of Diodes	real	0.85 [V]
RB_DIODE	Bulk Resistance of Diodes	real	15m [Ohm]
RR_DIODE	Reverse Resistance of Diodes	real	0.3Meg [Ohm]
VF_GTO	Forward Voltage of GTO Models	real	1.1 [V]
RB_GTO	Bulk Resistance of GTO Models	real	20m [Ohm]
RR_GTO	Reverse Resistance of GTO Models	real	0.2Meg [Ohm]

* These parameters must be predefined variables, e.g. the outputs from control algorithm blocks.

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Example

In this example, a DC voltage source E1 is applied to a Three-Phase Three-Phase RL Load RL31 through a Three-Phase Three-Level Inverter _3L3_GTOS1. The control signals for the inverter are decided by a Three-Level Three Phase control block _3L3_VBC1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

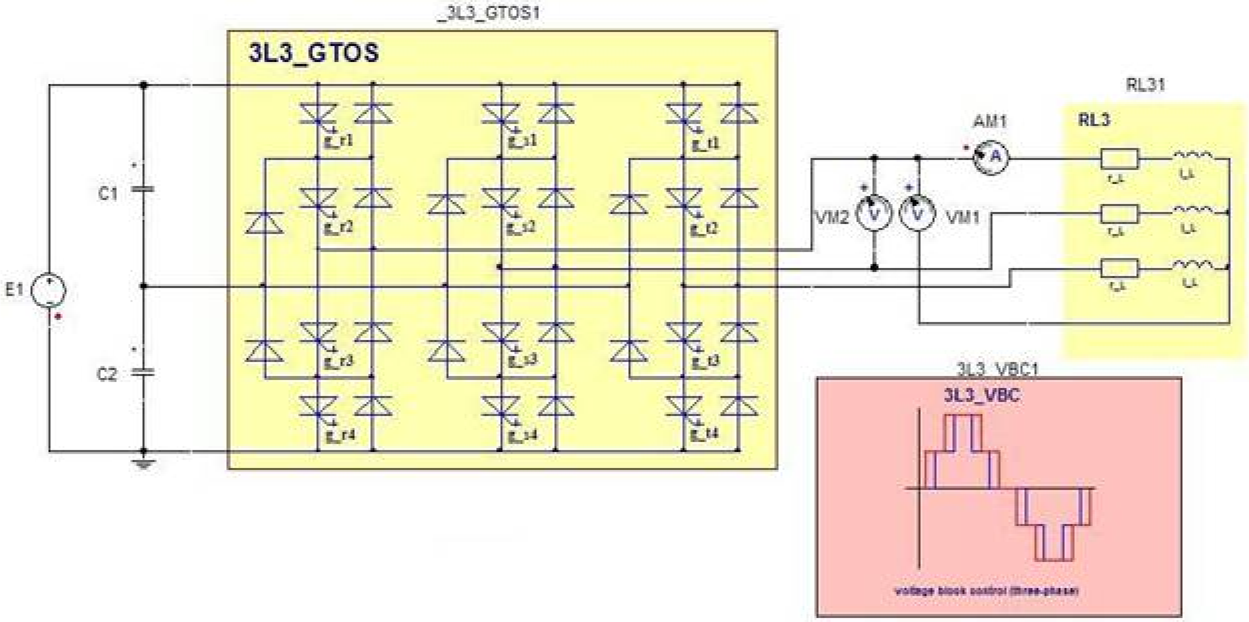

Figure 2. Application example of the Three-Phase Three Level Inverter model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	2.8k [V]

Three-Phase Three Level Inverter 3L3_ GTOS1	G_R1	G_R1
	G_R2	G_R2
	G_R3	G_R3
	G_R4	G_S4
	G_S1	G_S1
	G_S2	G_S2
	G_S3	G_S3
	G_S4	G_S4
	G_T1	G_T1
	G_T2	G_T2
	G_T3	G_T3
	G_T4	G_T4
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three-Level Three Phase _3L3_VBC1	FREQUENCY	50 [Hz]
	ALPHA	60 [degree]
Three-Phase RL Load RL31	R_L	3 [Ohm]
	L_L	2m [H]

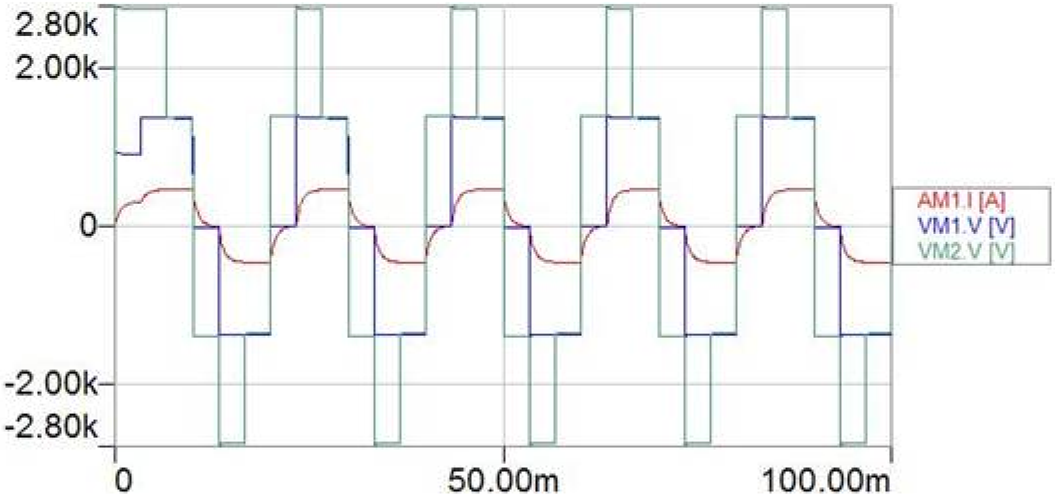

Figure 3. Simulation results

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References

Single-Phase Two Level Inverter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

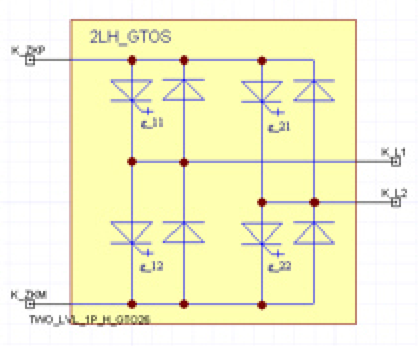

Figure 1. Component symbol

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Description

This model describes a topology consisting of power electronic devices. The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Netlist Syntax

MODEL TWO_LVL_1P_H_GTO ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_ZKP:= %0, K_ZKM:= %1, K_L1:= %2, K_L2:= %3 (G_11:= @G_11, G_12:= @G_12, G_21:= @G_21, G_22:= @G_22, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_GTO:= @VF_GTO, RB_GTO:= @RB_GTO, RR_GTO:= @RR_GTO) SRC: DB(Lib:=@ModelLibraryName) ;

Possible control algorithms:

See also Two Level Square Wave

See also Two Level Natural Sampling

See also Four Quadrant Current Control

See also Four Quadrant Natural Sampling

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_ZKP	DC Terminal (Plus)	electrical
K_ZKM	DC Terminal (Minus)	electrical
K_L1	AC Terminal 1	electrical
K_L2	AC Terminal 2	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
G_11	Control Signal Upper Transistor Phase 1	real	G_11*
G_12	Control Signal Lower Transistor Phase 1	real	G_12*
G_21	Control Signal Upper Transistor Phase 2	real	G_21*
G_22	Control Signal Lower Transistor Phase 2	real	G_22*
VF_DIODE	Forward Voltage of Diodes	real	0.85 [V]
RB_DIODE	Bulk Resistance of Diodes	real	15m [Ohm]

RR_ DIODE	Reverse Resistance of Diodes	real	0.3Meg [Ohm]
VF_GTO	Forward Voltage of GTO Models	real	1.1 [V]
RB_GTO	Bulk Resistance of GTO Models	real	20m [Ohm]
RR_ GTO	Reverse Resistance of GTO Models	real	0.2 Meg [Ohm]

* These parameters must be predefined variables, e.g. the outputs from control algorithm blocks.

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Example

In this example, a sinusoidal voltage source ET1 is applied to a Single-Phase Two Level Inverter _2LH_GTOS1 through a Four-Quadrant Current Controller FOUR_QS_IBAND. The output of the inverter is connected to a first-order RC load. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

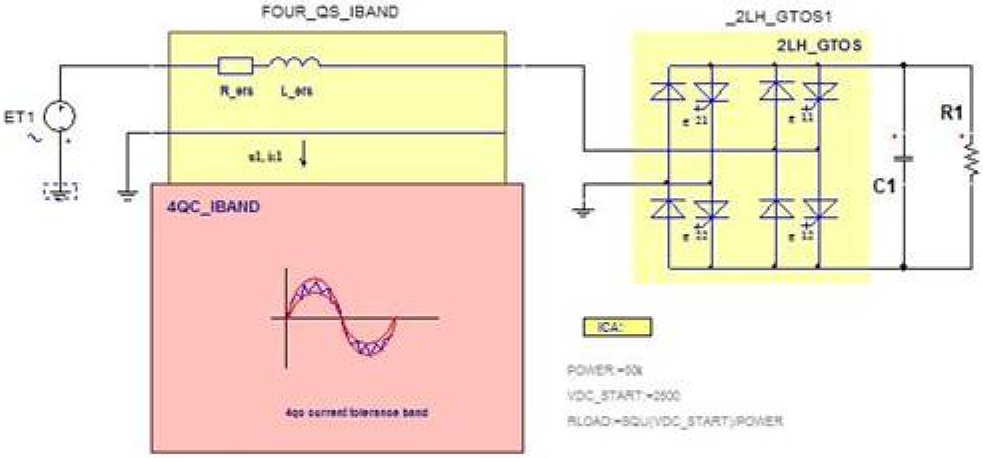

Figure 2. Application example of the Single-Phase Two Level Inverter model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source (Sinusoidal) ET1	AMPL	2000 [V]
	FREQ	1/0.06 [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]

Single-Phase Two Level Inverter 2L3_GTOS1	G_11	G_11
	G_12	G_12
	G_21	G_21
	G_22	G_22
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Four-Quadrant Current Control FOUR_QS_IBAND	R_ERS	20m [Ohm]
	L_ERS	100m [H]
	U1_AMPL	2000 [V]
	FREQUENCY	16.67 [Hz]
	PHI_IC1	0 [degree]
	DELTA_1	1 [A]
	P2	POWER*
Resistor R1	R	RLOAD*
Capacitor C1	C	500m [F]
	V0	VDC_START*
Initial Values FML_INIT1	POWER	500k
	VDC_START	2500
	RLOAD	SQU(VDC_START)/POWER

* These parameters are defined by the Initial Value Block FML_INIT1.

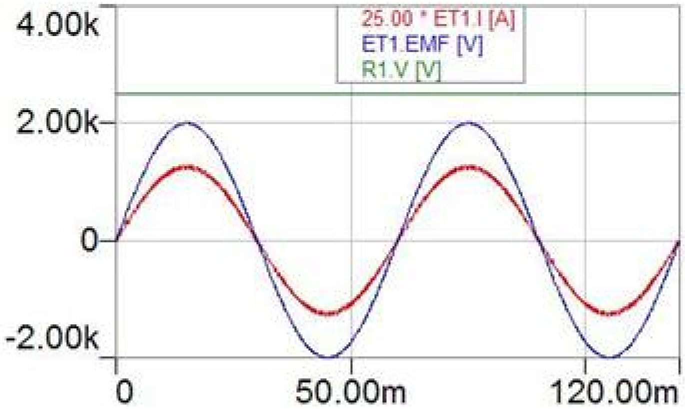

Figure 3. Simulation results-voltage and current of ET1 (ET1.EMF and ET1.I) and output voltage of the inverter (R1.V)

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References

Two Level Inverter Equivalent Circuit

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

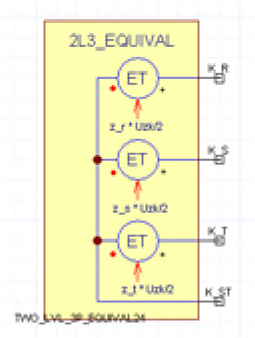

Figure 1. Component symbol

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Description

This model describes an equivalent circuit for a two-level voltage source inverter. It consists of three controlled voltage sources in star-connection. The gate control signals must have the following values: 1 for positive output voltage, -1 for negative output voltage of the corresponding phase, and 0 for output voltage = 0. The gate control signals corresponding to the upper valves of a phase module generated by the control algorithms 2L_NSAMP and 2L_SQW can be used to define the state of an output line.

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Netlist Syntax

MODEL TWO_LVL_3P_EQUIVAL ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_R:= %0, K_S:= %1, K_T:= %2, K_ST:= %3 (V_DC:= @V_DC, Z_R:= @Z_R, Z_S:= @Z_S, Z_T:= @Z_T) SRC: DB(Lib:=@ModelLibraryName) ;

Possible control algorithms:

See also Two Level Square Wave

See also Two Level Natural Sampling

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_R	First Inverter Output Terminal (Phase R)	electrical
K_S	Second Inverter Output Terminal (Phase S)	electrical
K_T	Third Inverter Output Terminal (Phase T)	electrical
K_ST	Star Connection of Voltage Sources	electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
V_DC	DC Voltage	real	0.52k [V]
Z_R	Control Signal Phase R	real	Z_R*
Z_S	Control Signal Phase S	real	Z_S*
Z_T	Control Signal Phase T	real	Z_T*

* These parameters must be predefined variables, e.g. the outputs from control algorithm blocks.

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Three-Phase Two Level Inverter

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

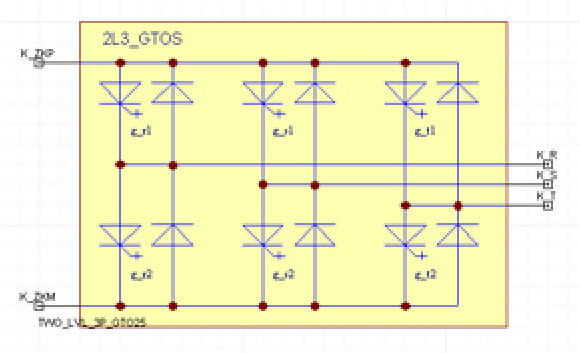

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
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Description

This model describes a Three-Phase Two Level Inverter topology consisting of power electronic devices. The power semiconductor models display static behavior. Their v-i characteristic is calculated by an equivalent line.

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Netlist Syntax

MODEL TWO_LVL_3P_GTO ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_ZKP:= %0, K_ZKM:= %1, K_R:= %2, K_S:= %3, K_T:= %4 (G_R1:= @G_R1, G_R2:= @G_R2, G_S1:= @G_S1, G_S2:= @G_S2, G_T1:= @G_T1, G_T2:= @G_T2, VF_DIODE:= @VF_DIODE, RB_DIODE:= @RB_DIODE, RR_DIODE:= @RR_DIODE, VF_GTO:= @VF_GTO, RB_GTO:= @RB_GTO, RR_GTO:= @RR_GTO) SRC: DB(Lib:=@ModelLibraryName) ;

Possible control algorithms:

See also Two Level Square Wave

See also Two Level Natural Sampling

Top

Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_ZKP	DC Terminal (Plus)	electrical
K_ZKM	DC Terminal (Minus)	electrical
K_R	First Inverter Output Terminal (Phase R)	electrical
K_S	Second Inverter Output Terminal (Phase S)	electrical
K_T	Third Inverter Output Terminal (Phase T)	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
G_R1	Control Signal Upper Transistor Phase R	real	G_R1*
G_R2	Control Signal Lower Transistor Phase R	real	G_R2*
G_S1	Control Signal Upper Transistor Phase S	real	G_S1*
G_S2	Control Signal Lower Transistor Phase S	real	G_S2*
G_T1	Control Signal Upper Transistor Phase T	real	G_T1*
G_T2	Control Signal Lower Transistor Phase T	real	G_T2*

VF_ DIODE	Forward Voltage of Diodes	real	0.85 [V]
RB_ DIODE	Bulk Resistance of Diodes	real	15m [Ohm]
RR_ DIODE	Reverse Resistance of Diodes	real	0.3Meg [Ohm]
VF_GTO	Forward Voltage of GTO Models	real	1.1 [V]
RB_GTO	Bulk Resistance of GTO Models	real	20m [Ohm]
RR_ GTO	Reverse Resistance of GTO Models	real	0.2 -Meg [Ohm]

* These parameters must be predefined variables, e.g. the outputs from control algorithm blocks.

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Example

In this example, a Three-Phase Two Level Inverter 2L3_GTOS1 is connected to a Three-Phase RL Load RL31. The control signals for the inverter are sent out by a Natural Sampling block _ 2L_NSAMP1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

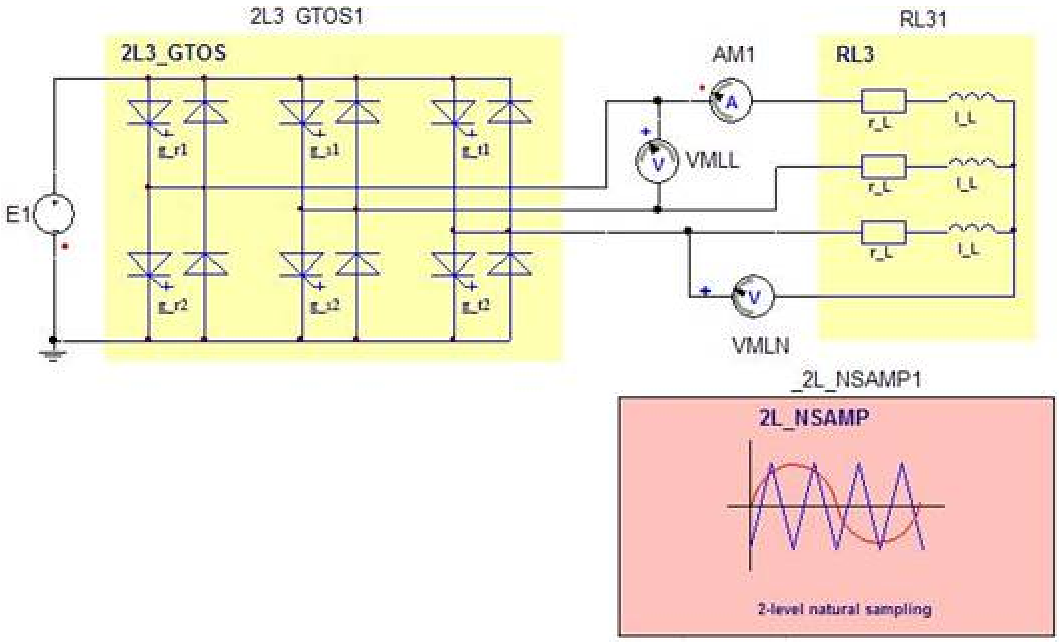

Figure 2. Application example of the Three-Phase Two Level Inverter model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source E1	EMF	500 [V]

Three-Phase Two Level Inverter 2L3_ GTOS1	G_R1	G_R1
	G_R2	G_R2
	G_S1	G_S1
	G_S2	G_S2
	G_T1	G_T1
	G_T2	G_T2
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2 Meg [Ohm]
Three Phase RL Load RL31	R_L	1 [Ohm]
	L_L	2m [H]

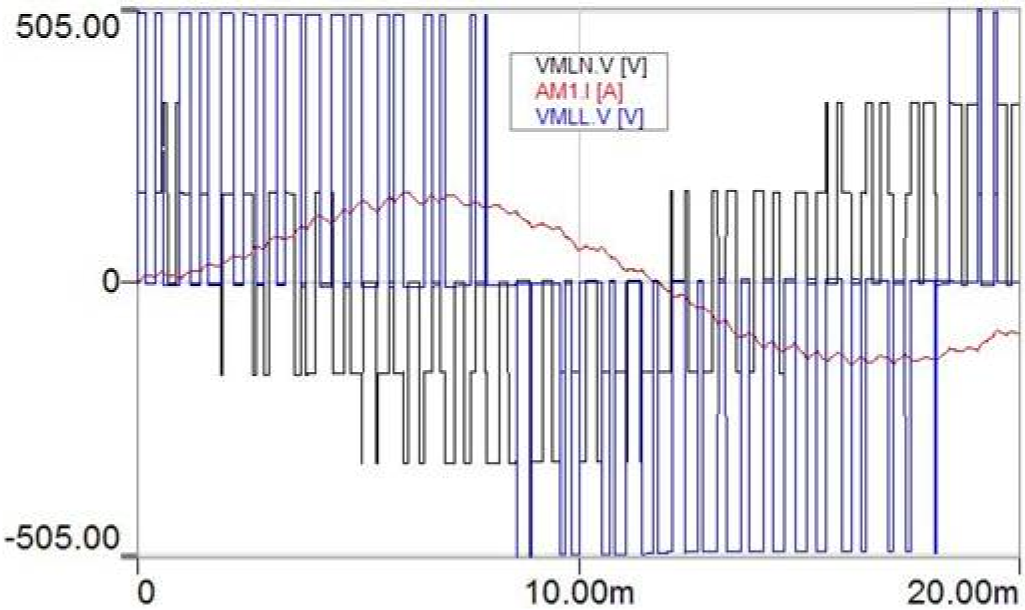

Figure 3. Simulation results – line-to-line voltage(VMLL.V), phase voltage(VMLN.V) and line current (AM1.I)

Top

References

PWM

- Flasher Switch Model (flasher_switch)
- PWM controlled Switch with Load Resistance (pwm_load)
- PWM Controlled Switch (pwm_switch)

Flasher Switch

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

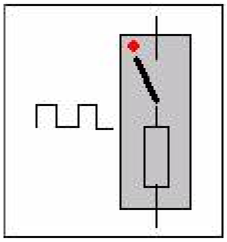

Figure 1. Component symbol

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- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The PWM load model represents a combination of an ideal switch model, a load resistance, and the PWM model. The switch remains closed for a fraction, dc, of the period time period. During this time, the load resistance determines the current flowing through the PWM load. The current stays at zero for the remaining time of the period. The parameter phase shifts the positive edge of the PWM. If the phase is set to '0', the switch closes with the start of every new period. The first closing of the switch can be delayed with td. As long as the simulation time is smaller than td, the switch remains open.

Top

Assumptions and Limitations

- The minimum time step should consider the PWM times.
- The synchronization on the edges of the PWM depends on the selected HMIN.

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Mathematical Description

Top

Netlist Syntax

MODEL flasher_switch ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (period:= @period, dc:= @dc, ron:= @ron, roff:= @roff, td:= @td, phase:= @phase) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
period	Period Time	real	1 [s]
dc	Duty Cycle	real	0.5
phase	Phase Shift	real	0 [deg]
td	Initial Delay	real	0 [s]
ron	On-Resistance	real	1m [Ohm]
roff	Off-Resistance	real	1G [Ohm]

Top

Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Switch Voltage [V]	Output	real
i	Switch Current [A]	Output	real
rval	Switch Resistance	Output	real

Top

Example

In this example, battery1 is connected to a Lamp (advanced model) through a Flasher Switch. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

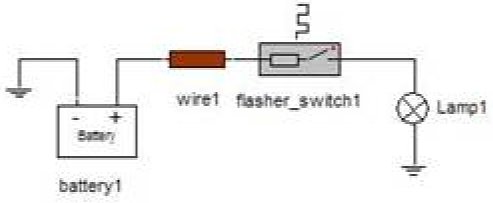

Figure2. Application example of the PWM Switch model

Table 4. System Parameters

Component	Parameter	Value [unit]
Battery (basic model) battery1	rin	10m [Ohm]
	vnom	12 [V]
Wire (Level 1) wire1	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^oC]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^oC]
	timelt	150 [^oC]
Flasher Switch flasher_switch1	period	1 [s]
	dc	0.5
	phase	0 [deg]
	td	0 [s]
	ron	1m [Ohm]
	roff	1G [Ohm]

Lamp- Advanced Lamp1	pnom	55 [W]
	vnom	12 [V]
	tnom	2k [ºC]
	tamb	20 [ºC]
	ton	1.8k [ºC]
	tmax	2.2k [ºC]
	alpha	45m [1/K]
	roff	1G [Ohms]
	tdoff	10m [s]
	ct	2.5m [Ws/K]
	conductivity_share	50m [W]
	enable_break	1

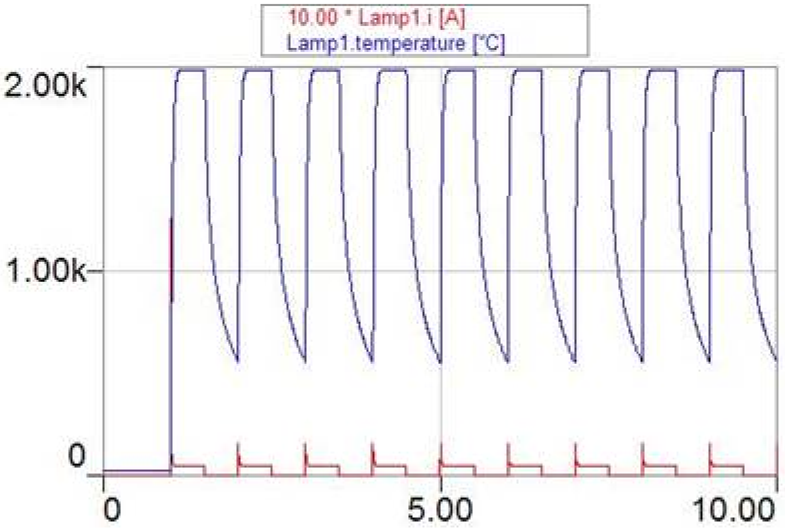

Figure 3. Simulation results

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References

PWM Load

Library: Add Ons/Automotive	Modeling Language: SML	Version Number: Twin Builder 2025.2

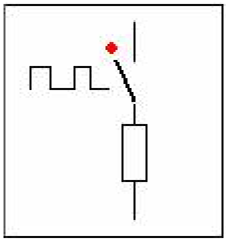

Figure 1. Component symbol

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- Assumptions and Limitations
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Description

The PWM load model represents a combination of an ideal switch model, a load resistance, and the PWM model. The switch remains closed for a fraction, dc, of the time period. During this time, the load resistance determines the current flowing through the PWM load. The current stays at zero for the remaining time of the period. The parameter phase shifts the positive edge of the PWM. If the phase is set to '0', the switch closes with the start of every new period. The first closing of the switch can be delayed with td. As long as the simulation time is smaller than td, the switch remains open.

Top

Assumptions and Limitations

- The minimum time step should consider the PWM times.
- The synchronization on the edges of the PWM depends on the selected HMIN.

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Mathematical Description

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Netlist Syntax

MODEL pwm_load ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (period:= @period, dc:= @dc, r:= @r, phase:= @phase, td:= @td) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
period	Period Time	real	1 [s]
dc	Duty Cycle	real	0.5
phase	Phase Shift	real	0 [degree]
td	Initial Delay	real	0 [s]
r	On Resistance	real	1 [Ohm]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Voltage [V]	Output	real
i	Current [A]	Output	real
state	Switch State	Output	real

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Example

In this example, battery1 is connected to an alternator (average model) and a PWM Load pwm_load1. The mechanical output of the alternator is connected to engine, whose speed is decided by a 2D Lookup Table. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

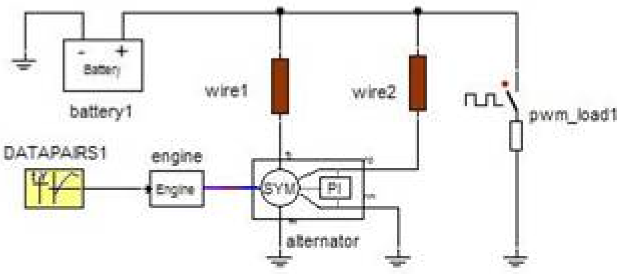

Figure2. Application example of the PWM Switch model

Table 4. System Parameters

Component	Parameter	Value [unit]
Battery (basic model) battery1	rin	10m [Ohm]
	vnom	12 [V]
Alternator (average model) alternator	rs	30m [Ohm]
	ls	0.2m [H]
	re	3.5 [Ohm]
	le	0.8 [H]
	k	50m [V/(A*rad/s)]
	p	6 [l]
	vd	0.7 [V]
	vref	14 [V]
	p_gain	0.2
	i_gain	0.1 [1/s]
Wire (Level 1) wire1/wire2	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^{o}C]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^{o}C]
	timelt	150 [^{o}C]
Engine (Speed Source)	n	DATAPAIRS1.VAL* [Nms/rad]

PWM Load pwe_load1	period	1 [s]
	dc	0.5
	phase	0 [degree]
	td	0 [s]
	r	1 [Ohm]
Resistor Load	R	1 [Ohm]

DATAPAIRS1.VAL is the output value of the 2D Lookup Table DATAPAIRS1.

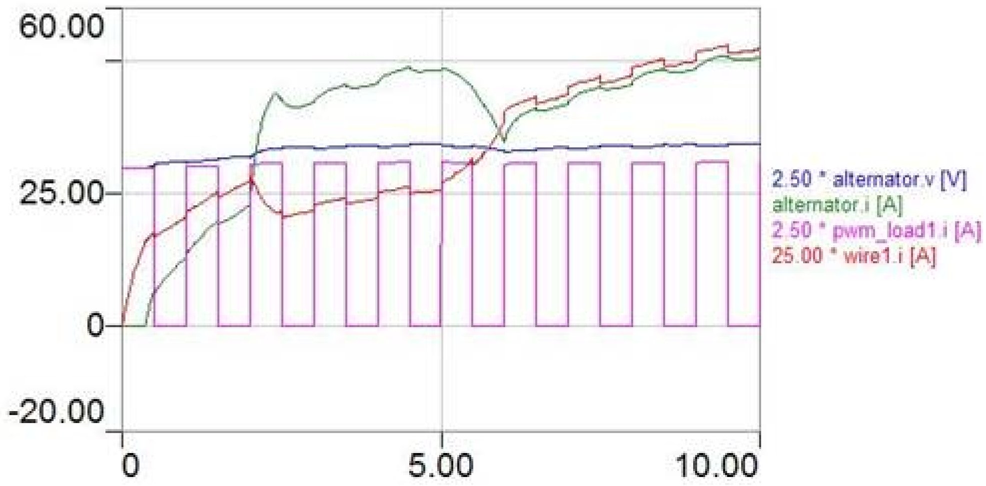

Figure 3. Simulation results

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References

PWM Switch

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

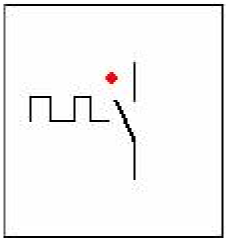

Figure 1. Component symbol

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- Parameters
- Input/Output Quantities
- Example
- References

Description

The PWM switch model represents a combination of an ideal switch model and the PWM model. The switch remains closed (zero resistance) for a fraction, dc, of the time period. The parameter phase shifts the positive edge of the PWM. If the phase is set to '0', the switch closes with the start of every new period. The first closing of the switch can be delayed with the help of the parameter td. As long as the simulation time is smaller than td, the switch remains open.

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Assumptions and Limitations

- The minimum time step should consider the PWM times.
- The synchronization on the edges of the PWM depends on the selected HMIN.

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Mathematical Description

Top

Netlist Syntax

MODEL pwm_switch ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (period:= @period, dc:= @dc, phase:= @phase, td:= @td) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
period	Period Time	real	1 [s]
dc	Duty Cycle	real	0.5
phase	Phase Shift	real	0 [degree]
td	Initial Delay	real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Voltage [V]	Output	real
i	Current [A]	Output	real
state	Switch State	Output	real

Top

Example

In this example, battery1 is connected to an alternator (average model) and a PWM Switch pwm_switch2. The mechanical output of the alternator is connected to engine, whose speed is decided by a 2D Lookup Table. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

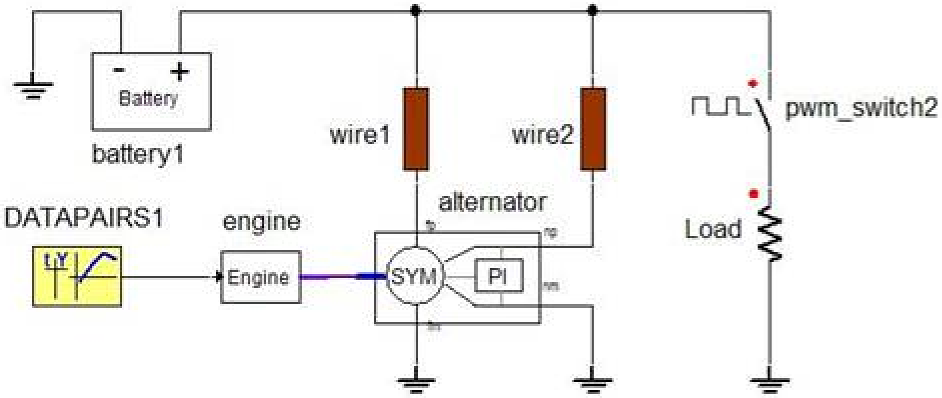

Figure2. Application example of the PWM Switch model

Table 4. System Parameters

Component	Parameter	Value [unit]
Battery (basic model) battery1	rin	10m [Ohm]
	vnom	12 [V]
Alternator (average model) alternator	rs	30m [Ohm]
	ls	0.2m [H]
	re	3.5 [Ohm]
	le	0.8 [H]
	k	50m [V/(A*rad/s)]
	p	6 [l]
	vd	0.7 [V]
	vref	14 [V]
	p_gain	0.2
	i_gain	0.1 [1/s]
Wire (Level 1) wire1/wire2	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^{o}C]
	rho	1.78n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^{o}C]
	timelt	150 [^{o}C]
Engine (Speed Source)	n	DATAPAIRS1.VAL* [Nms/rad]

PWM Switch pwm_switch2	period	1 [s]
	dc	0.5
	phase	0 [degree]
	td	0 [s]
Resistor Load	R	1 [Ohm]

DATAPAIRS1.VAL is the output value of the 2D Lookup Table DATAPAIRS1.

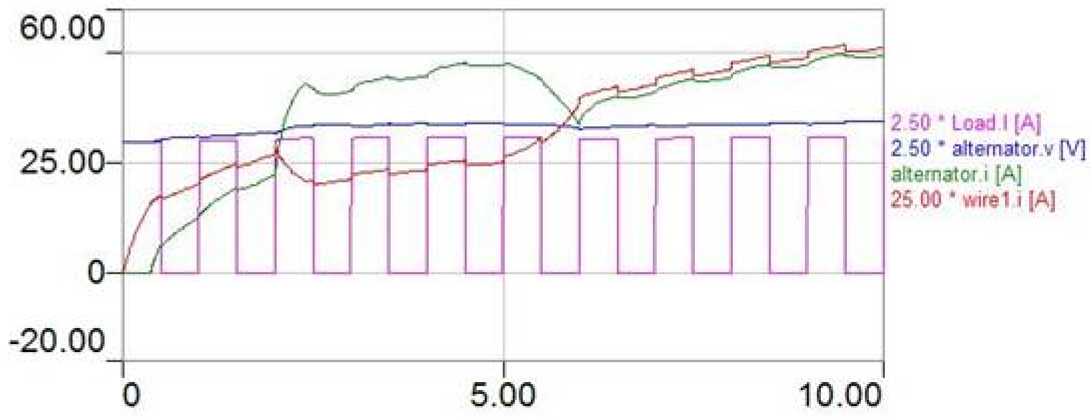

Figure 3. Simulation results

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References

Relays

The control circuitry of all relay models consists of an inductor and a resistor. The state of the relay contacts is detected from the voltage across the resistor, which is proportional to the current flowing through it. The load switches are modeled as controlled resistances. After a relay state change is detected, the resistance values are changed. The transition can be step-by-step or as a linear resistance change following a ramp function. The type of the transition can be set using the parameter enable_ramp, the slope of the ramp tdmk (transition off to on), and tdbrk (transition on to off). If no ramp is selected, these parameters determine the delay between the time a new relay state is detected and the time the load switch resistance changes. A static free-wheeling diode is included in all of the relay models.

The model neglects the following:

- The feedback of the movement on the control circuitry
- Thermal effects

All models contain built-in animation to display relay states on a sheet. If a relay changes its state, the contacts in the symbol are adapted accordingly.

When setting the minimum simulator time step, the time constant of the control circuitry (L/R) and the transition times (off to on and on to off) must be considered.

The following types of relays are provided. Note that for each type, both the Single Direction and BiDirection (bidir) versions are documented together.

- Basic Model of a One-PoleTwo-Throws Relay (rly1p2t, rly1p2t_bidir)
- Basic Model of a Two-Pole, Two-Throws Relay (rly2p2t, rly2p2t_bidir)
- Basic Model of a Normally Closed Relay (rlync, rlync_bidir)
- Basic Model of a Normally Open Relay (rlyno, rlyno_bidir)
- Basic Relay Model - Two Poles, Crosstrap (rlyxstr, rlyxstr_bidir)

Relay — One Pole, Two Throws

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

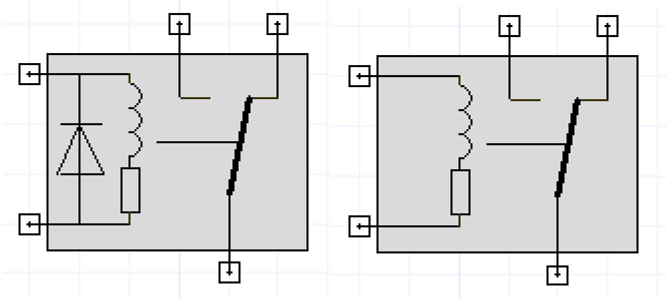

Figure 1. Component symbol for single and bidirection models

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Description

The model represents a relay with a single pole, double throw switch. As long as the voltage across the resistor of the control circuitry remains below the level defined by vpull and above the level defined by vdrop, the load terminal stays connected with the *normally closed pin*.

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Assumptions and Limitations

The model doesn't take into account the following effects:

- The feedback of the movement on the control circuitry
- Thermal effects

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Mathematical Description

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Netlist Syntax

MODEL rly1p2t ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, com:= %2, nop:= %3, ncp:= %4 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

MODEL rly1p2t_bidir ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, com:= %2, nop:= %3, ncp:= %4 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
drp	Control Pin 1	Electrical
drm	Control Pin 2	Electrical
nop	Load Pin – Normally Open	Electrical
ncp	Load Pin – Normally Closed	Electrical
com	Common Load Pin	Electrical

Note: If terminals ncp and nop are unconnected in the schematic they are automatically connected to ground through a 1e+9 Ohm resistor in the netlist.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
lcoil	Coil Inductance	real	0.5 [H]
rcoil	Coil Resistance	real	5 [Ohm]
vpull	Resistor Voltage for Switching On	real	12 [V]
vdrop	Resistor Voltage for Switching Off	real	2 [V]
ron	On-Resistance (Load Side)	real	5m [Ohm]

roff	Off-Resistance (Load Side)	real	10Meg [Ohm]
tdmk	Delay Off-On	real	0.2 [s]
tdbrk	Delay On-Off	real	3m [s]
enable_ramp	Selection Transition Type	real	l

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
vin	Control Voltage [V]	Output	real
iin	Control Current [A]	Output	real
ino	Load Current (normally open pin) [A]	Output	real
inc	Load Current (normally closed pin) [A]	Output	real
rval_no	Resistance Load Side (normally open pin) [Ohm]	Output	real
rval_nc	Resistance Load Side (normally closed pin) [Ohm]	Output	real

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Example

In this example, two Lamps – Lamp and Lamp1 are connected to the Battery battery1 through the One-Pole Two-Throw Relay rly1p2t1 and the switch S1. Either Lamp or Lamp1 is turned on depending on the position of rly1p2t1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3 and Figure 4.

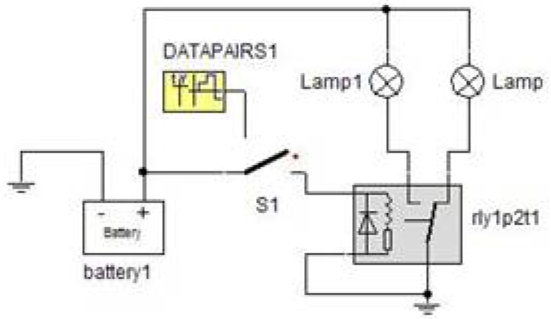

Figure 2. Application example of the Relay-One Pole, Two Throws model

Table 4. System Parameters

Component	Parameter	Value [unit]

Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Lamp- Advanced Lamp1/Lamp	pnom	20 [W]
	vnom	12 [V]
	tnom	2k [^{o}C]
	tamb	20 [^{o}C]
	ton	1.4k [^{o}C]
	tmax	2.2k [^{o}C]
	alpha	45m [1/K]
	roff	1G [Ohms]
	tdoff	10m [s]
	ct	5m [Ws/K]
	conductivity_ share	50m [W]
	enable_break	1
Relay – One Pole, Two Throw rly1p2t1	lcoil	0.2 [H]
	rcoil	5 [Ohm]
	vpull	12 [V]
	vdrop	2 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

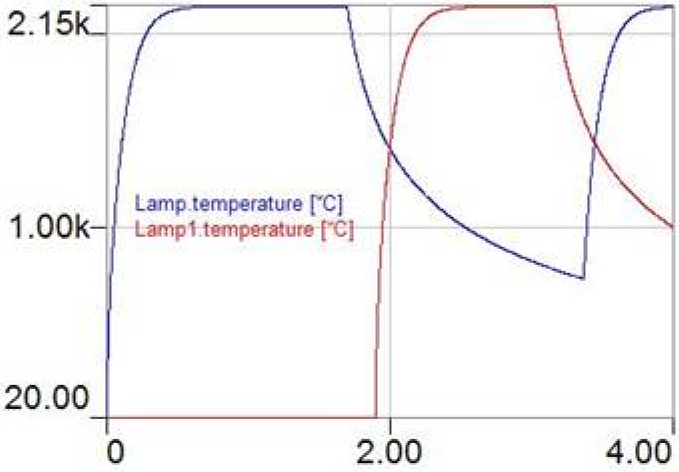

Figure 3. Simulation results – temperatures of Lamp1 and Lamp

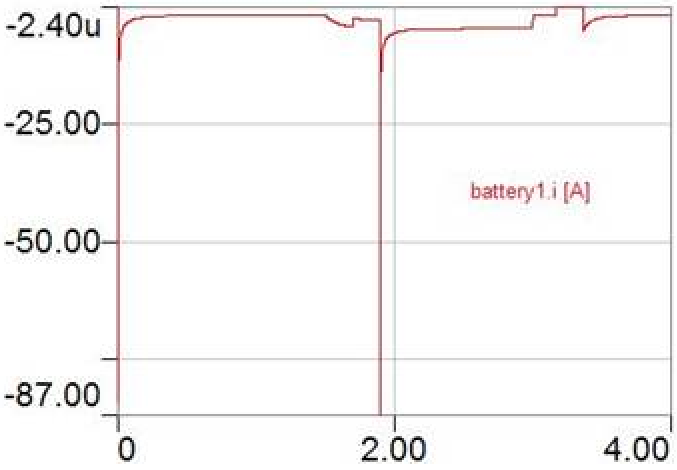

Figure 4. Simulation results – current through battery1

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References

Relay Two Poles, Two Throws

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

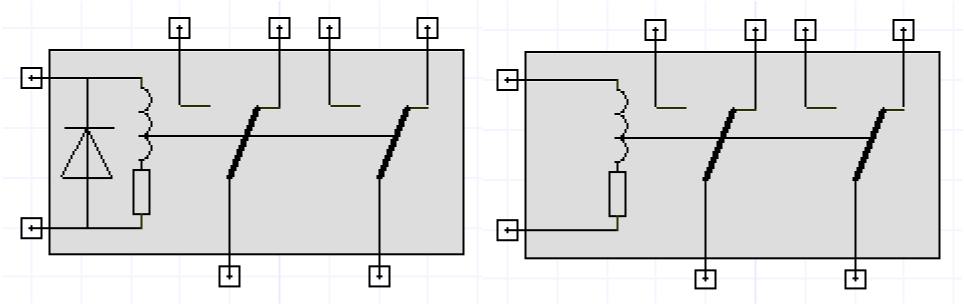

Figure 1. Component symbol for single and bidirection models

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- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a relay with a double pole, double throw switch. As long as the voltage across the resistor of the control circuitry stays below the level defined by vpull and above the level defined by vdrop, the load terminal remains connected with the *normally closed pins*.

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Assumptions and Limitations

The model doesn't take into account the following effects:

- The feedback of the movement on the control circuitry.
- Thermal effects.

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Mathematical Description

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Netlist Syntax

MODEL rly2p2t ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, com1:= %2, nop1:= %3, ncp1:= %4, com2:= %5, nop2:= %6, ncp2:= %7 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

MODEL rly2p2t_bidir ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, com1:= %2, nop1:= %3, ncp1:= %4, com2:= %5, nop2:= %6, ncp2:= %7 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
drp	Control Pin 1	Electrical
drm	Control Pin 2	Electrical
com1	Common Load Pin 1	Electrical
nop1	Load Pin Normally Open 1	Electrical
ncp1	Load Pin Normally Closed 1	Electrical
com2	Common Load Pin 2	Electrical
nop2	Load Pin Normally Open 2	Electrical
ncp2	Load Pin Normally Closed 2	Electrical

Note: If terminals ncp1, ncp2, nop1 and nop2 are unconnected in the schematic they are automatically connected to ground through a 1e+9 Ohm resistor in the netlist.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
lcoil	Coil Inductance	real	0.5 [H]
rcoil	Coil Resistance	real	5 [Ohm]
vpull	Resistor Voltage for Switch-	real	12 [V]

	ing On		
vdrop	Resistor Voltage for Switching Off	real	2 [V]
ron	On-Resistance (Load Side)	real	5m [Ohm]
roff	Off-Resistance (Load Side)	real	10Meg [Ohm]
tdmk	Delay Off-On	real	0.2 [s]
tdbrk	Delay On-Off	real	3m [s]
enable_ ramp	Selection Transition Type	real	l

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
vin	Control Voltage [V]	Output	real
iin	Control Current [A]	Output	real
rval_no	Resistance Load Side (normally open pin) [Ohm]	Output	real
rval_nc	Resistance Load Side (normally closed pin) [Ohm]	Output	real

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Example

In this example, a self-holding circuit is modeled. Once the relay rly2p2t1 is closed, one of the relay contacts is used to shorten the switch S1. Therefore the relay remains closed even though the S1 opens again. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3 and Figure 4.

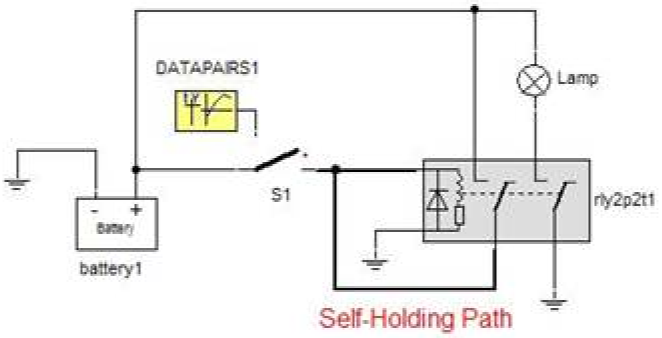

Figure 2. Application example of the Relay-Two Pole, Two Throws model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Lamp- Advanced Lamp	pnom	20 [W]
	vnom	12 [V]
	tnom	2k [^{o}C]
	tamb	20 [^{o}C]
	ton	1.4k [^{o}C]
	tmax	2.2k [^{o}C]
	alpha	45m [1/K]
	roff	1G [Ohms]
	tdoff	10m [s]
	ct	5m [Ws/K]
	conductivity_ share	50m [W]
	enable_break	1
Relay – Two Pole, Two Throw rly1p2t1	lcoil	0.1 [H]
	rcoil	20 [Ohm]
	vpull	8 [V]
	vdrop	5 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.1 [s]
	tdbrk	3m [s]
	enable_ramp	1

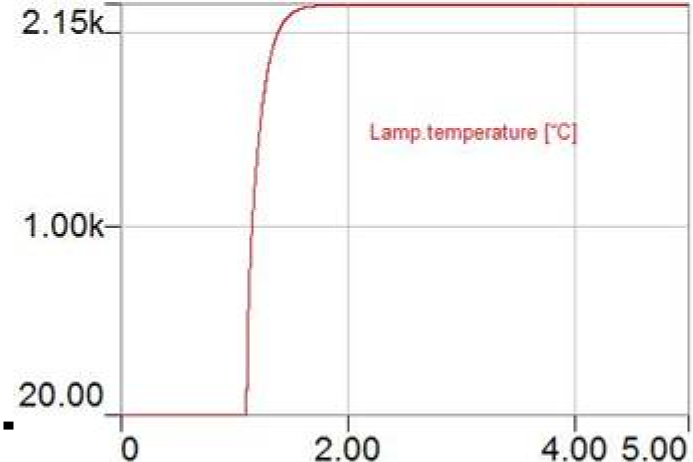

Figure 3. Simulation results – temperatures of Lamp

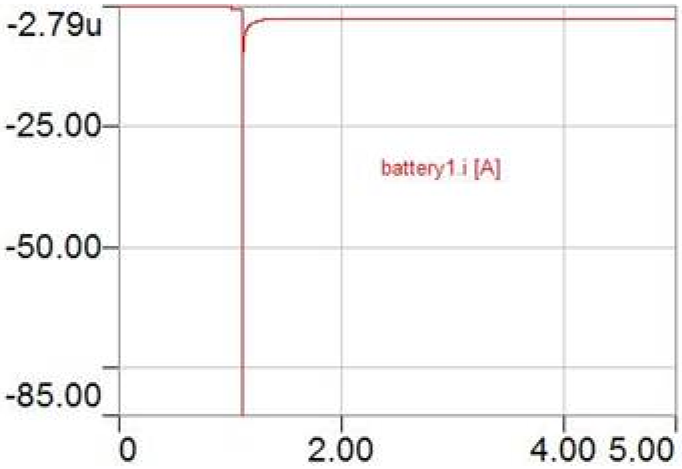

Figure 4. Simulation results – current through battery1

Top

References

Relay — Normally Closed

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

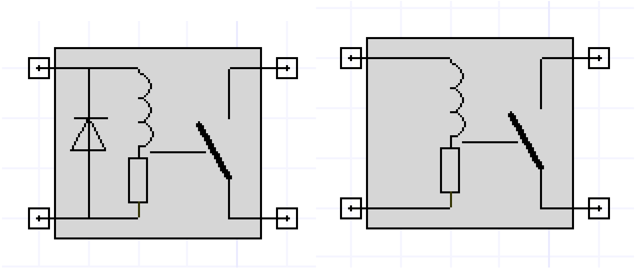

Figure 1. Component symbol for single and bidirection models

Description

The model represents a relay with a single pole, single throw switch. As long as the voltage across the resistor of the control circuitry stays below the level defined with vpull and above the level defined with vdrop, the relay remains closed.

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Assumptions and Limitations

The model doesn’t take into account the following effects:

- The feedback of the movement on the control circuitry
- Thermal effects

Top

Mathematical Description

Top

Netlist Syntax

MODEL rlync ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p:= %2, m:= %3 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:-:=@ModelLibraryName) ;

MODEL rlync_bidir ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p:= %2, m:= %3 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:-:=@ModelLibraryName) ;

Top

Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
drp	Control Pin 1	Electrical
drm	Control Pin 2	Electrical
p	Load Pin 1	Electrical
m	Load Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
lcoil	Coil Inductance	real	0.5 [H]
rcoil	Coil Resistance	real	5 [Ohms]
vpull	Resistor Voltage for Switching On	real	12 [V]
vdrop	Resistor Voltage for Switching Off	real	2 [V]
ron	On-Resistance (Load Side)	real	5m [Ohms]
roff	Off-Resistance (Load Side)	real	10Meg [Ohms]
tdmk	Delay Off-On	real	0.2 [s]
tdbrk	Delay On-Off	real	3m [s]
enable_ramp	Selection Transition Type	real	l

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
vin	Control Voltage [V]	Output	real
iin	Control Current [A]	Output	real
vout	Load Voltage [V]	Output	real
iout	Load Current [A]	Output	real
rval	Resistance Load Side [Ohm]	Output	real

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Example

In this example, the Single-Filament Lamp lamp_sf1 is connected to the Battery battery1 through the Normally-Close Relay Relais when the switch S1 is closed at t=0.2s. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3 and Figure 4.

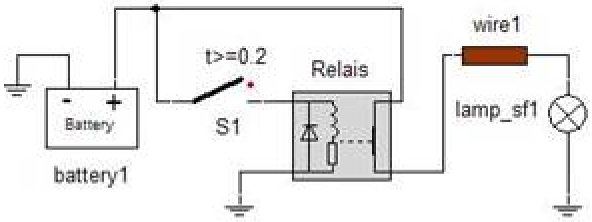

Figure 2. Application example of the Relay-Normally Open model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Lamp-Single Filament Lamp_sf1	ct	0.2m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	rt	5k [K/W]
	r0	5 [Ohm]
	tref	20 [^{o}C]
	k	100f [W/K^4]

Relay – Normally Open Relais	lcoil	0.2 [H]
	rcoil	5 [Ohm]
	vpull	12 [V]
	vdrop	2 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

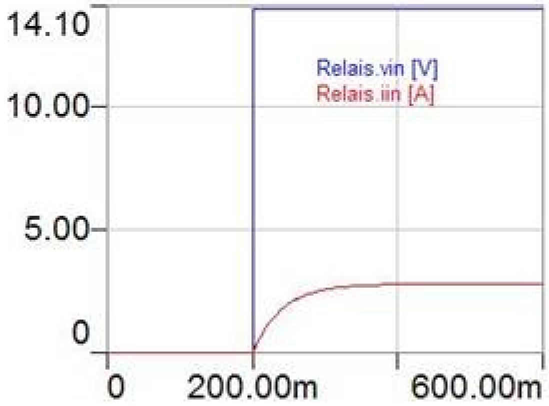

Figure 3. Simulation results – control input voltage and current of the relay rlyno1

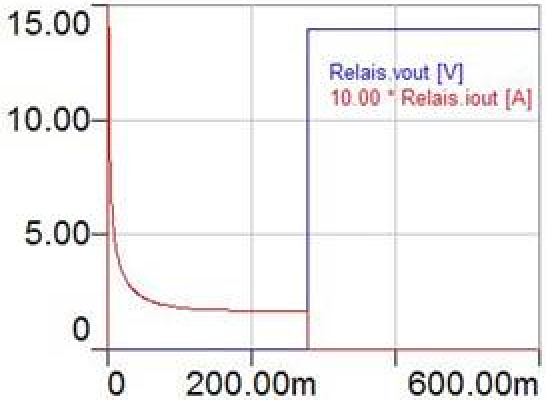

Figure 4. Simulation results – Output voltage and current of the relay rlyno1

Top

References

Relay — Normally Open

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

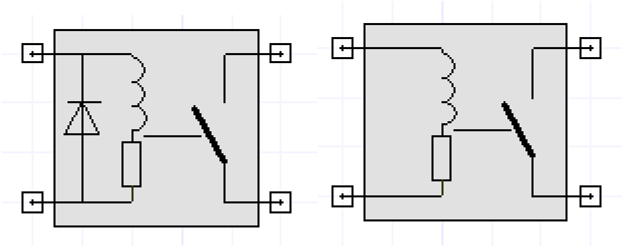

Figure 1. Component symbol for single and bidirection models

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a relay with a single pole, single throw switch. As long as the voltage across the resistor of the control circuitry stays below the level defined by vpull and above the level defined by vdrop, the relay remains open.

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Assumptions and Limitations

The model doesn’t take into account the following effects:

- The feedback of the movement on the control circuitry
- Thermal effects

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Mathematical Description

Top

Netlist Syntax

MODEL rlyno ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p:= %2, m:= %3 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:-:=@ModelLibraryName) ;

MODEL rlyno_bidir ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p:= %2, m:= %3 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:-:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
drp	Control Pin 1	Electrical
drm	Control Pin 2	Electrical
m	Load Pin 1	Electrical
m	Load Pin 2	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
lcoil	Coil Inductance	real	0.5 [H]
rcoil	Coil Resistance	real	5 [Ohms]
vpull	Resistor Voltage for Switching On	real	12 [V]
vdrop	Resistor Voltage for Switching Off	real	2 [V]
ron	On-Resistance (Load Side)	real	5m [Ohms]
roff	Off-Resistance (Load Side)	real	10Meg [Ohms]
tdmk	Delay Off-On	real	0.2 [s]
tdbrk	Delay On-Off	real	3m [s]
enable_ramp	Selection Transition Type	real	1

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
vin	Control Voltage [V]	Output	real
iin	Control Current [A]	Output	real
vout	Load Voltage [V]	Output	real
iout	Load Current [A]	Output	real
rval	Resistance Load Side [Ohm]	Output	real

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Example

In this example, the Single-Filament Lamp lamp_sf1 is connected to the Battery battery1 through ilament 1 of the double-filament lamp Lamp is connected to the battery battery1 through the Normally-Open Relay rlyno1 when the switch S1 is closed at t=0.2s. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3 and Figure 4.

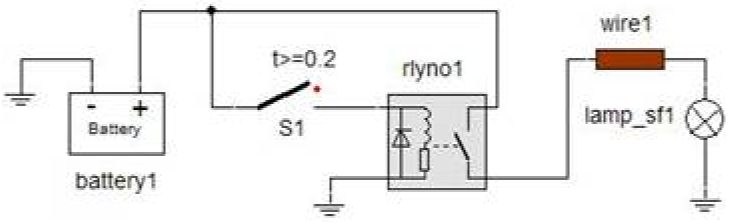

Figure 2. Application example of the Relay-Normally Open model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Lamp-Single Filament Lamp_sf1	ct	0.2m [Ws/K]
	alpha	45m [1/K]
	tamb	20 [^{o}C]
	rt	5k [K/W]
	r0	5 [Ohm]
	tref	20 [^{o}C]
	k	100f [W/K^4]

Relay – Normally Open rlyno1	lcoil	0.5 [H]
	rcoil	5 [Ohm]
	vpull	12 [V]
	vdrop	2 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

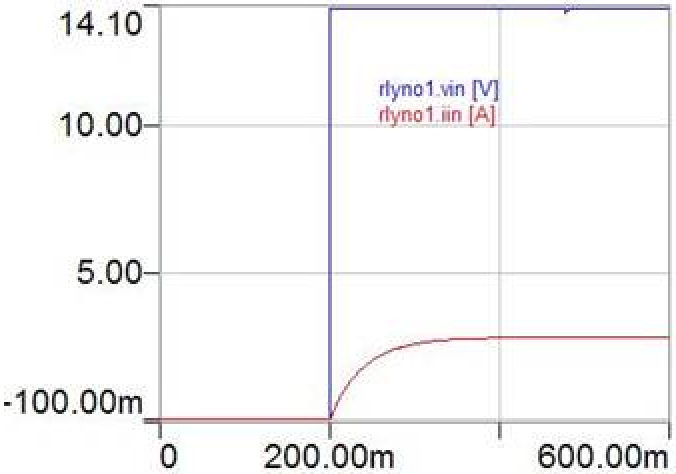

Figure 3. Simulation results – control input voltage and current of the relay rlyno1

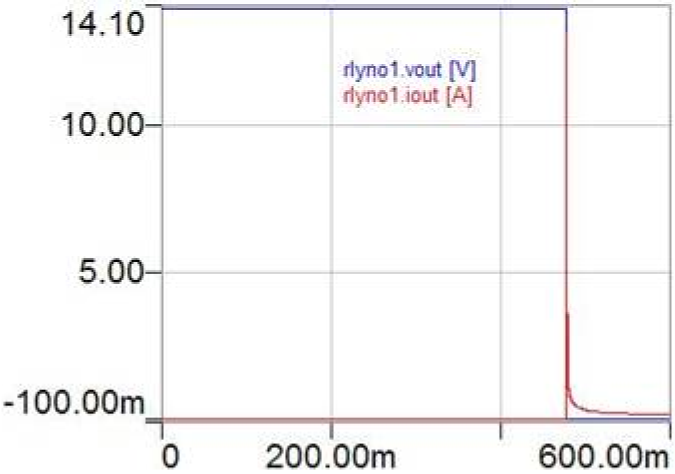

Figure 4. Simulation results – Output voltage and current of the relay rlyno1

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References

Relay — Two Poles, Crosstrap

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

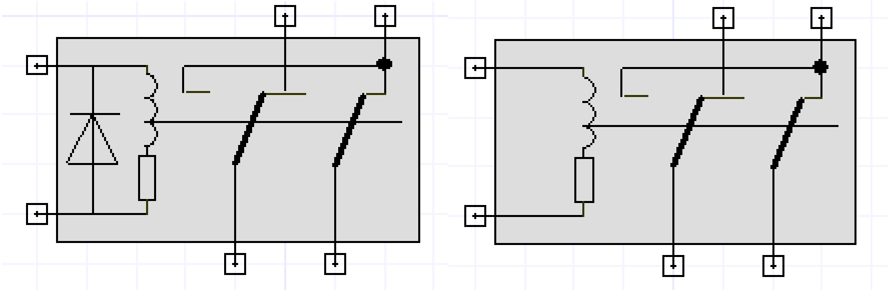

Figure 1. Component symbol for single and bidirection models

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a relay with a double pole, double throw switch. As long as the voltage across the resistor of the control circuitry stays below or equal to the level defined with vpull and above or equal to the level defined with vdrop, the load terminals p1 - m1 and p2 - m2 remain connected. Otherwise, p1 is connected with m2 and p2 with m1.

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Assumptions and Limitations

The model doesn't take into account the following effects:

- The feedback of the movement on the control circuitry.
- Thermal effects.

Top

Mathematical Description

Top

Netlist Syntax

MODEL rlyxstr ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p1:= %2, p2:= %3, m1:= %4, m2:= %5 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

MODEL rlyxstr_bidir ?InstanceName(@InstanceName):(@(Refbase)@(ID)) drp:= %0, drm:= %1, p1:= %2, p2:= %3, m1:= %4, m2:= %5 (lcoil:= @lcoil, rcoil:= @rcoil, vpull:= @vpull, vdrop:= @vdrop, ron:= @ron, roff:= @roff, tdmk:= @tdmk, tdbrk:= @tdbrk, enable_ramp:= @enable_ramp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
drp	Control Pin 1	Electrical terminal
drm	Control Pin 2	Electrical terminal
p1	Load Pin P1	Electrical terminal
p2	Load Pin P2	Electrical terminal
m1	Load Pin M1	Electrical terminal
m2	Load Pin M2	Electrical terminal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
lcoil	Coil Inductance	real	0.5 [H]
rcoil	Coil Resistance	real	5 [Ohm]
vpull	Resistor Voltage for Switching On	real	12 [V]
vdrop	Resistor Voltage for Switching Off	real	2 [V]
ron	On-Resistance (Load Side)	real	5m [Ohm]
roff	Off-Resistance (Load Side)	real	10Meg [Ohm]

tdmk	Delay Off-On	real	0.2 [s]
tdbrk	Delay On-Off	real	3m [s]
enable_ ramp	Selection Transition Type	real	I

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
vin	Control Voltage [V]	Output	real
iin	Control Current [A]	Output	real
rval_no	Resistance Load Side (normally open pin) [Ohm]	Output	real
rval_nc	Resistance Load Side (normally closed pin) [Ohm]	Output	real

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Example

In this example, two Lamps – Lamp and Lamp1 are switched on alternatively according to the status of the switch S1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3 and Figure 4.

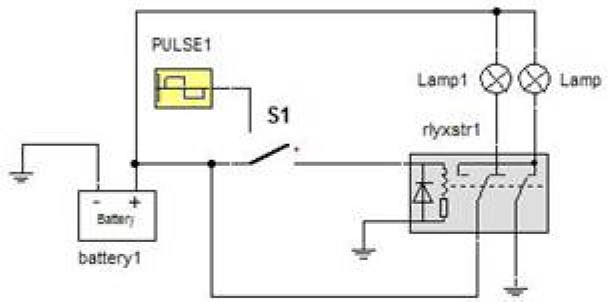

Figure 2. Application example of the Relay-Two Poles, Crosstrap model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]

Lamp- Advanced Lamp/Lamp1	pnom	20 [W]
	vnom	12 [V]
	tnom	2k [ºC]
	tamb	20 [ºC]
	ton	1.4k [ºC]
	tmax	2.2k [ºC]
	alpha	45m [1/K]
	roff	1G [Ohms]
	tdoff	10m [s]
	ct	2m [Ws/K]
	conductivity_share	50m [W]
	enable_break	1
Relay – Two Poles, Crosstrap rlyxstr1	lcoil	0.2 [H]
	rcoil	5 [Ohm]
	vpull	10 [V]
	vdrop	3 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

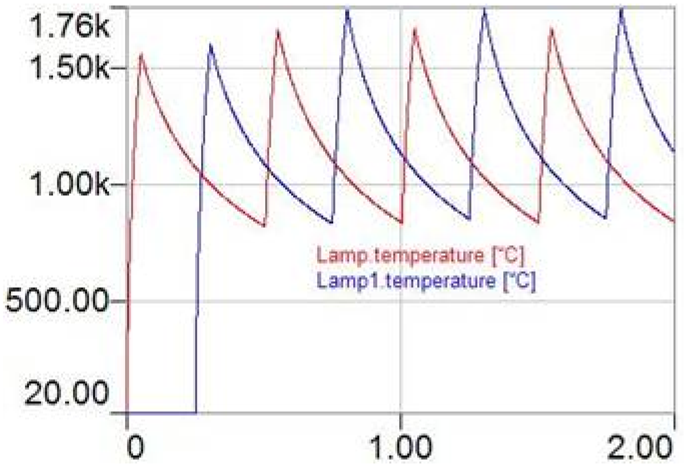

Figure 3. Simulation results – temperatures of Lamp1 and Lamp

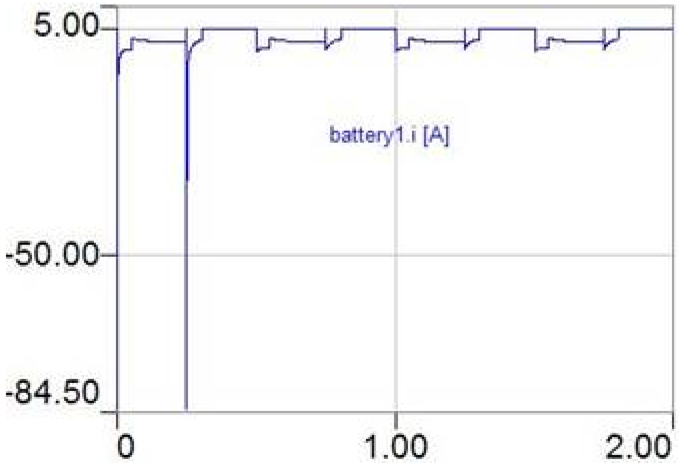

Figure 4. Simulation results – current through battery1

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References

Wire

- Wire Advanced
- Wire Basic

Wire Advanced

The advanced wire models simulate the electrical and thermal behavior of wires. These models have three available model levels for thermal behavior (static, quasi-dynamic, and dynamic) and two available model types for electrical behavior (with and without specific inductance).

Available models:

- Thermal Wire (ThermalWire)
- Wire (wire)

Top

Mathematical Description

Electrical Behavior

Wire Resistance

The wire models calculate resistance using the following formula:

$$R = R_0 \times (1 + \alpha \times (\Theta_c - \Theta_{ref}))$$

where R_0 is the wire's nominal resistance (calculated from the length, cross-sectional area, and resistivity, using the formula $R_0 = \rho^* (L/A)$), $\alpha$is the wire conductor's temperature coefficient, and Θ_c and Θ_{ref} are the conductor's current temperature and reference temperature, respectively. Values for wire length, conductor area, resistivity, current temperature, and reference temperature can be entered as model parameters.

Wire Inductance

The wire models have an optional length-dependent inductance that can be activated or deactivated when an instance of a wire model component is placed on a schematic sheet. If the inductance is activated, the inductance per unit length of a given wire can be entered as a model parameter.

Wire Destruction

The wire models use two methods to simulate wire destruction due to melting. . The first method is to change the value of two nonconservative outputs when the melting temperatures for the wire insulation and wire conductor have been exceeded. The second method is an optional circuit break feature. When this feature is enabled and the wire conductor's melting temperature has been exceeded, the wire model changes from its conducting resistance to its off-state resistance after a specified blowing delay. The off-state resistance and blowing delay for a particular wire can be entered as model parameters.

Thermal Behavior

The wire models have three model levels for thermal behavior. Each model level has a different method for determining wire insulator temperature and conductor temperature.

Level 1

Level 1 wire models consist of static thermal behavior modeling. The wire insulator and conductor temperature are both equal to the value at the nonconservative or conservative node used for the model's ambient temperature input.

The Level 1 wire model is best used in simulation models for which ambient temperature remains constant and for which the effects of power dissipation on the modeled wire are negligible.

Level 2

Level 2 wire models consist of quasi-dynamic thermal behavior modeling. The wire insulator and conductor temperatures are calculated separately and are equal to the sum of the ambient temperature and a term that depends on the amount of power being dissipated in the modeled wire. The ambient temperature is equal to the value at the nonconservative or conservative node used for the model's ambient temperature input. The term that depends on power dissipation is determined from a thermal network for which the input is the power currently being dissipated in the wire.

Due to its accurate handling of the thermal effects of power dissipation, this wire model is best suited for simulation models for which the effects of power dissipation on the modeled wire are significant and for which ambient temperature remains constant.

Level 3

Level 3 wire models consist of fully dynamic thermal behavior modeling. The wire insulator and conductor temperatures are determined separately from a thermal network, using two inputs: the power currently being dissipated in the wire, and the wire's ambient temperature.

This wire model has very accurate thermal behavior modeling and is best suited for simulation models for which the effects of power dissipation on the modeled wire are significant and for which the ambient temperature does not remain constant.

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References

Thermal Wire

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

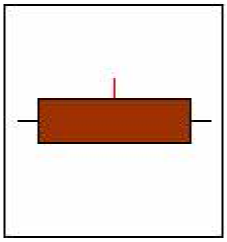

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This component models the electrical and thermal behavior of a wire. The component has three available modeling levels for thermal behavior and two available model types for electrical behavior. By default, the ambient temperature of the wire is entered via a conservative thermal-nature pin connected to an external thermal network.

For more details on the thermal model levels and electrical model types of this component, see Wires Advanced.

Top

Assumptions and Limitations

The **DIA** parameter refers to the diameter of the wire including the insulator, while the **AREA** is the cross-sectional area of the metal conductor.

NOTE: Be sure that the diameter of the metal conductor associated with the **AREA** parameter is smaller that the **DIA** parameter entered or an error will result.

For more details on the assumptions and limitations of different thermal model levels and electrical model types of this component, see Wires Advanced.

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Mathematical Description

The Conductor State ok is set to 1 when conductor temperature is below melting temperature, 0 when conductor temperature exceeds melting temperature. The Insulator state is set to 1 when insulator temperature is below melting temperature, and 0 when conductor temperature exceeds melting temperature.

For more details on the mathematical descriptions of different thermal model levels and electrical model types of this component, seeWires Advanced.

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Netlist Syntax

Netlist generated by Special Component Dialog.

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Positive Terminal	Electrical
n2	Negative Terminal	Electrical
amb	Ambient temperature (this node is visible only if the **Thermal circuit** radio button has been selected in the component dialog box)	Thermal

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
dia	Diameter of conductor and insulator (outer diameter)	real	2 [m]
area	Cross sectional area of conductor	real	0.6793u [m^2]
l	Length of wire	real	1 [m]
lval	Specific inductance	real	10n [H/m]
i0	Initial current of conductor	real	45 [A]
tamb	Ambient temperature	real	20 [^{o}C]
tinit	Initial temperature	real	20 [^{o}C]
tref	Reference temperature	real	20 [^{o}C]
enable_ break	Enable circuit break	real	0
tdoff	Blowing delay	real	1 [s]
roff	Off resistance	real	1G [Ohm]
rho	Resistivity of conductor	real	1.72n [ohm m]
alpha	Temperature coefficient of conductor	real	3.93m [1/K]
spgc	Specific gravity of conductor	real	9k [kg/m^3]
shcc	Specific heat capacity of conductor	real	0.38k [J/(K kg)]
kc	Thermal conductivity of conductor	real	0.401k [W/(K m)]
tcmelt	Melting temperature of conductor	real	1084 [^{o}C]
spgi	Specific gravity of insulator	real	1.3k [kg/m^3]
shci	Specific heat capacity of insulator	real	1.5k [J/(K kg)]
timelt	Melting temperature of insulator	real	150 [^{o}C]
ki	Thermal conductivity of insulator	real	0.16 [W/(k m)]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Wire Voltage [V]	Output	real
i	Wire Current [A]	Output	real
tblow	Blowing delay [s]	Output	real
ok	Conductor state	Output	real
ins_ok	Insulator state	Output	real
temp	Wire temperature [^{o}C]	Output	real

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Example

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References

Wire

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

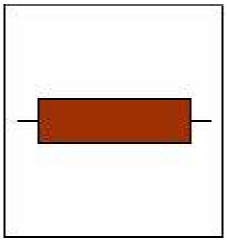

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

This component models the electrical and thermal behavior of a wire. The component has three available modeling levels for thermal behavior and two available model types for electrical behavior. By default, the ambient temperature of the wire is entered via a non-conservative input pin.

For more details on the thermal model levels and electrical model types of this component, seeWires Advanced.

Top

Assumptions and Limitations

The **DIA** parameter refers to the diameter of the wire including the insulator, while the **AREA** is the cross-sectional area of the metal conductor.

NOTE: Be sure that the diameter of the metal conductor associated with the **AREA** parameter is smaller that the **DIA** parameter entered or an error will result.

For more details on the assumptions and limitations of different thermal model levels and electrical model types of this component, see Wires Advanced.

Top

Mathematical Description

The Conductor State ok is set to 1 when conductor temperature is below melting temperature, 0 when conductor temperature exceeds melting temperature. The Insulator state is set to 1 when insulator temperature is below melting temperature, and 0 when conductor temperature exceeds melting temperature.

For more details on the mathematical descriptions of different thermal model levels and electrical model types of this component, see Wires Advanced.

Top

Netlist Syntax

Netlist generated by Special Component Dialog.

Top

Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Positive Terminal	Electrical terminal
n2	Negative Terminal	Electrical terminal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
dia	Diameter of conductor and insulator (outer diameter)	real	2m [m]
area	Cross sectional area of conductor	real	0.6793u [m^2]
l	Length of wire	real	1 [m]
lval	Specific inductance	real	10n [H/m]
i0	Initial current of conductor	real	45 [A]
tamb	Ambient temperature	real	20 [^oC]
tinit	Initial temperature	real	20 [^oC]
tref	Reference temperature	real	20 [^oC]
enable_break	Enable circuit break	real	0

tdoff	Blowing delay	real	1 [s]
roff	Off resistance	real	1G [Ohm]
rho	Resistivity of conductor	real	1.72n [ohm m]
alpha	Temperature coefficient of conductor	real	3.93m [1/K]
spgc	Specific gravity of conductor	real	9k [kg/m^3]
shcc	Specific heat capacity of conductor	real	0.38k [J/(K kg)]
kc	Thermal conductivity of conductor	real	0.401k [W/(K m)]
tcmelt	Melting temperature of conductor	real	1084 [^{o}C]
spgi	Specific gravity of insulator	real	1.3k [kg/m^3]
shci	Specific heat capacity of insulator	real	1.5k [J/(K kg)]
timelt	Melting temperature of insulator	real	150 [^{o}C]
ki	Thermal conductivity of insulator	real	0.16 [W/(k m)]

Top

Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Wire Voltage [V]	Output	real
i	Wire Current [A]	Output	real
tblow	Blowing Delay [s]	Output	real
ok	Conductor state	Output	real
ins_ok	Insulator state	Output	real
temp	Wire Temperature [^{o}C]	Output	real

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Example

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References

Wire Basic

Available models:

- Wire - T-Equivalent Circuit (WIRE_T)
- Wire - Gamma-Equivalent Circuit (WIRESEGM)

Wire T-Model

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

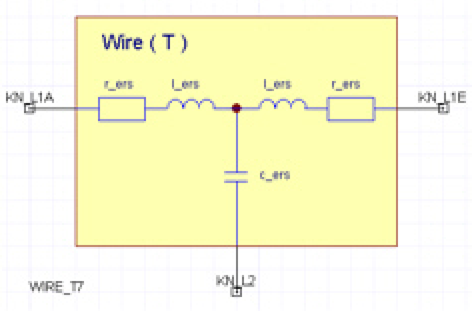

Figure 1. Component symbol

- Description
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Description

This model describes a double-wire cable. The default values for the parameter were determined by measuring a double-litz wire cable with a length of 4 m and a conductor area of 1.5 mm. The parameters R_ERS and L_ERS represent half of the entire cable length. The specified value is assigned to each corresponding component.

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Assumptions and Limitations

Top

Mathematical Description

Top

Netlist Syntax

MODEL WIRE_T ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1A:= %0, KN_L1E:= %1, KN_L2:= %2 (R_ERS:= @R_ERS, L_ERS:= @L_ERS, C_ERS:= @C_ERS) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1A	Pin 1	electrical
KN_L1E	Pin 2	electrical
KN_L2	Pin 3	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
R_ERS	Equivalent Resistance of Half Wire	real	25m [Ohm]
L_ERS	Equivalent Inductance of Half Wire	real	2.5u [H]
C_ERS	Capacitance of Wire	real	0.2n [F]

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Example

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References

Wire – Gamma Model

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

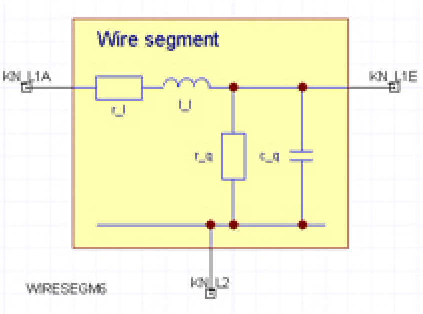

Figure 1. Component symbol

- Description
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Description

This model provides a double-wire cable model. The default parameter values were determined by measuring a double-litz wire cable with a length of 4 m and a conductor area of 1.5 mm.

To increase the precision, several model instances can be connected in series. In this case you can simulate location-dependent phenomena (single-dimensional). One segment always represents a constant length. Either parameters of a defined cable segment are known, or the parameters of the entire cable must be converted into length per segment.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL WIRESEGM ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1A:= %0, KN_L1E:= %1, KN_L2:= %2 (R_L:= @R_L, L_L:= @L_L, R_Q:= @R_Q, C_Q:= @C_Q) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1A	Pin 1	electrical
KN_L1E	Pin 2	electrical
KN_L2	Pin 3	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
R_L	Resistance (Serial Connection)	real	47m [Ohm]
L_L	Inductance (Serial Connection)	real	5.2u [H]
R_Q	Resistance (Parallel Connection)	real	7Meg [Ohm]
C_Q	Inductance (Parallel Connection)	real	0.18n [H]

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Example

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References

Power Load

- DC Link with Resonant Circuit (DCLINK_SRC)
- Advanced Lamp Model (lamp_adv)
- Dynamic Lamp Model with Thermal Network Connection (lamp_filament)
- Model of a Single-Filament Lamp (lamp_sf)
- Dynamic Model of a Double-Filament Lamp (lamp_thermal_2f)
- Three Phase Symmetric Resistive-Inductive Load (RL3)
- Behavior Model of a Spark Plug (spark_plug)

DC Link

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

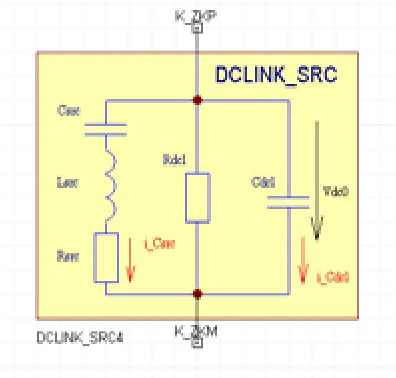

Figure 1. Component symbol

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Description

This model can be used to describe a DC link with a harmonic absorber. The resistance RPDCL is used to model the capacitance losses.

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Assumptions and Limitations

Top

Mathematical Description

The natural frequency of the series resonant circuit must be equal to the estimated harmonic components of the DC link voltage. The value of either the capacitor or the inductor must be given, so that the other one can be calculated.

$$\mathrm{LSRC} = \frac{1}{(2 \cdot \pi \cdot f_n)^2 \cdot \mathrm{CSRC}} \qquad \mathrm{CSRC} = \frac{1}{(2 \cdot \pi \cdot f_n)^2 \cdot \mathrm{LSRC}}$$

Top

Netlist Syntax

MODEL DCLINK_SRC ?InstanceName(@InstanceName):(@(Refbase)@(ID)) K_ZKP:= %0, K_ZKM:= %1 (CSRC:= @CSRC, LSRC:= @LSRC, RSRC:= @RSRC, CDCL:= @CDCL, RPDCL:= @RPDCL, VDC0:= @VDC0, I_CSRC:= @I_CSRC, I_CDCL:= @I_CDCL) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
K_ZKP	DC Terminal (Plus)	electrical
K_ZKM	DC Terminal (Minus)	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
CSRC	Capacitance of the Resonance Circuit	real	7.13m [F]
LSRC	Inductance of the Resonance Circuit	real	3.2m [H]
RSRC	Resistance of the Resonance Circuit	real	10m [Ohm]
CDCL	Capacitance of the DC Link	real	10m [F]
RPDCL	Resistance of the DC Link	real	0.1Meg [Ohm]
VDC0	Initial Voltage	real	2.8k [V]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
I_CSRC	Current of Resonant Circuit	Input/Output	real
I_CDCL	Current through the D.C.Link Capacitor	Input/Output	real

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Example

In this example, the Three-Phase Power Supply THREE_PHASE_Z1 is connected to the Six-Pulse Thyristor Bridge B6C1. The output of B6C1 serves as the voltage source to the buck converter circuit through the DC Link DCLINK_SRC1. Finally the output of the buck converter is applied to the DC Permanent Magnetic Machine DCMP1. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation resultsare shown in Figure 3 and 4.

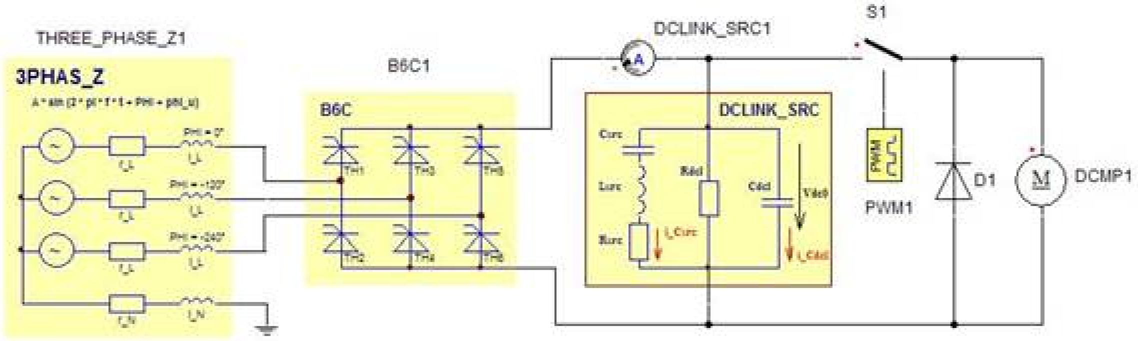

Figure 2. Application example of the D.C.Link model

Table 4. System Parameters

Component	Parameter	Value [unit]
Three-Phase Power Supply _THREE_ PHASE_Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.0024 [Ohm]
	L_L	0.0015u [H]
	R_N	0.16 [Ohm]
	L_N	0.1u [H]

Thyristor Bridge –B6C1	ALPHA	30 [degree]
	Frequency	50 [Hz]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	1Meg [Ohm]
DC Link DCLink_SRC1	CSRC	7.13m [F]
	LSRC	3.2m [H]
	RSRC	10m [Ohm]
	CDCL	10m [F]
	RPDCL	0.1Meg [Ohm]
	VDC0	525 [V]
PWM PWM1	PEROID	100u [s]
	DC	0.5
	TD	0 [s]
	PHASE	0 [degree]
Diode (Equivalent Line) Diode 1	VF	0.8 [V]
	RB	1m [Ohm]
	RR	100k [Ohm]
DC Permanent Magnetic Excitation DCPM1	LOAD	50 [Nm]
	RA	1 [Ohm]
	LA	10m [H]
	KE	1 [Wb]
	J	75m [Kg m^2]
	IA0	0 [A]
	N0	0 [rpm]
	PHI0	0 [degree]

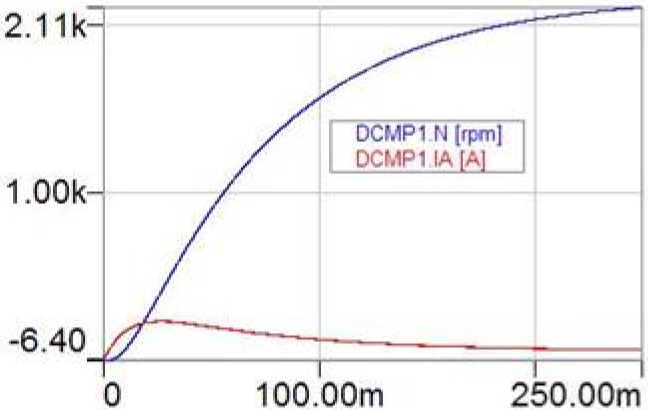

Figure 3. Simulation results – Speed and Current of the DC Permanent Magnetic Machine DCMP1

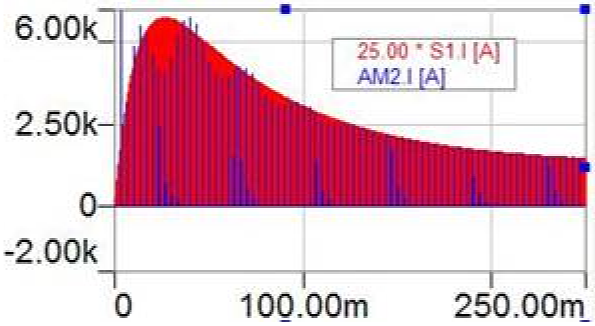

Figure 4. Simulation results – output current of the thyristor bridge and the switch current

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References

Lamp — Advanced

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

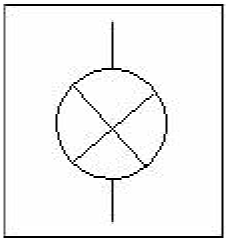

Figure 1. Component symbol

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Description

The advanced lamp model is based on the single filament model, and it provides the following additional features:

- Over-temperature detection
- Pre-processing of input values

The model uses a temperature-dependent resistance to represent electrical lamp properties. The losses generated inside the filament are fed into a thermal network. Power is transmitted to the ambient by thermal power conduction and radiation. The internal parameters of the models are calculated from the input data. The filament resistance is calculated from the nominal power at nominal temperature.

The total thermal power transferred from the filament to the ambient at nominal temperature equals the electrical losses at nominal temperature. The parameters of the thermal network (thermal resistance and radiation coefficient) are calculated from this information. The distribution of the power transferred into power conduction and radiation defines the parameter conductivity_share, which determines the share of the power conduction on the overall power transfer. The parameter ct (thermal capacitance of the filament) must be adapted to the measurement data (e.g., current vs. time).

The model contains built-in over-temperature detection with animation. If the filament temperature exceeds a defined limit tmax, the destruction of the lamp can be modeled. If the parameter enable_break is set to '1', the filament resistance is increased up to the value specified by roff. The slope of the resistance change can be set using the time tdoff.

The state of the lamp is displayed at the output state. If the lamp is off (the filament temperature is below the value of ton), the value of state is '0'. A value of '1' represents the on-state, while a value of '-1' represents filament destruction.

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Assumptions and Limitations

The time constant of the thermal network must be considered for the minimum time step of the simulator. If one of the time constants becomes quite small, it may be necessary to reduce HMIN into the range of nanoseconds.

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Mathematical Description

Power transferred by thermal power conduction:

$$P_c - \frac{T_{Filament} - T_{amb}}{rt}$$

Filament resistance:

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref}))$$

Power transferred by radiation (units in Kelvin):

$$P_{Rad} = k \cdot (T^4_{Filament} - T^4_{amb})$$

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Netlist Syntax

MODEL lamp_adv ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (tnom:= @tnom, pnom:= @pnom, ct:= @ct, alpha:= @alpha, tamb:= @tamb, tmax:= @tmax, enable_break:= @enable_break, vnom:= @vnom, conductivity_share:= @conductivity_share, ton:= @ton, roff:= @roff, tdoff:= @tdoff) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical terminal
n2	Pin 2	Electrical terminal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
pnom	Nominal Power Consumption	real	20 [W]
vnom	Nominal Voltage	real	12 [V]
tnom	Nominal Working Temperature	real	2k [^{o}C]
tamb	Ambient Temperature	real	20 [^{o}C]
ton	Minimum Temperature for On-State	real	1.4k [^{o}C]
tmax	Maximum Temperature	real	2.2k [^{o}C]
alpha	Temperature Coefficient	real	45m [1/K]
roff	Resistance after Blowing	real	1G [Ohms]
tdoff	Blowing Delay	real	10m [s]
ct	Thermal Capacitance	real	5m [Ws/K]
conductivity_share	Share of Heat Conduction on Heat Transfer	real	50m [W]
enable_break	Flag Enable Circuit Break, 1=on	real	1

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Lamp Voltage [V]	Output	real
i	Lamp Current [A]	Output	real
temperature	Filament Temperature [^{o}C]	Output	real

state	Lamp State	Output	real

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Example

In this example, the Advanced Lamp Lamp1 is connected directly to the battery battery1. Self-heating leads to increased lamp resistance until it reaches the nominal temperature. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

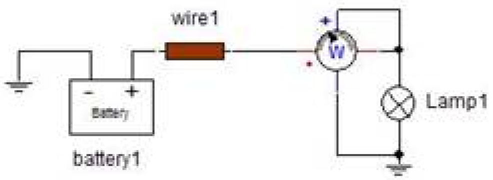

Figure 2. Application example of the Lamp-Advanced model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	12 [V]
	rin	10m [Ohm]
Lamp- Advanced Lamp1	pnom	55 [W]
	vnom	12 [V]
	tnom	2k [^{o}C]
	tamb	20 [^{o}C]
	ton	1.8k [^{o}C]
	tmax	2.2k [^{o}C]
	alpha	45m [1/K]
	roff	1G [Ohms]
	tdoff	10m [s]
	ct	2.5m [Ws/K]
	conductivity_share	50m [W]
	enable_break	1

Thermal Static wire Wire1 (Level 1) Thermal Static wire Wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^oC]
	rho	1.78n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^oC]
	timelt	150 [^oC]

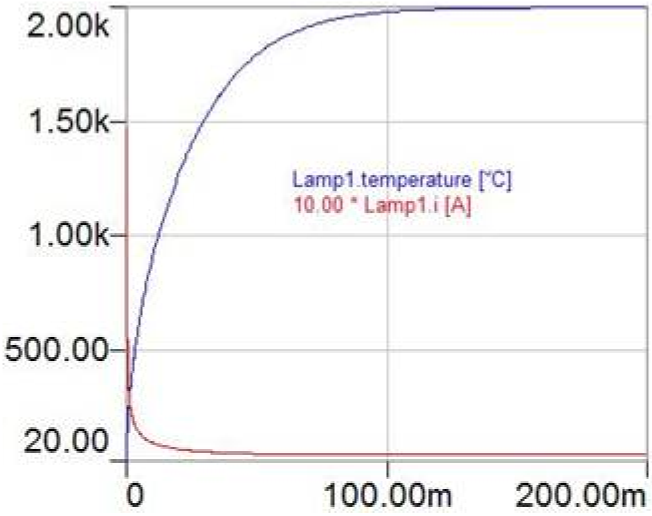

Figure 3. Simulation results

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References

Lamp – Filament

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

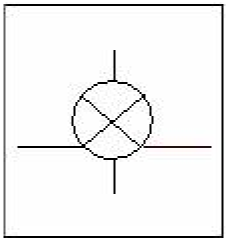

Figure 1. Component symbol

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Description

The model represents a lamp using a temperature-dependent resistance to represent electrical lamp properties. The losses generated inside the filament are fed into a thermal network. The filament temperature calculated within the thermal network is used to calculate the filament resistance. Power is transmitted to the ambient by thermal power conduction and radiation. The model provides two thermal pins, for the filament and ambient to connect to an outer thermal network.

The temperature, connected with a thermal pin, must be provided in Kelvin. The model then converts degrees Kelvin into degrees Celsius.

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Assumptions and Limitations

The time constant of the thermal network must be considered for the minimum time step of the simulator. If one of the time constants becomes quite small, it may become necessary to reduce HMIN into the range of nanoseconds.

Top

Mathematical Description

Power transferred by thermal power conduction can be calculated as:

$$P_c = \frac{T_{Filament} - T_{amb}}{rt}$$

Filament resistance:

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref}))$$

Power transferred by radiation (units in Kelvin):

$$P_{Rad} = k \cdot (T^4_{Filament} - T^4_{amb})$$

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Netlist Syntax

MODEL lamp_filament ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1, n_fil:= %2, n_th:= %3 (ct:= @ct, alpha:= @alpha, temp0:= @temp0, rt:= @rt, r0:= @r0, tref:= @tref, k:= @k) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical
n_th	Thermal Connection to Ambient	Thermal
n_fil	Thermal Connection to Filament	Thermal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	2.5 [Ohm]
alpha	Temperature Coefficient	real	45m [1/K]

tref	Reference Temperature	real	20 [ºC]
rt	Thermal Resistance	real	5k [K/W]
ct	Thermal Capacitance	real	0.2m [Ws/K]
k	Emission Coefficient	real	100f [W/K^4]
temp0	Temperature at t=0	real	20 [ºC]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Terminal Voltage [V]	Output	real
i	Lamp Current [A]	Output	real
temperature	Filament Temperature [ºC]	Output	real

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Example

In this example, the switch S2 shortens the load when time t is between 2 and 3s. Fuse1 protects the circuit as long as S2 is shorted. After cooling down fuse1 allows the current flow again. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

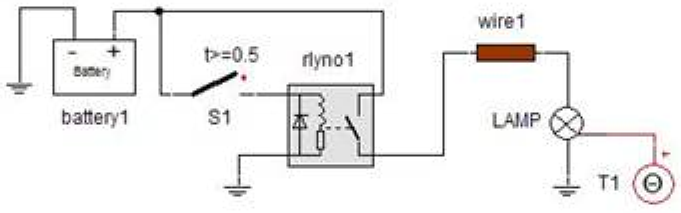

Figure 2. Application example of the fuse with three rc combinations

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]

Lamp-Filament LAMP	r0	2.5 [Ohm]
	alpha	45m [1/K]
	tref	20 [^{o}C]
	rt	5k [K/W]
	ct	0.1m [Ws/K]
	k	100f [W/K^{4}]
	temp0	20 [^{o}C]
Thermal Static wire Wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^{2}]
	l	500m [m]
	tref	20 [^{o}C]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^{o}C]
	timelt	150 [^{o}C]
Relay – Normally Open rlyno1	lcoil	0.5 [H]
	rcoil	5 [Ohm]
	vpull	12 [V]
	vdrop	2 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

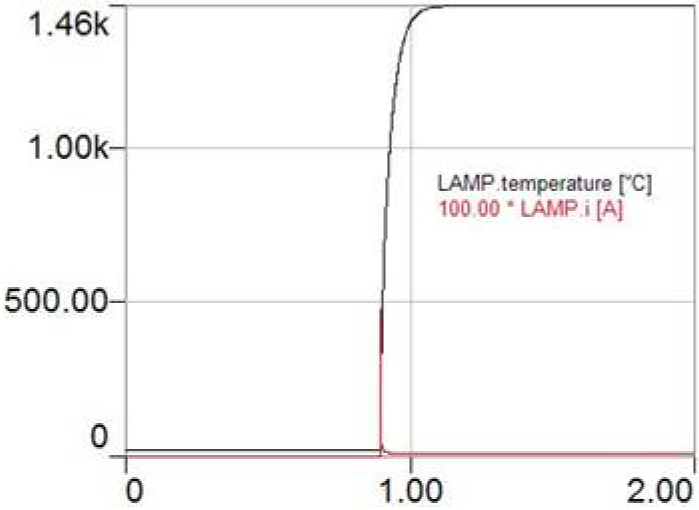

Figure 3. Simulation results

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References

Lamp – Single Filament

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

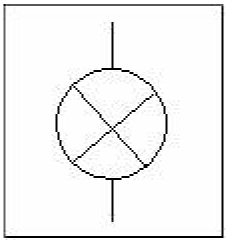

Figure 1. Component symbol

- Description
- Assumptions and Limitations
- Mathematical Description
- Netlist Syntax
- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a lamp using a temperature-dependent resistance represent electrical lamp properties. The losses generated inside the filament are fed into a thermal network. The filament temperature calculated within the thermal network is used to calculate the filament resistance. Power is transmitted to the ambient by thermal power conduction and radiation.

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Assumptions and Limitations

The time constant of the thermal network must be considered for the minimum time step of the simulator. If one of the time constants becomes quite small, it may become necessary to reduce HMIN into the range of nanoseconds.

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Mathematical Description

Power transferred by thermal power conduction:

$$P_c = \frac{T_{Filament} - T_{amb}}{rt}$$

Filament resistance:

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref}))$$

Power transferred by radiation (units in Kelvin):

$$P_{Rad} = k \cdot (T^4_{Filament} - T^4_{amb})$$

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Netlist Syntax

MODEL lamp_sf ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (ct:= @ct, alpha:= @alpha, tamb:= @tamb, rt:= @rt, r0:= @r0, tref:= @tref, k:= @k) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
r0	Resistance at Reference Temperature	real	2.5 [Ohm]
alpha	Temperature Coefficient	real	45m [1/K]
tref	Reference Temperature	real	20 [^{o}C]
rt	Thermal Resistance	real	5k [K/W]
ct	Thermal Capacitance	real	0.2 [Ws/K]
k	Emission Coefficient	real	100f [W/K^4]

tamb	Ambient Temperature	real	20 [°C]

Top

Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Terminal Voltage [V]	Output	real
i	Lamp Current [A]	Output	real
temperature	Filament Temperature [°C]	Output	real

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Example

In this example, self-heating leads to the increased lamp resistance until the nominal temperature is reached. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

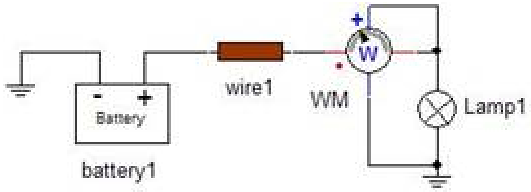

Figure 2. Application example of the Lamp-Single Filament model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	12 [V]
	rin	10m [Ohm]
Lamp- Single Filament LAMP	r0	1 [Ohm]
	alpha	45m [1/K]
	tref	20 [°C]
	rt	5k [K/W]
	ct	0.2m [Ws/K]
	k	250f [W/K^4]
	tamb	THETA

Thermal Static wire Wire1 (Level 1)	dia	2m [m]
	area	0.6793u [m^2]
	l	1 [m]
	tref	20 [^{o}C]
	rho	1.78n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^{o}C]
	timelt	150 [^{o}C]

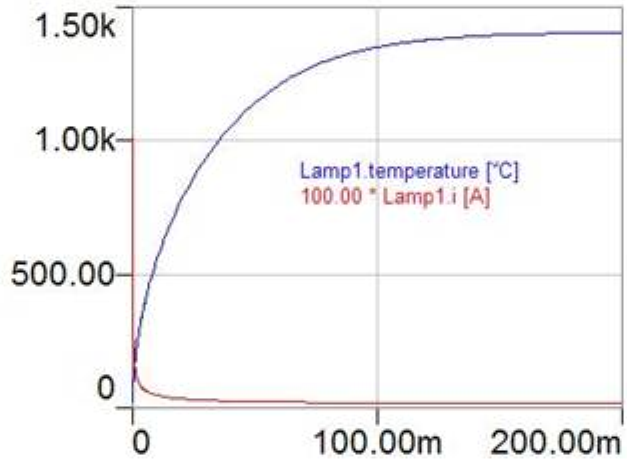

Figure 3. Simulation results

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References

Lamp – Double Filament

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

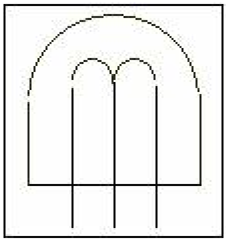

Figure 1. Component symbol

- Description
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- Netlist Syntax
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- Parameters
- Input/Output Quantities
- Example
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Description

The model uses two single filament models and a thermal network to represent electrical lamp properties. The losses generated inside the filaments are fed into a thermal network. The filament temperatures calculated within the thermal network are used to calculate the filament resistances.

The following properties are modeled:

- The power conduction and radiation from the two filaments to the ambient
- The radiation between the two filaments

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Assumptions and Limitations

The time constant of the thermal network must be considered for setting the simulation time step. If one of the time constants becomes quite small, it may be necessary to reduce HMIN into the range of nanoseconds.

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Mathematical Description

Power transferred by thermal power conduction:

$$P_c = \frac{T_{Filament} - T_{amb}}{rt}$$

Radiation between filaments:

$$P_{Rad} = k \cdot (T_{Filament1}^4 - T_{Filament2}^4)$$

Power transferred by radiation (units in Kelvin):

$$P_{Rad} = k \cdot (T_{Filament}^4 - T_{amb}^4)$$

Filament resistance:

$$R_{val} = R_0 \cdot (1 + \alpha \cdot (T - T_{ref}))$$

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Netlist Syntax

MODEL lamp_thermal_2f ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, nm:= %1, n2:= %2 (ct1:= @ct1, alpha1:= @alpha1, rt1:= @rt1, r01:= @r01, tref:= @tref, k1:= @k1, r02:= @r02, alpha2:= @alpha2, rt2:= @rt2, ct2:= @ct2, k2:= @k2, kmut:= @kmut, tamb:= @tamb) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Terminal Lamp 1	Electrical
n2	Terminal Lamp 2	Electrical
nm	Common pin	Electrical

Top

Parameters

Table 2

Name	Description	Data	Default

		Type	Value [Unit]
r01	Resistance at Reference Temperature – Lamp 1	real	2.5 [Ohm]
alpha1	Temperature Coefficient – Lamp 1	real	45m [1/K]
rt1	Thermal Resistance – Lamp 1	real	5k [K/W]
ct1	Thermal Capacitance – Lamp 1	real	0.5m [Ws/K]
k1	Emission Coefficient – Lamp 1	real	400f [W/K^4]
r02	Resistance at Reference Temperature – Lamp 1	real	2.5 [Ohm]
alpha2	Temperature Coefficient – Lamp 2	real	45m [1/K]
rt2	Thermal Resistance – Lamp 2	real	5k [K/W]
ct2	Thermal Capacitance – Lamp 2	real	0.5m [Ws/K]
k2	Emission Coefficient – Lamp 2	real	200f [W/K^4]
kmut	Emission Coefficient Lamp 1 – Lamp 2	real	10f [W/K^4]
tref	Reference Temperature	real	20 [^{o}C]
tamb	Ambient Temperature	real	20 [^{o}C]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v1	Voltage – Lamp 1 [V]	Output	real
i1	Current – Lamp 1 [A]	Output	real
temperature1	Filament Temperature – Lamp 1 [^{o}C]	Output	real
v2	Voltage – Lamp 2 [V]	Output	real
i2	Current – Lamp 2 [A]	Output	real
temperature2	Filament Temperature – Lamp 2 [^{o}C]	Output	real

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Example

In this example, filament 1 of the double-filament lamp Lamp is connected to the battery battery1 through the relay rly1p2t1 when the switch S1 is open. When S1 is closed, filament 2 of Lamp is connected to battery1 instead, and filament 1 is disconnected. Battery 1 also serves as the control input for rly1p2t1 through S1, which is open at time interval [0, 1.5s], closed at [1.5, 3], and stays open when simulation time t>3s. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

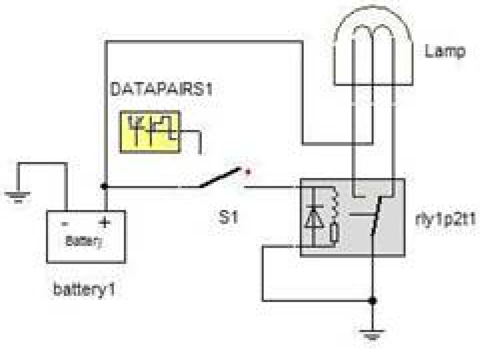

Figure 2. Application example of the Lamp-Double Filament model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Lamp- Double Filament Lamp	r01	2.5 [Ohm]
	alpha1	45m [1/K]
	rt1	5k [K/W]
	ct1	0.5m [Ws/K]
	k1	400f [W/K^4]
	r02	2.5 [Ohm]
	alpha2	45m [1/K]
	rt2	5k [K/W]
	ct2	0.5m [Ws/K]
	k2	200f [W/K^4]
	kmut	10f [W/K^4]

Relay – One Pole, Two Throw rly1p2t1	lcoil	0.5 [H]
	rcoil	5 [Ohm]
	vpull	12 [V]
	vdrop	2 [V]
	ron	5m [Ohm]
	roff	10Meg [Ohm]
	tdmk	0.2 [s]
	tdbrk	3m [s]
	enable_ramp	1

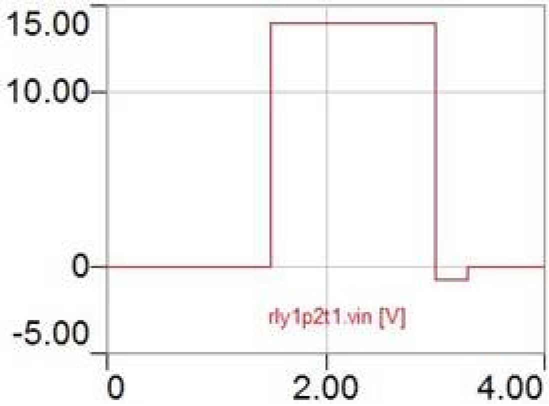

Figure 3. Simulation result-control voltage for the relay rly1p2t1

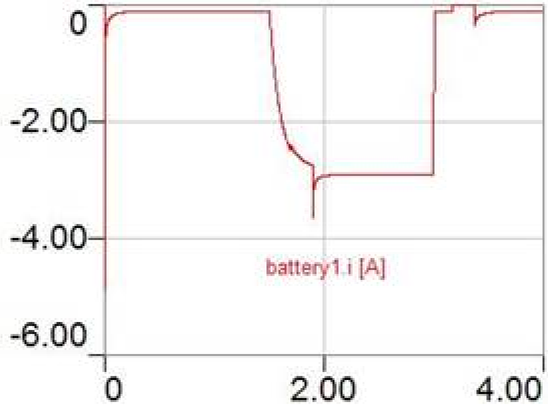

Figure 4. Simulation result-battery current

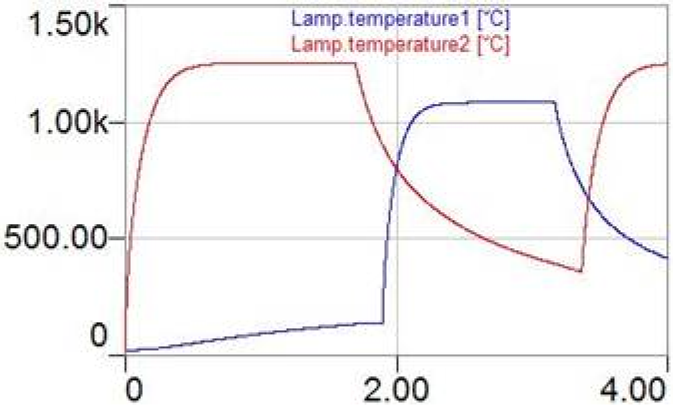

Figure 5. Simulation results-lamp temperatures

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References

Three-Phase RL Load

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

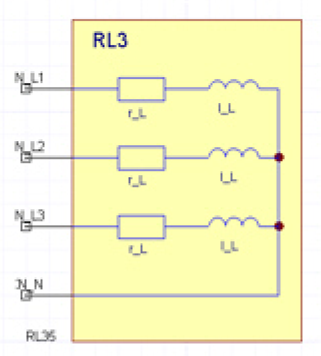

Figure 1. Component symbol

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Description

This model provides a symmetric R-L load to be connected to a three-phase power system or converter.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL RL3 ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_N:= %3 (R_L:= @R_L, L_L:= @L_L) SRC: DB

(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1	AC Terminal (Line 1)	electrical
KN_L2	AC Terminal (Line 2)	electrical
KN_L3	AC Terminal (Line 3)	electrical
KN_N	AC Terminal (neutral)	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
R_L	Resistance	real	1 [Ohm]
L_L	Inductance	real	1m [H]

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Example

This example features a Three Phase Three Level Inverter _3L3_GTOS1 with a Three-Phase RL Load RL31. A Three Level Three Phase control block _3L3_VBC1 sends out the control signals for the GTO inverter. The schematic of the system is shown in Figure 2, the system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

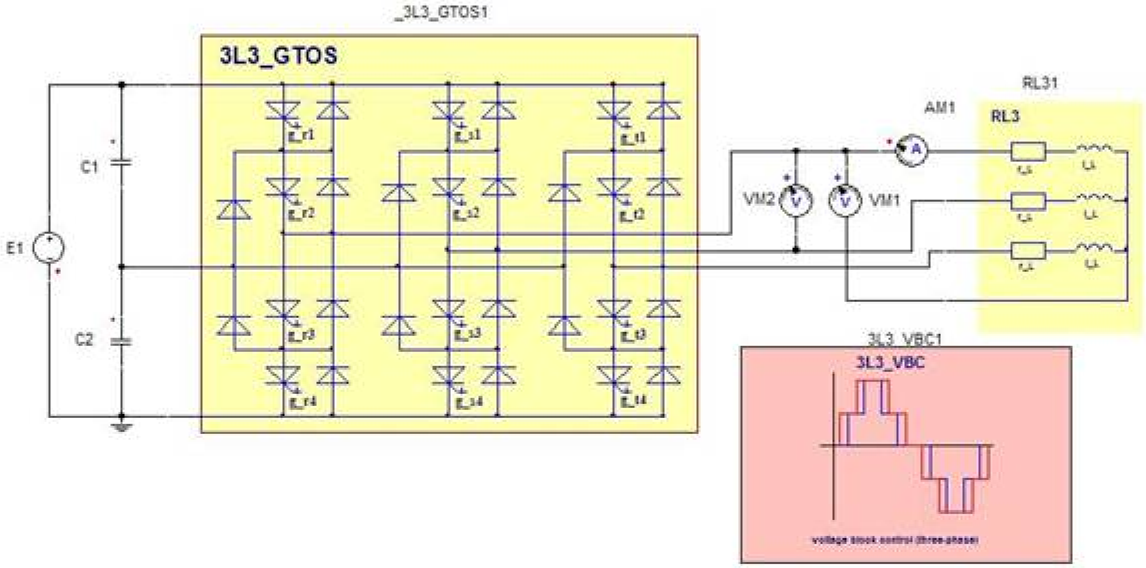

Figure 2. Application example of the Three-Phase RL Load model

Table 3. System Parameters

Component	Parameter	Value [unit]
Voltage Source (DC) E1	EMF	2.8k [V]
Capacitor C1	C	5m [F]
	V0	1.4k [V]
Capacitor C2	C	5m [F]
	V0	1.4k [V]

Three Phase Three Level Inverter_3L3_GTOS1	G_R1	g_r1
	G_R2	g_r2
	G_R3	g_r3
	G_R4	g_r4
	G_S1	g_s1
	G_S2	g_s2
	G_S3	g_s3
	G_S4	g_s4
	G_T1	g_t1
	G_T2	g_t2
	G_T3	g_t3
	G_T4	g_t4
	VF_DIODE	0.85 [V]
	RB_DIODE	15m [Ohm]
	RR_DIODE	0.3Meg [Ohm]
	VF_GTO	1.1 [V]
	RB_GTO	20m [Ohm]
	RR_GTO	0.2Meg [Ohm]
Three Phase RL Load RL31	R_L	3 [Ohm]
	L_L	2m [H]

Three Phase Three Phase Control Logic _ 3L3_VBC1	FREQUENCY	50 [Hz]
	ALPHA	60 [degree]
	G_R1	g_r1
	G_R2	g_r2
	G_R3	g_r3
	G_R4	g_r4
	G_S1	g_s1
	G_S2	g_s2
	G_S3	g_s3
	G_S4	g_s4
	G_T1	g_t1
	G_T2	g_t2
	G_T3	g_t3
	G_T4	g_t4

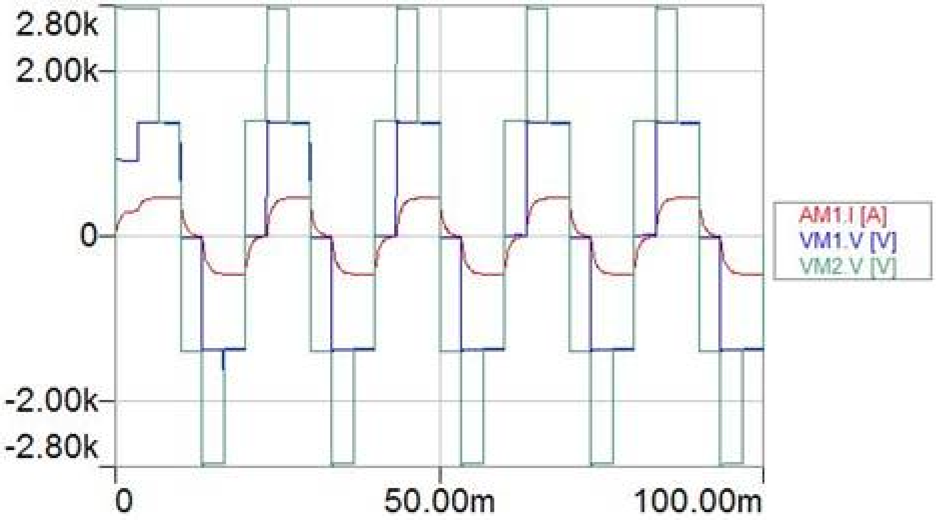

Figure 3. Simulation results – phase current (AM1.I), phase voltage (VM1.V) and line voltage (VM2.V)

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References

Spark Plug

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

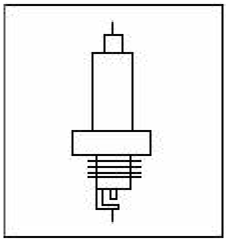

Figure 1. Component symbol

Description

The model represents a spark plug using four states to simulate the model behavior:

- The transition from Blocking to On state, where the voltage rises over the firing threshold vstrike and the spark plug starts to arc across the gap.
- The On state, where the spark plug stays on.
- The transition from On state to Blocking, where the current falls below the specified limit isus.
- The Blocking state, where the spark plug stays off.

Blocking State

The spark plug does not conduct current (except a very small leakage current). The absolute value of the voltage across the spark plug terminals does not exceed the striking voltage vstrike.

Transition from Blocking to On State

If the absolute value of the voltage applied to the spark plug has exceeded the striking voltage vstrike, the spark plug voltage starts decreasing following a ramp function. The slope of the ramp function defines the time tdon.

On State

The voltage across the terminals is determined by the arc voltage varc and the negative voltage drop across an internal resistor. This resistor models the conductivity increase depending on the current flow. Therefore, its resistance is negative.

Transition from On State to Blocking

If the absolute value of the current flowing through the spark plug falls below the sustaining current level isus, the spark plug voltage starts increasing following a ramp function. The slope of the ramp function defines the time tdon.

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Assumptions and Limitations

The transition time tdon and tdoff must be considered for the setting the simulation time step (HMIN<tdon/4 or HMIN<tdoff/4 respectively).

Top

Mathematical Description

Top

Netlist Syntax

MODEL spark_plug ?InstanceName(@InstanceName):(@(Refbase)@(ID)) n1:= %0, n2:= %1 (varc:= @varc, ron_diff:= @ron_diff, vstrike:= @vstrike, tdon:= @tdon, tdoff:= @tdoff, isus:= @isus, I:= @I) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
n1	Pin 1	Electrical
n2	Pin 2	Electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

vstrike	Striking Voltage	real	15k [V]
varc	Arc Voltage	real	1.5k [V]
isus	Sustaining Current	real	5 [A]
tdon	On-Delay	real	0.1m [s]
tdoff	Off-Delay	real	0.1m [s]
ron_diff	Differential On-Resistance	real	-0.5 [Ohm]
L	Parasitic Inductance	real	0.1u [H]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Terminal Voltage [V]	Output	real
i	Current [A]	Output	real
state	State of Spark Plug, -1 blocking, 0 transition, 1 on	Output	real

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Example

In this example, the Spark Plug Spark is connected to a Battery battery1 through a linear Transformer TFR1PW1. The connection between Spark and battery1 is decided by the BJT NPN51, whose control signal is sent out by the PWM block PWM1. The schematic of the system is shown in Figure 2, the system parameters are listed in Table 4, and a magnified portion of the simulation results (the transition of Spark from On state to Blocking) are shown in Figure 3.

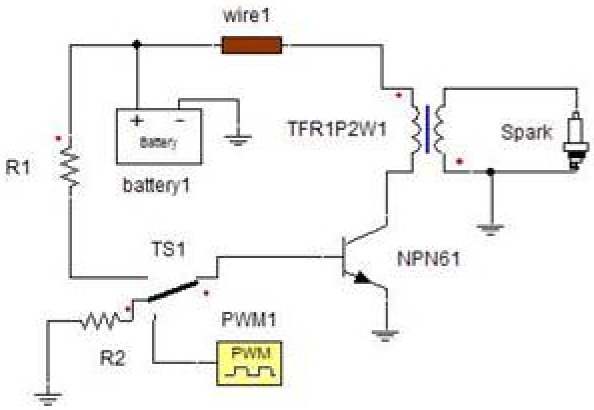

Figure 2. Application example of the Three-Phase RL Load model

Table 4. System Parameters

Component	Parameter	Value [unit]
Basic Battery battery1	rnom	14 [V]
	rin	10m [Ohm]
Resistor R1	R	33 [Ohm]
Resistor R2	R	330 [Ohm]
Thermal Wire wire1 (Level 1)	dia	3m [m]
	area	0.6793u [m^2]
	l	0.5 [m]
	rho	1.72n [ohm m]
	alpha	3.93m [1/K]
	tcmelt	1084 [^oC]
	timelt	150 [^oC]
	tref	20 [^oC]
NPN BJT(Electrical Level 1, Thermal Level 0) NPN61 (only parameters whose value is changed are listed here, the rest of the parameters take the default value)	BI0	2 [A/A]
	VEARLY	1Meg [V]
	ISAT0	10f [A]
	TEMP0	20 [^oC]
	VBREAK_CE	10k [V]
	VBREAK_BE	500 [V]
	IBREAK_C	10k [A]
Linear Two-Winding Transformer TRF1P2W1	LM	1m [H]
	LS1	10n [H]
	LS2	1n [H]
	RFE	1.0e+018 [Ohm]
	RCU1	1m [Ohm]
	RCU2	10u [Ohm]
	KTR	10
	IP0	0 [A]
	IS0	0 [A]

PWM PWM1	PERIOD	10m [s]
	DC	0.95
	TD	0 [s]
	PHASE	0 [degree]
Spark Plug Spark	varc	1.5k [V]
	isus	1 [A]
	tdon	50u [s]
	tdoff	0.1m [s]
	ron_diff	-2 [Ohm]
	L	0.1u [H]

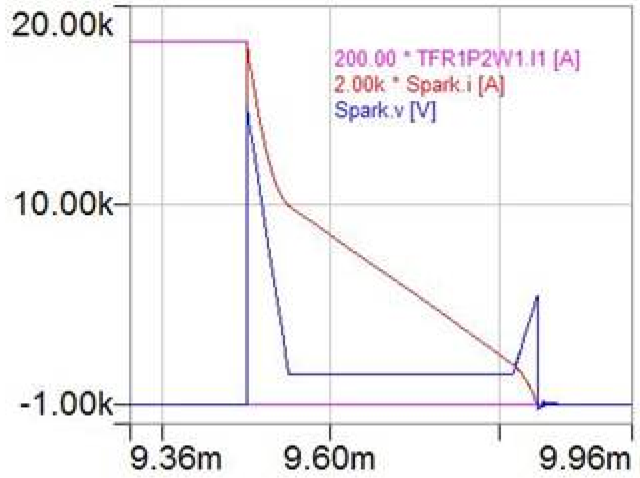

Figure 3. Simulation results

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References

Power Source

- Single Phase Power System with System Impedance (SINGLE_PHASE_Z)
- Ideal three Phase Power Supply (THREE_PHASE)
- Symmetrical 3-Phase Power System with System impedances (THREE_PHASE_Z)

Single-Phase Power Supply

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

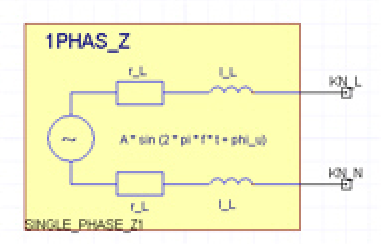

Figure 1. Component symbol

- [Description](#description)
- [Assumptions and Limitations](#assumptions-and-limitations)
- [Mathematical Description](#mathematical-description)
- Netlist Syntax
- Conservative Pins
- Parameters
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Description

This component describes a single-phase power supply with internal impedances.

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Assumptions and Limitations

The default values of the equivalent resistors and inductances were determined considering standard DIN EN 60555 (VDE 0838).

Top

Mathematical Description

The equivalent circuit of the Single-Phase Power Supply model is shown in Figure 2. Where r_L and l_L are line resistance and inductance respectively, and E is a sinusoidal voltage source.

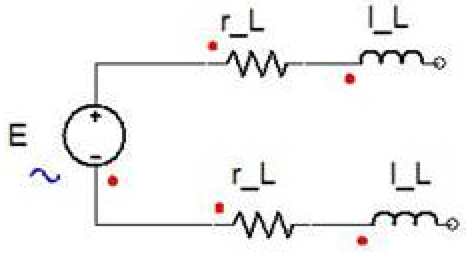

Figure 2. Equivalent circuit of the Single-Phase Power Supply model

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Netlist Syntax

MODEL SINGLE_PHASE_Z ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L:= %0, KN_N:= %1 (AMPLITUDE:= @AMPLITUDE, FREQUENCY:= @FREQUENCY, PHI_U:= @PHI_U, R_L:= @R_L, L_L:= @L_L) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L	AC Terminal 1	electrical
KN_N	AC Terminal 2	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
AMPLITUDE	Amplitude	real	0.325k [V]
FREQUENCY	Frequency	real	50 [Hz]
PHI_U	Voltage Phase Shift	real	0 [deg]
R_L	Line Resistance	real	0.24 [Ohm]
L_L	Line Inductance	real	0.15u [H]

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Example

In this example, a Single-Phase Power Supply _1PHAS_Z1 is connected to a first-order RL load through a Single Phase A.C. Chopper W1C1. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

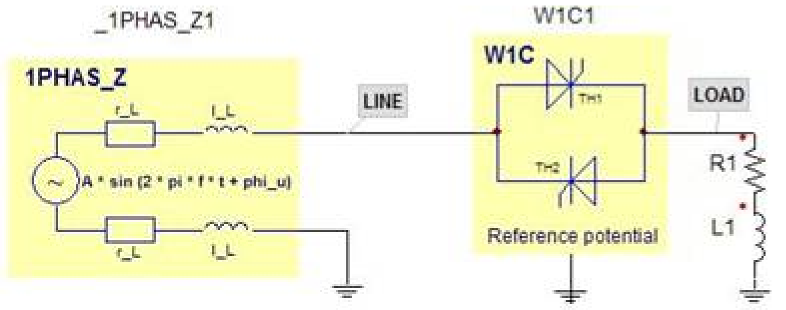

Figure 3. Application example of the Single-Phase Power Supply model

Table 3. System Parameters

Component	Parameter	Value [unit]
Single-Phase Power Supply _1PHAS_ Z1	AMPLITUDE	0.325k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	0.15u [H]
Single Phase A.C. Chopper W1C1	ALPHA	60 [degree]
	FREQUENCY	50 [Hz]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	0.1Meg [Ohm]
Resistor R1	R	5 [Ohm]
Inductor L1	L	10m [H]
	i0	0 [A]

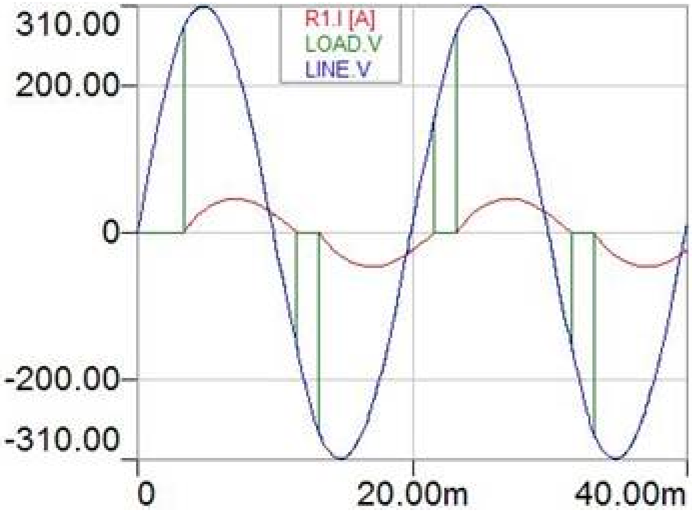

Figure 4. Simulation results

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References

Ideal Three-Phase Power Supply

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

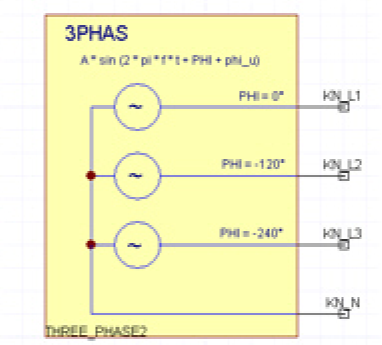

Figure 1. Component symbol

- Description
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- Mathematical Description
- Netlist Syntax
- Conservative Pins
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Description

This model describes an ideal three-phase power system. The terminal KN_N can be left unconnected. The parameter PHI_U defines a symmetrical phase shift of the three line voltages.

Top

Assumptions and Limitations

The internal impedance of the power system is not taken into account, and hence no power losses are considered.

Top

Mathematical Description

Top

Netlist Syntax

MODEL THREE_PHASE ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_N:= %3 (AMPLITUDE:= @AMPLITUDE, FREQUENCY:= @FREQUENCY, PHI_U:= @PHI_U) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1/KN_L2/KN_L3	AC Terminal Line 1/2/3	electrical
KN_N	Ground Connection	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
AMPLITUDE	Amplitude of Line Voltage	real	0.325k [V]
FREQUENCY	Frequency	real	50 [Hz]
PHI_U	Phase Shift of Line Voltage	real	0 [deg]

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Example

In this example, two Ideal Three-Phase Power Supply _3PHAS1 and _3PHAS2 are connected to a resistance load through a Line Commuted Converter. The waveforms of_3PHAS2 is shifted 60 degrees from those of _3PHAS1. Notice that the neutral terminal of both power supplies is left unconnected, and that of the converter is connected to ground. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results (line voltages and the voltage across the load) are shown in Figure 3.

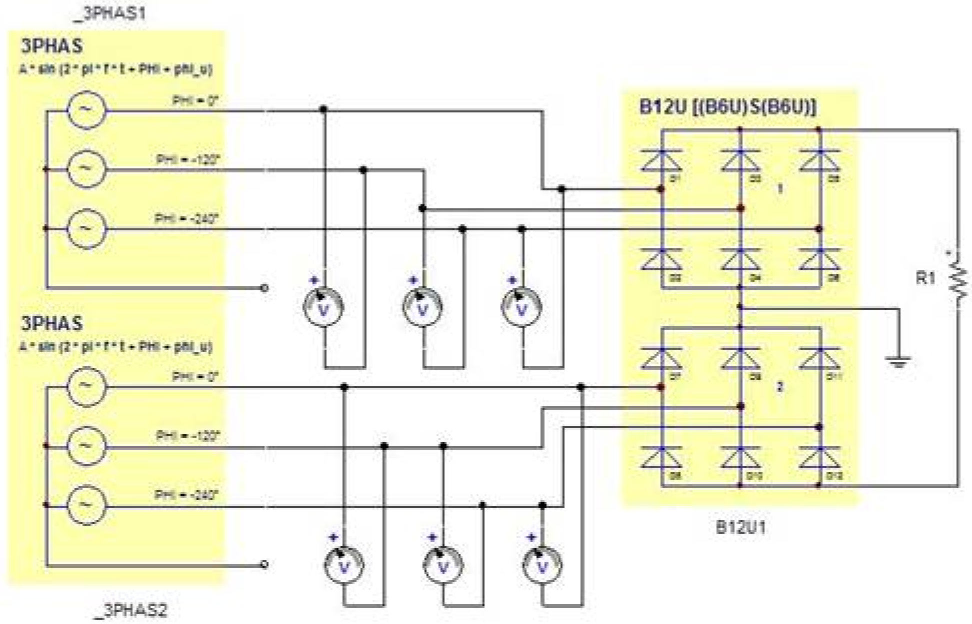

Figure 2. Application example of the Ideal Three-Phase Power Supply model

Table 3. System Parameters

Component	Parameter	Value [unit]
Ideal Three-Phase Power Supply _ 3PHAS1	AMPLITUDE	0.311k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
Ideal Three-Phase Power Supply _ 3PHAS2	AMPLITUDE	0.311k [V]
	FREQUENCY	50 [Hz]
	PHI_U	60 [deg]
B12 Bridge B12U1	VF	0.8 [V]
	RB	1m [Ohm]
	RR	1Meg [Ohm]
Resistor R1	R	5 [Ohm]

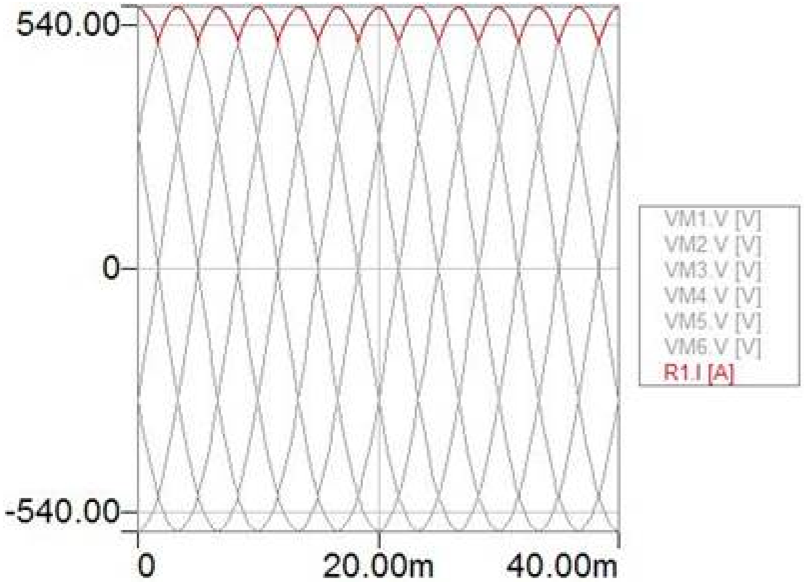

Figure 3. Simulation results

[Top](#)

References

Three-Phase Power Supply with Impedance

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

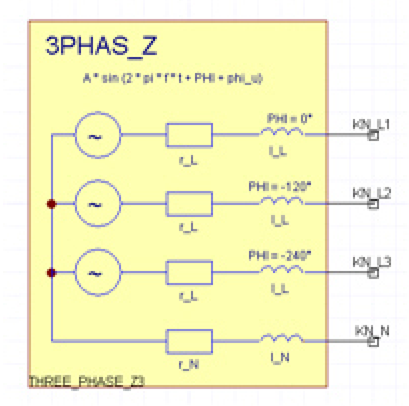

Figure 1. Component symbol

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Description

This macro provides a three-phase power system with internal impedances. The terminal KN_N can be left unconnected. The parameter PHI_U defines a symmetrical phase shift of the three line voltages.

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Assumptions and Limitations

The default values of the impedances were determined considering DIN EN 60555 (VDE 0838).

Top

Mathematical Description

The equivalent circuit of the Three-Phase Power Supply model is shown in Figure 2. Where r_L and l_L are line resistance and inductance respectively, and r_N and l_N are a the resistance and inductance of the neutral line, respectively. Sinusoidal voltage sources E2 and E3 are shifted 120 and 240 degrees from E1.

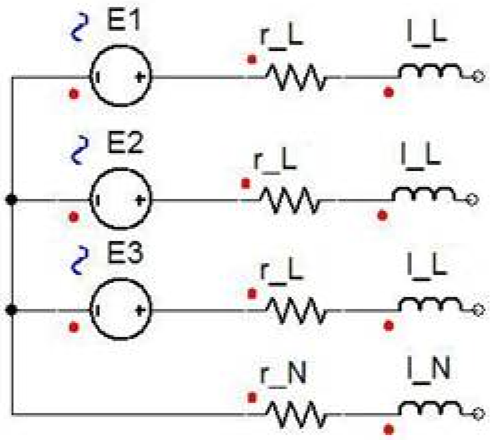

Figure 2. Equivalent circuit of the Three-Phase Power Supply model

Top

Netlist Syntax

MODEL THREE_PHASE_Z ?InstanceName(@InstanceName):(@(Refbase)@(ID)) KN_L1:= %0, KN_L2:= %1, KN_L3:= %2, KN_N:= %3 (AMPLITUDE:= @AMPLITUDE, FREQUENCY:= @FREQUENCY, PHI_U:= @PHI_U, R_L:= @R_L, L_L:= @L_L, R_N:= @R_N, L_N:= @L_N) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data Type
KN_L1	AC Terminal Line 1	electrical
KN_L2	AC Terminal Line 2	electrical
KN_L3	AC Terminal Line 3	electrical
KN_N	Ground Connection	electrical

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
AMPLITUDE	Amplitude of Line Voltage	real	0.325k [V]
FREQUENCY	Frequency	real	50 [Hz]
PHI_U	Phase Shift of Line Voltage	real	0 [deg]
R_L	Line Resistance	real	□0.24 [Ohm]
L_L	Line Inductance	real	0.15u [H]
R_N	Resistance to Neutral	real	0.16 [Ohm]
L_N	Inductance to Neutral	real	0.1u [H]

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Example

In this example, a Three-Phase Power Supply _3PHAS_Z1 is connected to a first-order RL load through an Inverse Parallel Connected Thyristor Bridge B6C2L1. That the neutral terminal of _ 3PHAS_Z1 is connected to ground. The delay angles of the thyristor bridge is controller by PI current controller DUR_IREG1, and I_SET is the current reference. The schematic of the example is shown in Figure 3, system parameters are listed in the table 4, and the simulation resultsare shown in Figure 4 and 5.

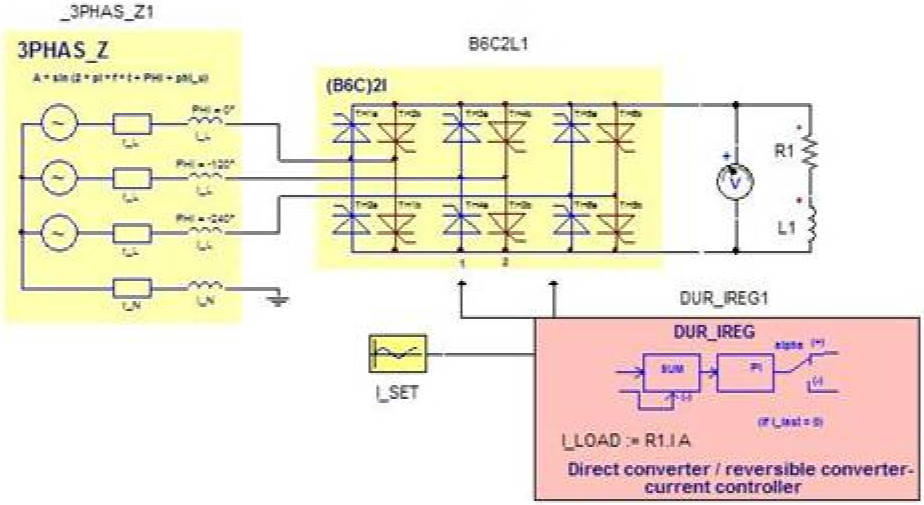

Figure 3. Application example of the Three-Phase Power Supply model

Table 3. System Parameters

Component	Parameter	Value [unit]

Three-Phase Power Supply _ 3PHAS_Z1	AMPLITUDE	0.311k [V]
	FREQUENCY	50 [Hz]
	PHI_U	0 [deg]
	R_L	0.24 [Ohm]
	L_L	50n [H]
	R_N	1n [Ohm]
	L_N	1n [H]
B6 Bridge – Inverse Parallel Connection B6C2L1	ALPHA1	DUR_ IREG1.ALPHA1
	ALPHA2	DUR_ IREG1.ALPHA2
	PHI_U	50 [deg]
	VF	0.8 [V]
	RB	1m [Ohm]
	RR	1Meg [Ohm]
Resistor R1	R	1 [Ohm]
Inductor L1	L	10m [H]
	i0	0 [A]
Sine Wave I_SET	Amplitude	0.3k
	Frequency	16.667 [Hz]
	Delay	0 [s]
	Phase	0 [degree]
	Offset	0
Current Control for Direct Convert DUR_IREG1	I_NOM	I_SET.VAL
	I_LOAD	R1.I
	Kp	10m
	Ki	1
	TA	0.1m [s]

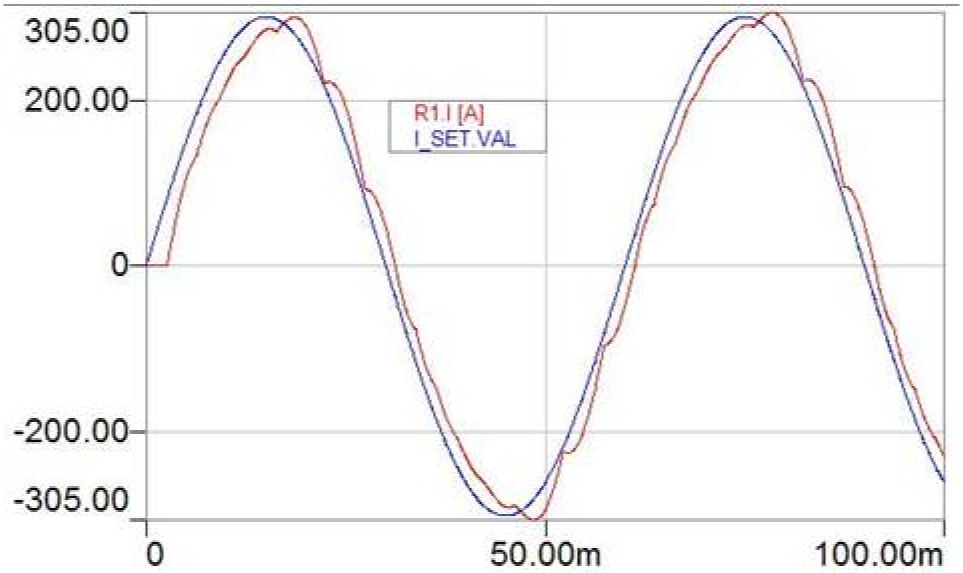

Figure 4. Simulation results – load current vs. current reference

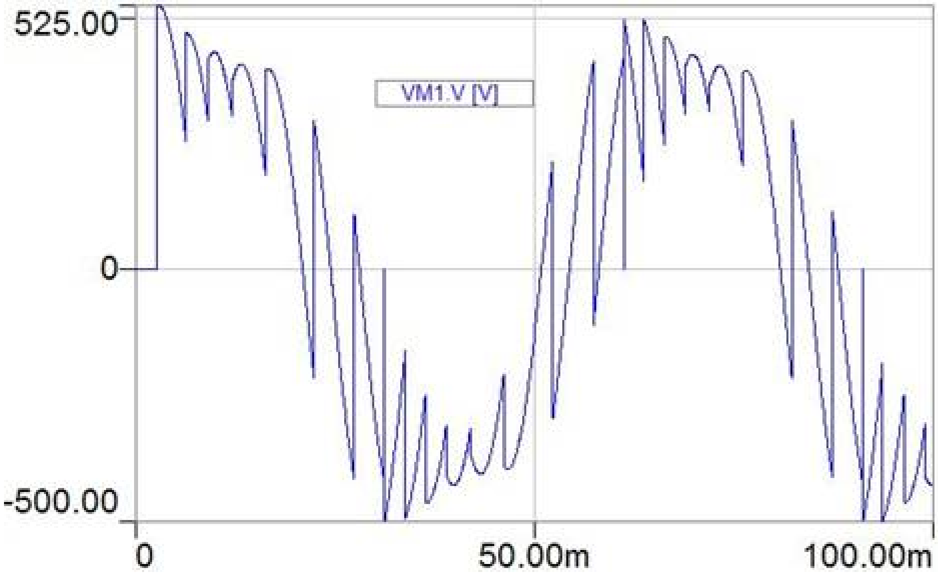

Figure 5. Simulation results – output voltage of the Inverse Parallel Connected Thyristor Bridge B6C2L1

Top

References

Power Storage

- Static Battery Model (battery)
- Fuel Cell (FUELCELL)
- Battery (LBATT_A)

Battery Basic Model

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

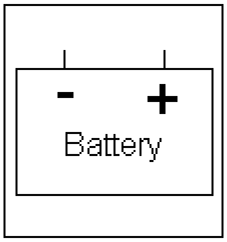

Figure 1. Component symbol

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- Example
- References

Description

The basic battery model uses a simple equivalent circuit containing an ideal voltage source and a resistance representing the internal voltage drop inside the battery.

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Assumptions and Limitations

The model is based on the following assumptions:

- The state of charge is not calculated.
- Thermal effects are not taken into account.

Top

Mathematical Description

The equivalent circuit of the Basic Battery model is shown in Figure 2. Where vnom is the ideal voltage source, and rin is the internal resistor.

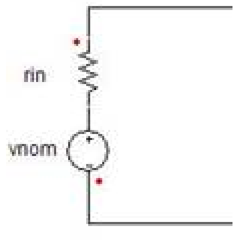

Figure 2. Equivalent circuit of the Basic Battery model

Top

Netlist Syntax

MODEL battery ?InstanceName(@InstanceName):(@(Refbase)@(ID)) np:= %0, nm:= %1 (vnom:= @vnom, rin:= @rin) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
np	Positive Terminal	Electrical terminal
nm	Negative Terminal	Electrical terminal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
vnom	No-Load Voltage	real	14 [V]
rin	Internal Resistance	real	10m [Ohms]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Terminal Voltage [V]	Output	real
i	Terminal Current [A]	Output	real

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Example

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References

Fuel Cell

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

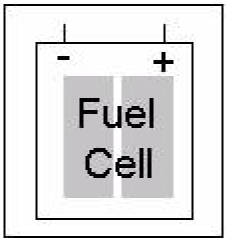

Figure 1. Component symbol

- Description
- Assumptions and Limitations
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- Netlist Syntax
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Description

This model represents a fuel cell used to design energy systems in future mobile and stationary electrical applications. This model's approach combines physical processes with empirical parameterization.

This model is valid for almost every PEM fuel cell with a Nafion membrane and can easily be adapted to a specific fuel cell.

The model calculates the stationary voltage-current behavior in a normal range of gas pressures and temperatures. It can be used with Oxygen or Air as a cathodic gas. Complete stacks, consisting of an arbitrary number of parallel or series-connected cells, can easily be simulated. The model provides the series or parallel number of cells as an input parameter.

Top

Assumptions and Limitations

This model is based on the following assumptions:

- Non-stationary effects like the starting phase are not taken into account.

- Thermal dynamics are not considered.

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Mathematical Description

This model is based on the combination of a physical system description [1] and empirical approaches [2] that were combined and supplemented by Mann et al. [3] to facilitate simple parameterization. The terminal voltage V of a single cell is modeled as a sum of three terms, as follows:

$$V_{cell} = E + \eta_{act} + \eta_{ohmic}$$

η_{act}: **activation overvoltage due to electrochemical kinetics**

η_{ohmic}: **ohmic overvoltage mainly due to the electrolyte (membrane) resistance**

where E is the equilibrium voltage of the following electrochemical reaction:

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

From thermodynamics, the equilibrium voltage can be expressed as the following:

$$V_{eq} = 1.229V - 0.85 \cdot 10^{-3} \cdot (T - 298.15\ K)\frac{V}{K} + 4.3085 \cdot 10^{-5} \cdot T \cdot \Bigg[\ln\Bigg(\frac{\dot{p}_{H_2}}{p^\circ}\Bigg) + \frac{1}{2}\ln\Bigg(\frac{\dot{p}_{O_2}}{p^\circ}$$

T: Temperature $\quad$ $\dot{p}_{H_2}$ **and** $\dot{p}_{O_2}$: **efective hydrogen/oxygen pressure at the electrodes**

These pressures differ significantly from the externally applied gas pressures due to humidification and concentration gradients in the electrodes. p = 101325Pa identifies the standard pressure. Using some geometrical assumptions, the effective hydrogen pressure can be calculated through the following:

$$\dot{p}_{H_2} = 0.5 \cdot p_{H_2O}^{sat} \cdot \left[\frac{2 \cdot P_{H_2}}{\exp\left(\frac{1.653 \cdot I_{cell}}{T^{1.334} \cdot A_{\varnothing}} \frac{cm^2 K^{1.334}}{A}\right) \cdot p_{H_2O}^{sat}} - 1 \right]$$

P_{H_2}: gas pressure at the hydrogen inlet

I_{cell}: cell current

$A_{\varnothing}$: cross-sectional area of the cell

$p_{H_2O}^{sat}$: water steam pressure (taken from the t

The effective oxygen pressure depends on the cathodic operational mode. When the cathode is supplied with pure oxygen, the effective oxygen pressure becomes the following:

$$\dot{p}_{O_2} = p_{H_2O}^{sat} \cdot \left[\frac{P_{O_2}}{\exp\left(\frac{4.192 \cdot I_{cell}}{T^{1.334} \cdot A_{\varnothing}} \frac{cm^2 K^{1.334}}{A}\right) \cdot p_{H_2O}^{sat}} - 1 \right]$$

To activate over potential, an empirical approach is used:

$$\eta_{act} = \zeta_1 + \zeta_2 \cdot T + \zeta_3 \cdot T \cdot \ln\left(\dot{c}_{O_2} \frac{cm^3}{mol}\right) + \zeta_4 \cdot T \cdot \ln\left(\frac{I_{cell}}{A}\right)$$

Here ζ_1, ..., ζ_4, are model parameters. The effective oxygen concentration is calculated through the following:

$$\dot{c}_{O_2} = \frac{\frac{\dot{p}_{O_2}}{p^\circ}}{5.08 \cdot 10^6 \cdot \exp\left(\frac{-498K}{T}\right)} \frac{mol}{cm^3} \qquad \dot{c}_{H_2} = \frac{\frac{\dot{p}_{H_2}}{p^\circ}}{1.09 \cdot 10^6 \cdot \exp\left(\frac{77K}{T}\right)} \frac{mol}{cm^3}$$

According to Mann [3], the constant parameters are listed as the following:

$$\xi_1 = -0.948(\pm 0.0004)\mathrm{V} \qquad \xi_{2a} = 2.86 \cdot 10^{-3}\frac{\mathrm{V}}{\mathrm{k}} \qquad \xi_{2b} = 2 \cdot 10^{-4}\frac{\mathrm{V}}{\mathrm{k}}$$

$$\xi_{2c} = 4.3 \cdot 10^{-5}\frac{\mathrm{V}}{\mathrm{k}} \qquad \xi_3 = (7.6 \pm 0.2) \cdot 10^{-5}\frac{\mathrm{V}}{\mathrm{k}} \qquad \xi_4 = -(1.93 \pm 0.05) \cdot 10^{-4}\frac{\mathrm{V}}{\mathrm{k}}$$

The ohmic over potential $\eta ohmic$ is calculated from the current I_{cell} and the internal resistance $R^{internal}$ according Ohm's law $\eta ohmic = I_{cell}{*}R^{internal} = I_{cell}{*}\,(R^{electronic} + R^{proton})$. $R^{electronic}$ is the ohmic electronic resistance in the electrodes and the connectors. It is provided as a model parameter and is usually much smaller than the protonic resistance R^{proton} of the membrane. The membrane resistance is calculated from $R^{proton} = r_M{*}\,l/A$, where l is the thickness, and A is the membrane area. r_M is the specific membrane resistance, which depends on the membrane water content [4] l in the following fashion [3]:

$$r_M = \frac{181.6 \cdot \left[1 + 0.3 \cdot \left(\frac{I_{cell}}{A}\frac{cm^2}{A}\right) + 0.062 \cdot \left(\frac{T}{303K}\right)^2 \left(\frac{I_{cell}}{A}\frac{cm^2}{A}\right)^{2.5}\right]}{\left[\lambda - 0.634 - 3.0 \cdot \left(\frac{I_{cell}}{A}\frac{cm^2}{A}\right)\right] \exp\left[4.18 \cdot \left(\frac{T - 303K}{T}\right)\right]}\,\Omega\mathrm{cm}$$

The water content parameter l, which usually varies between 0 and approximately 25, is provided as an input parameter. Under 'normal' operating conditions, its value is approximately 12-13. Because we have used predominantly constructive data as model parameters, it is relatively easy to parameterize.

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Netlist Syntax

UMODEL FUELCELL_B_PLIB ?InstanceName(@InstanceName):(@(Refbase)@(ID)) np:= %0, nm:= %1 (ph2:= @ph2, po2_air:= @po2_air, cathode_mode:= @cathode_mode, temperature:= @temperature, area:= @area, d:= @d, lambda:= @lambda, re:= @re, parallel_cells:= @parallel_cells, series_cells:= @series_cells) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
np	Positive Terminal	Electrical terminal
nm	Negative Terminal	Electrical terminal

Top

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ph2	Hydrogen Pressure	real	2.5k [hPa]
po2_Air	Oxygen or Air Pressure	real	2.5k [hPa]
cathode_ mode	Mode: 0=Oxygen, 1=Air	real	0
temperature	Cell Temperature	real	60 [^{o}C]
areaA	Membrane Area	real	50.6 [cm^2]
d	Membrane Thickness	real	178 [μm]
lambda	Membrane Water Content	real	12
re	Electronic Resistance	real	1m [Ohms]
parallel_cells	Number of Parallel Connected Cells	real	1
series_cells	Number of Series Connected Cells	real	1

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
v	Voltage [V]	Output	real
i	Current [A]	Output	real
vcell	Cell voltage [V]	Output	real
icell	Cell current [A]	Output	real
veq	Equilibrium Voltage [V]	Output	real
ph2_eff	Effective Hydrogen Pressure [hPa]	Output	real
po2_eff	Effective Oxygen Pressure [hPa]	Output	real
co2_eff	Effective Oxygen Concentration [mol/cm]	Output	real
ch2_eff	Effective Hydrogen Concentration [mol/cm]	Output	real
eta_act	'Activation' Overvoltage [V]	Output	real
v_ ohmic	Ohmic Voltage Drop [V]	Output	real
idens	Current Density [A/cm]	Output	real

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Example

This example shows a battery charging system under variable load conditions with a fuel cell as a low voltage power source, a boost converter to increase the voltage to bus voltage level, and a 42V battery. Since the Fuel Cell model does not contain any dynamics, simulation parameters are very uncritical. The model is designed to be fed by varying pressure inputs. Therefore, it can be combined with pressure storage or pipe models to introduce dynamics caused by gas flow. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

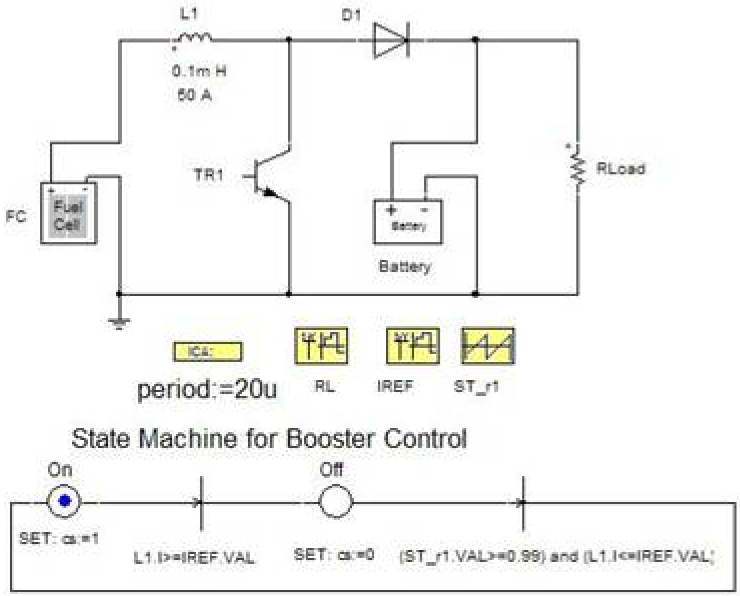

Fig.2. Application example of the Fuel Cell model

Table 4. System Parameters

Component	Parameter	Value [unit]

Fuecl Cell FC	ph2	2.5k [hPa]
	po2_Air	2.5k [hPa]
	cathode_mode	0
	temperature	60 [^{o}C]
	areaA	50.6 [cm^{2}]
	d	178 [μm]
	lambda	12
	re	1m [Ohms]
	parallel_cells	40
	series_cells	1

Standard Batter Model Battery1	ad0	1.20 [g/cm^2]
	temperature	25 [^{o}C]
	cap	0.1k [Ah]
	r_curr	5 [A]
	r_time	20 [h]
	nom_res	10m [Ohms]
	num_cells	6
	ad_full	1.28 [g/cm^3]
	ad_disc	1.01 [g/cm^3]
	nom_temp	25 [^{o}C]
	f_low_cap	0.6m
	f_hi_cap	1.02
	low_temp	-20 [^{o}C]
	f_plate_cap	0.3
	f_slow_cap	1.03
	sdpd	0.25 [%/day]
	sd_t	16.37 [^{o}C]
	flt_curr	2m [A/Ah]
	flt_volt	2.3 [V]
	gass_th	2.39 [V]
	gass_sl	0.2 [V]
	t_coeff_ocv	0.15m [V/^{o}C]
	t_coeff_res	7.5m [1/^{o}C]
	soc_coeff_res	0.5
Diode D1 (Exponential Function)_	ISAT	1p [A]
	VT	35 [mV]
	RR	100k [ohmh]
Bipolar Junction Transistor TR1 (Exponential Function)_	ISAT	1p [A]
	VT	35 [mV]
	RR	100k [ohmh]
Inductor L1	n0	0 [rpm]
	j	75m [kg m^2]
Resistor Rload	R	RL.VAL

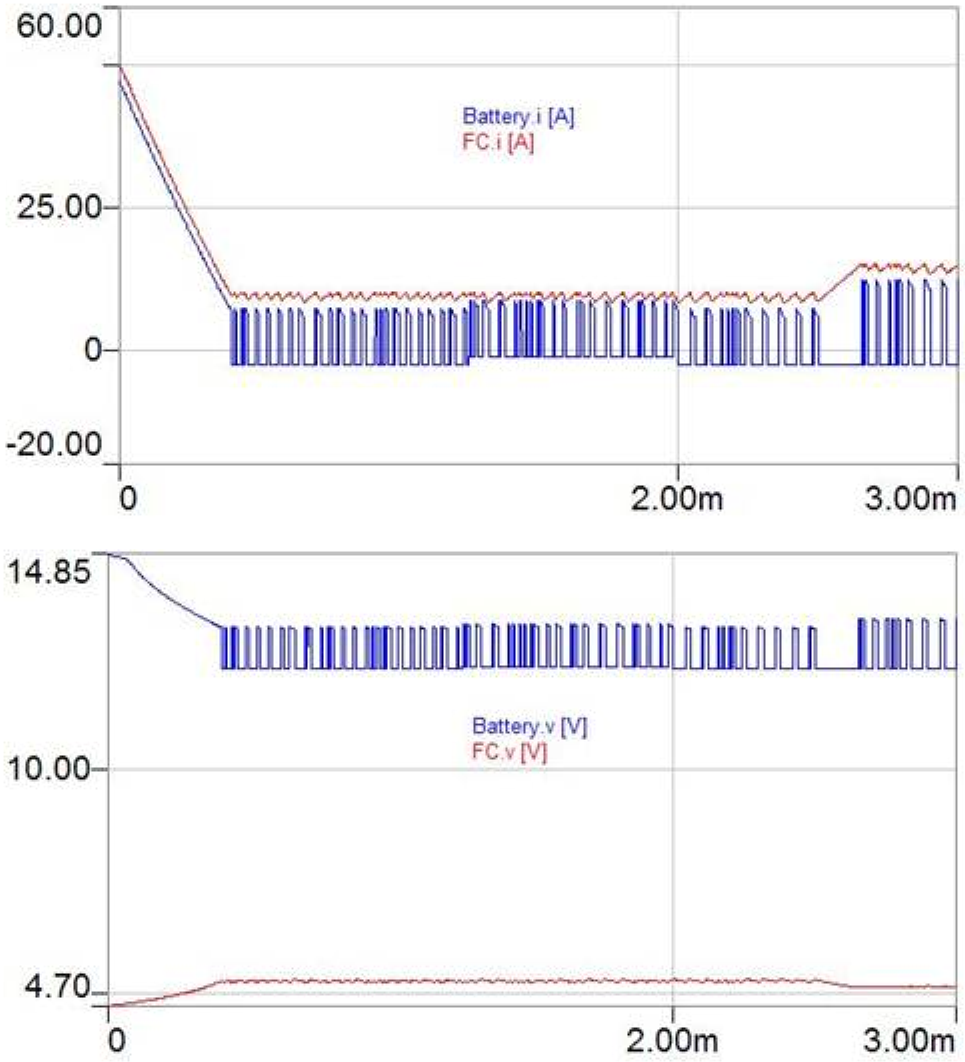

Figure 3. Simulation results of the Fuel Cell model

Top

References

[1] Amphlett J.C, et al (1995). *J.Electrochem*. Soc.,Vol. 142(1), 1-8.

[2] Amphlett J.C., et al (1995). *J.Electrochem*. Soc., Vol. 142(1), 9-15.

[3] Mann R.F., et al (2000). *J. Power Sources 86*, 173-180.

[4] Springer T.E., et al (1991). *J. Electrochem*. Soc. Vol. 138(8), 2334-2342.

Battery — Advanced Model

Library: Power_System	Modeling Language: SML	Version Number: Twin Builder 2025.2

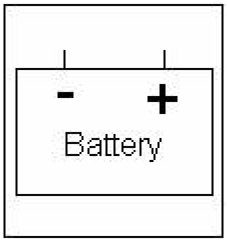

Figure 1. Component symbol

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- Conservative Pins
- Parameters
- Input/Output Quantities
- Example
- References

Description

The model represents a lead-acid battery model, which is used to design and optimize electrical on-board automobile systems and to design other stand-alone and mobile applications. The voltage-current characteristics of these batteries are modeled in charge and discharge operation.

To model the mismatch between charged electrical and stored chemical energy, the model includes several loss effects during charging. Apart from this, the internal resistance varies with temperature and state-of-charge to yield a realistic voltage behavior under load. Therefore, the model can be used for charge balance simulations and for loss-of-load predictions. The model is implemented as a C-model.

The battery model is a behavioral model of a lead-acid battery. Its purpose is to predict voltage - current characteristics of common lead acid batteries like starter batteries. The model can be used for charge balance simulations and for loss-of-load predictions. Because the electrolytic double layer is not considered, dynamic effects in the time range up to several seconds are not well modeled. The model may also fail in predicting the terminal behavior under very high current loads and/or low voltages. It is designed to generate reasonable results in a temperature range from -20°C up to +50°C and currents up to ten times the rated current.

The accumulation of electrical charge in the battery is modeled through a RC electrical network consisting of three capacitors connected via two resistors. The density (or specific gravity) of the electrolyte is used as a charge equivalent.

This approach models the diffusive effects of charge storage in lead-acid batteries. The electrical charge of the three capacitors correlate with the charge stored in three different spatial regions of the system: near the plates ('plate'), at an intermediate distance from the plates ('middle'), and far off the plates ('inner'). The charge at the plate capacity drives a nonlinear voltage source, which is connected to the battery terminals via an internal resistance. The internal resistance depends on temperature and state-of-charge (SOC). The SOC is defined in terms of the acid concentration in the middle region.

The capacities are calculated from the parameters cap, ad_full, ad_disc, f_plate_cap, and f_slow_cap. The resistances and their temperature dependencies are computed using temperature, r_curr, r_time, nom_temp, f_low_cap, f_hi_cap, and low_temp.

The terminal voltage of the battery is calculated from the acid density at the plate, the ohmic voltage loss on the internal resistance, and several other corrections due to temperature and high-rate charging currents at elevated SOC (state of charge). Under zero current conditions, the terminal voltage is mainly influenced by the parameters ad0, temperature, num_cells, and t_coeff_ocv. The internal resistance depending on SOC is calculated by using temperature, nom_res, t_coeff_res, and soc_coeff_res.

To model the mismatch between terminal current and electrochemical charge storage, several shunt currents are used. At all operating conditions, the self discharge current permanently reduces the SOC. It is influenced by the parameters sdpd and sd_t.

During charging, float and gassing currents are subtracted from the terminal current. While float current occurs at slightly elevated terminal voltages, the gassing current evolves at a higher voltage and SOC. Float current is influenced by the parameters flt_curr, flt_volt, and gass_th. Parameters that influence the gassing current mainly include: flt_volt, gass_th, and gass_sl.

Main effects include the following:

- Phenomenological description of battery internal correlations.
- Dependence of equilibrium voltage on state-of-charge (SOC), temperature, and current.
- Gassing of the battery during overcharge.
- Variation of the internal resistance with SOC and temperature.
- Voltage increase due to gassing.
- Variation of the effective battery capacity with discharge current and temperature.

Effects not considered by the model include the following:

- Physical description of internal processes and their links.
- Consideration of differences in the behavior of positive and negative electrodes.
- Water loss due to gassing.
- Temperature changes during operation.

- Aging effects.
- Deviations between different cells.
- Dynamics due to double layer capacities at the electrodes.

Top

Assumptions and Limitations

- OCV and internal resistance are assumed to vary linearly with temperature.
- Gassing is assumed to set in above cell voltages of gass_th.
- The temperature is considered to remain constant during simulation. No heat exchange dynamics are included in the model.

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Mathematical Description

Parameterization

The description of the complex nonlinear behavior of a battery requires about 25 parameters to be specified. To simplify the model, these parameters are predefined with average values suitable to many typical starter batteries with a flooded electrolyte and flat plates. Only the rated capacity (cap) and discharge time (r_time) are needed to simulate the terminal behavior of these batteries with reasonable accuracy. These data can be found on the battery manufacturer's data sheets (for starter batteries, the discharge time is usually 20 hours).

To increase the simulation accuracy, several other parameters can be varied. To improve characterization of a specific battery, it is desirable to specify the following data:

- The number of cells inside the battery and the nominal open circuit voltage at full charge and 25^{o}C (12V starter batteries consist of 6 electrochemical cells).
- Discharge curves (voltage vs. time or charge) at different discharge rates and temperatures.
- Internal resistance data near full charge, which may be obtained from voltage-drop data at different discharge currents or transient voltage curves.
- Self discharge data.
- Terminal voltage response at several charge currents and SOC.

With this information, it would be possible to fully parameterize the model. The following procedure will help improve simulation accuracy after you find the suited parameters. Due to missing information, it might not be possible to determine all parameters with similar precision. In such cases, reasonable assumptions must be made for the affected parameters, or default values can be used.

Parameterization Procedure

Step 1:

Start with all parameters at their default values. Only cap, r_curr, r_time, nom_temp, num_cell, and nom_res have to be entered from the data sheet. nom_res can be calculated from the voltage drop near to the start of a constant current discharge. For starter batteries, it ranges from several milliohms to several ten milliohms.

Step 2:

The open circuit voltage OCV at nom_temp can be set by varying ad0 and running simulations with zero battery current. As a rule of thumb, the acid concentration is linked to the cell voltage through the following equation:

$$\mathrm{ad0} = \frac{\mathrm{OCV}}{\mathrm{num\_cells}} - 0.845$$

It may be necessary to increase the ad_full parameter to obtain a good fit with experimental data.

Step 3:

To determine parameter f_slow_cap, estimate the maximum capacity of the battery in the slow discharge limit neglecting self discharge. This can be done by extrapolating capacity vs. rate data or by using its low rate limit. Dividing the obtained value by cap results in f_slow_cap. f_slow_cap always has to be greater than 1.

Step 4:

The parameter f_plate_cap can be obtained by comparing discharge runs to experimental data. Increasing f_plate_cap shifts more battery capacity to the plate, which then is not restricted by diffusion. It might also be necessary to vary f_slow_cap and cap slightly to improve the fit of simulation data with experimental curves.

Using Simplorer's Experiment Tool program and its Multi-simulation feature can accelerate this procedure significantly.

Step 5:

Comparing discharge curves in the region a short time before complete discharge (the "knee" region) might require changing internal resistance with SOC. This means the parameter soc_coeff_res must be adjusted. soc_coeff_res terms the fractional change of internal resistance between full charge and complete discharge. For example, the default value of soc_coeff_res (0.5) leads to r_discharged 1.5*nom_res at nom_temp.

When changing soc_coeff_res significantly, it might become necessary to repeat step 4.

Step 6:

At low temperatures, lead-acid batteries lose a fraction of their capacity at nom_temp. Typically their capacity drops to about 60% at -20°C (the default values for f_low_cap and low_temp). Usually these parameters can be obtained from the battery data sheet. To obtain parameter f_hi_cap, discharge simulations with rated_current have to be performed at different temperatures. Varying f_hi_cap allows you to adjust the capacities obtained at the different temperatures to the data sheet values. It may also be necessary to vary t_coeff_ocv and t_coeff_res. OCV and internal resistance are assumed to vary linearly with temperature. Generally, increasing t_coeff_ocv and decreasing t_coeff_res raises the capacity vs. temperature curve.

Step 7:

The self discharge is modeled as a constant current discharge current that depends on battery temperature, as follows:

$$I_{self} - \frac{sdpd}{100} \cdot \frac{cap}{24hrs} \cdot \exp\left(\frac{T - T_0}{sd\_t}\right)$$

Since different combinations of self discharge data are found on data sheets of different battery manufacturers, the parameters sdpd and sd_t must be calculated from the available data.

Step 8:

In the charging operation, two shunt currents are included in the model: float current and gassing current.

Float current: Float current information is mostly found on the battery data sheet. In the model, the float current sets in when cell voltage reaches a value where there is a slight temperature-corrected version of parameter gass_th. Upon increasing terminal voltage, the float current increases up to a cell voltage equal to gass_th'. Above this limit, the gassing current sets in, and the float current remains constant. Going by this definition, the float current reaches flt_cur at a terminal voltage of flt_volt.

Gassing current: Gassing is assumed to set in above cell voltages of gass_th'. The gassing current scales exponentially with cell voltage, as follows:

$$I_{gass} = r\_curr \cdot \left[\exp\left(\left(\frac{V_{cell} - gass\_th'}{gass\_sl}\right) - 1\right)\right]$$

If there is available gassing data, the parameters can be obtained by using this equation.

Step 9:

Following the preceding steps should result in a well parameterized model. For specific simulations only, initial acid density ad0 and temperature must be set. Parameter ad0 sets identical acid densities for all three spatial regions (capacitors). This initialization matches a battery after a sufficient resting period.

The temperature is considered to remain constant during simulation. No heat exchange dynamics are included in the model.

Several model parameter groups must be defined in a self consistent manner. Following are the most important constraints:

- The triple cap, r_curr, and r_time must fulfill the condition: cap = r_curr * r_timecap r_curr*r_time

- f_cap_slow > f_hi_cap, 1.0 > f_slow_cap

- ad_full > ad_disc > 1.0
- 0 < fc < 1.0

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Netlist Syntax

UMODEL LBATT_A_PLIB ?InstanceName(@InstanceName):(@(Refbase)@(ID)) np:= %0, nm:= %1 (ad0:= @ad0, temperature:= @temperature, cap:= @cap, r_curr:= @r_curr, r_time:= @r_time, nom_res:= @nom_res, num_cells:= @num_cells, ad_full:= @ad_full, ad_disc:= @ad_disc, nom_temp:= @nom_temp, f_low_cap:= @f_low_cap, f_hi_cap:= @f_hi_cap, low_temp:= @low_temp, f_plate_cap:= @f_plate_cap, f_slow_cap:= @f_slow_cap, sdpd:= @sdpd, sd_t:= @sd_t, flt_curr:= @flt_curr, flt_volt:= @flt_volt, gass_th:= @gass_th, gass_sl:= @gass_sl, t_coeff_ocv:= @t_coeff_ocv, t_coeff_res:= @t_coeff_res, soc_coeff_res:= @soc_coeff_res) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
np	Positive Terminal	Electrical terminal
nm	Negative Terminal	Electrical terminal

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
ad0	Initial Acid Density	real	1.27 [g/cm^2]
temperature	Battery Temperature	real	25 [^{o}C]
cap	Rated Capacity	real	0.1k [Ah]
r_curr	Rated Discharge Current	real	5 [A]
r_time	Rated Discharge Time	real	20 [h]
nom_res	Internal Resistance at full charge and nominal temperature	real	10m [Ohms]
num_cells	Number of Cells	real	6
ad_full	Acid Density at Full Charge	real	1.28 [g/cm^3]
ad_disc	Acid Density at Complete Discharge	real	1.01 [g/cm^3]
nom_temp	Nominal Temperature	real	25 [^{o}C]
f_low_cap	Fraction of Capacity at Low Temperature	real	0.6m
f_hi_cap	Gain Limit of Capacity at High Temperature	real	1.02
low_temp	Low Temperature where f_ low_cap is Specified	real	-20 [^{o}C]
f_plate_cap	Fraction of Capacity near plate	real	0.3
f_slow_cap	Capacity Gain in the Slow Discharging Limit	real	1.03
sdpd	Self Discharge Rate per Day	real	0.25 [%/day]
sd_t	Temperature Dependency of Self-Discharge	real	16.37 [^{o}C]
flt_curr	Float Current	real	2m [A/Ah]
flt_volt	Cell Voltage where Float Current is Reached	real	2.3 [V]
gass_th	Gassing Threshold Voltage at 25^{o}C	real	2.39 [V]
gass_sl	Scaling of Gassing Current with Terminal Voltage	real	0.2 [V]
t_coeff_ocv	Temperature Coefficient of OCV	real	0.15m [V/^{o}C]
t_coeff_res	Temperature Coefficient of	real	7.5m

	Full Charge Internal Resistance		[1/^{o}C]
soc_coeff_res	Coefficient for Internal Resistance Variation with SOC	real	0.5

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
V	Terminal Voltage [V]	Output	real
V_cell	Cell Voltage [V]	Output	real
I	Cell Current [A] (negative on discharge, positive on charge)	Output	real
SOC	State of Charge	Output	real
ad_plate	Acid Density Near Plates [g/cm^3]	Output	real
ad_middle	Acid Density in Middle Reservoir [g/cm^3]	Output	real
ad_in	Acid Density far off Plates [g/cm^3]	Output	real
resistance	Internal Resistance [Ohm]	Output	real
cha_dis_current	Effective Charge/Discharge Current [A]	Output	real
flt_current	Float Current [A]	Output	real
g_current	Gassing Current [A]	Output	real
sd_current	Self Discharge Current [A]	Output	real

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Example

In this example, the Intermittent Starter starter1 is connected to a fully charged batter Battery 1 through a ideal switch S1. The control signal of S1 is generated by a 2D LookUp Table CONTROL. The schematic of the example is shown in Figure 2, system parameters are listed in the table 4, and the simulation results are shown in Figure 3.

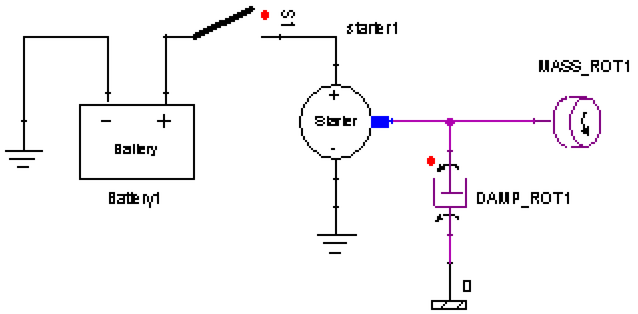

Figure 2. Application example of the Advanced Battery model

Table 4. System Parameters

Component	Parameter	Value [unit]

Advanced Battery Model Battery1	ad0	1.27 [g/cm^2]
	temperature	25 [^{o}C]
	cap	0.1k [Ah]
	r_curr	5 [A]
	r_time	20 [h]
	nom_res	10m [Ohms]
	num_cells	6
	ad_full	1.28 [g/cm^3]
	ad_disc	1.01 [g/cm^3]
	nom_temp	25 [^{o}C]
	f_low_cap	0.6m
	f_hi_cap	1.02
	low_temp	-20 [^{o}C]
	f_plate_cap	0.3
	f_slow_cap	1.03
	sdpd	0.25 [%/day]
	sd_t	16.37 [^{o}C]
	flt_curr	2m [A/Ah]
	flt_volt	2.3 [V]
	gass_th	2.39 [V]
	gass_sl	0.2 [V]
	t_coeff_ocv	0.15m [V/^{o}C]
	t_coeff_res	7.5m [1/^{o}C]
	soc_coeff_res	0.5
Starter1	ra	5m [Ohm]
	la	1m [H]
	ke	10m
	j	10m [kg m^2]
	cf	1m [Nms/rad]
	n_clutch	0.8k [rpm]
	n0	0 [rpm]
DAMP_ROT1	DAMPING	0.1 [Nms/rad]
MASS_ROT1	PHI0	0 [rpm]
	J	75m [kg m^2]

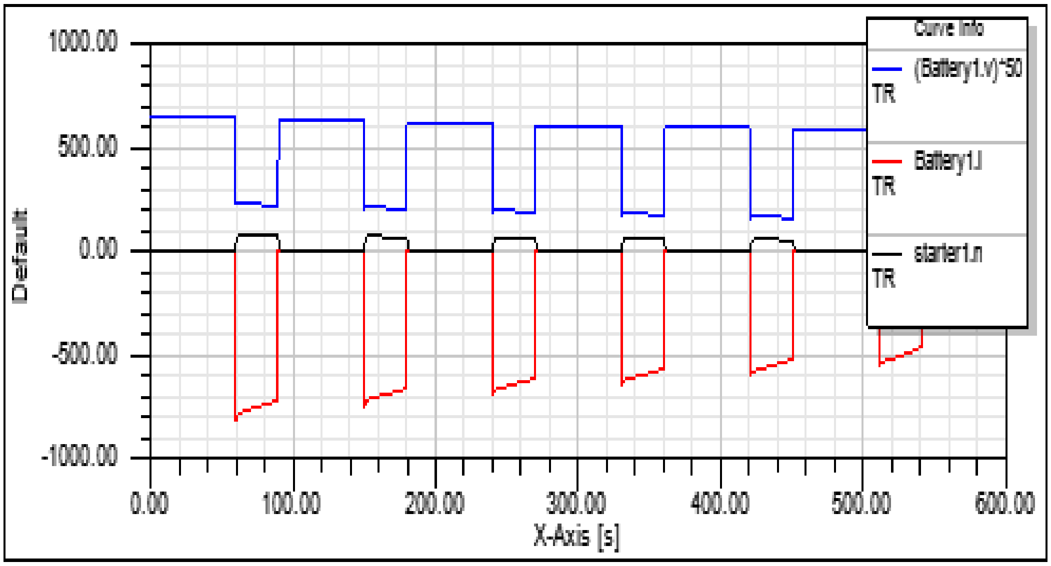

Figure 3. Simulation results of the Advanced Battery model

The following shows the schematic of the battery recharging:

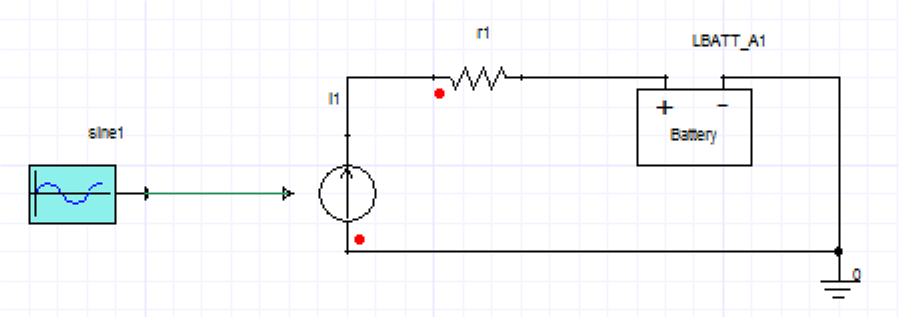

Figure 4. Example of the Battery recharging

The simulation results for the battery recharging:

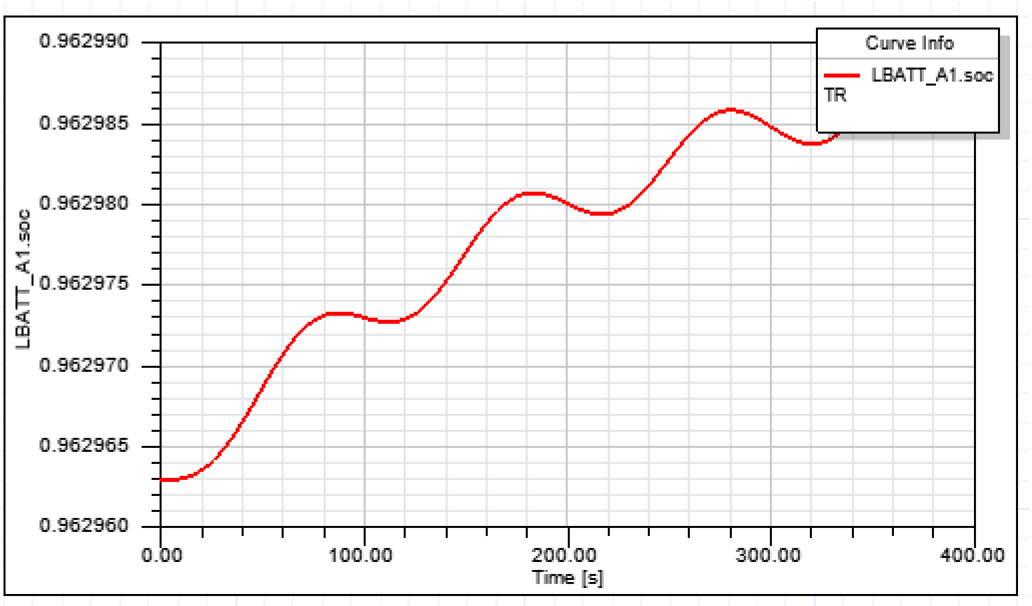

Figure 5. Simulation results of the Battery Recharging model

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References

[1] Crompton T.R. (1993). *Battery Reference Book*. Second edition, Butterworth-Heinemann.

[2] Linden D. (1995). *Handbook of Batteries*. Second edition, McGraw-Hill.

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