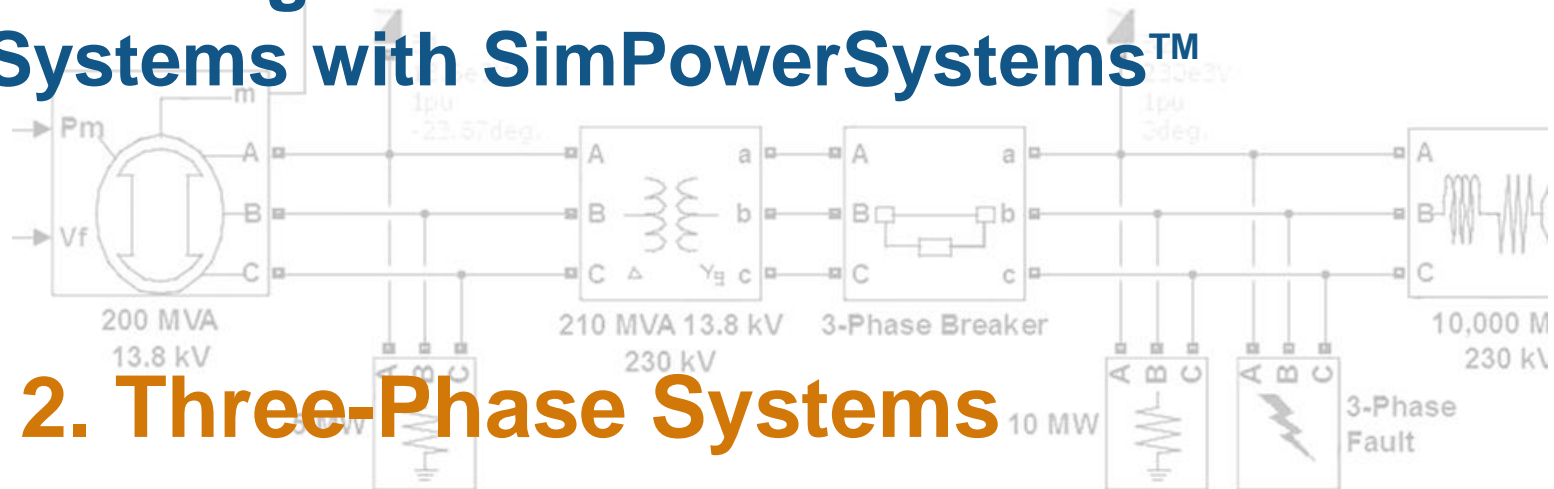


SimPowerSystems Hands-on Workshop: Modeling and Simulation of Electrical Power Systems with SimPowerSystems™



2. Three-Phase Systems

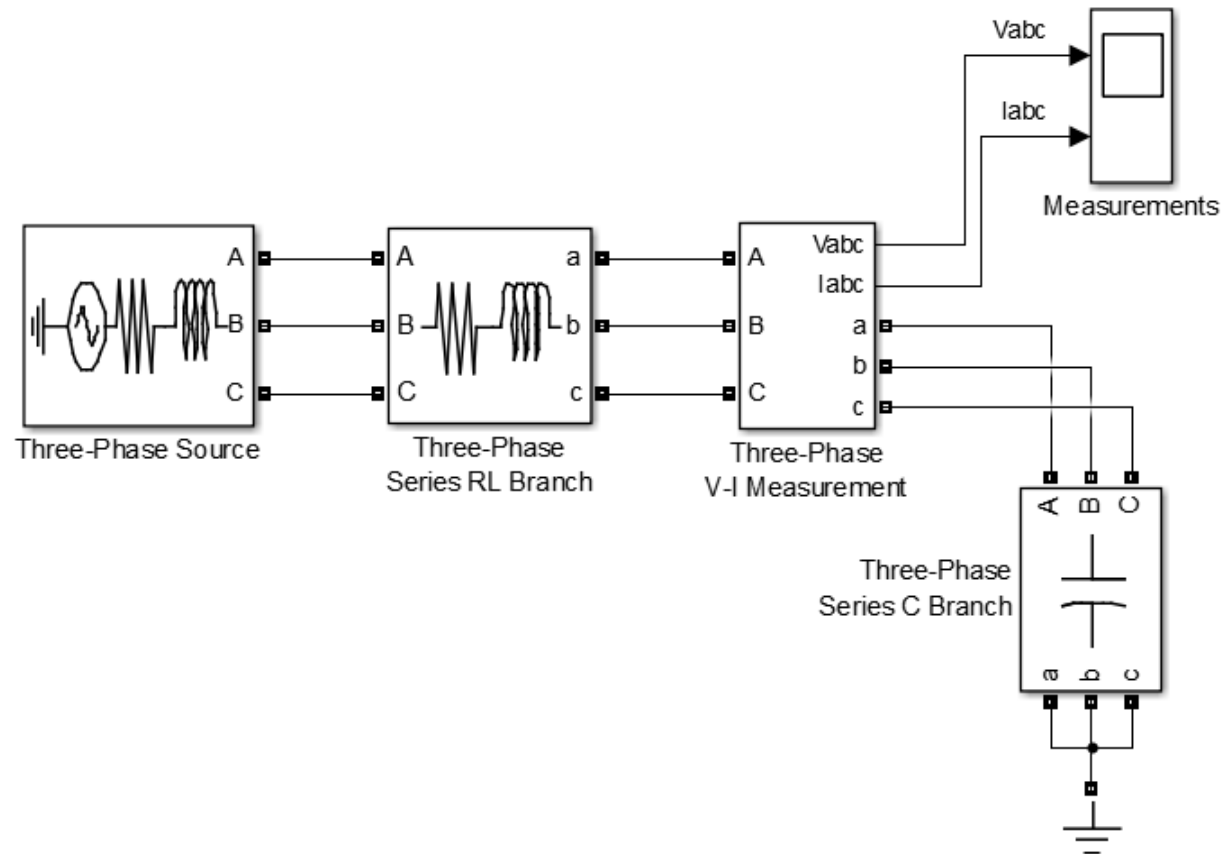


Carlos Osorio
Principal Application Engineer
MathWorks – Natick, MA

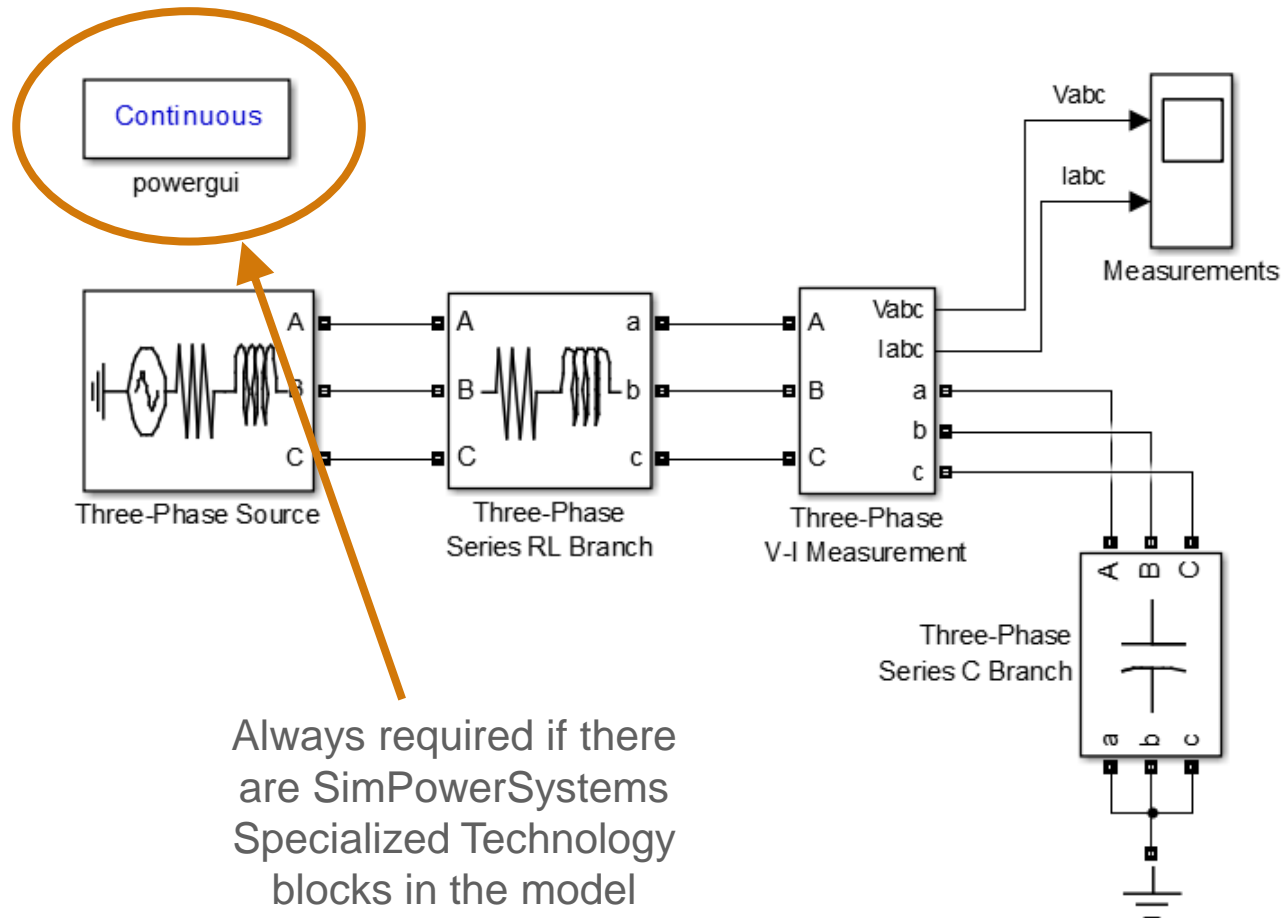
Outline

- Measurements
- State initialization
- Transformers
- Star vs. delta connections
- Floating vs. neutral connections
- Reference frame transformations

Build a simple three-phase circuit

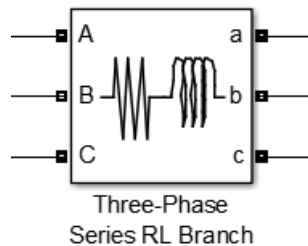
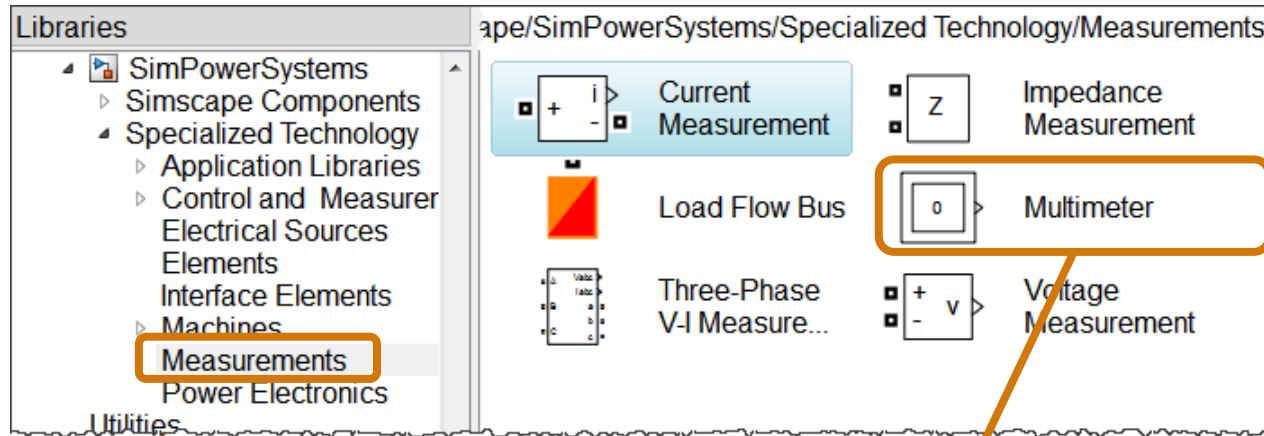


Build a simple three-phase circuit

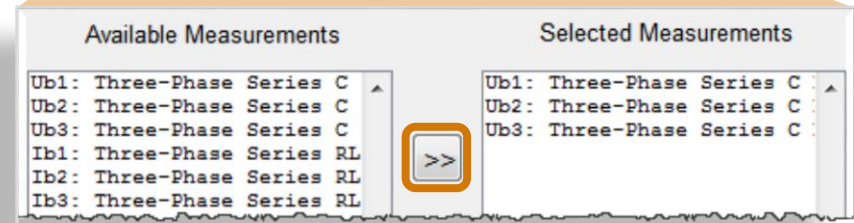
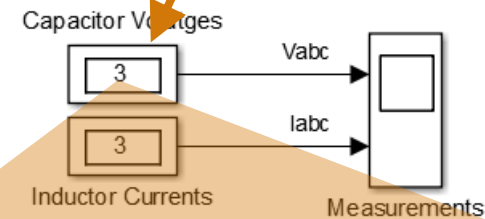


```
>> threephase_rlc
```

Multimeter measurements

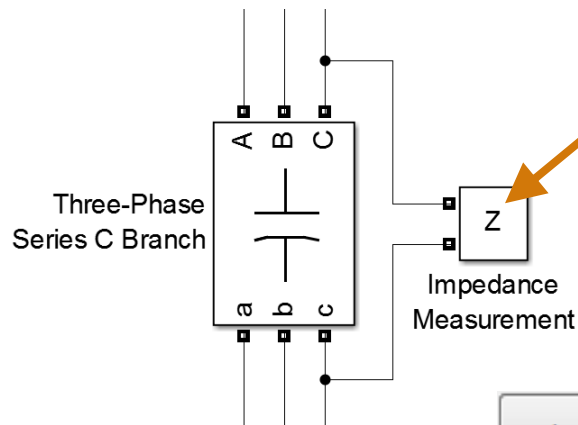
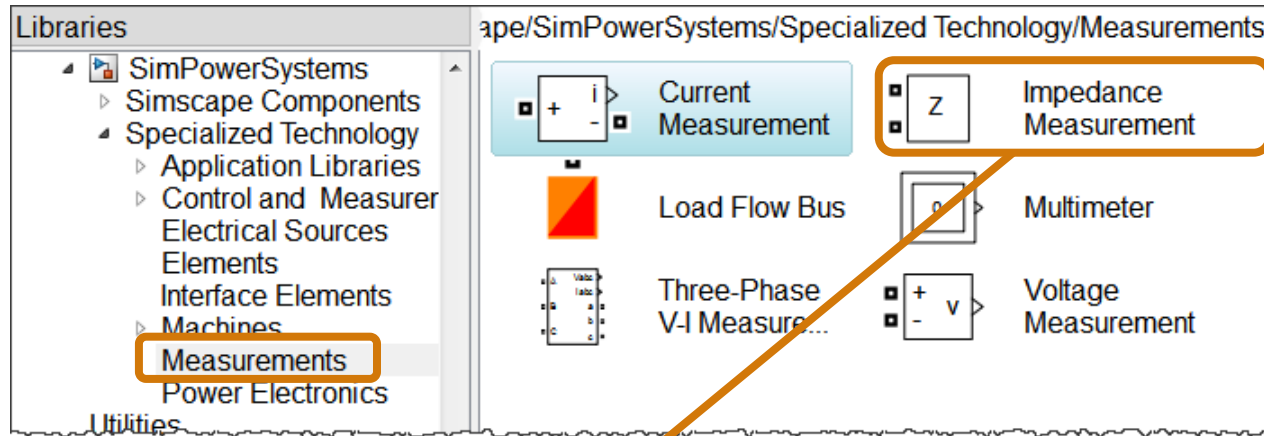


Measurements **Branch currents**



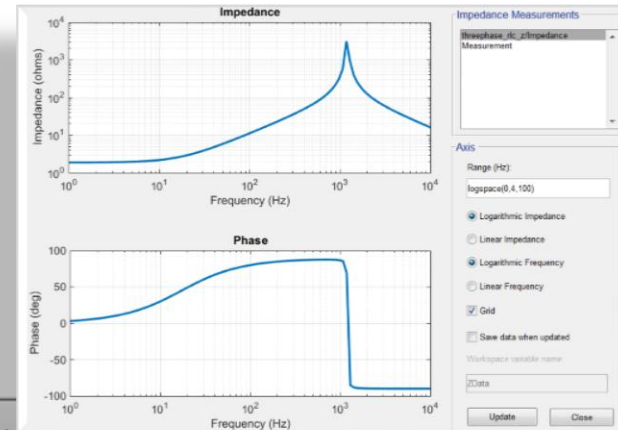
```
>> threephase_rlc_mm
```

Impedance measurement



powergui

Impedance vs Frequency Measurement



```
>> threephase_rlc_z
```

State initialization

Independent states

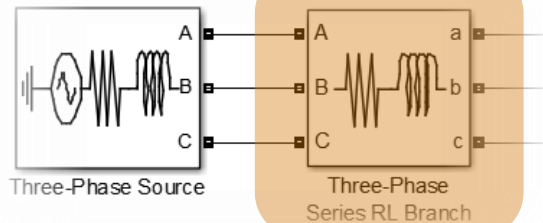
Initial electrical state values for simulation:

1	'Uc' phase_A: Three-Phase Series C Branch	=	-14.64 V
2	'Uc' phase_B: Three-Phase Series C Branch	=	-1.771e+04 V
3	'Uc' phase_C: Three-Phase Series C Branch	=	1.773e+04 V
4	'Il' phase_A: Three-Phase Source	=	7.715 A
5	'Il' phase_B: Three-Phase Source	=	-3.862 A
6	'Il' phase_C: Three-Phase Source	=	-3.853 A

DEPENDENT STATES: (initial values are not computed)

'Il_phase_A: Three-Phase Series RL Branch' Il
 'Il_phase_B: Three-Phase Series RL Branch' Il
 'Il_phase_C: Three-Phase Series RL Branch' Il

Dependent states



Settings

Set selected electrical state:

-14.64

Force initial electrical states:

☐ To Steady State

☐ To Zero

Reload states:

From File...

From diagram

Format:

112.3 (best of)

Sort values by:

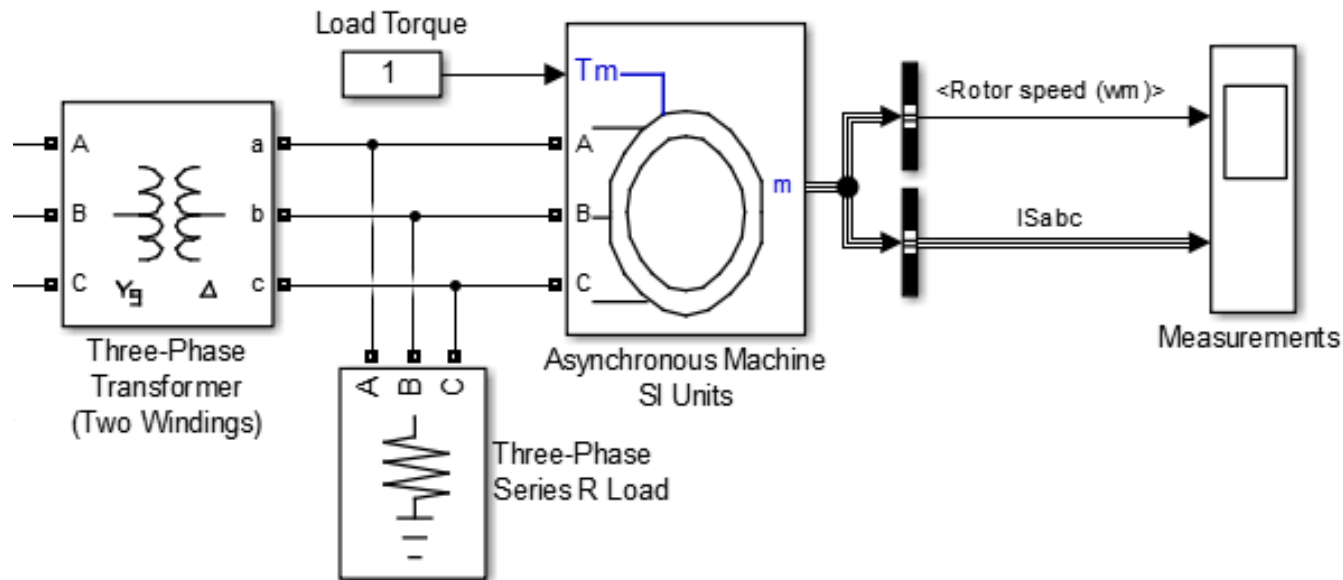
State number

Save Initial States...

powergui

Initial States Setting


Complete the simple three-phase circuit



```
>> threephase_rlc_motor
```


Complete the simple three-phase circuit

Recommended variable-step solver

 [Warning: You have required continuous-time simulation of a system containing switches or nonlinear elements.
The ode23tb variable-step stiff solver with relative tolerance set to 1e-4 generally gives best accuracy and simulation performance.
For some highly nonlinear models it may be necessary to set the "Solver reset method" parameter to "Robust".
See "Improving Simulation Performance" chapter in SimPowerSystems documentation for additional information on how to select an appropriate integration method.
To ignore SimPowerSystems warnings, select "Disable SimPowerSystems warnings" in the Powergui Preferences tab.]

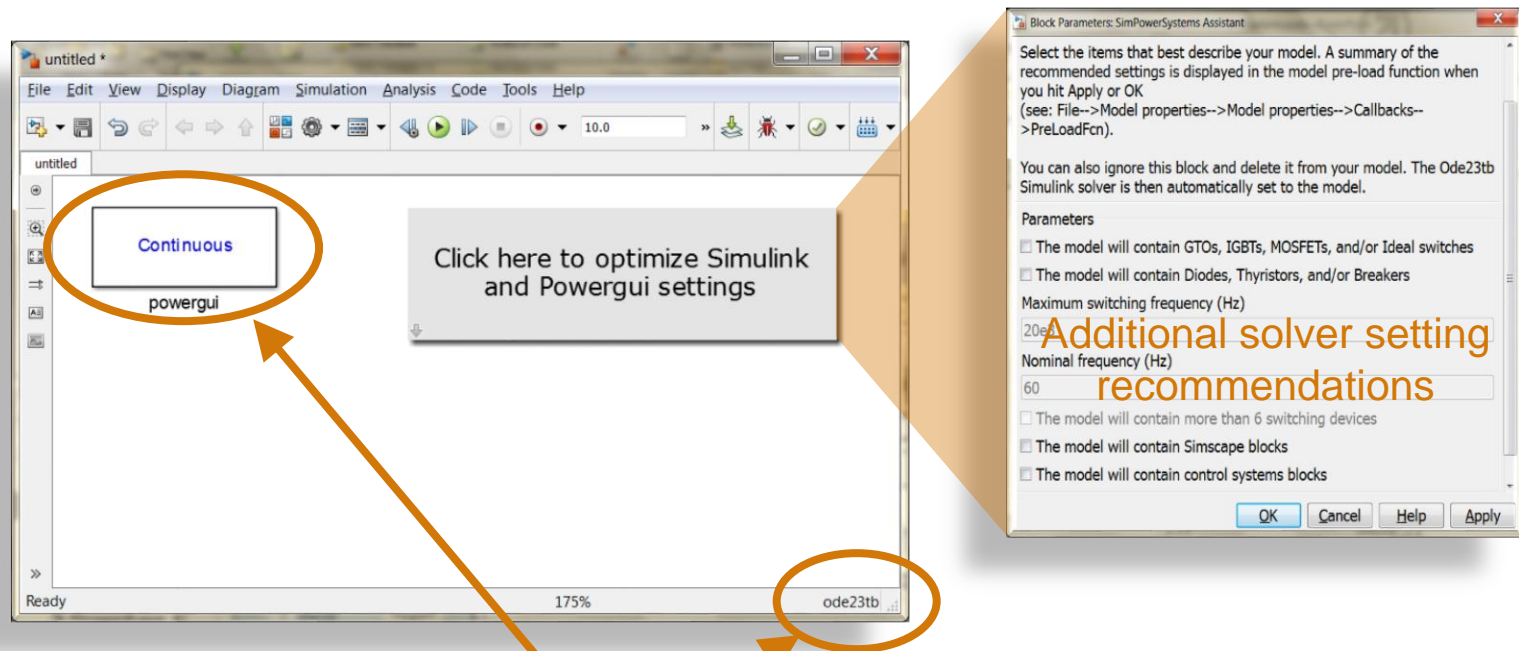
Setting the recommended solver configuration



Solver options	
Type:	Variable-step
Max step size:	auto
Min step size:	auto
Initial step size:	auto
Solver reset method:	Fast
Solver:	ode23tb (stiff/TR-BDF2)
Relative tolerance:	1e-4
Absolute tolerance:	auto
Shape preservation:	Disable All

Complete the simple three-phase circuit

Recommended variable-step solver

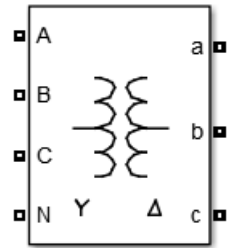


Automatically opens a model that includes the **powergui** block and sets the solver to the recommended settings

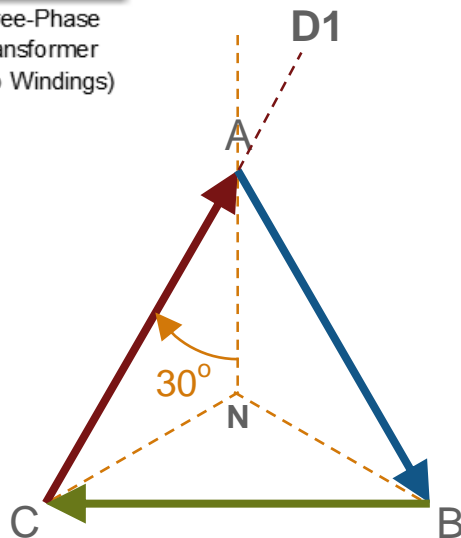
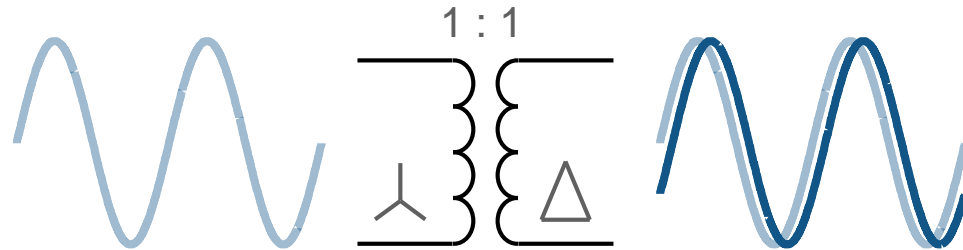
```
>> power_new
```

Transformers

Phase shifting



Three-Phase Transformer
(Two Windings)



Winding 1 connection (ABC terminals):	Yg
Winding 2 connection (abc terminals) :	Delta (D1)
<input type="checkbox"/> Saturable core	Y
Measurements	Yn
	Yg
	Delta (D1)
	Delta (D11)

D1: Adds 30° to the phase (lead)

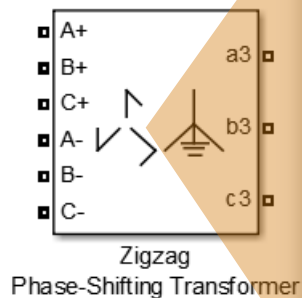
D11: Subtracts 30° from the phase (lag)

```
>> transformer_phaseshifting
```

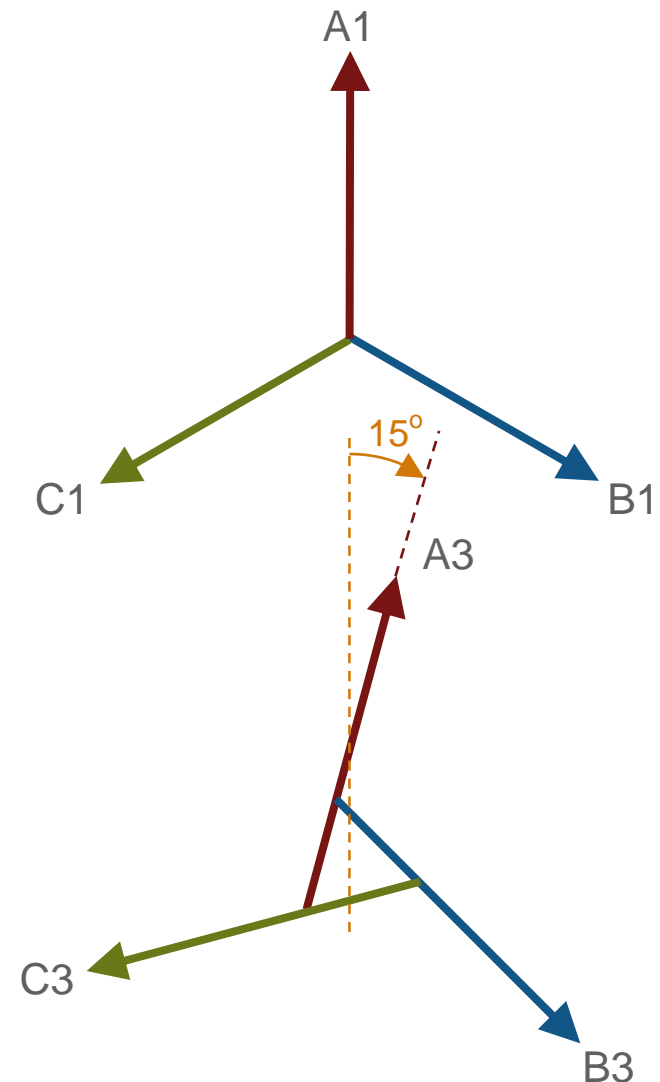
Transformers

Zig-zag transformers

- Zig-zag transformers are used to facilitate phase shifts between 0° and 30°
- Zig-zag transformers use three windings to achieve the desired phase shift

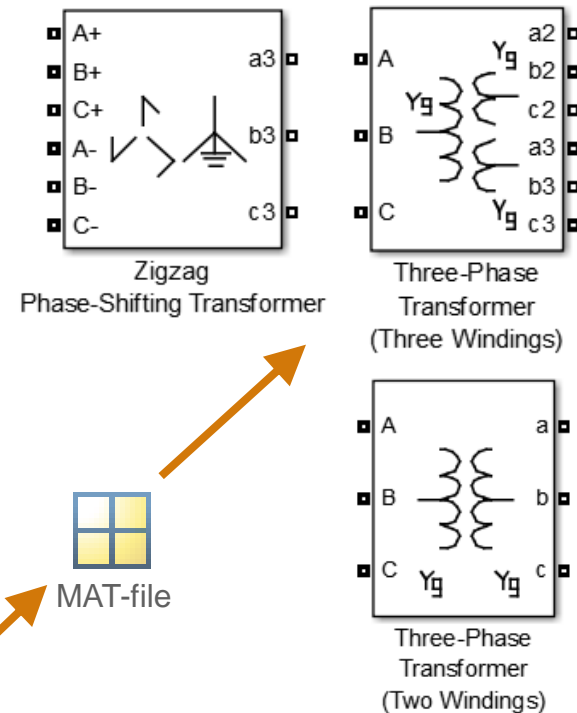
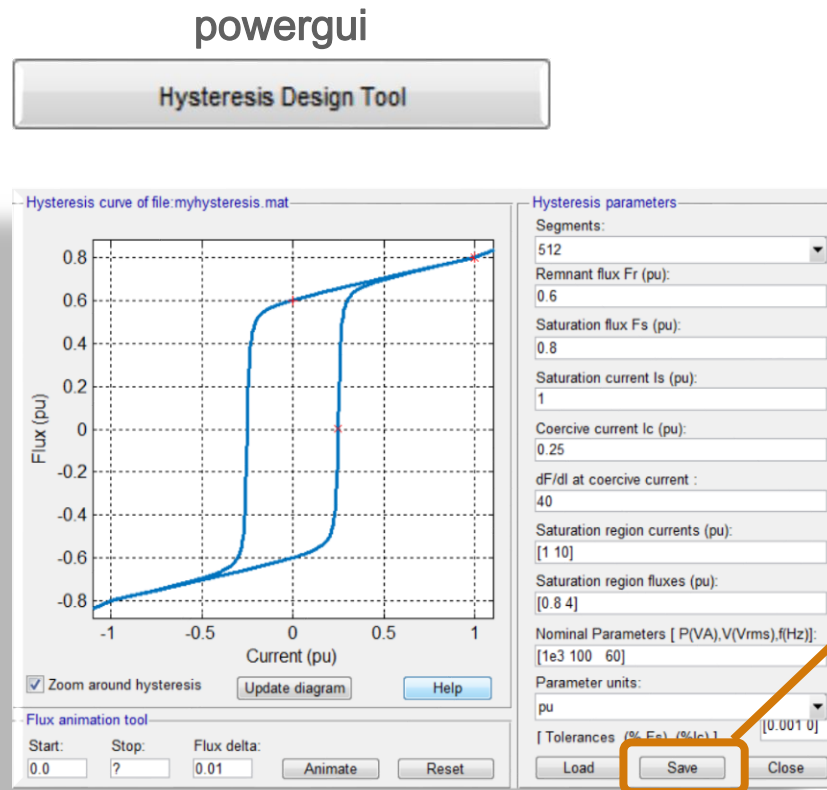


Nominal power and frequency [Pn(VA) fn (Hz)] :
[100e6 60]
Primary (zig-zag) nominal voltage Vp (VrmsPh-Ph) :
10e3
Secondary nom. voltage _phase shift [V3(VrmsPh-Ph) Phi(Deg)]
[30e3 +15]
Winding 1 zig-zag [R1 L1] (pu)
[0.002 0.08]
Winding 2 zig-zag [R2 L2] (pu)
[0.002 0.08]
Winding 3 secondary [R3 L3] (pu)
[0.002 0.08]
Magnetizing branch [Rm Lm] (pu)
[500 500]



Transformers

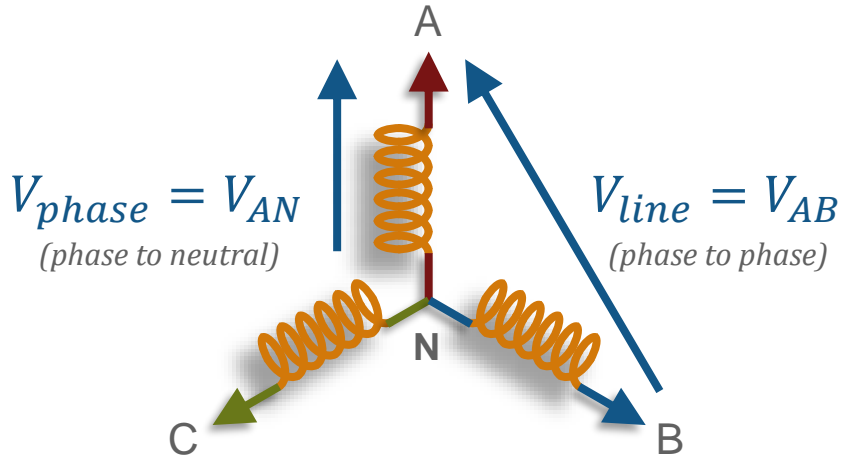
Saturation and hysteresis



When modeling hysteresis it is recommended to use a discrete solver for better accuracy and simulation performance

```
>> transformer_saturation
```

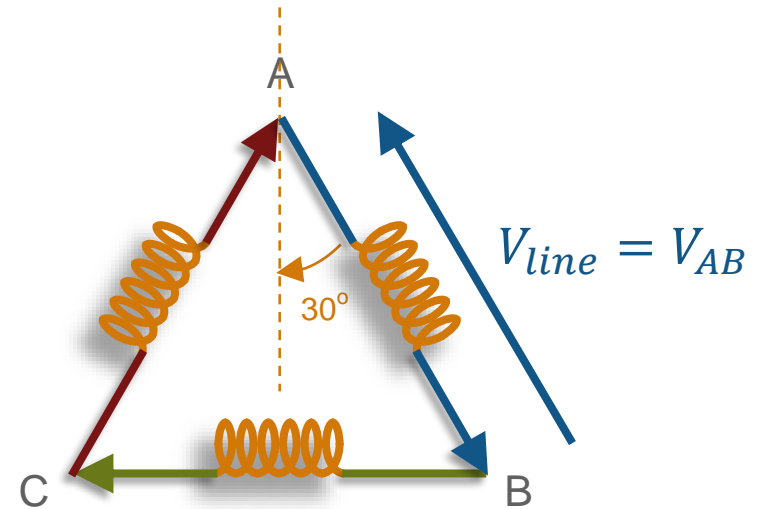
Star vs. delta connections



Star

$$V_{line} = \sqrt{3} V_{phase}$$

$$I_{line} = I_{phase}$$



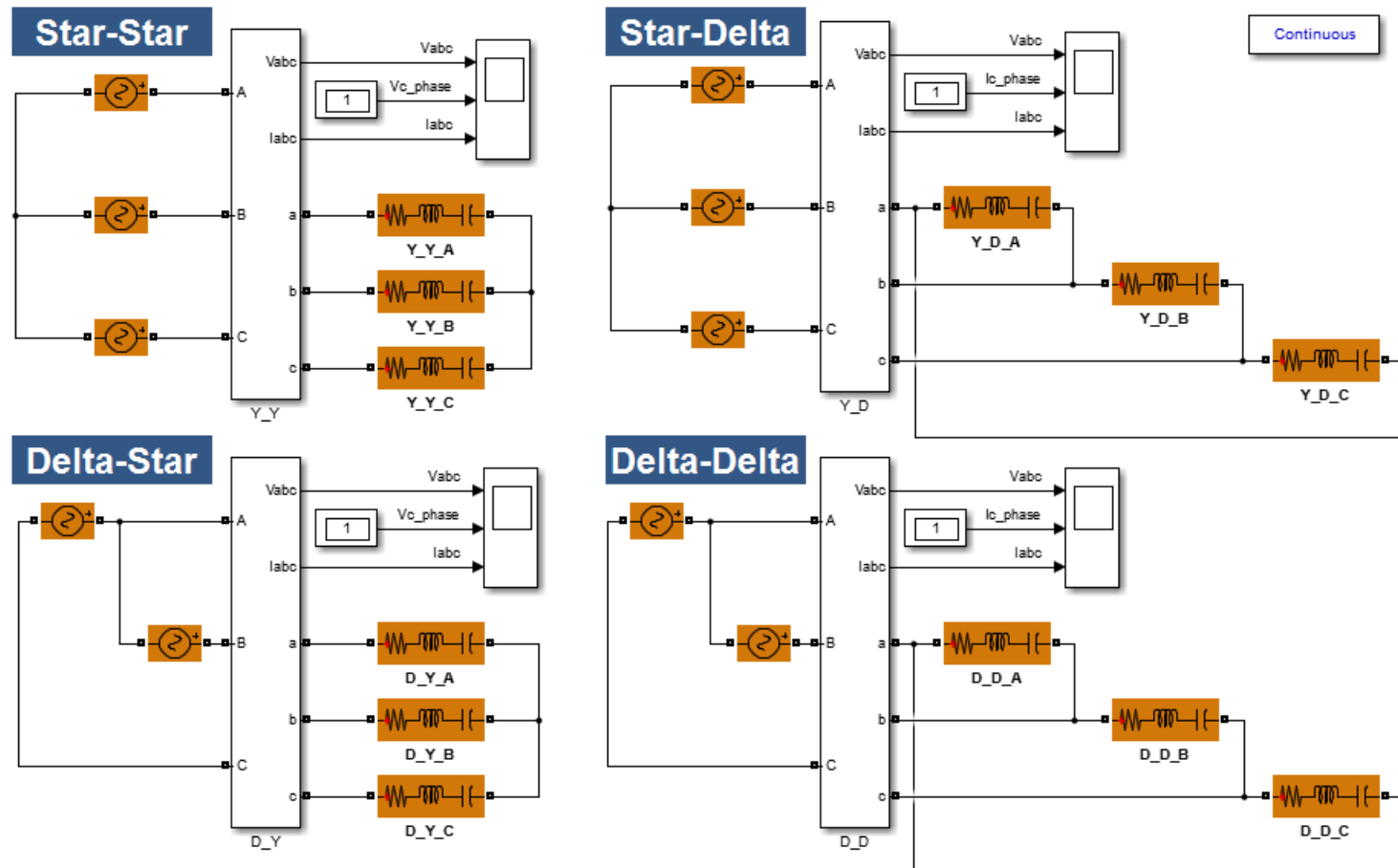
Delta

$$V_{line} = V_{phase}$$

$$I_{line} = \sqrt{3} I_{phase}$$

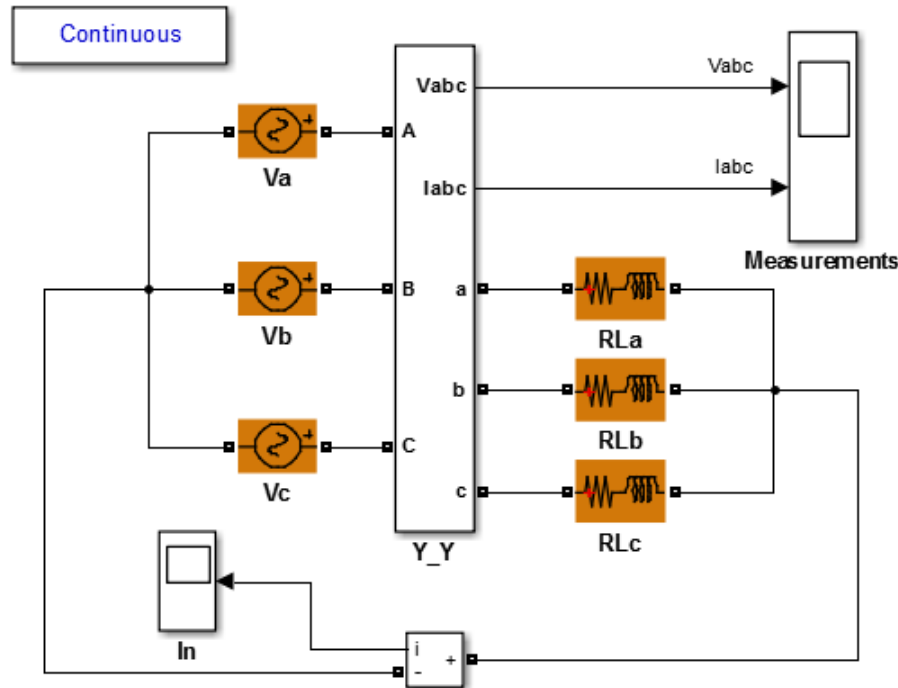
$$V_{peak} = \sqrt{2} V_{rms}$$

Star vs. delta connections



```
>> star_delta
```

Floating vs. neutral connections



- In a three-phase system, a floating star-connected load containing inductors will result in dependent states because of the following equation.

$$I_a + I_b + I_c = 0$$

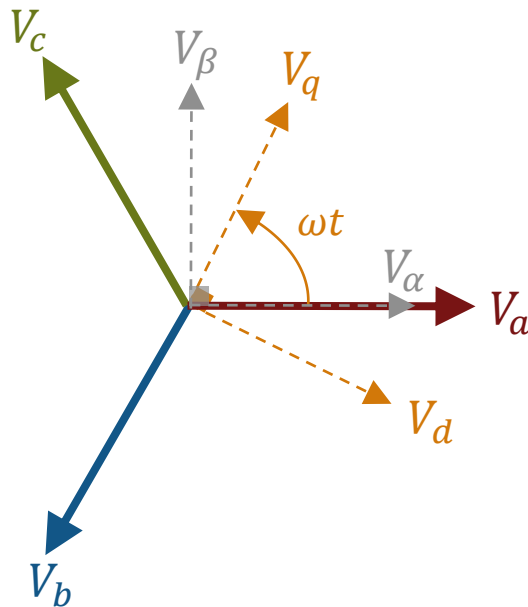
- If the supply is star-connected and a neutral or ground connection is made between source and load, then there is no longer a dependent state.

$$I_a + I_b + I_c = I_n$$

```
>> floating_neutral
```


Reference frame transformations

Park and Clarke transforms



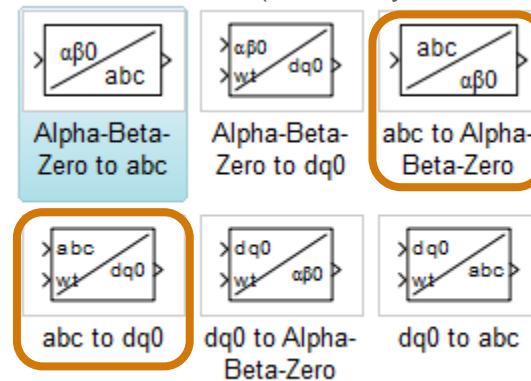
$$V_\alpha = \frac{2}{3}V_a - \frac{1}{3}V_b - \frac{1}{3}V_c$$

$$V_\beta = \frac{1}{\sqrt{3}}V_b - \frac{1}{\sqrt{3}}V_c$$

$$V_0 = \frac{1}{3}V_a + \frac{1}{3}V_b + \frac{1}{3}V_c$$

Clarke

(stationary reference frame)



Park

(rotating reference frame)

$$V_d = \frac{2}{3}V_a \sin(\omega t) + \frac{2}{3}V_b \sin\left(\omega t - \frac{2}{3}\pi\right) + \frac{2}{3}V_c \sin\left(\omega t + \frac{2}{3}\pi\right)$$

$$V_q = \frac{2}{3}V_a \cos(\omega t) + \frac{2}{3}V_b \cos\left(\omega t - \frac{2}{3}\pi\right) + \frac{2}{3}V_c \cos\left(\omega t + \frac{2}{3}\pi\right)$$

$$V_0 = \frac{1}{3}V_a + \frac{1}{3}V_b + \frac{1}{3}V_c$$

```
>> park_clarke
```

