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

2. Three-Phase Systems

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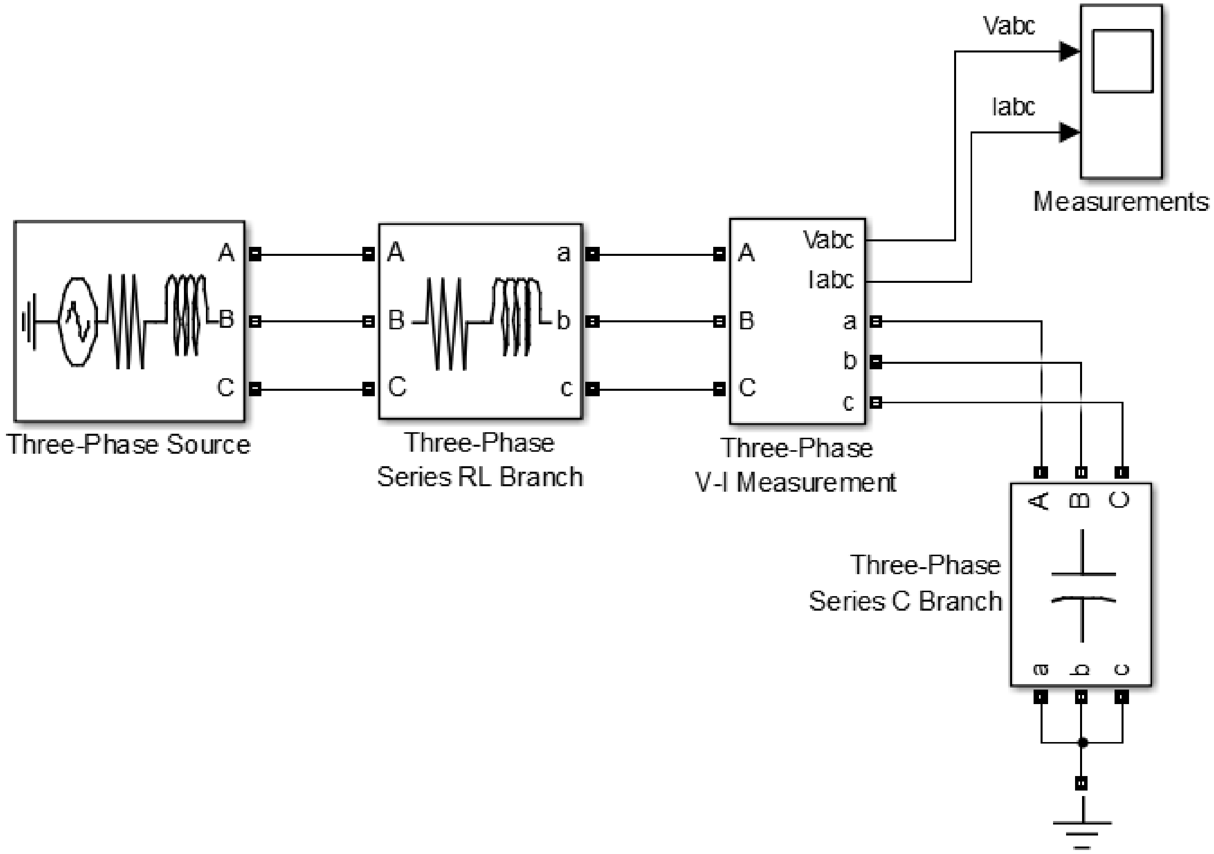
MathWorks – Natick, MA

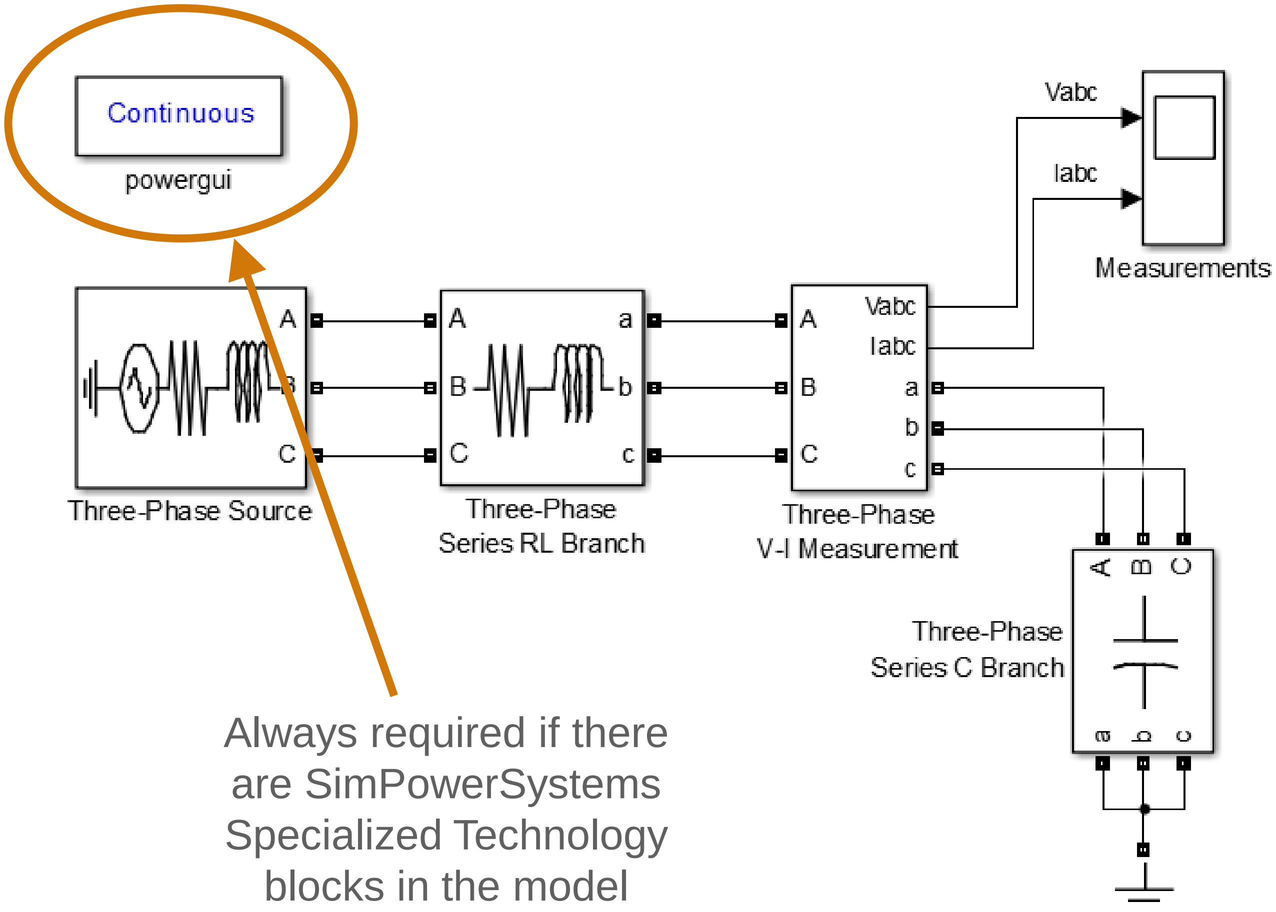
Outline

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

Build a simple three-phase circuit



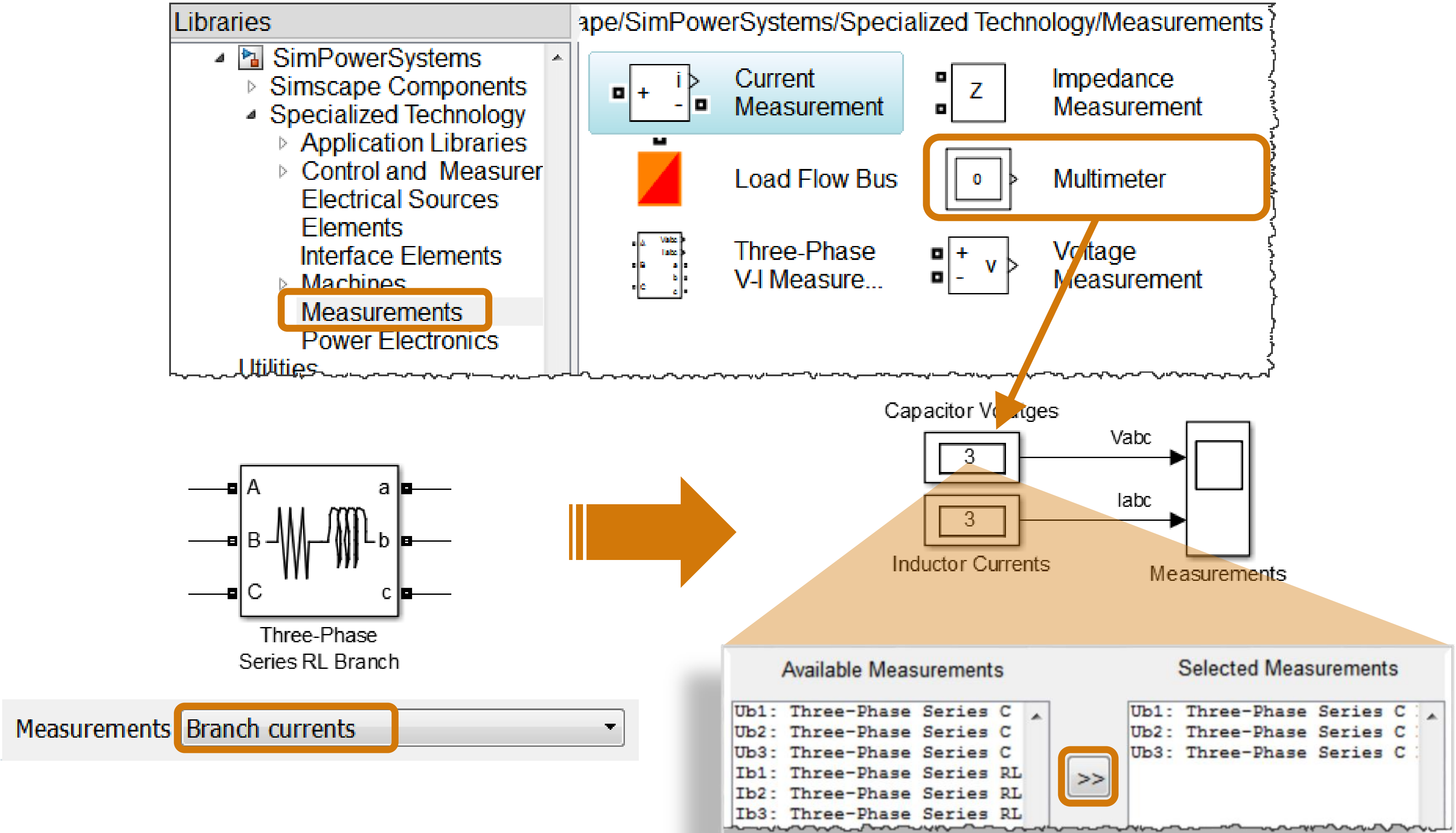
Build a simple three-phase circuit



Always required if there are SimPowerSystems Specialized Technology blocks in the model

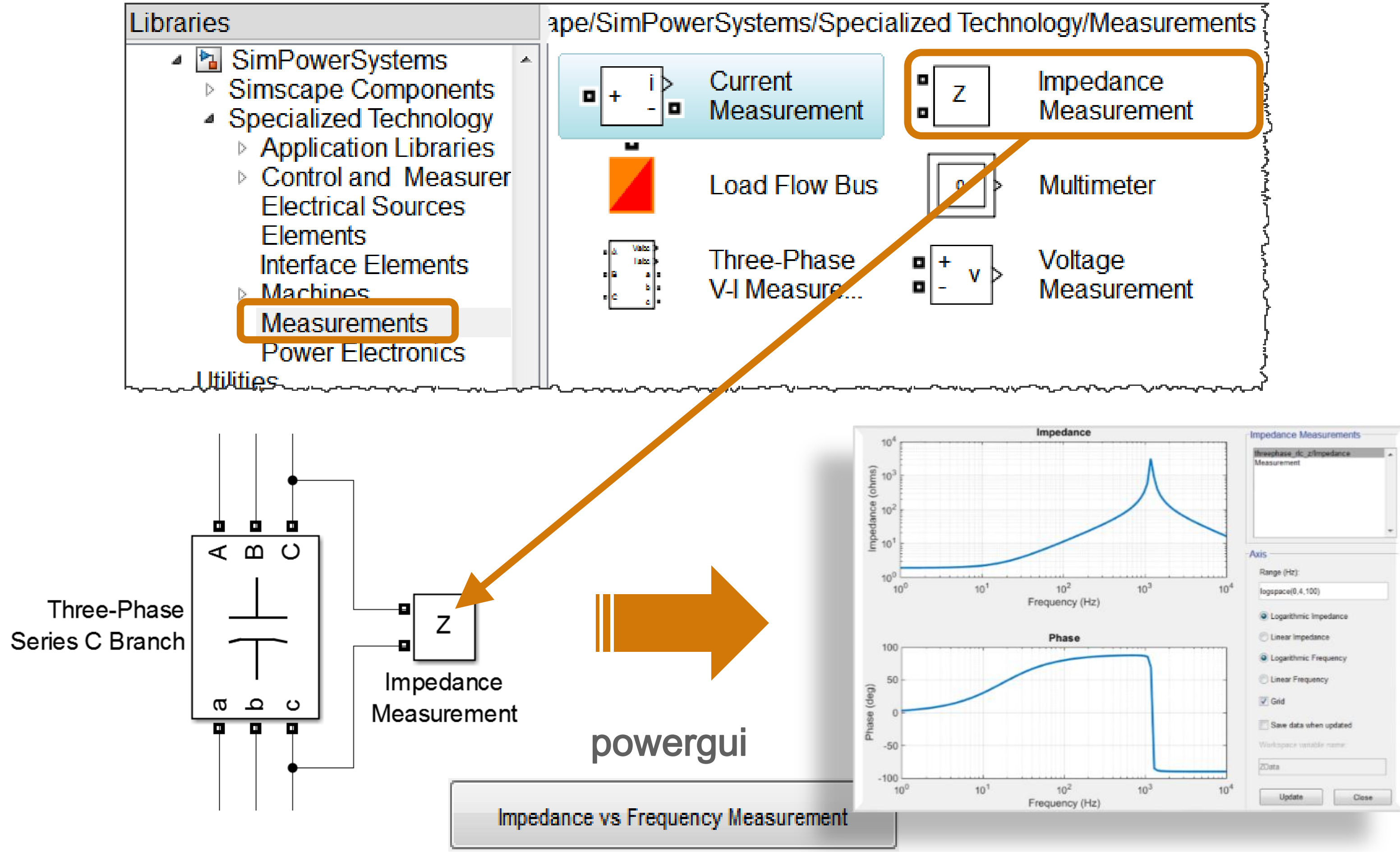
```
>> threephase_rlc
```

Multimeter measurements



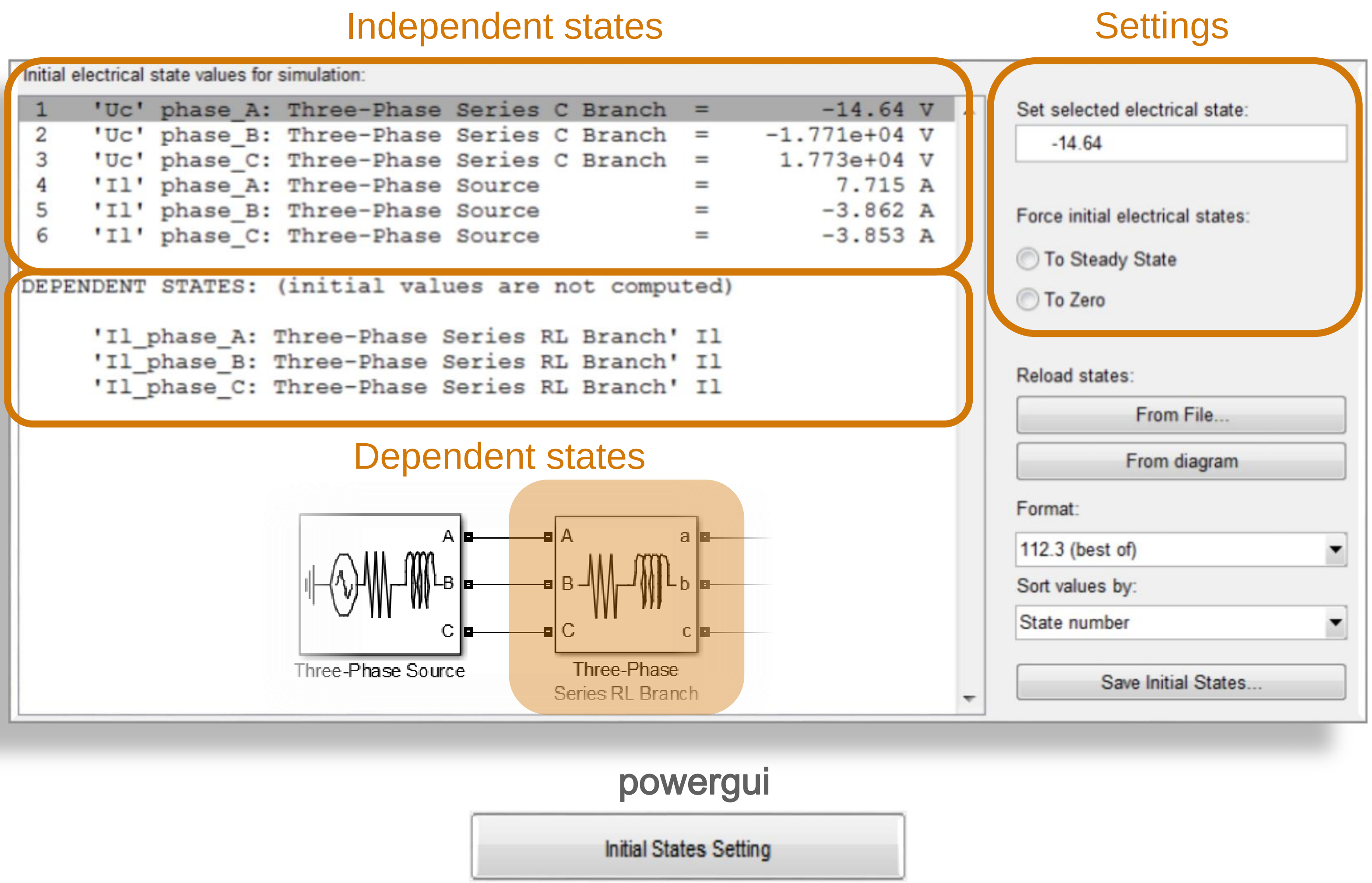

```
>> threephase_rlc_mm
```

Impedance measurement

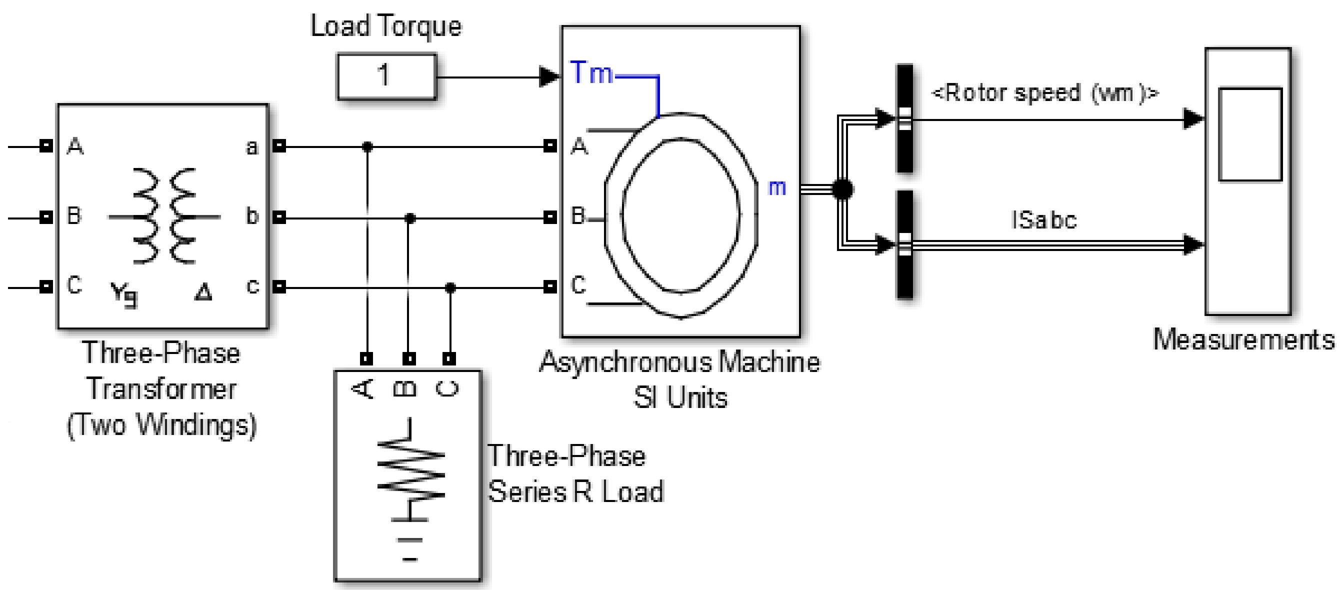



```
>> threephase_rlc_z
```

State initialization



Complete the simple three-phase circuit



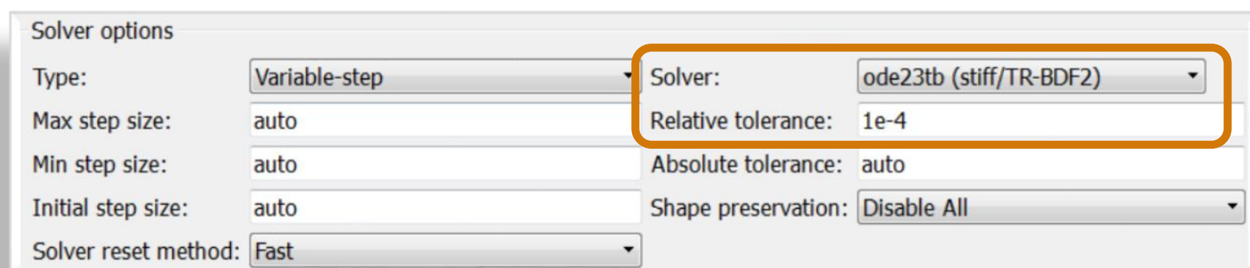

```
>> threephase_rlc_motor
```

Complete the simple three-phase circuit

Recommended variable-step solver

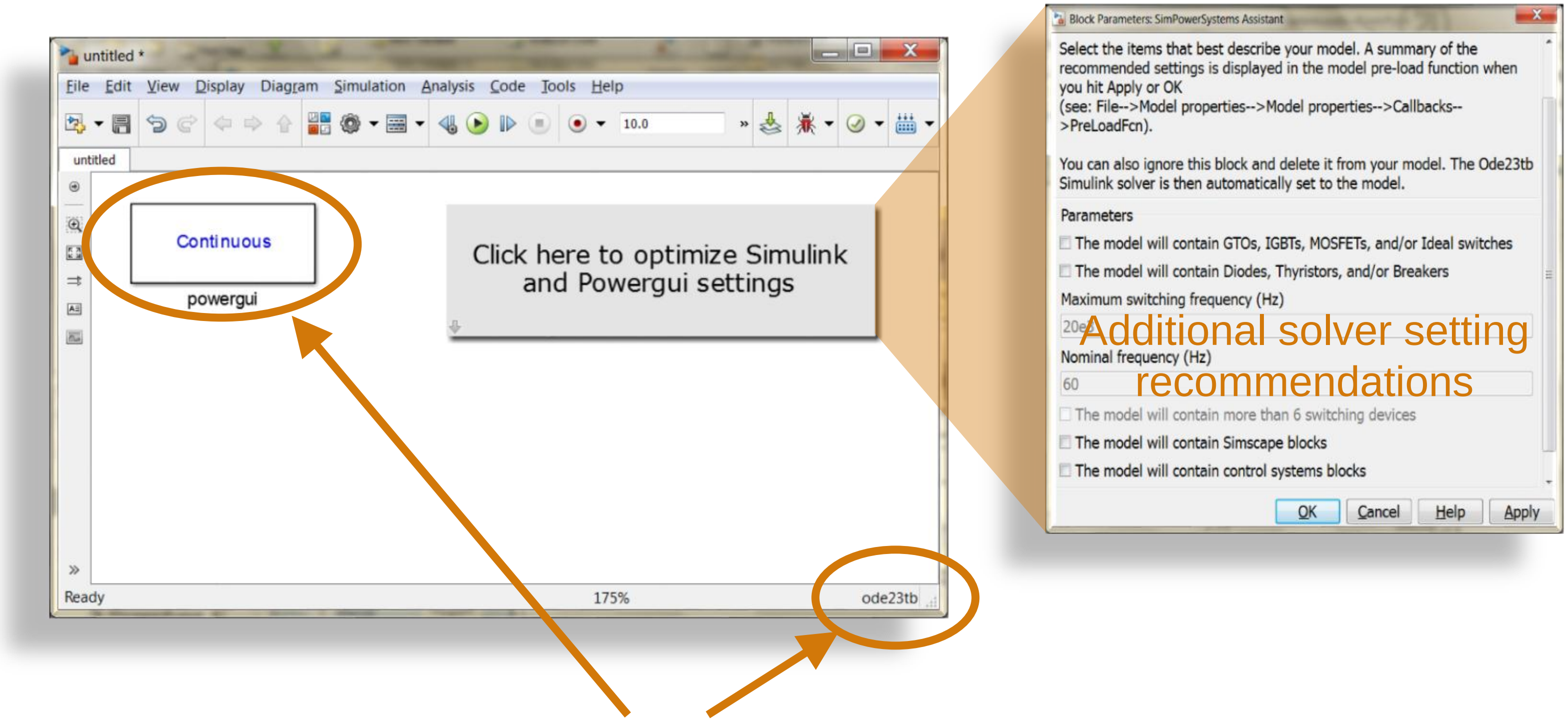
```
[ Warning: You have required continuous-time simulation of a system
containing switches or nonlinear elements.
The ode23tb variable-step stiff solver with relative tolerance set to
1e-4 generally gives best accuracy and simulation performance.
For some highly nonlinear models it may be necessary 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



Complete the simple three-phase circuit

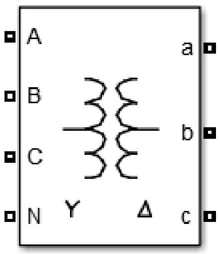
Recommended variable-step solver



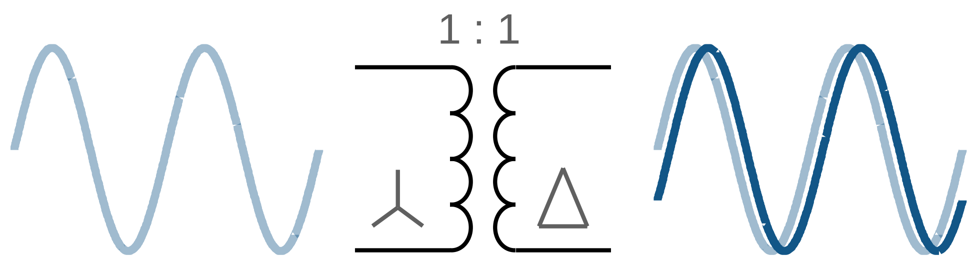
Automatically opens a model that includes the **powergui** block and sets the solver to the recommended settings

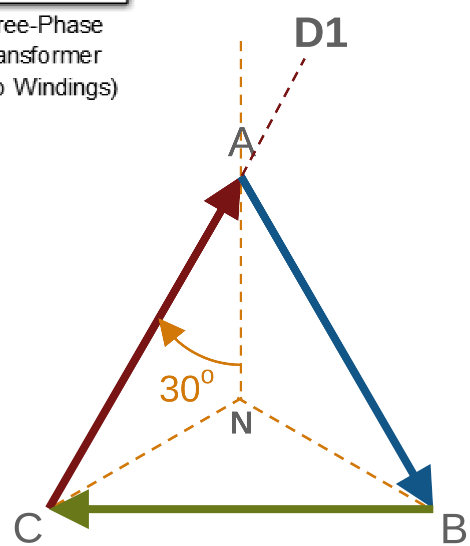
```
>> power_new
```

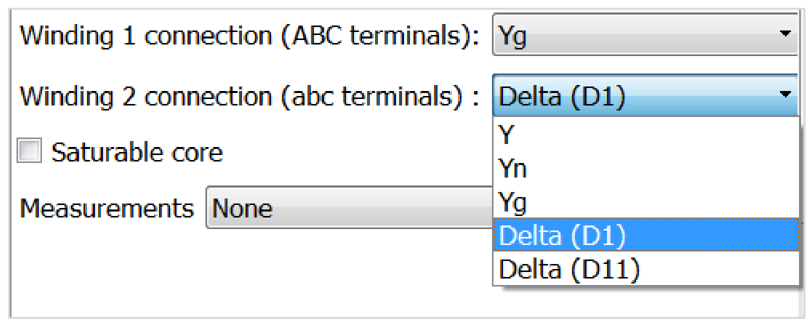
Transformers
Phase shifting



Three-Phase Transformer (Two Windings)







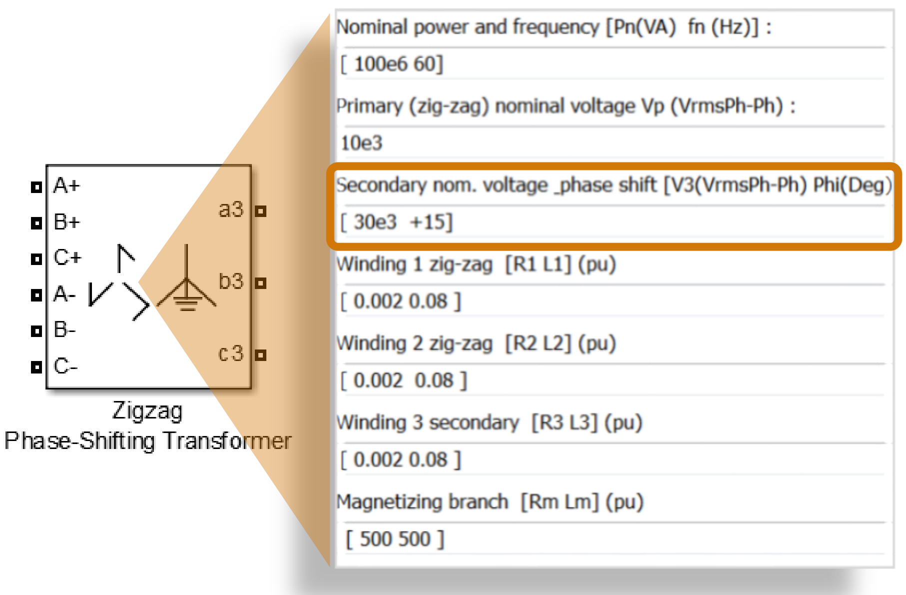
D1: Adds 30° to the phase (lead)
D11: Subtracts 30° from the phase (lag)

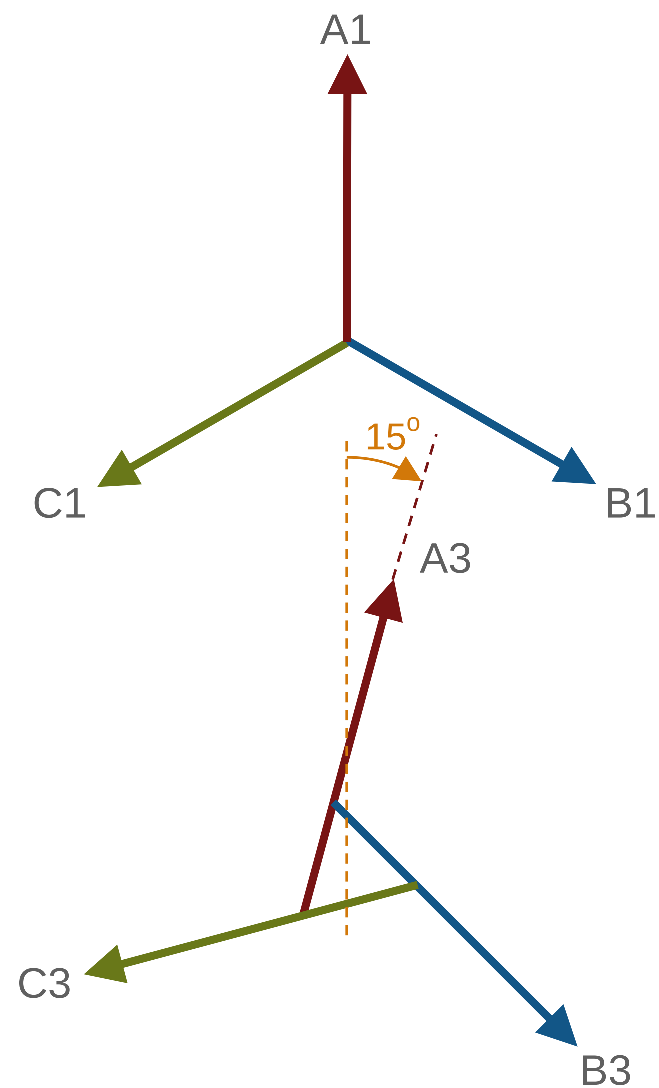
```
>> transformer_phaseshifting
```

Transformers

Zig-zag transformers

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

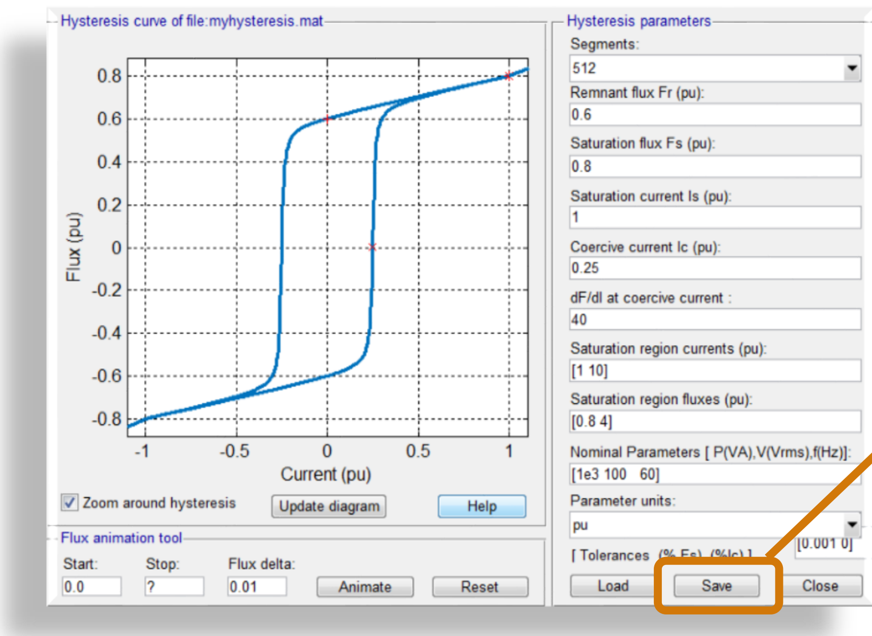


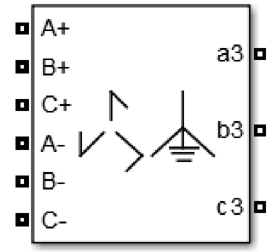


Transformers

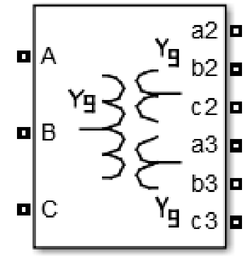
Saturation and hysteresis

powergui

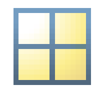




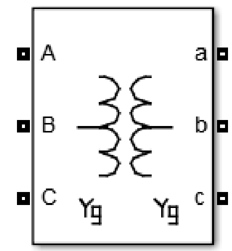
Zigzag
Phase-Shifting Transformer



Three-Phase
Transformer
(Three Windings)



MAT-file

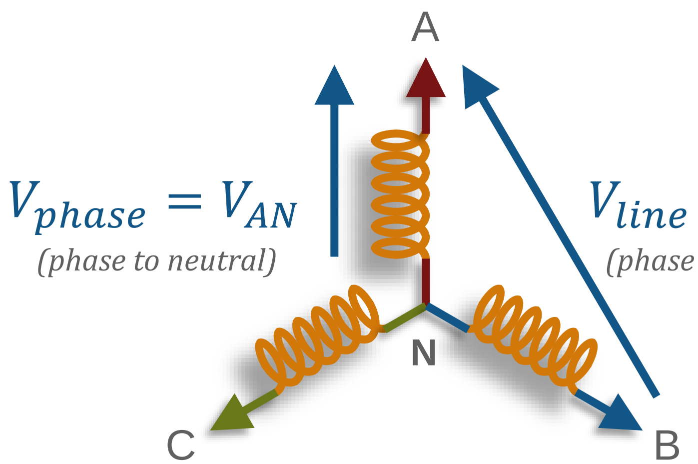


Three-Phase
Transformer
(Two Windings)

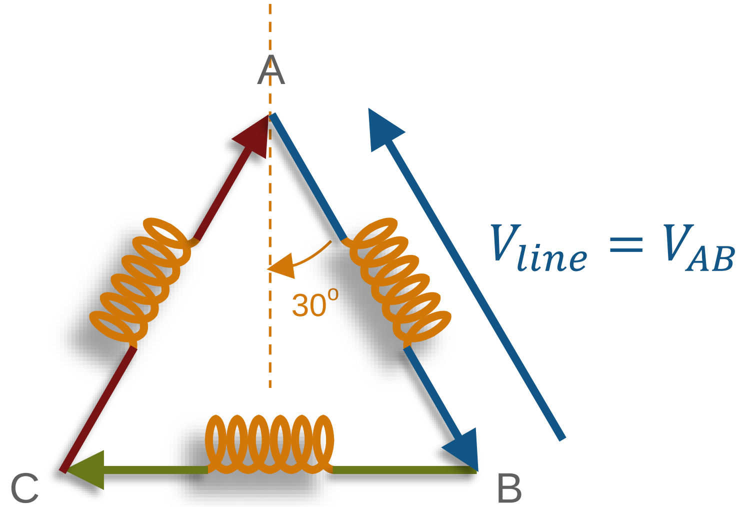
When modeling hysteresis it is recommended to use a discrete solver for better accuracy and simulation performance

```
>> transformer_saturation
```

Star vs. delta connections



Star



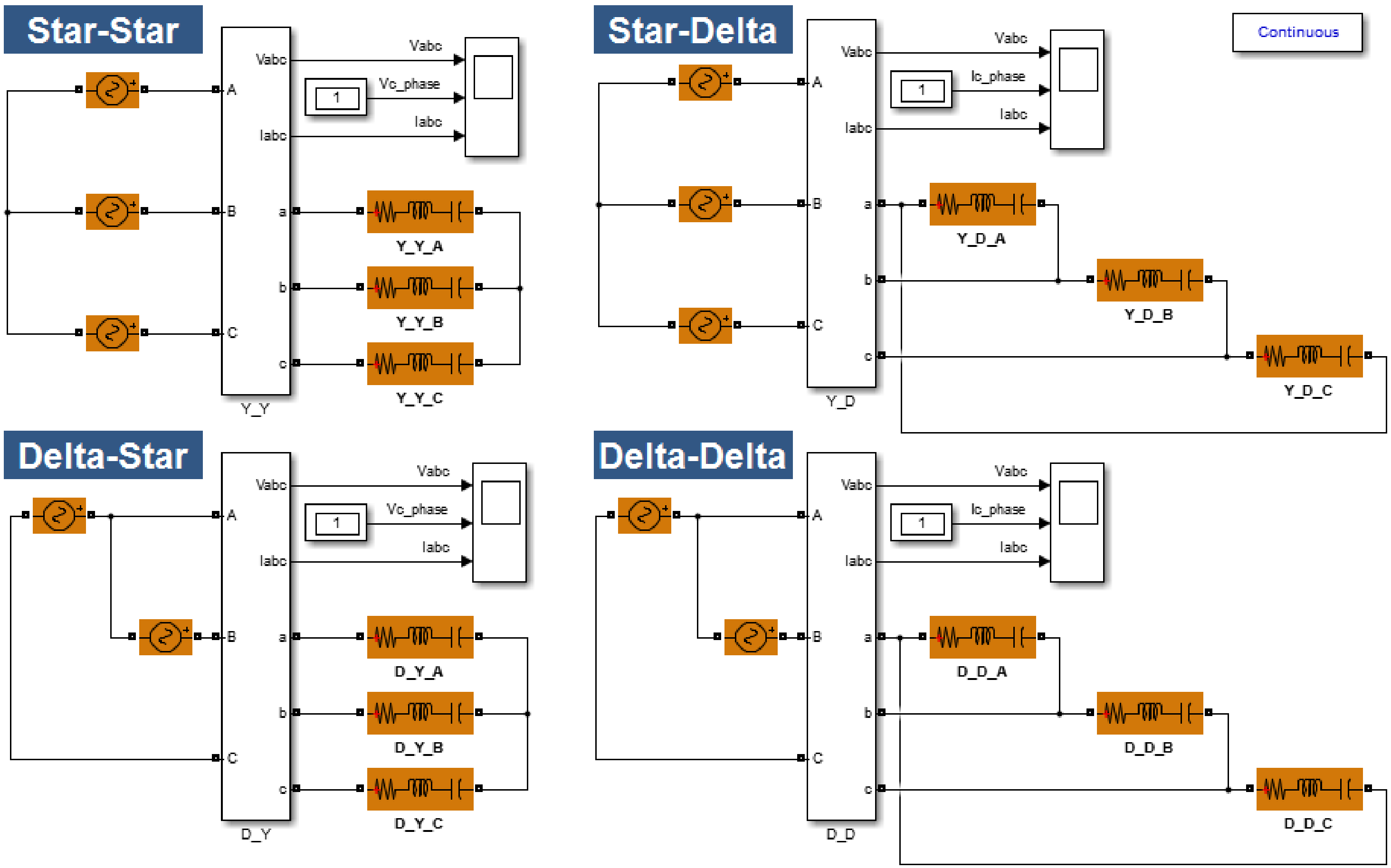
Delta

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

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

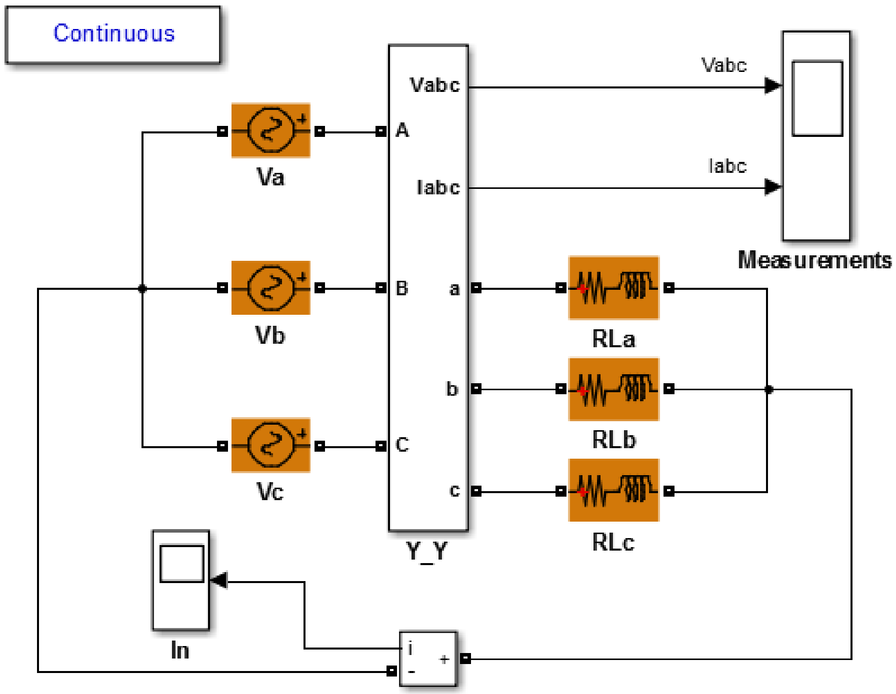
$$V_{peak} = \sqrt{2}\, V_{rms}$$

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.

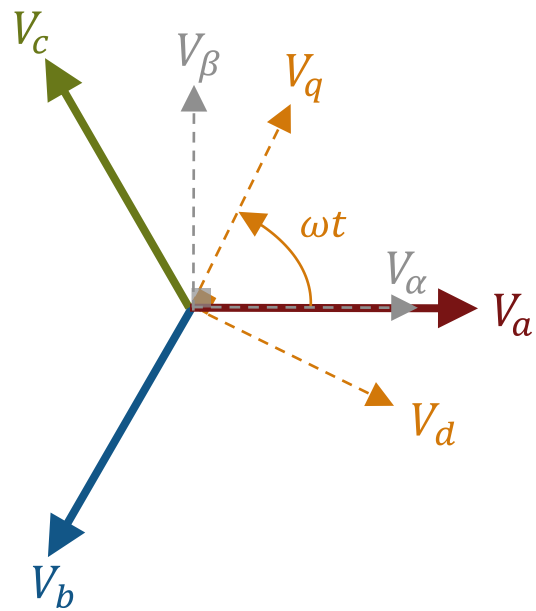
$$I_a + I_b + I_c = I_n$$

```
>> floating_neutral
```

Reference frame transformations

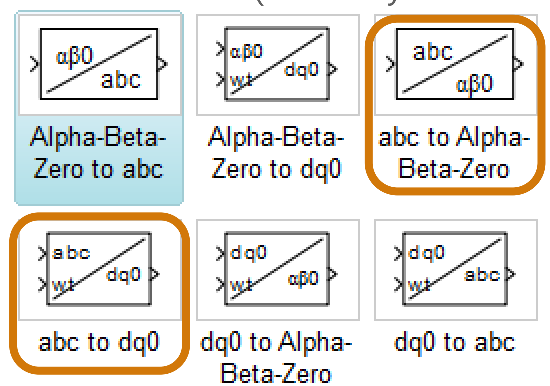
Park and Clarke transforms

$$V_\alpha = \frac{2}{3}V_a - \frac{1}{3}V_b - \frac{1}{3}V_c$$
$$V_\beta = \frac{1}{\sqrt{3}}V_b - \frac{1}{\sqrt{3}}V_c$$
$$V_0 = \frac{1}{3}V_a + \frac{1}{3}V_b + \frac{1}{3}V_c$$



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
```