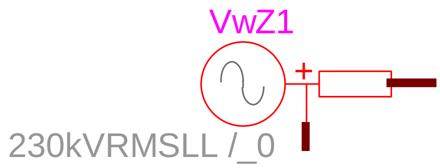
AC voltage source and impedance



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1 Available versions

This is a 3-phase device. It provides an ideal voltage source model behind a Thevenin impedance.

1.1 Default color coding

The default color coding changes the device line color to red to indicate that the source is active in steady-state. The source is active in steady-state when its start time is smaller than 0.

1.2 Pins

The default version of "V with Impedance" has two 3-phase pins. The user can optionally connect to the pin "k" (k-pin) before the impedance. The m-pin is the one on the right of the impedance and connecting to network side.

Two other options are available:

1. The 3-phase ground pin of the source can be accessed. This option provides to the user 3 wires that can be connected as needed. If the wires are not connected to any other devices, the source will become floating. By default, when this 3-phase ground pin is not shown, these 3 wires are connected to the ground in the Y-ground configuration.
2. The 1-phase neutral pin of the source can be accessed. This pin allows to access the neutral point of the source connected in Y configuration. The user may connect 1-phase devices to the neutral pin. By default the source is connected in the Y-ground configuration (the neutral pin is grounded).

1.3 Parameters

There are two main data sections (tabs) in this device.

1.3.1 Data tab

The first tab allows entering a cosine source equation for the ideal voltage source behind the Thevenin impedance:

$v(t) = V_m \cos(\omega t + \theta)$

$\omega = 2\pi f$

- ❑ Positive sequence voltage data
  This option allows to enter only the positive sequence voltage and the source is assumed balanced with the positive sequence voltage being the voltage of phase-A.
- ❑ Generic 3-phase voltage source data
  This option allows to enter a balanced or unbalanced voltage source by specifying all phase voltages.
- ❑ V_m amplitude of the cosine waveform, any value, default units are V. Any other unit selections will be internally converted to V.
- ❑ f frequency in Hertz, must be greater than 0.
- ❑ θ phase angle, default units are degrees.
- ❑ t_{start} start time, if t < t_{start} the source is shorted. If t_{start} < 0, the source is active in the steady-state solution.
- ❑ t_{stop} stop time, if t > t_{stop} the source is shorted. The stop time must be greater than the start time.
- ❑ Show 3-phase ground pin
  The 3-phase ground pin of the source can be accessed. This option provides to the user 3 wires that can be connected as needed. If the wires are not connected to any other devices, the source will become floating. By default, when this 3-phase ground pin is not shown, these 3 wires are connected to the ground in the Y-ground configuration.
- ❑ Show Neutral pin
  The 1-phase neutral pin of the source can be accessed. This pin allows to access the neutral point of the source connected in Y configuration. The user may connect 1-phase devices to the neutral pin. By default the source is connected in the Y-ground configuration (the neutral pin is grounded).
- ❑ Load-Flow solution device: see Section 2.

1.3.2 Impedance tab

The second section allows entering the source impedance. It is coupled RL-branch with an impedance matrix given by the series connection of R and L. In the steady-state solution notation the impedance matrix is:

$$\mathbf{Z} = \mathbf{R} + j\omega\mathbf{L} \qquad (1)$$

The matrices **R** and **L** can be entered directly or using sequence data. The matrices or sequence data can be also calculated from Short-circuit data input.
It is noted that one may consider this impedance as a generic impedance

$$\mathbf{Z} = \mathbf{R} + j\mathbf{X} \qquad (2)$$

where $\mathbf{R}$ is the real part and $\mathbf{X}$ is the imaginary part that can be negative.
The power variant Fortescue transformation matrix is used in EMTP to calculate the full matrices from sequence components. EMTP does not use sequence data in its solution.

1.3.2.1 Short-circuit data input

When this option is used the following options are available. The index 1 is used to designate positive-sequence, the index 2 is used to designate negative sequence and the index 0 is used to designate zero-sequence.

- ❑ Nominal voltage The nominal voltage of this device, line-to-line, $V_{th\,LL}$
- ❑ S base This is the S power base used for converting pu data
- ❑ S 3-phase short-circuit The 3-phase short-circuit power, S_3
- ❑ S 1-phase short-circuit The 1-phase short-circuit power, S_1

- ❑ I 3-phase short-circuit — The 3-phase short-circuit current, I_3
- ❑ I 1-phase short-circuit — The 1-phase short-circuit current, I_1
- ❑ X1/R1 ratio
  - This ratio allows to determine R1 (positive-sequence resistance), X_1 / R_1
  - R1=0 is when this ratio is unchecked
  - It is allowed to enter a negative ratio for X_1 being capacitive
- ❑ X0/R0 ratio
  - This ratio allows to determine R0 (zero-sequence resistance), X_0 / R_0
  - R0=0 is when this ratio is unchecked
  - It is allowed to enter a negative ratio for X_0 being capacitive
- ❑ Update R and L data

  When the use pushes this button, the sequence data tables for R and L (shown below button) are updated. This update occurs automatically when the user leaves this tab or pushes the OK button.

  In addition, the fields above the button and related to various input options are also calculated and updated.
- ❑ Update Short-Circuit data

  When the user pushes this button, the short-circuit data inputs (shown above button) are updated. The computations will be made assuming a balanced impedance and acceptable values. Impedance data can be entered directly by selecting the “Impedance data input” option.

Since it is assumed that the source impedance is balanced, the negative-sequence impedance is equal to positive-sequence impedance: $X_2 = X_1$, $R_2 = R_1$.

Rules:

1. It is possible to enter either S_3 or I_3.
2. When S_3 input option is checked, it is possible to also provide S_1 data and the I_1 input option is disabled.
3. If S_1 data is not provided (unchecked) it is assumed that the impedance $\mathbf{Z}$ is decoupled and all sequence impedances are equal.
4. When I_3 input option is checked, it is possible to also provide I_1 data and the S_1 input option is disabled.
5. X_1 / R_1 ratio must be entered to allow calculating R_1, otherwise $R_1 = 0$.
6. X_0 / R_0 ratio must be entered to allow calculating R_0, otherwise $R_0 = 0$.

The following formulas are used.

$$k_1 = \frac{X_1}{R_1} \tag{3}$$

$$k_0 = \frac{X_0}{R_0} \tag{4}$$

$$V_{th} = \frac{V_{th\,LL}}{\sqrt{3}} \tag{5}$$

where V_{th} is the nominal Thevenin voltage of the source as line-to-ground and positive sequence.

$$S_3 = 3 V_{th} I_3 \tag{6}$$

$$I_3 = \frac{S_3}{3V_{th}} = \frac{V_{th}}{\sqrt{R_1^2 + X_1^2}} = \frac{V_{th}}{\sqrt{X_1^2\left(1+\frac{1}{k_1^2}\right)}} \tag{7}$$

From (7) it is possible to compute

$$X_1 = \frac{V_{th}}{I_3\sqrt{1+\frac{1}{k_1^2}}} \tag{8}$$

and use (3) to calculate R_1. If the ratio k_1 is not provided (not selected) then

$$X_1 = \frac{V_{th}}{I_3} \tag{9}$$

When the power S_1 or the current I_1 are not specified, then $R_0 = R_1$ and $X_0 = X_1$.

When the power S_1 or the current I_1 is specified, in the case of S_1 input it is needed to first extract the current I_1 from

$$I_1 = \frac{S_1}{3V_{th}} \tag{10}$$

The short-circuit current I_1 is also found from

$$I_1 = \frac{3V_{th}}{|R_0 + jX_0 + 2R_1 + j2X_1|} = \frac{3V_{th}}{\sqrt{(R_0+2R_1)^2 + (X_0+2X_1)^2}} \tag{11}$$

If the ratio k_0 is not available ($R_0 = 0$) then

$$X_0 = \sqrt{\frac{9V_{th}^2}{|I_1|^2} - (2R_1)^2} - 2X_1 \tag{12}$$

It assumed that the term in the root square function is positive, since an error will be flagged otherwise and EMTP will assume $X_0 = X_1$.
If the ratio k_0 is specified, according to (11):

$$\left(k_0^2+1\right)R_0^2 + \left(4R_1 + 4k_0X_1\right)R_0 + 4R_1^2 + 4X_1^2 - \left(\frac{3V_{th}}{|I_1|}\right)^2 = 0 \tag{13}$$

The above equation has two solutions for R_0 and only the positive solution will be retained. If it is found that a real number solution is not possible, an error condition will occur and it will be assumed that $R_0 = R_1$. Once R_0 has been found, X_0 can be calculated from (4).

1.3.2.2 Impedance data input

This option allows to input impedance data directly.

1.3.3 IC tab

On the third data tab (IC) it is allowed to enter manual initial conditions for inductance current.

1.4 Netlist format

This device allows method-based scripting. The object data and methods are described in the script file referenced by the device Script.Open.Dev attribute.

Example of data:

```
_Vsine_z;SM_BUS4a;6;2;s9a,BUS4a,
13.8kVRMSLL,60,0,-1,1E15,PVbus:SM_BUS4,1,1,1Ohm,1,0,?v,?i,?p,
_Vsine_z;SM_BUS4b;6;2;s9b,BUS4b,
13.8kVRMSLL,60,-120,-1,1E15,0,?v,?i,?p,
_Vsine_z;SM_BUS4c;6;2;s9c,BUS4c,
13.8kVRMSLL,60,120,-1,1E15,0,?v,?i,?p,
0.0019044 0.0019044 0.0019044
```

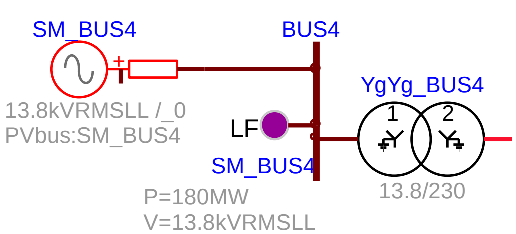
0.1228338 0.7279569 0.2119093

Field	Description
_Vsine_z	Part name
SM_BUS4a	Instance name, any name.
6	Total number of pins
2	Number of pins given in this data section
s9a	Signal name connected to k-pin (positive), any name
BUS4a	Signal name connected to m-pin, any name
V_m	Amplitude
F	frequency, default is 60
Θ	Phase angle
t_{start}	Start time
t_{stop}	Stop time
PVbus:SM_BUS4	Load-Flow solution device name (type:name format)
1	Resistance data units
1	Sequence data selection for Resistance
1	Inductance data units
1	Sequence data selection for Inductance
0	Initial current on this phase
?v	Request for voltage scope, sent to scope group vb (branch voltages), optional
?i	Request for current scope, sent to scope group ivs (voltage source currents), optional
?p	Request for power scope, sent to scope group p (branch power), optional
Phase b data	Same as for phase a, except last value is "initial current on phase b" followed by optional scopes on this phase
Phase c data	Same as for phase b
R matrix	Resistance matrix data: one line when sequence, 3 lines for matrix
L matrix	Inductance matrix data: one line when sequence, 3 lines for matrix

Source data fields are saved in ParamsA, ParamsB and ParamsC device attributes. The ModelData attribute is used to save the **R** and **L** matrices.
If there is an extra pin for source neutral (ground), its signal will appear after the k-pin signal and will be appended with the phase character.

2 Load-Flow model

This device does not participate (open-circuit) into the Load-Flow solution. It can reference a Load-Flow solution device (see "Load-Flow solution device" on the first data tab) for automatically retrieving its steady-state voltage phasors from the Load-Flow solution file.
The "Load-Flow solution device" can be an LF device or "BUS:". It establishes a link (a reference) for retrieving data from a load-flow solution. In this example (below) the source SM_BUS4 is disconnected in the load-flow solution and is referring to LF device SM_BUS4 for its load-flow solution data automatically retrieved by EMTP from the "Load-Flow solution data file" during the subsequent Steady-state and/or Time-domain solutions, when "Start from Load-Flow solution" is turned on in the EMTP>Simulation Options.



If the selection is "BUS:" the connected stator signal name (bus) will be used to retrieve data. *You must enforce the signal name by making it visible*. This method is optional; it is suggested to use the LF device naming approach shown above.

A load function ("Load now" button) is also available on the first data tab to manually load the steady-state voltage phasors and optionally eliminate the reference to the Load-Flow solution device.

3 Steady-state model

This device is represented in steady-state for automatic harmonic initialization. The harmonic initialization process must solve the network for all available source frequencies. The steady-state phasor value of a given source is only evaluated if the source frequency is equal to the solved frequency and $t_{start} < 0 < t_{stop}$. The source (behind the Thevenin impedance) is a short-circuit otherwise. This phasor is *independent* from the source frequency and is evaluated as:

$$v_{ss} = V_m \left(\cos\theta + j\sin\theta\right) \tag{14}$$

The Thevenin impedance equation is given by equation (1) and evaluated at each harmonic.

4 Initial conditions

Automatic initial conditions are found from the steady-state solution. Manual initial conditions can be provided for the self-inductance currents.

5 Frequency Scan model

The source automatically participates at each scan frequency according to equation (14). The source frequency is set to the scanned frequency. The source (behind the Thevenin impedance) participates only if $t_{start} < 0 < t_{stop}$, it is a short-circuit otherwise. The Thevenin impedance equation is given by equation (1) and evaluated at each frequency.

6 Time-domain model

The device is evaluated at each simulation time-point according to the equation:

$$v(t) = V_m \cos\left(\omega\left(t - t_{start}\right) + \theta\right) \qquad \text{for } t \geq t_{start} \tag{15}$$

The source is active (not a short-circuit) for $t_{start} \leq t \leq t_{stop}$. The source behind the Thevenin impedance becomes a short-circuit otherwise.
The Thevenin impedance matrix is discretized and solved according to EMTP integration methods.