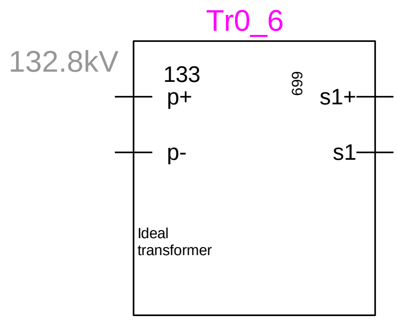
Ideal unit m-windings transformer



Jean Mahseredjian, 2019-12-28 22:19:00

1 Description

This device provides an ideal transformer unit with m secondary windings. It is using only 1-phase pins connectable to any General Signal. There are no losses in both primary and secondary windings. There is at least one winding on the secondary side. The addition of windings changes the drawing of this device and annotates for winding voltages. A two-winding-secondary case is presented in Figure 1. The first version is using the standard drawing, the second version is created by selecting “Show windings” on the Drawing data tab.

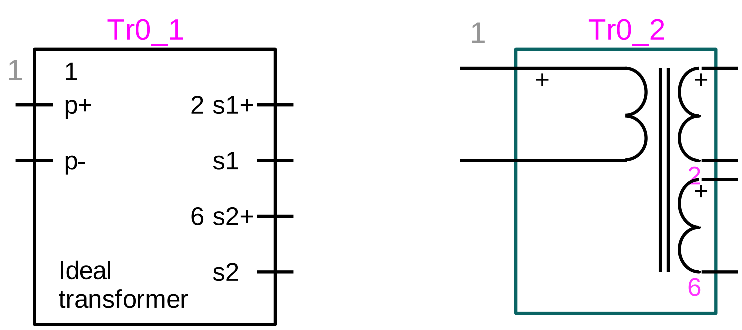


Figure 1 Two windings on secondary version

It is also possible to use this device as Voltage-controlled-voltage source or Amplifier.

2 Parameters and rules

The winding voltages are used to calculate the ratio of each winding in relation to the primary winding.

Since this is a pure (no losses) transformer model, some configurations may result in mathematically impossible conditions and should be avoided. EMTP will try to fix incorrect configurations by issuing warning messages. The users should avoid the warning messages.

It is not allowed to delete any pins or to change a pin Phase attribute.

2.1 Ratio tab

The first tab allows entering winding data:

- **Number of secondary windings**: any number of windings.
- **Primary winding voltage**: allows entering primary winding voltage.
- **Secondary voltage**: all secondary winding voltages are entered in this section. The number of rows is given by the “Number of secondary windings”. It is also allowed to insert winding voltages, by selecting a grid row and hitting the Insert key. This data is used only to calculate transformation ratios.
- **Power Amplifier Mode**: When this option is selected, this device becomes a power amplifier. The primary current is multiplied by the transformation ratio (gain), whereas the voltage remains the same on primary and secondary sides. This means that the power entering the secondary is amplified by the gain (secondary over primary voltage ratio) when it exits the primary.
- **Voltage Controlled Voltage Source Mode**: If selected the transformer primary winding will not drain any current and the device will act as a voltage controlled voltage source.
- **Control all Ratios**: used to control transformation ratios for all windings.
- **Control individual Ratios**: used to control individual ratios listed in the adjacent text field. Controlled windings (numbered from top to bottom) are listed using a space separator.

2.1.1 Control options

When any one of control options is selected, the transformer drawing changes to show a control bundle. The control bundle has a breakout for each controlled winding. The breakout is identified as Wx, where x is the winding number.

When a control signal has the value 0, it means that the previous or initial value of the corresponding winding ratio is preserved.

2.2 Misc tab

The second tab (Misc) is for numerical solution options:

- **Detect discontinuity due to a Ratio change**: If this option is selected, then any change in ratio will trigger a discontinuity and move into Backward Euler integration method when the user has selected “Trapezoidal and Backward Euler” numerical integration in Simulation Options. If this option is not selected then some cases may result into numerical oscillations. The current of a capacitor, for example, gives numerical oscillations when its voltage is suddenly changed.
- **Resolve network equations after a Ratio change**: If this option is selected, then all network equations will be resolved when any transformer winding is given a change of ratio. This option is applicable only when “Simultaneous switching” is turned on in the current design. The consequence is that a change in ratio is immediate in transformer equations and there is no time-step delay with the corresponding control signal.

3 Netlist format

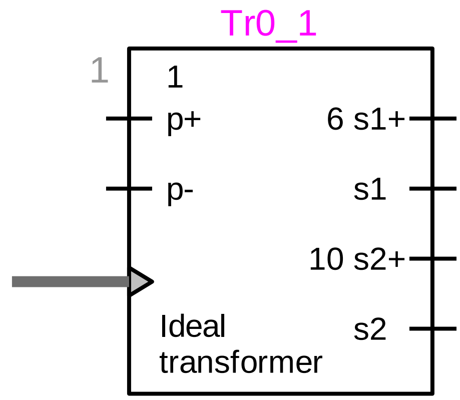


Figure 2 Example

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.

The Netlist of the device shown in Figure 2 is given by:

```
_Tr0;Tr0_1;8;8;Pp,Pm,TOPW1,BOTW1,TOPW2,BOTW2,s12W2,s12W1,
1,2,1,0,0,0,0
6
10
```

Field	Description
_Tr0	Part name
Tr0_1	Instance name, any name.
8	Total number of pins
8	Number of pins given in this data section
Pp	Signal name connected to i-pin
Pm	Signal name connected to j-pin
TOPW1	Signal name connected to k1-pin (s1+)
BOTW1	Signal name connected to m1-pin (s1)
TOPW2	Signal name connected to k2-pin (s2+)
BOTW2	Signal name connected to m2-pin (s2)
s12W2	Control signal name for controlling winding 2 ratio
s12W1	Control signal name for controlling winding 1 ratio
1	Voltage with units on the primary side
2	Number of windings on the secondary
1	Voltage units on the secondary side
0	1 means that Detect discontinuity is on
0	1 means Resolve network equations is on
0	1 means that the device is used as a voltage-controlled-voltage source
0	1 means Power Amplifier Mode is used
Winding voltages	One winding voltage in each row, as many rows as windings on secondary

The number of signals on the secondary side is twice the number of windings.

The comma separated data fields are saved into the ParamsA device attributes. The secondary winding voltages are saved into the ModelData attribute.

4 Steady-state model

The load-flow model is identical to the steady-state model.

4.1 Transformer with multiple secondary windings

The basic formulation is similar to the “ideal unit” transformer device, only now there are as many voltage equations as windings. For the two-winding case shown in Figure 3, the voltage equations are given by:

$$v_{k1} - v_{m1} - g_1 v_i + g_1 v_j = 0 \quad (1)$$

$$v_{k2} - v_{m2} - g_2 v_i + g_2 v_j = 0 \quad (2)$$

where g_1 is the gain (secondary over primary) of winding 1 and g_2 is the gain of winding 2. The current equation of the current flowing from i-pin to j-pin is now given by:

$$i_{ij} = -g_1 i_{k1m1} - g_2 i_{k2m2} \quad (3)$$

This means that the currents entering the nodes due to this device are given by:

$$i_{k1} = i_{k1m1} \quad (4)$$

$$i_{m1} = -i_{k1m1} \quad (5)$$

$$i_i = -g_1 i_{k1m1} - g_2 i_{k2m2} \quad (6)$$

$$i_j = g_1 i_{k1m1} + g_2 i_{k2m2} \quad (7)$$

$$i_{k2} = i_{k2m2} \quad (8)$$

$$i_{m2} = -i_{k2m2} \quad (9)$$

4.2 Voltage Controlled Voltage Source Mode

If the device is used as a Voltage-controlled-voltage source then its current on primary side is simply given by:

$$i_{ij} = 0 \quad (10)$$

The voltage equations remain the same as above.

4.3 Power Amplifier Mode

If this device is used as a power amplifier (two ports) then the voltage equation is:

$$v_{k1} - v_{m1} - v_i + v_j = 0 \quad (11)$$

and the current equation is:

$$i_{ij} = -g_1 i_{k1m1} \quad (12)$$

where according to (11) the voltages on input and output ports are equal ($v_{k1m1} = v_{ij}$), but the current on primary side (ij-port) is multiplied by the gain g (secondary over primary). This results into amplification of power from port k1m1 to port ij.

It is also possible to use multiple secondary ports, in which case the voltage equations (two ports on secondary) are given by:

$$v_{k1} - v_{m1} - v_i + v_j = 0 \quad (13)$$

$$v_{k2} - v_{m2} - v_i + v_j = 0 \quad (14)$$

The current equation is the same as (3). This means that the power of ij-port is the sum of powers from k1m1 and k2m2 ports after multiplication by individual gains. This also means that all port voltages are equal. If the user imposes inconsistent conditions, such as connection of ideal voltage sources to ports, then EMTP may take corrective actions that may not correspond to the above formulas. The user should avoid connecting ideal voltage sources to amplifier ports on secondary side.

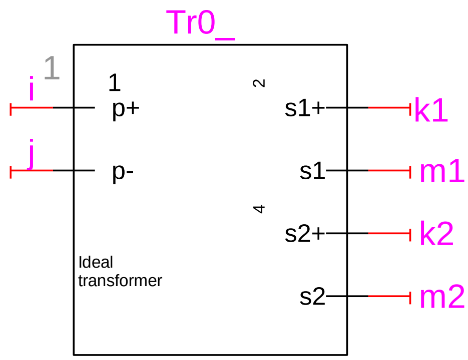


Figure 3 Ideal transformer with two secondary windings

5 Load-Flow model

Identical to the steady-state version.

6 Frequency Scan model

Identical to the steady-state version.

7 Time-domain model

The model equations are the same as for the steady-state solution. The time-domain model allows controlling the transformer ratios, Voltage-controlled-voltage source gains or power amplifier gains by selecting the optional control options (**Control all Ratios** or **Control individual Ratios**).