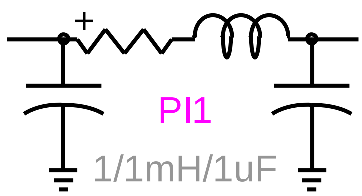
PI device



Jean Mahseredjian, 4/22/2013 7:11:00 AM

1. Available versions

Available versions are shown in Figure 1-1. This device can be multiphase, 1-phase or 3-phase. The multiphase version is the generic version.

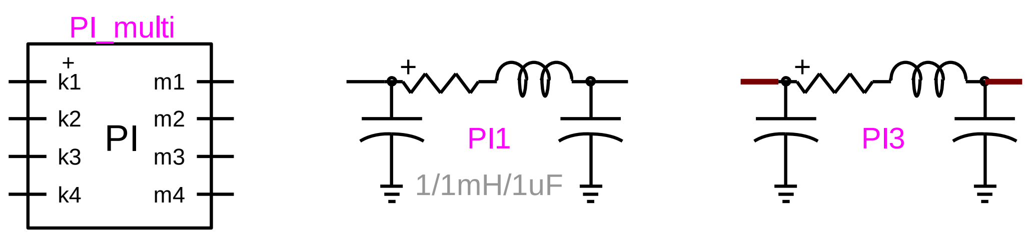


Figure 1-1 Available versions

The electrical equivalent of the 3-phase case is presented in Figure 1-2. It is assumed that the capacitances on the k-side are identical to the capacitances on the m-side. Although usually symmetric, it is allowed to enter non-symmetric matrices. The RL branches are also coupled.

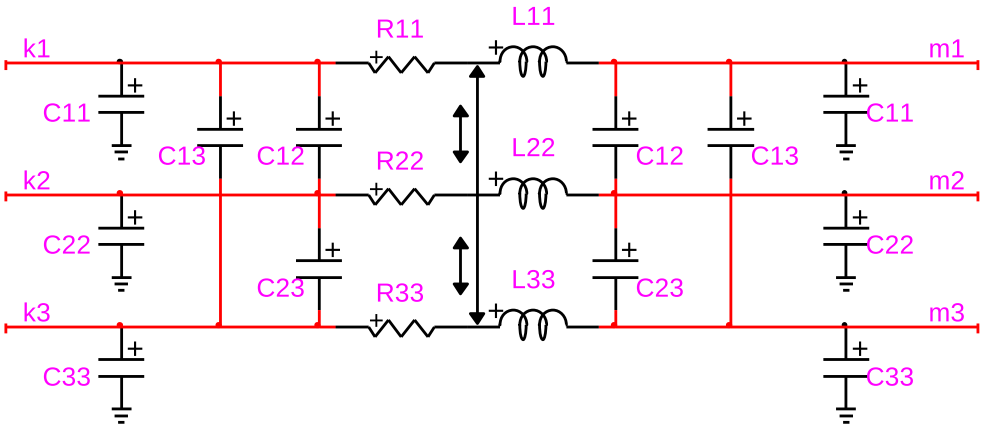


Figure 1-2 The electrical equivalent of the 3-phase version

1.1. When changing phases

It is acceptable to change the line type attached to the 1-phase or 3-phase versions of this device. Although it can be ambiguous and should be used with care, EMTP tries to accommodate by applying the following rules.

- When the device is in its 1-phase state and its signal is changed to 3-phase, but the device is not double-clicked (followed by a click on the OK button), balanced conditions are assumed and the 1-phase quantities are automatically propagated to the new phases. Coupling matrices become diagonal.
- When the device is in its 3-phase state and its signal is changed to 1-phase, but the device is not double-clicked (followed by a click on the OK button), phase-a quantities are automatically retained in EMTP for the 1-phase version.

1.1. The generic version of PI

1.1.1. Parameters

The generic version of PI has at least two pins (left k-side and right m-side). Any of the pins can be connected to the Ground device. The parameters are:

- R — resistance matrix
- L — inductance matrix, it also allowed to enter B matrix ($B=L^{-1}$)
- C — capacitance matrix, zero value cells mean open-circuit
- G — conductance matrix, zero value cells mean open-circuit
- i_0 for L — manual initial current vector for the inductances
- v_0 for C (k side) — manual initial voltage vector for capacitances to ground on the k-side
- v_0 for C (m side) — manual initial voltage vector for capacitances to ground on the m-side

The capacitance matrix C and the conductance matrix G are optional in the multiphase version.

In addition to entering matrices directly, the 3-phase version allows entering “Sequence Data”. EMTP uses the following equation to convert sequence data into an actual coupled matrix (with self for diagonal cells and mutual for off-diagonal cells):

$$R_{self} = \frac{(n-1)R_1 + R_0}{n} \tag{1}$$

$$R_{mutual} = \frac{R_0 - R_1}{n} \tag{2}$$

where n is the number of phases (3 for 3-phase), R_1 stands for positive sequence and R_0 is for zero sequence. The same equations are used for L and C.

Note that the entered capacitance matrix is internally divided by 2 and placed on each side of the PI-section. This is also true when "Sequence Data" input is used.

It is noticed that the entered capacitance matrix is actually the nodal admittance (capacitance) matrix. If the notation of Figure 1-2 is kept then the matrix corresponding to the left hand side (same as on the right hand side) is actually

$$\frac{C}{2} = C' = \begin{bmatrix} C'_{11} & C'_{12} & C'_{13} \\ C'_{21} & C'_{22} & C'_{23} \\ C'_{31} & C'_{32} & C'_{33} \end{bmatrix} = \begin{bmatrix} C11 + C12 + C13 & -C12 & -C13 \\ -C21 & C22 + C21 + C23 & -C23 \\ -C31 & -C32 & C33 + C31 + C32 \end{bmatrix} \tag{3}$$

The G matrix (not shown in Figure 1-2) is connected in parallel with the C matrix. It is also internally divided by 2 and placed on each side of the PI-section. Its definition is identical to the one given by equation (3).

1.1.2. Generic rules

It is allowed to enter symmetric, non-symmetric and diagonal matrices.
At least one matrix, R, L or C should be non-zero. It is not allowed to create a short-circuit branch.
Some matrices or some combinations of matrices may create numerical instability problems. There is no specific testing in EMTP for such conditions and the user must verify the physical significance.

It is not allowed to delete pins.

1.1.3. 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.

The Netlist format is related to the device version. The generic multiphase "PI multiphase" version format is given below.

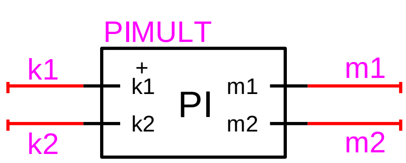


Figure 1-3 Example of a 2-phase PI

This is a 2-phase example according to Figure 1-3:

```
_PI;PIMULT;4;4;k1,k2,m1,m2,
-2,1,1mH,1uF,1,1,1,1,
1 0
0 1
1 0
0 1
1 0
0 1
0 0 0
```

```
0 0 0
```

Field	Description
_PI	Part name. PI is the standard version. PIB is when the B matrix is used.
PIMULT	Instance name, any name.
4	Total number of pins
4	Number of pins given in this data section
k1	Signal name connected to k-pin, first pin from top to bottom
k2	Signal name connected to k-pin, second pin from top to bottom
m1	Signal name connected to m-pin, first pin from top to bottom
m2	Signal name connected to m-pin, second pin from top to bottom
-2	Number of phases, the negative sign means generic multiphase version
1	Units for the R matrix
1mH	Units for the L matrix
1uF	Units for the C matrix
1	Units for initial current i_0 for L
1	Units for initial voltage v_0 for C (k side)
1	Units for initial voltage v_0 for C (m side)
1	1 means that the C matrix is selected, the G matrix is not selected 2 means that C and G matrices are not selected 3 means that the C matrix is not selected, the G matrix is selected 4 means that the C and G matrices are selected
1S	Units for the G matrix, will appear only if the G matrix is selected
R	Resistance matrix rows, first in the ModelData attribute
L	Inductance matrix rows
C	Capacitance matrix rows, if selected
G	Conductance matrix rows, if selected
Initial conditions	Initial conditions rows listed as appearing in the IC data tab: current, voltage, voltage

The multiphase device data fields are saved in ParamsA (for comma separated section) and ModelData attributes.

A 3-phase version example is given by:

```
_PI;PI3phasea;6;2;s3a,s4a,
3,1,0,1mH,0,1uF,0,1,1,1,1,?v,
_PI;PI3phaseb;6;2;s3b,s4b,
?v,
_PI;PI3phasec;6;2;s3c,s4c,
?v,
1 0 0
0 1 0
0 0 1
1 0 0
0 1 0
0 0 1
1 0 0
0 1 0
0 0 1
0 0 0
0 0 0
0 0 0
```

In this version it is allowed to request a branch voltage scope “?v” (from k-node to m-node). The extra attributes ParamsB and ParamsC are used to save coma separated data for phases a and b. Phase a holds

common data. The code 3 (first after signals in ParamsA) stands for 3-phase version. The matrix units are followed by an extra code: 0 means matrix usage and 1 means sequence data usage. The ModelData contents are identical to the multiphase version.
The 1-phase version is identical to the 3-phase version with the number of phases set to 1.

1.2. Other versions

The standard library also provides modified symbol versions of PI. These are conveniently available to the user and the user may create other versions using the “Symbol Editor”.

2. Steady-state model

The PI device is represented in steady-state for automatic harmonic initialization and frequency scan solutions. The steady-state model is an impedance at the given frequency. The series part impedance is given by:

$$\mathbf{Z}_{RL} = \mathbf{R} + j\omega\mathbf{L} \tag{4}$$

The shunt (capacitance) admittance is given by:

$$\mathbf{Y}_{C} = j\omega\mathbf{C} \tag{5}$$

Bold characters are used to denote matrices.

3. Initial conditions

Automatic initial conditions are found from the steady-state solution. Manual initial conditions can be provided for the self-inductance currents and for the voltages of the capacitors connected to ground.

4. Frequency Scan model

Similar to the steady-state. The branch impedance is found at each frequency.

5. Time-domain model

The device is discretized according to the integration time-step and solved at each simulation time-point.