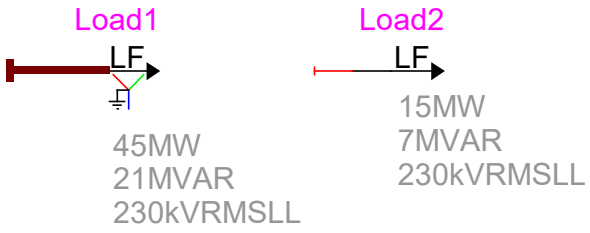
PQ load with load-flow (LF)



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1 Description

This device models a 1-phase or a 3-phase load. The 3-phase version of this device is a subcircuit containing three 1-phase devices. It can participate in the load-flow (LF) solution and all other solution options.

1.1 When changing phases

- When the device is in its 3-phase state and its signal is changed to 1-phase, phase-A quantities are automatically retained for the 1-phase version.
- When the device is in its 1-phase state and its signal is changed to 3-phase, balanced positive sequence conditions are assumed and phase-A data is copied into other phases.

1.2 Parameters

The generic version of “PQ load” device allows entering the following parameters:

- **Nominal Voltage** ($V_{load_{nominal}}$) is the nominal voltage of the load.
- **Active Power P** ($P_{nominal}$) is the load active power at nominal voltage.
- **Reactive Power Q** ($Q_{nominal}$) is the load reactive power at nominal voltage.
- **Np** is the coefficient representing the dependency of load active power on voltage. It is used for both the Load-Flow and Steady-State solutions. For the values of **Np** equal to 0, 1 and 2 we obtain the behavior at constant power, at constant current and constant impedance, respectively.

- **Nq** is the coefficient representing the dependency of load reactive power on voltage. It is used for both the Load-Flow and Steady-State solutions. For the values of **Nq** equal to 0, 1 and 2 we obtain the behavior at constant power, at constant current and constant impedance, respectively.
- **Frequency** is frequency at which the data is entered. Used for data conversion.

1.2.1 Show Ground Pin option

This option is for allowing access to the ground pin of the device in the 1-phase version. If the Ground pin is not shown, then the load is automatically connected to ground. If the Ground pin is made available by checking the "Show Ground pin" option, then it becomes ungrounded and allows to build various configurations, such as addition of extra elements in series with the load.

1.2.2 Positive sequence data input selector

This option is only available in the 3-phase variant of the device. If positive sequence data input is selected, only phase-A data input is allowed, the load is assumed balanced and phase-A data is copied into other phases. If generic 3-phase data input is selected instead, data can be entered for each phase individually.

1.2.3 Balanced option

This option is only available in the 3-phase variant of the device when generic 3-phase data input is selected. If unchecked, it becomes possible to provide different data for different phases. Otherwise, phase-A data are automatically copied into other phases.

1.2.4 Connection type selector

This selector is only available in the 3-phase variant of the device and allows the user to select the desired 3-phase load configuration: Wye (Y), Wye grounded (Yg) or Delta (D). In case of Wye connection, the neutral pin is made available, which allows to connect extra elements. In case of Delta connection, the entered active and reactive powers are considered phase-to-phase values.

1.2.5 Scopes

The scopes are available using the following format:
Device_name.R, Device_name.L or Device_name.C
Device_name is the generic device name. The L or C scopes are presented depending if the load is inductive or capacitive. For the 3-phase loads, the format changes to show subcircuit contents, as follows:
Device_name/Load_a.R (same for L or C).
Load_a, Load_b and Load_c are used for Wye connected loads, whereas Load_ab, Load_bc, Load_ca are used for Delta connections.
If P and/or Q powers are set to zero, then the corresponding scopes will not appear.

1.3 Rules

The default circuit calculated by EMTP® for Steady-state and Time-domain simulations is the parallel combination of equivalent R, L and C branches. The following rules are enforced (in the 3-phase variant, these rules apply to individual phase loads):

- If P=0 and Q=0 this device becomes disconnected (infinite impedance) in all solution methods.
- If $P \geq 0$ and $Q > 0$ an RL series equivalent can be optionally used in Frequency scan, Steady-state and Time-domain solutions.

The RL series equivalent is calculated using:

$$R + j\omega L = \frac{V_{load}^2}{P_{load} - jQ_{load}} \quad (1)$$

The resistance value in the parallel combination is given by:

$$R = \frac{V_{load}^2}{P} \quad (2)$$

When the entered $Q > 0$, the inductance value in the parallel combination becomes:

$$L = \frac{V_{load}^2}{\omega Q_{load}} \tag{3}$$

When the entered $Q < 0$, the capacitance value in the parallel combination is found from:

$$C = \frac{|Q_{load}|}{\omega V_{load}^2} \tag{4}$$

The parameters V_{load}, P_{load} and Q_{load} are determined according to the simulation options (see below).

2 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.

A Netlist example for the default device data in 1-phase case is given below:

```
_PQload;Load1;1;1;s1,
230kVRMSLL,15MW,0,7MVAR,0,60,1,0,?i,?p,
```

Field	Description
PQload	Part name, including code to account for user changes
Load1	Instance name, any name
1	Total number of pins
1	Number of pins given in this data section, this number is 2 when the ground pin is used
s1	Signal name connected to k-pin (positive), any name
230kVRMSLL	Voltage
15MW	Power P
0	Np
7MVAR	Power Q
0	Nq
60	Frequency
1	Retrieve Load-Flow solution when 1
0	Use RL series model when 1
Current scope	?i is the request for current scopes on all branches
Power scope	?p is the request for voltage scopes on all branches

The three-phase versions are based on subcircuits with 1-phase devices.

3 Load-Flow model

The Load-Flow model equations of this device are given by:

$$P_{specified} = P_{nominal}\left[\frac{V_{LF}}{V_{load_{nominal}}}\right]^{Np} \quad (5)$$

$$Q_{specified} = Q_{nominal}\left[\frac{V_{LF}}{V_{load_{nominal}}}\right]^{Nq} \quad (6)$$

The $P_{specified}$ and $Q_{specified}$ powers become the Load-Flow constraints for this device. The voltage V_{LF} is the actual voltage magnitude solution on the load bus. V_{LF} is found from the load-flow solution and may differ from $V_{load_{nominal}}$.

At the end of the Load-Flow solution, this device saves its voltages and currents into the “Load-Flow solution data file”.

If this device becomes disconnected from the rest of the network, then its power constraints cannot be enforced and the Load-Flow solution will not converge.

4 Steady-state model

The model impedance is found using equations (1) to (4).

If the “Retrieve Load-Flow solution data” checkbox is checked:

1. The voltage V_{LF} is found in the Load-Flow solution file “Load-Flow solution data file”.
2. Equations (5) and (6) are used to find $P_{specified}$ and $Q_{specified}$, then $P_{load} = P_{specified}$ and $Q_{load} = Q_{specified}$ in (1) to (4). When Np and Nq are zero, then $P_{specified} = P_{nominal}$ and $Q_{specified} = Q_{nominal}$.

The above option is activated only when a previously saved “Load-Flow solution data file” exists and “Start from Load-Flow solution” is turned on in the Simulation Options.

When the “Retrieve Load-Flow solution data” checkbox is not checked, the following conditions are applied in (1) to (4):

1. $V_{load} = V_{load_{nominal}}$.
2. $P_{load} = P_{nominal}$ and $Q_{load} = Q_{nominal}$.

5 Frequency Scan model

The equivalent load impedance is calculated at each frequency.
The following conditions are applied in (1) to (4):

1. $V_{load} = V_{load_{nominal}}$.
2. $P_{load} = P_{nominal}$ and $Q_{load} = Q_{nominal}$.

6 Time-domain model

The load is modeled as an RLC device.

The R, L or C values are calculated as in the Steady-State solution.
If the Steady-State solution does not precede the Time-domain solution, then the following conditions are applied in (1) to (4):

1. $V_{load} = V_{load_{nominal}}$.
2. $P_{load} = P_{nominal}$ and $Q_{load} = Q_{nominal}$.