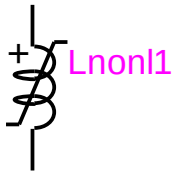
# L nonlinear device

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Jean Mahseredjian, 4/10/2016 2:43 PM

## 1 Available versions

The “L nonlinear device” device accepts both 1-phase and 3-phase signals. The 3-phase version is the equivalent of 3 decoupled branches (one for each phase). The only difference is that in the 3-phase version it is allowed to request scope data for the extra phases.

## 1.1 When changing phases

It is allowed to switch from 1-phase to 3-phase or from 3-phase to 1-phase. The user must only verify the scope requests according to requirements.

## 2 Description

This device is based on a piecewise linear representation of the flux-current inductor characteristic as shown in Figure 1. Linear interpolation is used between the data points.

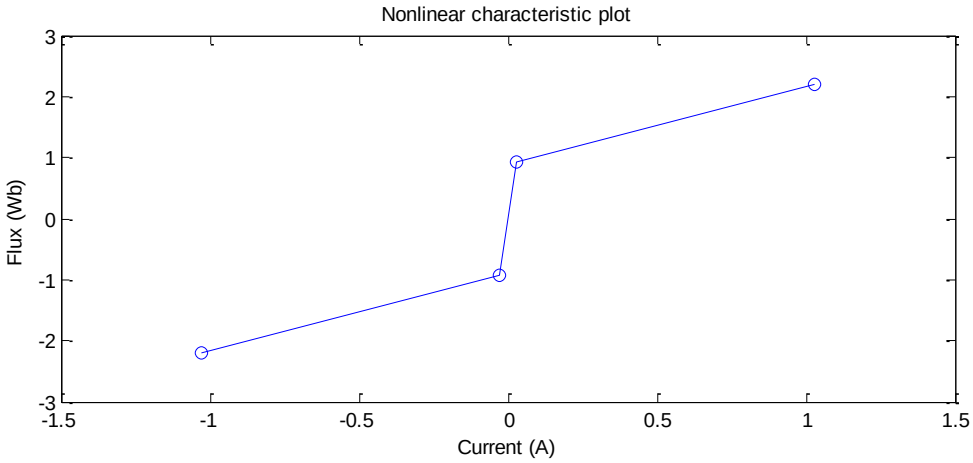


**Figure 1 Example of nonlinear inductance function**

## 2.1 Parameters

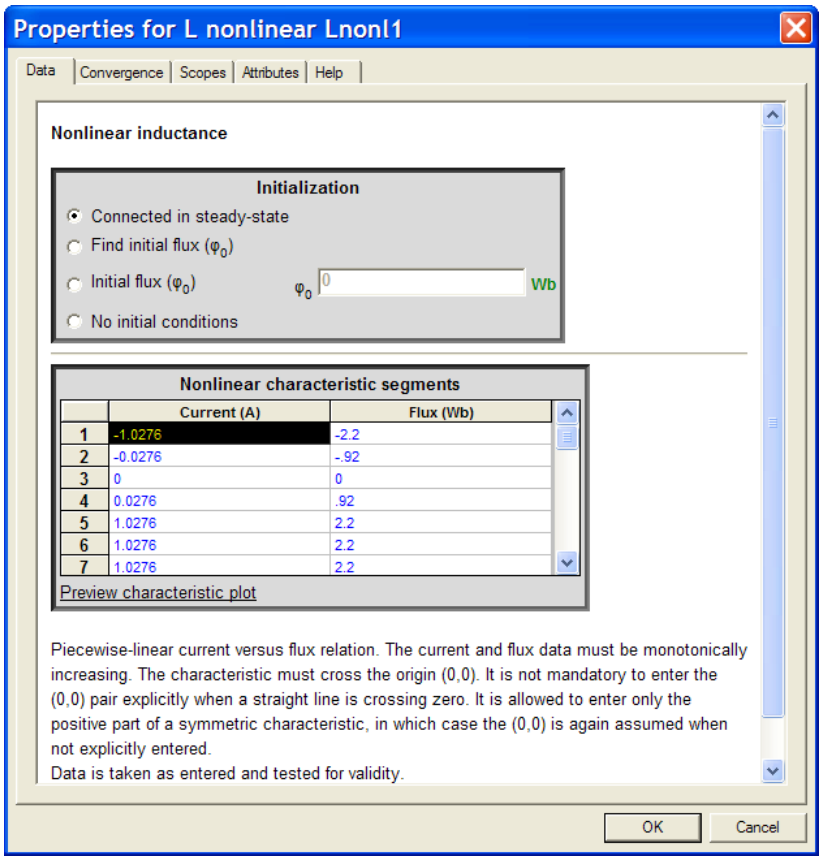


**Figure 2 The Data tab**

The Data tab (shown in Figure 2) allows selecting initialization options and entering the nonlinear characteristic.

- **Initialization**: allows selecting the steady-state initialization options

- **Connected in steady-state** means that a linear model is used for the linear harmonic steady-state solution. It is calculated from the slope of the first positive characteristic segment as being the inductance values $L_{ss}$.
- **Find initial flux** ($\varphi_0$): the device is disconnected in the steady-state solution. After the steady-state solution EMTP finds the flux $\varphi_0$ (flux at t=0) from the steady-state voltage phasor integral at t=0.
- **Initial flux** ($\varphi_0$): this option allows to select manually the initial flux $\varphi_0$ at t=0. This value can be any non-zero number. If zero is specified then there are no initial conditions. If a parameter is entered instead of a fixed value, then this option is activated (overrides the other selections) when the parameter is given a non-zero value.
- **No initial conditions**: means that this device is disconnected in the steady-state solution and the initial flux is zero.

❑ **Nonlinear characteristic segments**. This data section is used to enter the piecewise-linear current versus flux relation. The current and flux data must be monotonically increasing. The characteristic must cross the origin (0,0). It is not mandatory to enter the (0,0) pair explicitly.
It is allowed to enter only the positive part of the characteristic, in which case the (0,0) is again assumed when not explicitly entered.
The first (negative section) and last (positive section) data segments are extended to infinity in EMTP.
The data is taken as entered and tested for errors in EMTP.
The default number of data rows is 50, but the user can increase this size by selecting a row (click on the row number) and hitting the key “Insert”. Blank rows (empty rows) will be automatically eliminated at the following opening of device data forms.

# 3 Netlist format

Example of data:

```
_Lnonl;Lnonl1;2;2;s1,s2,
1,0,1e-08,?v,?i,?p,?f,>v,>i,>p,>f,
-1.0276 -2.2
-0.0276 -.92
0.0276 .92
1.0276 2.2
```

| Field | Description |
|---|---|
| Lnonl | Part name |
| Lnonl1 | Instance name, any name. |
| 2 | Total number of pins |
| 2 | Number of pins given in this data section |
| s1 | Signal name connected to k-pin, any name |
| s2 | Signal name connected to m-pin, any name |
| Initialization option | 1 is for “Connected in steady-state”<br>2 is for “Find initial flux ($\varphi_0$)”<br>3 is for “Initial flux ($\varphi_0$)”<br>4 is for “No initial conditions” |
| Initial flux | Entered $\varphi_0$ data.<br>If this value is using a named value (parameter defined in an upper level mask), then when the named value is not 0 it will automatically select the option 3 for the Initialization option defined above. |

| | |
|---|---|
| Tolerance | Relative tolerance, from the “Convergence” data tab |
| ?v | Request for voltage scope, sent to scope group vb (branch voltages), optional |
| ?i | Request for current scope, sent to scope group ib (branch currents), optional |
| ?p | Request for power scope, sent to scope group p (branch power), optional |
| ?f | Request for flux scope, sent to scope group flux (phi), optional |
| >v | Request for voltage observe, optional |
| >i | Request for current observe, optional |
| >p | Request for power observe, optional |
| >f | Request for flux observe, optional |
| Cur Phi data | The Current-Flux data |

The current-flux data is entered row-by-row with at least one white space between current and flux. Current is appearing on the first column and flux is appearing on the second column.

A 3-phase version example is given by:

```
_Lnonl;Lnonl1a;2;2;s154a,s155a,
1,0,1e-08,?v,?i,?p,?f,
_Lnonl;Lnonl1b;2;2;s154b,s155b,
,,,?v,?i,?p,?f,
_Lnonl;Lnonl1c;2;2;s154c,s155c,
,,,?v,?i,?p,?f,
-1.0276 -2.2
-0.0276 -.92
0 0
0.0276 .92
1.0276 2.2
```

The extra phases can provide optional scope requests (for the phase).

The comma separated data fields are saved into ParamsA, ParamsB and ParamsC attributes of this device. The current-flux data array is saved in the ModelData attribute.

# 4 Steady-state model

The steady-state model is given by a linear reactance $j\omega L$ calculated as explained above and for the “Connected in steady-state” option. The frequency $\omega$ may take more than one value in the linear steady-state harmonic superposition option.

# 5 Initial conditions

Automatic initial conditions are found from the steady-state solution only when the device is “Connected in steady-state”. The other initialization options are available in the “Initialization” data section described above.

# 6 Frequency Scan model

When the “Connected in steady-state” option is selected, the reactance $j\omega L$ is calculated at each frequency imposed by the frequency scan option.

# 7 Time domain representation

In the time-domain solution this device is a nonlinear function. It is solved through the iterative process of EMTP until convergence according to the relative tolerance option for the given device.