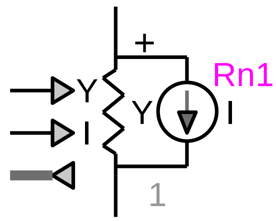
# R nonlinear controlled device



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## 1 Available versions

The R nonlinear controlled (RNC) device is only 1-phase.

## 2 Description

This device is used to model a nonlinear resistance using controlled resistance and admittance. It can be used to model arbitrary resistive devices with resistance calculated through control devices. The presence of the current source provides an option for creating a piecewise linear resistance function. Any segment k of such a function can be represented by the Norton circuit equivalent:

$$i_k = Y_k v_k + I_k \tag{1}$$

The $Y_k$ is actually the differential at the operating point k:

$$Y_k = \frac{\partial i_k}{\partial v_k} \tag{2}$$

In some modeling cases when the analytical expression of the model is not available, the value of $I_k$ can be estimated by perturbation of $v_k$. When an analytical formulation of the model is readily available, then the best precision of this model can be achieved by recalculating the values of admittance $Y_k$ and Norton current source $I_k$ at each solution time-point.

### *2.1 Parameters and Rules*

The Data tab allows entering all required parameters:

- Initial value of Y is $Y_{ss}$**.** When $Y_{ss}$ not 0, it is used by EMTP in its steady-state solution. Negative values of $Y_{ss}$ are tolerated although they might create numerical instability conditions in some networks.
- Disable the Norton current source control: checkbox used to force the Norton current to 0 and ignore the attached control signal.

- Relative tolerance: Specifies convergence tolerance when iterations occur in a network solution.
- Iterate with control equations: This option becomes active and forces iterations when the device (option) “Simultaneous switching” (see Options library) is present in the network and allows iterations for control system equations (“Re-solve control system equations”).
  This option is useful when it is required to achieve an accurate solution for an RNC device. The control signals are updated until convergence or until the “Maximum number of iterations” specified in the “Simultaneous switching” option is reached. It is henceforth possible to avoid or minimize the time-step delay between the solution of control equations and the equation of an RNC.
  It is recalled that if “Iterate with control equations” is not checked, then the control signal values are updated after the solution of electrical network equations (including an RNC device) and the solution moves to the next time-point without updating the RNC equations and re-solving the surrounding network equations.

The admittance Y value is set (controlled) through the control pin Y. The Norton current is controlled through the control pin I.

It is not allowed to delete any pins. Since parts of this device drawing are automatically redrawn by its script, it is not allowed to make changes through the Symbol editor or to perform device attribute or pin attribute changes.

When it is required to observe model data using a control device, then the available observables can be selected in the Observe tab. If an observable is selected then a breakout with its name will appear in the bundle.

# 3 Netlist format

The Netlist format can be explained using the following example:

```
_Rnc;Rn1;7;7;kp,mpin,Ycon,Icon,obs_v,obs_i,obs_p,
10,1,1e-06,0,?v,?i,?p,>v,>i,>p,
```

| Field | Description |
|---|---|
| _Rnc | Part name |
| Rn1 | Instance name, any name. |
| 7 | Total number of pins |
| 7 | Number of pins given in this data section |
| kp | Signal name connected to k-pin, any name |
| mpin | Signal name connected to m-pin, any name |
| Ycon | Control signal connected to the Y-pin. |
| Icon | Control signal connected to the I pin. |
| obs_v | See Parameters above |
| obs_i | See Parameters above |
| obs_p | Units for time in characteristic |
| Initial value of Y | See parameters above |
| Disable Norton current source | 1 means disable |
| Relative tolerance | Convergence tolerance for iterations |
| Iterate with controls | 1 means iterate |
| ?v, ?i, ?p | Optional scope requests. |
| >v, >i, >p, | Optional observable requests. |

The comma separated data fields are saved into ParamsA attribute of this device.

# 4 Steady-state model and Initial conditions

The steady-state model is a linear admittance when a non-zero $Y_{ss}$ value is entered. It becomes disconnected when the time-domain solution is entered. It can be used to force initial conditions into the surrounding network and continuity from steady-state into time-domain when the time-domain initial operation is predictable by the user. The control signal connected to the Y-pin must be initialized to $Y_{ss}$ for continuity between the steady-state network solution and the time-domain solution. This is equivalent to a device having a resistance segment connected to the origin.

# 5 Frequency Scan model

When a non-zero $Y_{ss}$ value is entered it is used to represent this device for all frequencies of a frequency scan.

# 6 Time domain representation

In the time-domain solution this device is solved at each time-point with the given $Y_k$ and $I_k$. The convergence data tab of this device provides a relative tolerance option. This is used to avoid updating $Y_k$ and $I_k$ in the EMTP equations when these values are within tolerance.

In the standard solution mode, there is a one time-step delay between the solution of electrical network equations and the control system equations. With this mode the solution is not necessarily simultaneous with network equations. It can however become simultaneous when $I_k$ is provided and there is no change in both $Y_k$ and $I_k$ between two solution time-points. This is equivalent to operating on the same segment between two time-points.

If the iterations between network and control equations are turned-on, this device may converge and achieve a simultaneous solution.