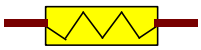
Protection: Thermal Element



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1 Introduction

The thermal element reproduces the overcurrent limits of equipment such as transformers or conductors. A library of components is available.

When the overcurrent limit is reached, this element is an open-circuit. The opening occurs at a zero-crossing of the current. Else, it is a closed ideal switch.

The tripping time of this element, which is actually a failing time, is available in the 'protection coordination function' and its tripping curves can be plotted the same way as overcurrent relays. See the Help tab of the "Protection coordination" device shown in Figure 1-1.

Figure 1-1 Protection coordination device.

2 Input Data tab

- **Equipment type**: Select the equipment type to model. Make a selection to get the overcurrent characteristic from a database (see Section 3).
- **Frequency**: Power frequency. The calculation of the RMS current is based on this value.
- **Rated power:** base current for per unit data.
- **Rated line-to-line voltage**: Used to calculate the base current for the value in per unit.
- **Enable**: If this box is checked, this thermal element is enabled. If not, this element is just a closed ideal switch.

The following inputs are the same for both levels.

- **Damage curve level *i*:** enable the level *i*.
- **I_{pkp}**: Pickup current in per unit. When the current reaches this threshold the timer determined by the inverse curve starts. The per unit base is calculated with the **Rated power** and the **Rated line-to-line voltage.**

Does not apply for 'Build your own' selection of Type of curve (see below).

- **Type of curve**: Select the type of time curve (see Section 4).
  If “Build your own curve” is selected:
  - **Number of points**: number of points to define the curve. The limit is 100.
  - **Table**: defines the time curve as a lookup table. The first column is the ratio of the actual current divided by the pickup current. The second column is the tripping time in seconds.

  A linear interpolation is used. No extrapolation is performed.
  A reset curve can be defined by putting negative tripping times for the ratio values between 0 and 1.
  For this selection, the timer is on at all times whether the current is above $\mathbf{I_{pkp}}$ or not. It is the user responsibility to put tripping times long enough for certain values of current so there is no tripping.
  - **Time dial**: Extra coefficient that multiplies the time points of the curve

  If “Definite time” is selected:
  - **Time dial**: tripping time in seconds
  - **Reset Time dial**: reset time in seconds
- **Time dial**: time multiplier. if **Type of curve** is “Build your own curve”, see definition above. For predefined curves, see Section 4.
- **Reset Time dial**: if **Type of curve** is “Build your own curve”, see definition above. For the predefined curves, see Section 4. If **Reset** is set to “Instantaneous”, **Reset Time dial** is the delay in seconds after what the element is reset when the current goes bellow the pickup current.

Table 2-1: Example of user-defined curve with the “Build your own curve” option. Both tripping and reset characteristics are defined. As an illustration: after an overcurrent, if the ratio 3, the tripping time is 3.647s; if 0.5, the reset time is 38.8 s.

	I / Ipkp	t (s)
1	0.1	-29.393
2	0.3	-31.978
3	0.5	-38.8
4	0.6	-45.469
5	0.7	-57.059
6	0.8	-80.833
7	0.9	-153.158
8	0.95	-298.46
9	0.98	-734.8
10	0.99999999	-1e5
11	1	1e5
12	1.1	134.407
13	1.5	22.682
14	2	9.522
15	3	3.647
16	4	2.002
17	5	1.297
18	6	1.297
19	7	0.709
20	8	0.569
21	9	0.474
22	10	0.407

- **Reset**:
  - "Instantaneous": the timer of the TOC (time-overcurrent) is reinitialized as soon as the measured current is below the pickup current and after a delay defined by **Reset Time dial**.
  - "Time": when the measured current is below the pickup current, a memory effect is considered and the TOC is reinitialized following a timing defined by a reset function associated to each curve.
- **Instantaneous function**: enable the instantaneous tripping function (ANSI function 50). As soon as the measured current is above the pickup current, a timer is launched. When the timer reaches the **Delay** associated with the function, the tripping request is sent and held during a time defined by **Reset delay**. If the measured current goes above the pickup current before the tripping request is sent, the timer is reset to zero.
- $\mathbf{I_{inst}}$: pickup current for the instantaneous overcurrent element (in per unit).
- **Delay**: delay in seconds for a tripping request flag to rise after the measured current is above the pickup current.
- **Reset delay**: Delay in seconds for the function to be reinitialized after a tripping request flag is raised.

3 Equipment characteristic database

According to the **Type of equipment** selection, different tables will be displayed.

3.1 Liquid-immersed distribution-power-regulating transformers

According to the category of transformer, the overload characteristic can be defined by one or two overcurrent curves as follows (see the Standard IEEE C57.12.00-2000).

- **Impedance:** Sequence impedance of the transformer in %.
- **Category:** defined in the Standard C57.12.00-2000.
- **Fault frequency:** defined in the Standards C57.12.00-2000. When "Frequent" or "Infrequent" and according to the **Category**, different types of overcurrent curves will be selected.

3.2 Feeder conductor

- **Material:** material of the conductor: Coper or Aluminum
- **Cross-sectional area:** in cmils
- $\mathbf{T_1}$**:** Initial conductor temperature in Celsius. Depends upon the cable loading and ambient conditions, and therefore cannot usually be determined accurately. It is common to conservatively assume that the initial temperature is equal to the rated maximum continuous temperature of the conductor.
- $\mathbf{T_2}$**:** Final conductor temperature in Celsius (short-circuit temperature limit). Maximum temperature that the insulation can be permitted to reach during a transient short-circuit condition without incurring severe permanent damage. Recommended short-circuit temperature limits, which vary according to the insulation type, are published by cable manufacturers.

Once all the above inputs are entered, click on the button 'Load damage curve' to populate the data for curves.

4 Types of curves

4.1 IEEE I2t

$$t_{tripping} = Tap\left[\frac{100}{\left(\frac{I}{I_{pkp}}\right)^2}\right] \quad (1)$$

$$t_{reset} = Tap\left[\frac{100}{\left(\frac{I}{I_{pkp}}\right)^{-2}}\right] \quad (2)$$

where Tap is the **Time dial** input data.

4.2 Definite time

$$t_{tripping} = Tap \tag{3}$$

$$t_{reset} = t_r \tag{4}$$

where t_r is the **Reset delay** data.

4.3 RI inverse characteristic

$$t_{tripping} = Tap\left[\frac{1}{0.339 - \frac{0.236}{I/I_{pkp}}}\right] \tag{5}$$

$$t_{reset} = t_r \tag{6}$$

4.4 Logarithmic inverse characteristic

$$t_{tripping} = 5.8 - \left[1.35 \ln\left(\frac{I/I_{pkp}}{Tap}\right)\right] \tag{7}$$

$$t_{reset} = t_r \tag{8}$$