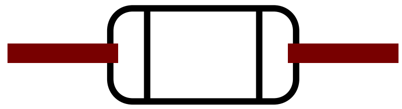
# Protection: Fuse





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## 1 Introduction

The fuse reproduces the overcurrent limit of fuse devices. Three overcurrent curves can be entered. The first one is the **Melting Time**. It is usually provided by manufacturers on log-log graphs and can be entered point-by-point. The accuracy level increases with the number of points. The other two curves are the **pre-arc** and **total clearance energy**. The energy $I^2t$ is provided on datasheets for both.

Two types (**Type** option) of fuses can be modelled:

- **Expulsion**: when the tripping time of one of the curves is reached, the fuse opens as an ideal switch at the first zero-crossing of the current.
- **Current limiting**: As the **pre-arc** and **clearance energy** increase, the resistance of the fuse increases and limits the current. Once the total clearance energy is reached, the fuse opens as an ideal switch at the first zero-crossing of the current.

  Two supplementary resistance values are inputs for this model: the **Melting** and the **Clearance**. When the $\mathbf{I_{pkp}}$ of the pre-arc element is reached, the resistance of the fuse is ramped from the **nominal** to the melting resistance. Once the pre-arc energy is reached, the fuse resistance is then ramped from the pre-arc to the clearance resistance. Once the clearance energy is reached, the fuse opens as an ideal switch at the first zero-crossing of the current.

  The values of the above resistances can be adjusted to match the *Peak Let-Thru* data from manufacturers. To do that, build the small circuit presented in Figure 1-1. Choose L2 in order to obtain the good value of the symmetrical current. Apply the fault at a zero crossing of the voltage to obtain the worst asymmetrical component. Run the simulation few times while adjusting the pre-arc and clearance resistances in order to match the *Peak Let-Thru* data of the fuse. The fault current is monitored as shown in Figure 1-2.

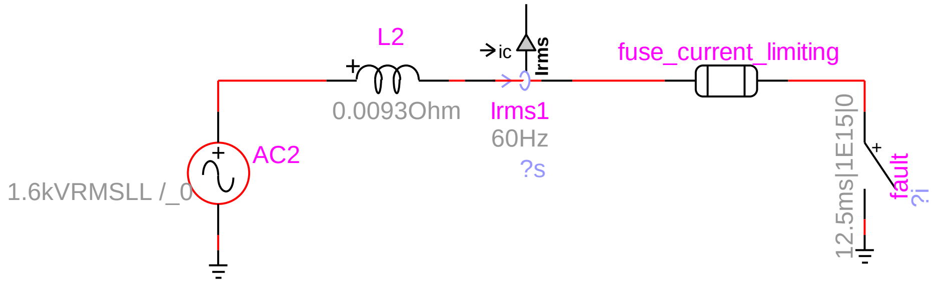


**Figure 1-1 Circuit for fuse resistance adjustment (see Toolbox examples folder currentLimitingVSexpulsion.ecf).**

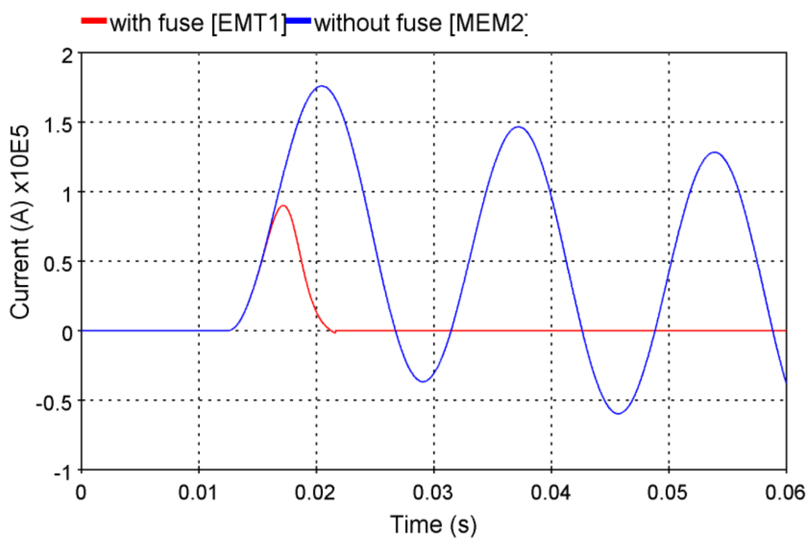


**Figure 1-2 Fuse limited short-circuit current and current without fuse**

The tripping time of this element, is available in the 'Protection coordination' device and its tripping curves can be plotted the same way as the overcurrent relays. See the help of 'Protection coordination' device.


**Figure 1-3 protection coordination device.**

For steady-state studies, the 'View tripping info' device (see Figure 1-4) can be used as well to display the opening time and steady-state currents in the graphical user interface.

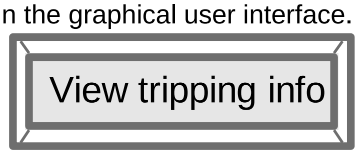


**Figure 1-4 "View tripping info" device.**

# 2 Input Data tab

- **Type**: Select the type of fuse: “Current limiting” of “Expulsion”.
- **Nominal resistance:** resistance of the fuse in continuous operation conditions.
- **Frequency**: Power frequency. The calculation of the RMS current is based on this value.
- **Rated current:** base current for per unit data.
- **Rated line-to-line voltage**
- **Melting resistance:** Only if the fuse is of Type “Current limiting” (see Section 1).
- **Clearance resistance:** Only if the fuse type is of Type Current limiting (see Section 1).
- **Enable**: If this box is checked the fuse functions are enabled. If not, the fuse is just a Nominal resistance.

The following inputs are the same for all levels.

Usually, for currents from the pickup to 20-30 pu depending on the manufacturer, the clearing time is defined by the melting curve defined in a log-log graph. This curve is intended to be entered in the Melting curve of the fuse.

For currents above the maximum current shown on the melting curve, two values of energies are provided: the “Pre-Arc” and total $I^2t$ in $A^2s$. Therefore, the “Pre-Arc energy” and “Clearing energy” options are intended to be “IEEE I2t” type with a pickup current Ipkp equal to the maximum current shown on the log-log graph.

- Enable the desired option first: “Melting curve”, “Pre-Arc energy” and “Clearing energy”.
- $\mathbf{I_{pkp}}$: 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 current** input.
  Does not apply for 'Build your own' selection of Type of curve (see below).
- **Type of curve**: Select the type of time curve (Section 3).
  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. <u>No extrapolation</u> 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 3.
- **Reset Time dial**: if **Type of curve** is “Build your own curve”, see definition above. For the predefined curves, see Section 3. If **Reset** is set to “Instantaneous”, **Reset Time dial** is the delay in seconds after which the element is reset when the current goes bellow the pickup current.

**Table 2-1: Sample 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 Type of curves

## 3.1 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.

## 3.2 Definite time

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

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

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

## 3.3 RI inverse

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

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

## 3.4 Logarithmic inverse

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

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