Calculation of the settings for an I_S-limiter measuring and tripping device

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The previously calculated tripping value I_T represents an **rms** value for the short-circuit current where the I_S-limiter has to trip at the first current rise. In order to determine whether tripping is necessary immediately after a short-circuit has occurred, the I_S-limiter's measuring and tripping device constantly monitors the instantaneous value (i) and the rate of rise (di/dt) of the current through the I_S-limiter. The I_S-limiter trips when the rate of current's rise (di/dt) reaches or exceeds a specified level $(di/dt)_T$, while the current flowing through the I_S-limiter has instantaneous values between i_2 (lower measuring range limit) and i_1 (upper measuring range limit). This limit for the rate of current's rise $(di/dt)_T$ and the measuring range limits i_2 and i_1 are called setting values; they are representing **instantaneous values**.

Selection of the measuring range limits i_1 and i_2

The values for i_1 and i_2 are determined by the conditions at the location where the I_S-limiter is installed (e.g. operating current, maximum short-circuit current, tripping value) and the type of the I_S-limiter. The lower measuring range limit i_2 is, for example, to be selected as approx. 1000 to 3000 Amperes above the peak value for the operating current. The measuring range (i_1-i_2) is in general 1000 A to 4000 A.

Calculation of the rate of current's rise

When the tripping value I_T (rms) and the measuring range limits i_1 and i_2 (instantaneous values) are known, the rate of current's rise within the measuring range (i_2 to i_1) is then to be calculated for all short-circuit times.

Figure 1 shows the development of current when connecting to an ohmic-inductive circuit ($\cos\varphi = 0.15$) which is typical for short-circuits in medium voltage systems, at various switching angles ψ; as a reference, the voltage curve is also given

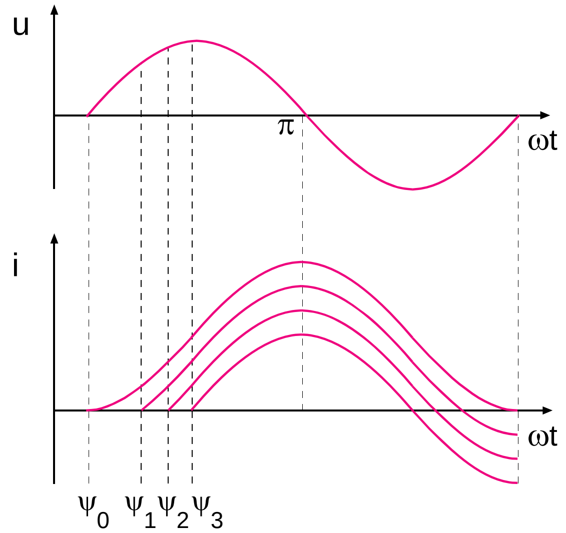

Figure 1

The extreme values for the rate of current's rise within the measuring range occur for the two limit cases (short-circuit current with full and without any DC component); therefore, only these two cases are displayed in figure 2.

Above the currents' curves, the curve for the rate of rise of both currents is shown in dashes, and only those parts of the curve which indicate the rate of rise within the measuring range are drawn in a continous style.

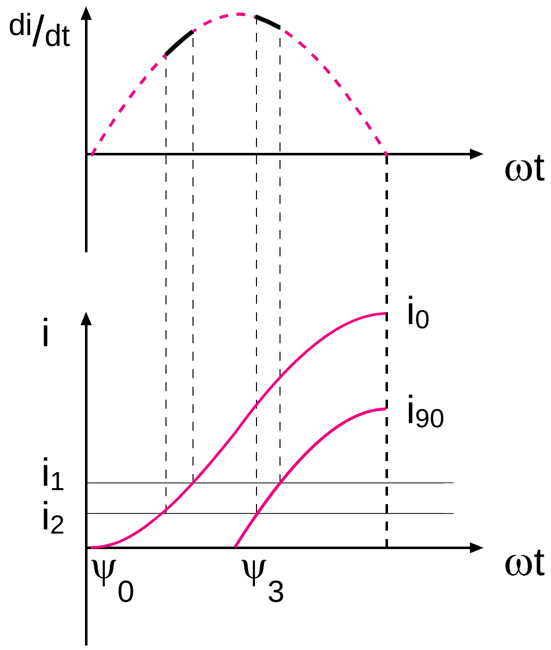

Figure 2

In order to determine the rate of current's rise to be used as a setting value, for each of the two current curves (with and without DC component) the maximum value of the rate of current's rise has to be calculated while the respective instantaneous value of the current is within the measuring range. In general as per figure 2, these are the rate of current's rise at the upper measuring range limit (i_1) for the current i_0 and the rate of current's rise at the lower measuring range limit (i_2) for the current i_{90}. The smaller of these two values gives then the setting rate of current's rise $(di/dt)_T$.

The rate of rise for the two current curves (with and without DC component) within the measuring range (i_2 to i_1) is calculated with equations **(1)** and **(2)**.

Current course in general form

$$i = \hat{i}\,[\sin(\omega t + \psi - \varphi) - e^{-\frac{R}{X}\bullet \omega t} \bullet \sin(\psi - \varphi)] \qquad \textbf{(1)}$$

$\hat{i}$ ⇒ Peak value of the tripping value ($\hat{i} = I_T \bullet \sqrt{2}$)

φ ⇒ Phase angle between voltage and short-circuit current (φ can be calculated from $tg\varphi = \frac{X}{R}$)

ψ ⇒ Switching angle at which the short-circuit occurs, in relation to the source voltage ($\psi = 0$ ⇒ short-circuit occurs at voltage zero)

i_0 ⇒ Current course with full DC component (short-circuit occurs in the voltage zero, where $\psi = 0°$)

i_{90} ⇒ Current course without DC component (short-circuit occurs almost at the maximum voltage, where $|\psi - \varphi| = 0°$)

Rate of rise of current in general form

$$di/dt = \hat{i} \bullet \omega\,[\cos(\omega t + \psi - \varphi) + \frac{R}{X} \bullet e^{-\frac{R}{X}\bullet \omega t} \bullet \sin(\psi - \varphi)] \qquad \textbf{(2)}$$

With a computer program, the values for ωt at the measuring range limits can be calculated by using equation **(1)** ($i_2 \rightarrow \omega t_2, i_1 \rightarrow \omega t_1$). Then, for equation **(2)**, the maximum value of the rate of current's rise has to be determined while the instantaneous value of the current is within the measuring range, i.e., $\omega t_2 \leq \omega t \leq \omega t_1$.

This calculation must be done for both current courses (with and without DC component); the lower of these two thus obtained values of the rate of current's rise leads to the setting rate of current's rise $(di/dt)_T$.