Calculation of the Tripping Value for Applications of I_S-Limiters

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Principle of the I_S-limiter

The I_S-limiter is a current limiting switching device which was developed by ABB Calor Emag in 1955 and, while undergoing constant further development, has been successfully in service in three phase and DC systems with rated voltages of up to 40.5 kV since then. I_S-limiters, with their current limiting effects, are used as follows:

- in couplings between systems,
- in generator feeders,
- in transformer feeders,
- to bridge reactors,
- for coupling of unit heating power stations.

The I_S-limiter is in principle a combination of an extremely fast-acting switch, which can conduct a high rated current but has a low switching capacity, and a fuse with a high breaking capacity mounted in parallel. In order to achieve the desired short opening time, a small charge is used as a stored energy mechanism to interrupt the switch (main conductor). When the main conductor has been opened, the current still flows through the parallel fuse, where it is limited within 0.6 milliseconds and then finally shut down at the next voltage zero.

The current flowing through the I_S-limiter is monitored in an electronic measuring and tripping device. A trip occurs as soon as an impermissibly high short-circuit current begins to flow. In order to determine during the first rise of the short-circuit current whether tripping of the I_S-limiter is necessary, the instantaneous current and the rate of rise of the current across the I_S-limiter are constantly measured and evaluated.

If the setpoints for instantaneous current and rate of rise of current are reached or exceeded at the same time, the I_S-limiter trips. The three phases function independently of each other.

By dividing the two functions of the switching device (i.e. conducting the operating current and limiting the current when a short-circuit occurs) into two paths, the I_S-limiter can on the one hand conduct a high operating current without loss and on the other hand limit the short-circuit current at the first rise.

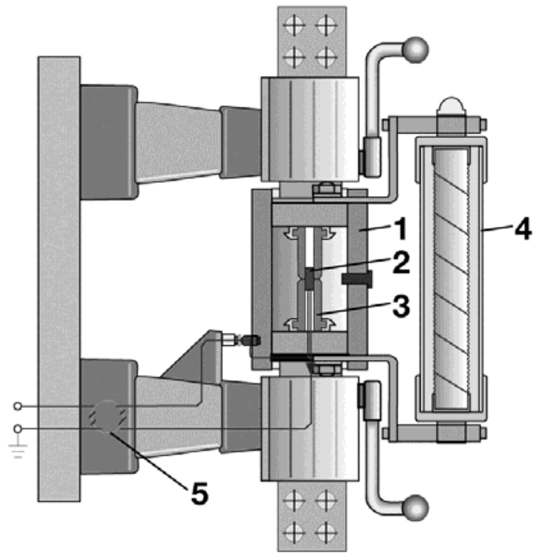

Figure 1:

Insert holder and insert

1 Insulating tube
2 Charge
3 Bursting bridge
4 Fuse
5 Insulator with pulse transformer

Calculation of the Tripping Value

How is the Tripping Value defined?

The tripping value (I_T) is the expected rms value of the first half wave of a short-circuit current flowing through the I_S-limiter, in which case the I_S-limiter must trip during the first current rise.

The use of current limiting switching devices is still relatively rare, and therefore the considerations involved in calculating the Tripping value are not generally known. An example (figure 2) is presented to explain how the tripping value of the I_S-limiter is calculated.

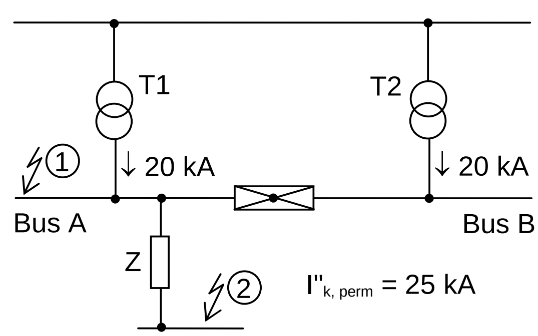

Figure 2: Example for calculation of the Tripping Values

If the short-circuit occurs at fault location (1) (busbar short-circuit), the tripping value would be 20 kA.

With a short-circuit at fault location (2), the I_S-limiter must still just trip when a short-circuit current of 25 kA flows through impedance Z (cable and reactor). The current through the I_S-limiter is then 12.5 kA. If, however, a current less than 25 kA flows through impedance Z, the outgoing feeder breaker can interrupt the short-circuit current and the I_S-limiter does not have to trip. The tripping value calculated for this example is therefore 12.5 kA.

Conclusion:

If the I_S-limiter trips on an expected current of 12.5 kA (rms) in the first current rise, the switchgear system is protected against excessively high short-circuit currents at all fault locations.

How is the Tripping Value generally calculated?

An equation in a general form is to be established using figure 3.

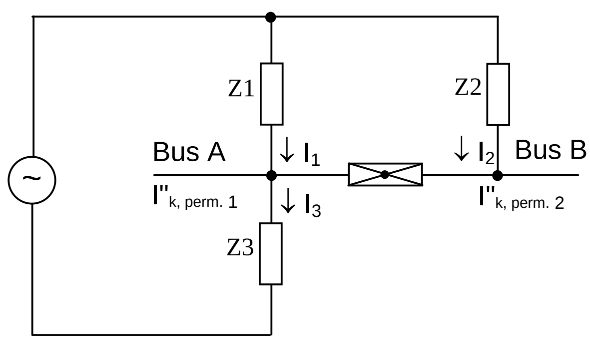

Figure 3: Simplified equivalent circuit diagram

Figure 3 shows the simplified equivalent circuit diagram of a system with two busbars A and B, which are fed via impedances Z1 and Z2 from a network assumed to be a constant-voltage constant-frequency system, and are coupled together by an I_S-limiter. Z1 and Z2 each represent the resulting impedance in the case of several parallel feeders supplying the relevant busbar. The impedance between busbar A and the location of the fault is expressed by Z3.

In addition, for the case of a busbar short-circuit (Z3 = 0) the following applies:

$$I_1 = I''_{k1} \ \text{ and } \ I_2 = I''_{k2}$$

These two currents (I''_{k1} and I''_{k2}) are likely to be familiar from normal short-circuit calculations.

For the general determination of the tripping value, a short-circuit is assumed behind Z3 (figure 3) with Z3 $\neq$ 0.

The I_S-limiter must trip when:

$$I_3 = I_1 + I_2 \geqq I''_{k,\,perm.1} \qquad \textbf{(1)}$$

As the ratio of the currents $\frac{I_1}{I_2}$ is determined by impedances Z1 and Z2, the following applies:

$$\frac{I_1}{I_2} = \frac{I''_{k1}}{I''_{k2}} \qquad \textbf{(2)}$$

Inserting equation **(2)** in **(1)** produces:

$$I_3 = I_2 \left(1 + \frac{I''_{k1}}{I''_{k2}}\right) \geqq I''_{k,\,perm.\,1}$$

In the limit case, the equals sign applies, and the partial current I_2 flowing from busbar B is equal to the tripping value I_{T2}:

$$I_{T2} \left(1 + \frac{I''_{k1}}{I''_{k2}}\right) = I''_{k,\,perm.\,1}$$

The tripping value I_{T2} is thus calculated as:

$$I_{T2} = I''_{k,\,perm.1} \bullet \frac{I''_{k2}}{I''_{k1} + I''_{k2}} \qquad \textbf{(3)}$$

For a short-circuit in the area of busbar B, the tripping value I_{T1} is calculated as:

$$I_{T1} = I''_{k,\,perm.2} \bullet \frac{I''_{k1}}{I''_{k1} + I''_{k2}} \qquad \textbf{(4)}$$

Normally, $I_{T1} \neq I_{T2}$. For I_S-limiter tripping units in the standard form, the smaller of the two calculated values is to be the setting for the tripping value.

What data are required for the calculation?

Equations **(3)** and **(4)** show that the quantities affecting the tripping value include the permissible short-circuit currents $I''_{k,\ perm.\ 1}$ and $I''_{k,\ perm.\ 2}$. In practical applications, these quantities are usually specified and can be taken as fixed. In this, they differ from the other quantities I''_{k1} and I''_{k2}, which also enter the calculation of the tripping value, but are mostly variable. I''_{k1} and I''_{k2} can change with the circuit condition, e.g. with the number or rating of the feed generators, transformers and motors.

It is usual for the tripping unit to be designed for a single tripping value only. In order to prevent the switchgear from being overloaded in any conceivable circumstances, this must be the lowest tripping value obtained from the calculation, taking account of all circuit conditions anticipated.

It can be seen from equations **(3)** and **(4)** that only the extreme values of the ratio I''_{k1}/I''_{k2} have to be known to determine the lowest tripping value.

When the ratio I''_{k1}/I''_{k2} is at a maximum, I_{T2} will assume its minimum, while with I''_{k1}/I''_{k2} at a minimum I_{T1} will be at a minimum.

In other words, to determine the tripping value only the circuit conditions with the largest imbalance of short-circuit severities on the two sides of the I_S-limiter have to be taken into account.

Practical experience to date has shown that standard versions of I_S-limiters (without additional tripping criteria), the tripping value should be greater or equal to twice the operating current. This prevents the I_S-limiter from tripping on faults which do not require it to trip.