Current Transformer Requirements for Non-Directional Overcurrent Protection

Application Note

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Contents:

1. Scope

This document introduces the requirements for current transformer in non-directional overcurrent protection applications. The selection of current transformer and suitable relay settings are described with an example. The presented rules apply to all overcurrent relays and protection functions of SPACOM and RED 500 protection relays.

Keywords: current transformer, overcurrent protection, short circuit

2. Introduction

For reliable and correct operation of the overcurrent protection the current transformer (CT) has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity and co-ordination of protection. But selecting the CT correctly a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications, but also on the network fault current magnitudes, desired protection objectives and actual CT burden. Furthermore, the protection relay settings should be defined in accordance with the CT performance as well as other factors.

3. Technical implementation

3.1. Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (Fn) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter “P” (meaning protection). The limits of errors for protective current transformers according to IEC 60044-1 are given in Table 3.1.-1.

Table 3.1.-1 Limits of error for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The class 5P gives better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering etc.) of the relay.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT will fulfill the specified accuracy. Beyond this level the secondary current of the CT will be distorted and it might have severe effects to the performance of the protection relay.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated as follows:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|} \quad (1),$$

where:

F_n is the accuracy limit factor with the nominal external burden S_n,

S_{in} is the internal secondary burden of the CT and

S is the actual external burden.

3.2. Non-directional overcurrent protection

3.2.1. Selecting the current transformer

Non-directional overcurrent protection does not set high requirements on the accuracy class and on the actual accuracy limit factor (F_a) of the CTs. It is however recommended to choose a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the relay is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$ (2),

where I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the relay. For that reason in practice even a few times smaller nominal primary current can be used than given by the formula (2).

3.2.2. Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage of the relay is to operate, then the start current should be set as follows:

Iset $<0.7 \times (I_{kmin} / I_{1n})$ (3),

where I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection relay inaccuracy, current transformer errors and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage O/C protection is defined. The operate time delay caused by the CT saturation is typically small enough when the relay setting is noticeably lower than F_a.

When defining the setting values to the low set stages, the saturation of the CT does not need to be taken into account and the start current setting is simply according to formula (3).

3.2.3. Delay in operation caused by saturation of CTs

The saturation of CT may cause delayed relay operation. The delay must be taken into account while setting the operate times of successive relays to ensure the time selectivity.

With definite time mode of operation the saturation of CT may cause a delay as long as the time constant of the DC-component of the fault current, when the current is only slightly higher than the starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT and on the operate time setting.

With inverse time mode of operation the delay should always be considered as being as long as the time constant of the DC-component.

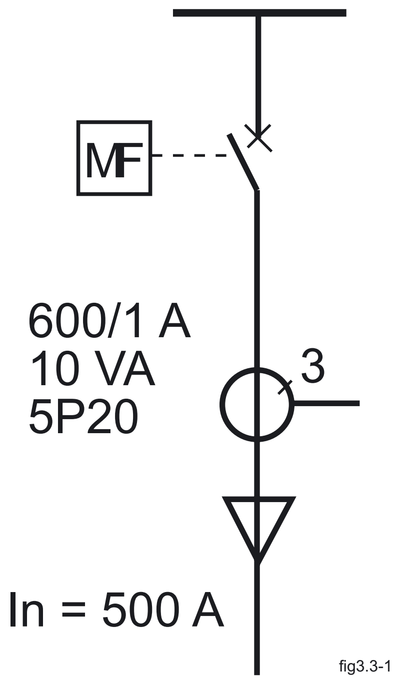
Further, with inverse time mode of operation and when high-set stages are not used the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise the inverse operation time can be further prolonged. Therefore, the accuracy limit factor Fa should be chosen as follows:

Fa >20*Iset / I1n (4),

where Iset is the primary start current setting of the relay

3.3. Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three stage definite time non-directional overcurrent protection.



3I>	1200 A 0.75 s	2.00 x I_{2n} 0.75 s
3I>>	1800A 0.50 s	3.00 x I_{2n} 0.50 s
3I>>>	3500 A 0.20 s	5.83 x I_{2n} 0.20 s

Fig. 3.3.-1 Example for three stage overcurrent protection.

The maximum three phase fault current is 41.7 kA and the minimum three phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next relay (not visible in the figure 3.3.-1). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition the start current settings have to be defined so that the relay operates with the minimum fault current and it will not operate with the maximum load current. The settings for all three stages are as per figure 3.3.-1.

For the application point of view the suitable setting for instantaneous stage (I>>>) in this example is 3 500 A (5.83 x I_{2n}). For the CT characteristics point of view the criteria given by the formula (2) is fulfilled and also the relay setting in considerably below the Fa. In this application the CT rated burden could have been selected much lower than 10 VA for economical reasons.

4. Summary

This document describes how to select a suitable current transformer for non-directional overcurrent protection. The given information is valid for SPACOM and RED 500 protection relays from ABB. The required calculation formulas are presented and a calculation example is included to show how to use the formulas. The correctly selected current transformer enable a fast short circuit protection and thus also minimize the damages caused by the short circuit whereas, the distortion of the secondary current of a saturated CT may endanger the operation, selectivity and co-ordination of protection.

5. References

IEC 60044-1. Instrument transformers – Part 1: Current transformers.

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