Compensated FS and ALF for current transformers

This application note explains Security Factor (FS) and Accuracy Limit Factor (ALF), what compensated FS and ALF mean, and how it is implemented in the TRAX software. To assist in the explanation of compensated FS and ALF, the basic operation principle of a current transformer will be described.

A Current Transformer (CT) is a common component found in the electric grid, allowing protective relays and measurement circuits to assess line current during normal and fault conditions. Protection and metering applications, respectively, require CTs with different types of cores. The metering CT core is more accurate but will saturate once a fault occurs. The protection CT core normally has a lower accuracy but operates during faults, i.e., larger line currents, without saturating. Accuracy limit factor (protective core) and security factor (meter core) both indicate the point at which core saturation occurs.

Note: Accuracy limit factor and security factor are defined for IEC Standard, for ANSI standard these parameters are not defined

Definitions

Accuracy limit factor (ALF)

ALF is the minimum factor between the rated current and the maximum transformed AC fault current at rated burden. If ALF is 10 and rated current is 200 A, the CT will be able measure at least 2000 A AC fault current. Note that a possible transient component in fault current will further limit the maximum transformed AC fault current. For protection CTs that follow the IEEE standard, the accuracy at 20 times rated current is specified, this can roughly be said to mean that the ALF = 20.

If burden is lower than rated, the ALF will be higher than rated.

Security factor (FS)

FS indicates the maximum output current that can be expected from a metering CT core at rated burden before the core will reach saturation. An FS value of 5 means that the maximum output current on the secondary side is lower than 5 times the rated secondary current.

If burden is lower than rated, the FS will be higher than rated.

Operation of a CT

The current transformer is connected in series with the line. As a result, the CT always tries to maintain the following relation regardless of what voltages are needed to drive the currents:

$$I_s = \frac{N_1}{N_2} I_P \qquad (1)$$

N_1/ N_2 is the turns ratio of the CT. This is an ideal approximation of the CT behaviour, where the secondary current I_s is a replicate of the primary current (I_P) with regard to transformed amplitude and phase.

A more complete model of the CT is found in Figure 1, where magnetization impedances, winding resistance, and burden are included.

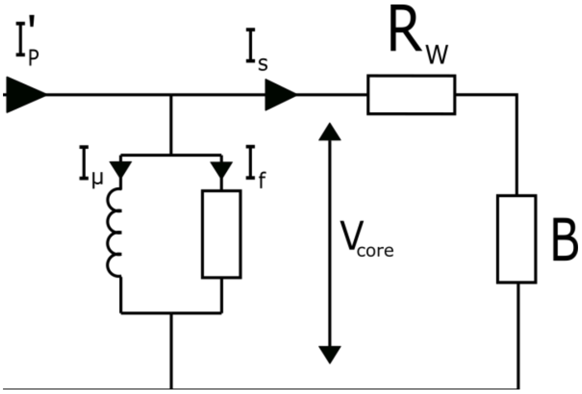

Figure 1: A more realistic CT model

The actual replicate of the primary current is now:

$$I'_P = \frac{N_1}{N_2} I_P \qquad (2)$$

It is important to note that I'_P is impossible to measure, instead, this ideal secondary current (I'_P) will split into two parts: I_{exc} and I_s. The observable current at the secondary side is I_s. This is the current flowing through the burden B. I_{exc} represents the current both needed to magnetize the CT core (I_μ) and supply the losses (I_f) that arise when doing this. I_{exc} is not linear and depends on the level of magnetization inside the core, which in turn depends on the voltage needed to drive I_s.

Each CT core has a maximum voltage (specified when manufactured) that it can output before the core saturates. How much current this voltage can drive in the circuit depends on the connected burden.

A protection CT core will normally be able to operate at a higher current than a metering CT core.

Compensated ALF and FS

From the previous section, one realises that the FS value will increase if the connected burden is lower than rated nameplate value. The maximum secondary voltage is the same for both situations, resulting in a higher current for lower burdens.

To calculate the compensated ALF or FS values, one uses:

$$ALF_{compensated} \approx ALF_n \times \frac{B_n + R_{ct} \times I_{sn}^2}{B + R_{ct} \times I_{sn}^2} \qquad (4)$$

$$FS_{compensated} \approx FS_n \times \frac{B_n + R_{ct} \times I_{sn}^2}{B + R_{ct} \times I_{sn}^2} \qquad (5)$$

Where “n” indicates nameplate value, B is the burden (in VA) and R_{ct} is secondary winding resistance temperature corrected to 75 °C.

Implementation in TRAX 1.6 software

The TRAX 1.6 software has a new field in the CT nameplate for each core, where compensated ALF or FS is calculated depending on the core type. The calculation only happens once all the needed parameters required by equation (4) and (5) have been obtained. The. winding resistance measurement (WRM) and burden must be measured; the remaining parameters are provided in the nameplate. It is possible to designate the CT tap at which the calculation should be performed by selecting the WRM value to use. The WRM value used for computation is temperature corrected regardless if the WRM value has been temperature corrected in the WRM app or not.

It is only possible to enable one calculation per core in the software.

Core 1

Label		Taps	3	Type	Meter
In service tap	1S2	FS Alf	20	Accuracy class	
Primary nominal current	200	Secondary nominal current	5	CT VA rating	15VA
Notes	Testing				
Compensated ALF/FS	Calculated at:	CT1 : 1S1-1S2	FS-C	25.05	

Figure 2: Example of compensated FS

An example is illustrated in Figure 2. The nameplate FS value is 20, and, as seen in the bottom line, “FS-C” (i.e., compensated FS) is calculated to 25.05. The field “Calculated at”, also shown in the bottom row, indicates that the calculation is made with the WRM value of tap S1-S2. The measured burden in this example is 12.49 VA, while the nameplate is 15 VA. This means the metering CT core will saturate when the secondary current is 25.05 times larger than the rated secondary current.

Warning

If using “Compensated FS/ALF” values to modify or design a protection system, it is up to the user to make sure these values are handled correctly. Deep knowledge about the protection system in question is needed to ensure correct performance. During a fault, both AC and DC currents can be present; compensated FS/ALF affects both.