RELAY PROTECTION SYSTEMS PERFORMANCE DUE TO CURRENT TRANSFORMER SATURATION

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Introduction

Relay protection systems are vital to the electrical power grid and form the base for the continuous development of a more complex transmission and distribution grid. Protective relays must be reliable, selective and fast, therefore the quality of the obtained measurement data from current and voltage transformers is essential. Technical requirements for current transformer (CT) selection depend on the protection function performed by a numerical protection system. To demonstrate the impact of inadequately selected CTs for protective relays, a series of primary test cases on CTs have been performed and analyzed. Furthermore, the impact of saturated CTs on the performance of various numerical protection algorithms has been analyzed.

Behavior of current transformers at increased primary current

The ideal CT would have equal primary and secondary amperage throughout the operation area. However, real CTs expose an incremental ratio error when increasing the primary current and constant impedance on the secondary side. The ratio error of the CTs depends not only on the impedance of the secondary circuit, but also on the type of transformer core. Namely, according to IEEE recommendations [1], there are two types of CTs: measuring and protective, with specially defined transformer characteristics in the operation area above the nominal operation.

The basic characteristic of the protective CT is linear transmission of the primary current above the nominal value. For example, a protective CT type 5P10 has an accuracy limit (ratio error) of 5% and an accuracy limit factor 10. This means that CT will give a maximum 5% ratio error when the fault current reaches 10 times the rated value. After that the secondary current of the CT will be distorted due to saturation.

To demonstrate the impact of the inadequate design of CTs, primary experiments were carried out on the measuring circuit of the relay protection system. In the test setup, the 75A / 5A transmission ratio transformer, the accuracy class 5P10 and the power of 5VA, were used. As a regulated power source, the ISA STS 5000 instrument was used to generate 800 AAC. The primary circuit contained five windings through the enclosed current transformer, expanding the test area up to 4000 AAC. Resistor load of 0.4Ω was connected to the secondary circuit, which corresponds to twice the nominal load. In addition to the regulated load itself, a numeric protective relay is connected with the activated event recording function. A simplified display of the metering circuit is shown in Fig 1 (left).

The test results are shown graphically on Fig. 1 (right) for the electrical currents at the primary circuit of the CT and the secondary circuit current converted to the primary value. It is shown how the secondary current waveform distortion increases significantly with the amplitude of the primary current. Furthermore, the waveform of the secondary current obtained from the protection relay record faithfully maps the measured current on the secondary side of CT.

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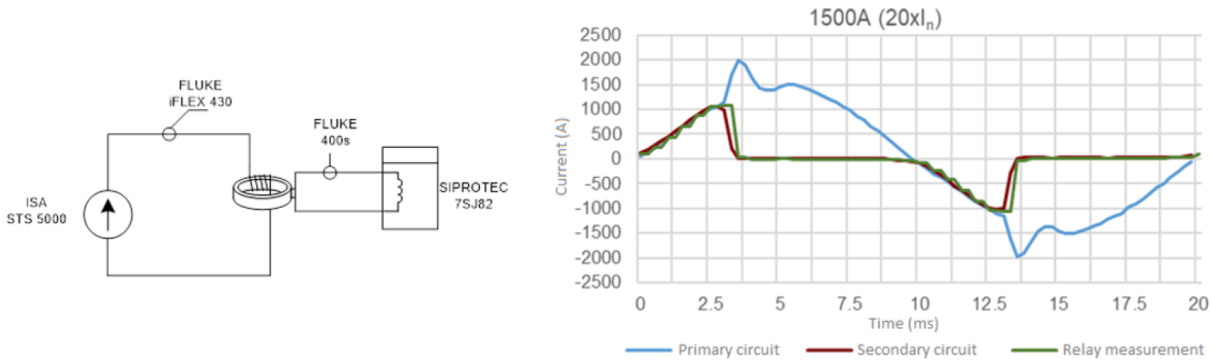

Figure 1: Simplified presentation of measurement layout (left) and measured waveforms (right).

Response of numerical algorithms for signal amplitude estimation

The secondary current signal values are the input parameters of the phasor estimation algorithms. They effectively filter out high-frequency perturbations/oscillations, harmonics, noise, and direct current components and determine the amplitude and phase of input signal.

Green color in Fig. 2 shows amplitude estimation of the DFT and H-DFT algorithms, with earlier measured CT secondary current distorted waveform as an input signal. Obviously, there is a significant deviation of both algorithms in scaled amplitude estimation, whereby the H-DFT algorithm achieves a slightly better result. The scaled primary circuit current amplitude is 1, while algorithms based on Fourier's transformation result are estimated between 0.21 and 0.25. Algorithms for overcurrent or short-time protection functions based on the amplitude estimation results trigger circuit breakers, which means that in case of poorly dimensioned current transformers there is a "underestimation" of the amplitude of the fault current that lead to unselectivity and unreadability of protection relays.

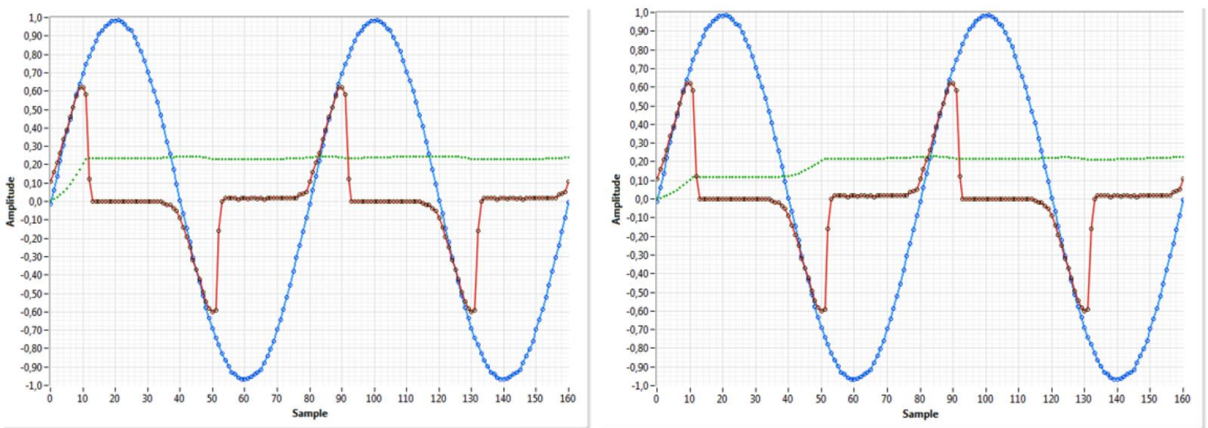

Figure 2: H-DFT (left) and DFT algorithm response (right) to current waveform of saturated transformer (1500A).

Conclusion

Inadequately designed current transformers have direct implications on reliability of protection relays so special attention must be paid when dimensioning CTs, not only from the aspect of thermal and mechanical stresses but also from the aspects of protective functions that would be implemented. Understanding the operation of numerical protection algorithms and from that necessary criteria for current transformers dimensioning, enable the fulfillment of all technical criteria with economic optimization of equipment and hence avoidance of unnecessary “over dimensioning” of CTs.

Referenzen

[1] C37.110-1996 - IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes