Current Transformers

Course Number: EE-03-949

PDH: 3

Approved for: AK, AL, AR, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

Course Author: Velmir Lackovic

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater).
If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

Introduction

The most important roles of instrument transformers are:

- To transform voltages or currents, from a high value to a value that can be easily handled by protection relays and associated instruments

- To separate and insulate the metering circuit from the high voltage

- To provide options for standardization of instruments and protection relays with rated currents and voltages

Instrument transformers are specific transformer types used for measurement of voltages and currents. The common engineering laws are also valid for the instrument transformers. For a short circuited transformer, it can be written:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} \quad (1)$$

For a transformer at no load, it can be written:

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad (2)$$

The first formula provides the current transformation in proportion to the primary and secondary turns. Second formula provides the voltage transformation in relation to the primary and secondary turns. The current transformer is based on expression (1). Ideally, in the case of a short-circuited transformer the secondary terminal voltage equals to zero and the magnetizing current can be neglected. The voltage transformer is based on expression (2). Ideally, it is a transformer under no-load, where the load current is zero and the voltage drop is caused by the magnetizing current and is therefore negligible.

In reality, the ideal conditions are not met as the instrument transformers have a burden in form of protection relays, instruments and cables. This creates a measuring error in the current transformer due to the magnetizing current, and in the voltage transformer due to the load current voltage drop. Single phase instrument transformer vector diagram is presented in Figure 1. The turn ratio is 1:1 to ease the representation. The primary terminal voltage "U_1" is multiplied with the vector subtraction of the voltage drop "I_1Z_1" from "U_1", which gives the electromagnetic force "E". "E" is the vector sum of the secondary terminal voltage "U_1" and the secondary voltage drop "I_2Z_2". The secondary terminal voltage "U_2" is presented as "I_2Z", where "Z" is the burden impedance. The "E" is created by the flux Ø, which lags "E" by 90°. The flux is created by the magnetizing current "I_m", which is in phase with Ø. "I_m" is the no load current "I_0" reactive component which is in phase with "E". The resistive part is the power loss component "I_f".

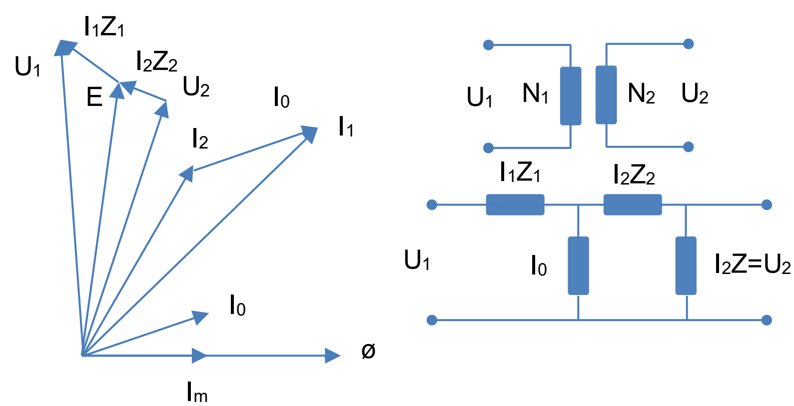

Figure 1. Instrument transformer principle

Measurement Error

Typically, the current transformer is loaded by impedance. It consists of relays, instruments and the cables. The induced electromagnetic force "E", needed to achieve the secondary current "I_2", through the complete burden "Z_2+Z", needs a magnetizing current "I_0", which is obtained from the primary side current. The factor "I_0" is not part of the current transformation and is not used instead of the rated ratio "K_n".

$$Nominal\ ratio\ K_n = \frac{I_1}{I_2} \qquad (3)$$

Real current ratio “K_d“ can be expressed as:

$$Real\ ratio\ K_d = \frac{I_1 - I_0}{I_2} \qquad (4)$$

where “I_1”, is the rated current of the primary and “I_2”, is the rated current of the secondary.

The measuring error “ε” is expressed as:

$$\varepsilon = \frac{K_n I_s - I_p}{I_p} \times 100 \qquad (5)$$

where “I_s”, is the secondary current and “I_p”, is current of the primary. The error in the reproduction will appear, both in amplitude and phase. The amplitude error is known as current, or ratio, error. Definition suggests that the current error is positive, if the current of the secondary is higher than the rated current ratio.

The phase angle error is known as phase error or phase displacement. The phase error is positive, if the secondary current is leading the primary. If the magnetizing current “I_0” is in phase with the secondary current “I_2” (the maximum error), according to equation 6, error ε can be expressed as:

$$\varepsilon = \frac{K_d - K_n}{K_d} \times 100 = \frac{\frac{I_1 - I_0}{I_2} - \frac{I_1}{I_2}}{\frac{I_1}{I_2}} \times 100 = \frac{I_0}{I_1} \times 100 \qquad (6)$$

“I_0” consists of two elements, a power-loss element “I_f”, that is in phase with the secondary voltage and a magnetizing element “I_m” that lags 90° and is in phase with the electromagnetic force “E”.

The magnetizing current that causes the measuring error, is dependent on several factors (as presented in Figure 2).

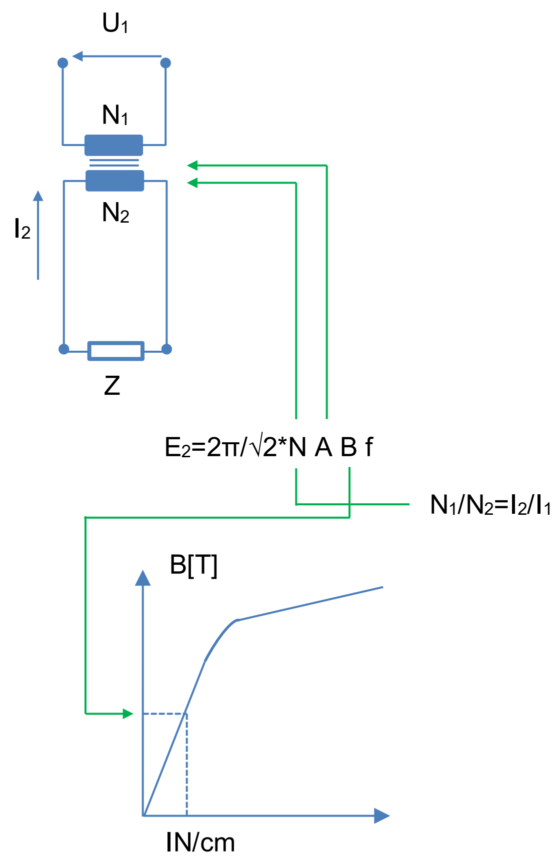

Figure 2. The factors affecting the output of the current transformers and magnetizing current

For the induced electromagnetic force “E”, the formula shown in Figure 2 can be used. The induced electromagnetic force is capable to carry burdens the same size as a transformer.

The burden is described in IEC 185 as the power in VA that can be connected to a current transformer at rated current of the secondary and at a given power factor (cos Ø=0,8 according to IEC 185). The rated current of the secondary is standardized to 1 and 5 A. The current transformer output voltage presents the transformer capability to carry burden. As presented in Figure 2, three factors will affect the electromagnetic force “E”. It’s the number of secondary turns “N”, the core area “A” and the induction in “B” [Wb/m^2]. The induction depends of the core material, which influences the size of the magnetizing current. Therefore, secondary turns and the core section are selected for specific application to give the required electromagnetic force output.

Output of the Current Transformer

The needed output of a current transformer depends on the application and the type of the connected load.

Metering or instruments - Active power, reactive power and current meters work under normal loading conditions. High accuracy for currents up to the rated current (5-120%) is needed for metering cores. Accuracy classes for metering cores are 0.1 (laboratory), 0.2, 0.5 and 1.

Protection and disturbance recording - The information about a primary disturbance must be transferred to the secondary side in the case of protection relays and disturbance recorders. For these cores a lower precision is needed but also a high capability to transform high fault currents and to allow protection relays to measure and clear the fault. Protection classes are 5P and 10P according to IEC 185. Additional cores for transient behavior are described in IEC 44-6.

A number of cores can be placed in each current transformer. Typically, from three to six cores are available. In that case one or two are used for measuring purposes, and two to four for protection purposes.

Metering Cores

Metering cores must be saturated 10-40 times the rated current depending of the type of burden, to protect instruments and meters from high fault currents. Typically, the energy meters have the lowest withstand capacity. Common values are 12-20 times the rated current. The instrument security factor "F_s", shows the overcurrent as a multiple of rated current at which the metering core will saturate. It is expressed as a maximum value and is applicable only at rated burden. At lower burdens the saturation value roughly increases to "n".

$$n = \frac{R_{CT} + \left(\frac{S}{I_n}\right)^2}{R_{CT} + \left(\frac{S_n}{I_n}\right)^2} \times F_s \qquad (7)$$

Purchase this course to see the remainder of the technical materials.