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Current Transformer Selection Using Matlab Model

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Abstract
The requirements for the correct functioning of power system protection equipment is the optimum selection of current transformers (CTs). The main purpose of a current transformer is to translate the primary current in a high voltage power system to single level that can be handled by delicate electromechanical or electronic device. For a power system engineer to accurately and successfully specify the different current transformers required for the protection of substation power transformers, the protection engineer has to pay attention to steady state performance as well as transient performance of current transformers. This paper presents a study on current transformer selection in a 132/33kV transmission substation using MATLAB model. This paper shows how the current transformer ratio, knee points voltage, thermal current, dynamic current and burden on the various cores can be selected together simultaneously to provide a low-cost, high-performance system. This work is expected to be a good reference source for the new generation utility protection engineers in selecting the CTs in power system installation.
Keywords: Current Transformer, Knee Points Voltage, Thermal Current, Dynamic Current, CT- Burden, MATLAB
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Introduction

Providing isolation of a problem area in the power system is the fundamental objective of power system protection. Protective relays act only after an abnormal or intolerable condition has occurred. They require reasonably accurate reproduction of the normal, tolerable and intolerable conditions in the power system for correct sensing and operation. This information input from the power system is usually through current transformers (CTs). A CT appears to be the simplest of electrical devices. For example, the bushing type ct is simply a winding on an insulated core which becomes a transformer only when placed over the primary conductor (zocholl, smaha, 1999). CTs provide insulation from the higher system voltages and a reduction of the primary current and voltage quantities. The normal rating of CT secondary has been standardized at 5A, with a second standard of 1A being used. However, changing the current transformer rating does not necessarily reduce the energy required for relay operation. With a constant VA, lower current means higher voltage and more insulation between the primary and the secondary. The measure of current transformer performance is its ability to reproduce accurately the primary current in secondary amperes both in wave shape and magnitude (Thinn Le Yee, 2008).

Unlike the voltage or power transformer, the current transformer consists of only one or very few turns as its primary winding. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole. Due to this type of arrangement, the current transformer is often referred too as a “series transformer” as the primary winding, which never has more than a very few turns, is in series with the current carrying conductor supplying a load (electronics tutorials, 2017).

The operation of current transformers (CTs) is similar to the conventional power transformer. CTs are basically step-up voltage transformers, on the other hand, these are step-down transformers in view of current. Current transformers play a vital role in the protection and measuring functions of a power system. The correct selection of current transformers will lead to the proper operation of protection and measuring equipment. The magnetic saturation of the current transformer core creates undesirable problems in protection devices and therefore a current transformer has to be designed to activate protection devices within the first few cycles of a fault, without letting its core to get saturated (wijayapala, karunanayake & madawala, 2016).

Failure of a protective system to perform its function correctly is often due to incorrect selection of the associated current transformer (IEEE C37.110-1996). Hence, current and voltage transformers must be regarded as constituting part of the protective system and must be carefully matched with the relays to fulfill the essential requirements of the protection system.

This paper addresses the issue of basic test necessary to ensure proper selection and applications of current transformer in power system protection system.

Material And Method

The core on which the secondary wire is wound plays a significant part in the performance of a CT. Core types include silicon steel, nickel alloy, or ferrite. The type of core determines price and accuracy. Accuracy is comprised

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by the actual input to output transfer ratio, as well as linearity and phase shift. While phase shift is of little significance for current measurements, in the measurement of power, an uncompensated phase shift will lead to large errors in measurement of real power and power factor. The MATLAB model for substation current transformer selection was designed using Graphical User Interface (GUI); a sub-program in MATLAB. Continuous testing of the program was carried out to ensure functionality. The developed model would enable power system engineers to carryout accurate specification and selection of current transformers.

Algorithm For Current Transformer Selection

Step 1 Read in the field data: transformer MVA, line voltage, expected fault current

Step 2 Determine the full load current (I_P) per phase using equation (1.1)

$$I_P = \frac{\text{Transformer MVA}}{\sqrt{3} \times \text{Line Voltage}} \quad 1.1$$

Step 3 Select the secondary current of CT (I_s) from table F3.6 considering

1. Distance of CT to control panel
2. Secondary current of CTs in service

Step 4 Select the corresponding secondary winding resistance (R_s) and that of conductor

Step 5 Determine the total power consumption (P_c) of instrument relay (VA)

Step 6 Calculate total burden (B_T) impose on CT using equation (1.2)

$$B_T = I_s^2 R_s + 2 I_S^2 R_L + P_c \quad 1.2$$

Step 7 Calculate the percentage error using equations (1.3) and (1.4)

$$5Pn = 0.05 * A_{LF} * I_p \quad 1.3$$

$$10Pn = 0.1 * A_{LF} * I_p \quad 1.4$$

Step 8 Calculate the knee point voltage (V_k) using equation (1.5)

$$V_K = \frac{B_T * A_{LF}}{I_S} \quad 1.5$$

Step 9 Check if total burden (BT) is less than the expected burden, if not modify the field data.

Step 10 Check if **5Pn** is less than **10Pn** and determine the core used for protection or metering.

Step 11 Calculate the fault current at CT installation

Step 12 Calculate the rated short time thermal current (I_{th}) using equation (1.6) and 1.7

$$I_{th} \geq I_{SC} \left[t + 0.05 \text{ x } \frac{50}{F}\right]^{1/2} \text{ kA r.m.s} \quad 1.6$$

I_{th} - Rated short time thermal current for 1 sec
I_{SC} - Short circuit current at CT. Location in kA r.m.s
T - Short circuit duration in sec
F - Rated system frequency

For system frequency of 50Hz

$$I_{th} \geq I_{sc} [t + 0.05]^{1/2} \text{ kA r.m.s} \quad 1.7$$

Step 13 Calculate the dynamic current (I_{dyn}) using equation (1.8)

$$I_{dyn} = 2.5 * I_{th} \quad 1.8$$

Step 14 Current transformer specifications.

The above process is represented in flow chart as shown in Figure 1.0

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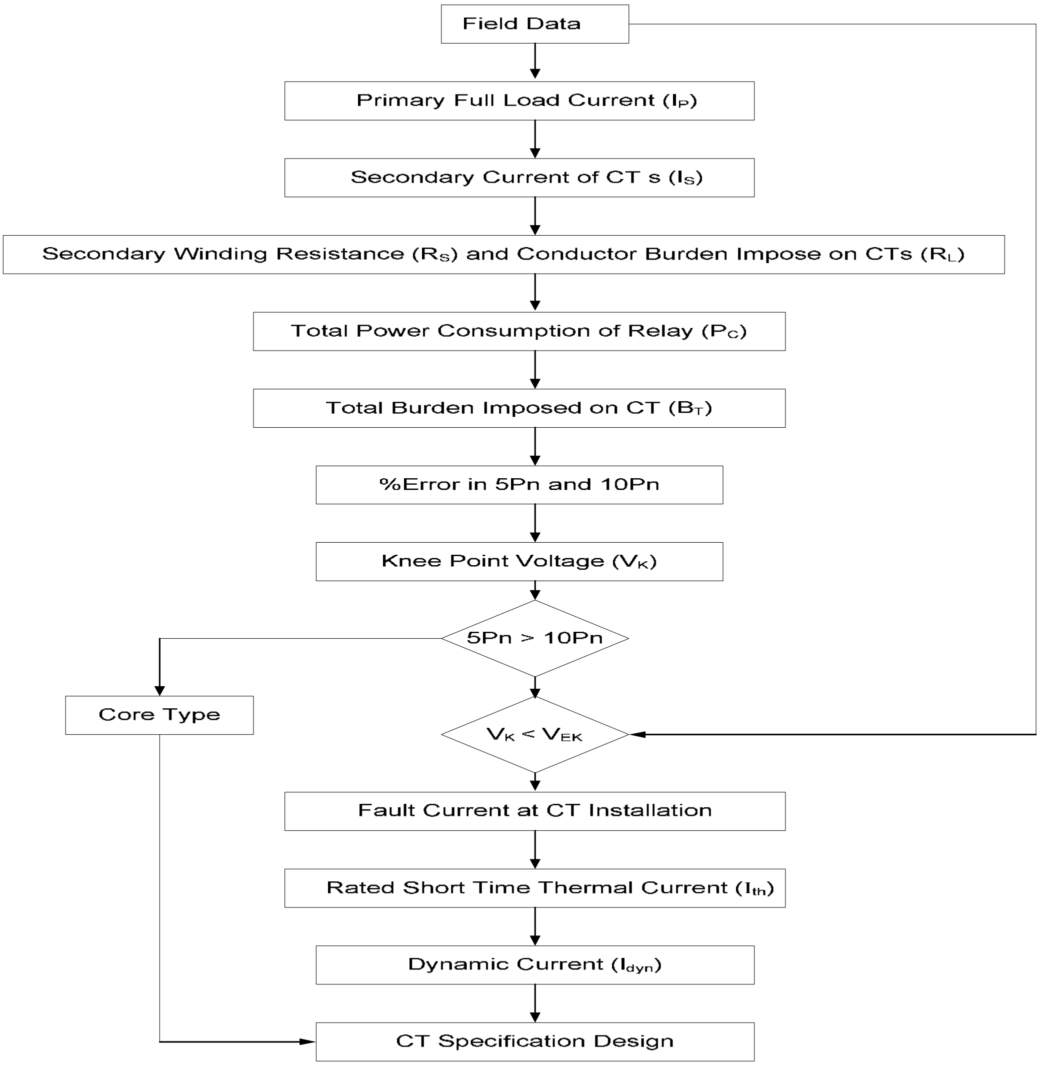

Figure 1.0: Current Transformer Specification Flow Chart

Results And Discussion

For a power system engineer to accurately and successfully specify the different current transformers required for the protection of substation power transformers on 132kV and 33kV sides, the under listed parameters are required: (1) Transformer rating (2) Short circuit current (3) Line voltages (4) Secondary current (5) Winding resistance (6) Conductor sizes (7) Burden impose on the current transformers.

It is difficult to avoid saturation during short circuit condition. In differential relays, saturation disturbs the balance and stability of protection scheme. Saturation occurs at the point in which the current transformer does not obey the law of increase in current equal to increase in voltage. The load or burden imposed on current transformer is very important, because loading a current transformer beyond its specified burden carrying capacity will eventually lead to saturation of the current transformer.

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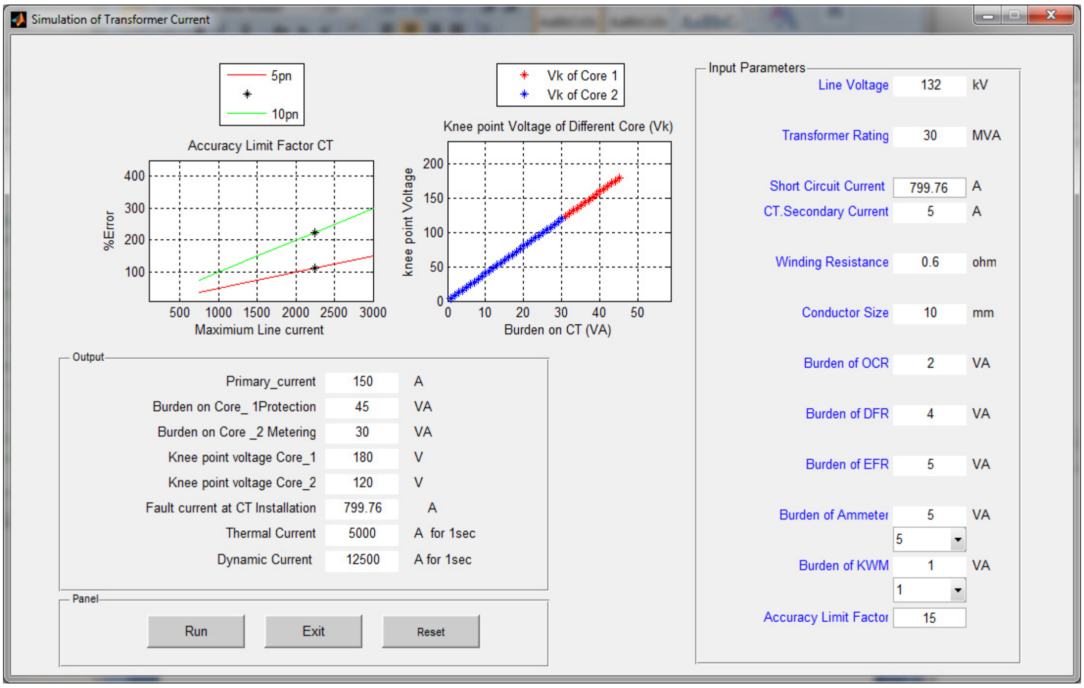

Figure 2.0: 132kV Current Transformer Specification Model

From figure 2.0, the primary current of the current transformer is 150A, the burden on core-1 is 45VA and the burden on core-2 is 30VA. Since core-1 have a higher burden than that of core-2, then core-1 is used for protection equipment while core-2 is used for metering only. It would be observed from the graph that the knee point voltage on core-1 is 180V and that of core-2 is 120V. These are limit beyond which the specified CTs will go into saturation.

Figure 2.0 further shows the relationship between the maximum line current and its transformation percentage (%) error. The Accuracy Limit Factor (ALF) is the highest primary current at which a current transformer still meets the specified requirements as regards total error. Its standard (n) is 15 and 20 with two different class of protection 5pn and 10pn. It should be noted that the CT core used for metering purposes should have minimum transformation error in order to avoid metering errors.

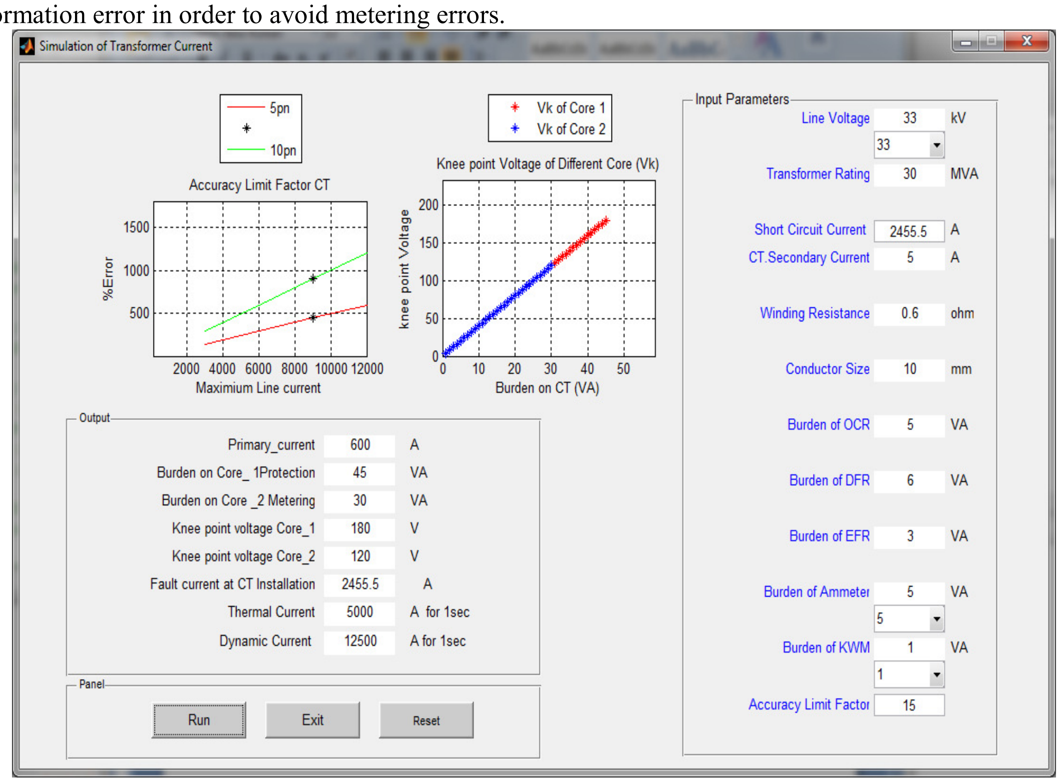

Figure 3.0: 33kV Current Transformer Specification Model

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From figure 3.0, the primary current of the current transformer is 600A, the burden on core-1 is 45VA and the burden on core-2 is 30VA. Since core-1 have a higher burden than that of core-2, then core-1 is used for protection equipment while core-2 is used for metering only. It would be observed from the graph that the knee point voltage on core-1 is 180V and that of core-2 is 120V. These are limit beyond which the specified CTs will go into saturation.

Conclusion

In order to properly apply protection and other devices in the sub-stations, a thorough understanding of the application is necessary. Application of CTs based on previous existing practices may take care of most of the applications but do not necessarily guarantee correct application of the devices in all situations. Too big CTs for an application where it is not warranted would mean wasted resources. A check of the application in detail, especially for critical installations is highly recommended. CT selection can play a large role in determining installation options, accuracy and performance of the metering and protection system. The type of metering system and the desired performance characteristics must be taken into consideration when selecting the type of CT to be used. Metering equipment must be considered depending on the type of CT inputs available.

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