

Analyzing Current Transformers Saturation Characteristics for Different Connected Burden Using LabVIEW Data Acquisition Tool

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Abstract—Current transformers are an integral part of power system because it provides a proportional safe amount of current for protection and measurement applications. However, when the power system experiences an abnormal situation leading to huge current flow, then this huge current is proportionally injected to the protection and metering circuit. Since the protection and metering equipment's are designed to withstand only certain amount of current with respect to time, these high currents pose a risk to man and equipment. Therefore, during such instances, the CT saturation characteristics have a huge influence on the safety of both man and equipment and on the reliability of the protection and metering system.

This paper shows the effect of burden on the Accuracy Limiting factor/ Instrument security factor of current transformers and the change in saturation characteristics of the CT's. The response of the CT to varying levels of overcurrent at different connected burden will be captured using the data acquisition software LabVIEW. Analysis is done on the real time data gathered using LabVIEW. Variation of current transformer saturation characteristics with changes in burden will be discussed.

Keywords—Accuracy limiting factor, burden, current transformer, instrument security factor, saturation characteristics.

I. INTRODUCTION

CURRENT TRANSFORMERS (CT's) are the most basic part of any power system as it is required for all the protection and metering functions. With advancement in solid-state technology, the reliability and accuracy of the devices have increased. Although the advancement has brought about great advantages but it has also made the devices more susceptible to the saturation characteristics of the current transformers. Hence, it becomes essential to study saturation characteristics adequately so that we will be able to protect the measuring and protection IED's [1].

The behavior of the CT with different connected burden on over-current condition will have a direct effect on the operation of protection scheme and the recording of energy, both of which are critical to any power system.

II. LABVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development

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environment for a visual programming language from National Instruments. It is used here as a data acquisition and recording tool to gather current transformer input and output current values [4].

The programming done is just for data gathering and no scaling or any other changes have been made to the raw data in LabVIEW.

A. Set Up

Input modules of LabVIEW have been connected in series with the primary and secondary of the CT respectively. Real time data is stored in the computer via input modules. The CT secondary is also connected with a variable resistor for variable burden [3], [5], [6].

A variable current source is connected to CT primary. The CT secondary is connected to a variable resistor and the LabVIEW data acquisition tool. Class 3 with 30VA CT is used for this setup. The CT ratio is 5:1 Amperes.

4-Channel Current Input C Series Module is used to gather current signals. It is designed to measure 5A rms nominal and up to 14 A peaks on each channel with channel-to-channel isolation [4].

III. KNEE POINT VOLTAGE

Knee point voltage, as per IEC 60044-1, is defined as the point on the curve where a voltage increment of 10% increases the current by 50% [7]. The Knee point voltage can also be calculated using (1). Therefore if we know the knee point voltage of any given CT, we can calculate the maximum secondary current at which the CT connected to a constant burden saturates using (1):

$$V_{knee} = K_{scen} \times I_{fs, max} \times (R_{ct} + R_{bn}) \quad (1)$$

where, V_{knee} = CT Knee point voltage, K_{scen} = Overcurrent Factor, $I_{fs, max}$ = Maximum secondary fault current, R_{ct} = CT secondary resistance, R_{bn} = Rated CT burden in ohms

IV. CT SATURATION AT DIFFERENT BURDENS

CT saturation current is directly related to the connected burden. If the connected burden is different from the rated burden then the CT saturates at a varied current than that given in the nameplate. The over current factor which specifies the current until which the CT does not saturate is dependent on the connected burden as shown below. If a low or high burden is connected to a CT, then the over current factor (K_{scen}) will

not be valid for that circuit as it is dependent on the burden connected [2]. The new operational overcurrent factor (K_{scco}) can be calculated as,

$$\begin{aligned} V_{knee} &= K_{sccn} \times I_{fs, \max} \times (R_{ct} + R_{bn}) \\ &= K_{scco} \times I_{fs, \max} \times (R_{ct} + R_{bo}) \end{aligned} \quad (2)$$

where, R_{bo} = Connected burden in ohms [2]. Since knee point voltage, V_{KNEE} will remain same on different connected burden simplifying (2) we get

$$K_{scco} = K_{sccn} \times \frac{(R_{ct} + R_{bn})}{(R_{ct} + R_{bo})} \quad (3)$$

Equation (3) shows that the new overcurrent factor varies proportionately to the connected burden. Therefore, the connected burden should be verified for proper CT saturation in case of overcurrent [1]-[2]. However, we want to calculate and verify the primary CT current at which the CT saturates, therefore by slightly modifying the formula we get:

$$I_{fs, \max} = \frac{V_{knee}}{K_{sccn} \times (R_{ct} + R_{bn})} \quad (4)$$

Using (4), different saturation currents are calculated and tabulated for 200%, 500% and 1000% of rated CT burden in Table I. It can be seen that the saturation current decreases with increase in burden. The decrease in saturation current is so drastic that with very high burden the CT is not able to correctly transform its rated current also. The calculated values are in RMS values. The values used for R_{ct} is measured from the actual CT used.

Figs. 1 and 2 show secondary current waveform of the CT with a burden connected which is 200% higher than the rated burden.

TABLE I
CALCULATED PRIMARY SATURATION CURRENT AT DIFFERENT BURDENS

	% of Rated Burden		
	200%	500%	1000%
V_{knee}	29	29	29
K_{scco}	0.71	0.29	0.14
R_{ct}	0.845	0.845	0.845
$I_{fs, \max \text{ secondary}}$	0.71	0.29	0.14
$I_{fs, \max \text{ primary}}$	3.58	1.45	0.72

The CT secondary current waveform is plotted together with a calculated CT secondary current waveform to compare the waveform distortion.

From Figs. 1 and 2, we can observe that with the increase in current flow in the CT primary the distortion in the secondary current waveform is more. Similarly, Figs. 3-8 show the saturation of CT with a burden connected which is 500% & 1000% higher than the rated burden.

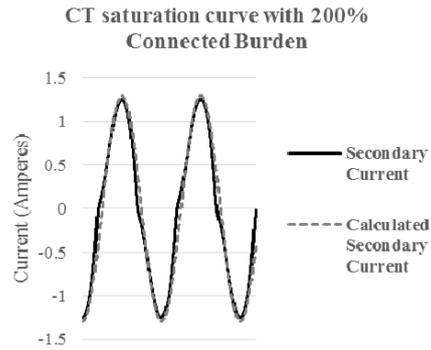


Fig. 1 CT secondary waveform with 200% connected burden and primary current, which equals 1.34 times the primary rated current

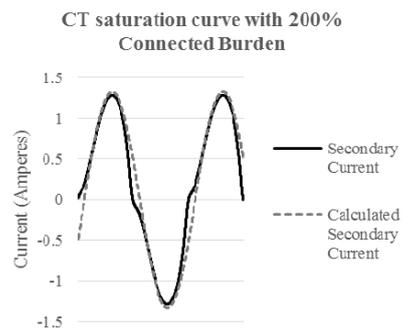


Fig. 2 CT secondary waveform with 200% connected burden and primary current, which equals 1.4 times the primary rated current

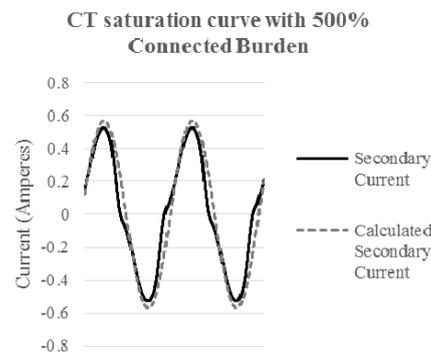


Fig. 3 CT secondary waveform with 500% connected burden and primary current, which equals 0.58 times the primary rated current

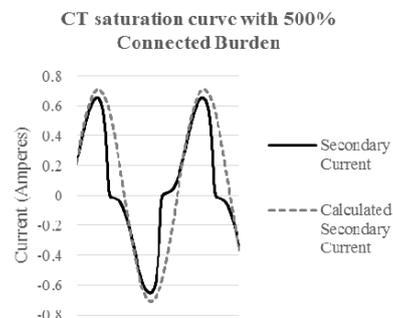


Fig. 4 CT secondary waveform with 500% connected burden and primary current, which equals 0.7 times the primary rated current

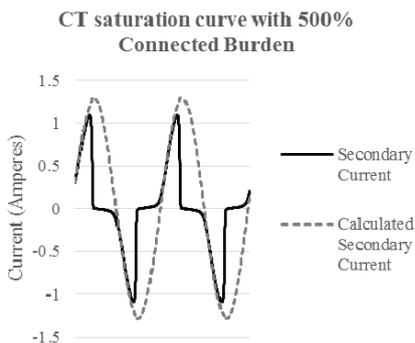


Fig. 5 CT secondary waveform with 500% connected burden and primary current, which equals 1.25 times the primary rated current

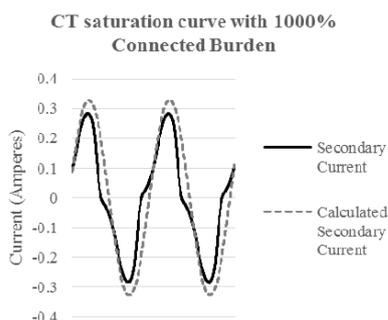


Fig. 6 CT secondary waveform with 1000% connected burden and primary current, which equals 0.32 times the primary rated current

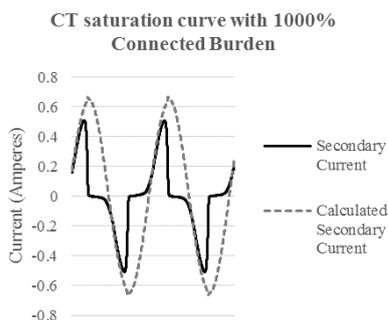


Fig. 7 CT secondary waveform with 1000% connected burden and primary current, which equals 0.65 times the primary rated current

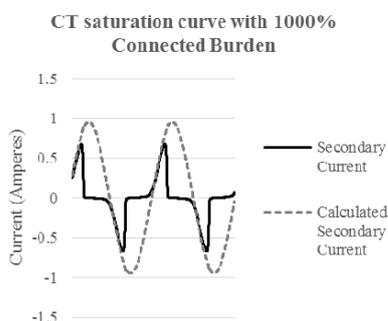


Fig. 8 CT secondary waveform with 1000% connected burden and primary current, which equals 0.9 times the primary rated current

Figs. 3-8 show that the when the primary current increases

beyond the saturation limit of the CT, the CT secondary current tends to decrease from the proportional value as per CT ratio. This is due to more current flowing through the magnetizing circuit of the CT than the CT secondary.

V. CT HEATING AND VIBRATION

Since more current is flowing in the CT magnetizing circuit when the CT is saturated, it gets heated up. This leads to deterioration of insulation in the CT, which may lead to CT failure if not identified and rectified on time. Also, as current increases beyond the saturation point, the CT vibration also increases. It gives a humming noise, which is not present when the CT is not saturated. Therefore, this increase in noise and vibration can be used as indication of CT saturation to conduct preventive maintenance.

VI. CONCLUSION

It can be concluded that for very high currents the CT will saturate and therefore the secondary current will not be a proportional representation of the primary current. It also shows that for very high Primary current the CT secondary current will be low thereby increasing relatively the chances of protection devices not detecting the very high currents. Similarly, energy recording will also be affected, as the meter will detect low current compared to the primary. Therefore, proper CT saturation point should be identified before installing a CT for any application. Also, it can be seen that the overcurrent factor of the current transformer is dependent on the connected burden. When the connected burden increases the effective over current factor decreases proportionately to the increase in burden.

The vibration and heating of current transformers can also be used to evaluate the saturation point of the current transformers. The increase in temperature of the current transformer when compared to the ambient temperature is an indication of CT saturation. Along with increased vibration of the current transformer core the heating of CT's can be used to evaluate the saturation point.

Increased vibration of CT core can also be taken as an indication of current transformer saturation. A proper study is needed to correctly identify the level of vibration with the CT saturation point but the increased vibration is an indication of current transformer saturation.

VII. LIMITATIONS

Due to the unavailability for high current source and measuring/recording instruments, the burden was increased to a very high level to saturate the CT at very low currents. In addition, the Direct current component introduced in the CT during a ground fault is not considered for this paper. During faulted condition in a power system the current transformer transforms positive sequence currents, negative sequence currents and zero sequence currents whose effects on the CT are not within the scope of this paper.

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