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Operation Analysis of Current Transformer with Transient Performance Analysis Using EMTP Software

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ABSTRACT: In this paper has detail about the current transformer sizing & there particular option according to there faction. Sizing & selection of current transformer with suitable knee (saturation) Voltage is depending upon the operation of function and according to type of relay. Used relays according to protection are like Line Main Differential Protection (Micom P54X), Line distance Protection (Micom P44X), Generator Protection (Micom P34X), Transformer Protection(Micom 64X). Mathematical model is developed for a current transformer to predict the transient performance with a complex burden consisting of inductance and resistance, taking core saturation into account. A typical 1200/5 A current transformer will be considered to simulation with various maximum offset fault currents. The flux response and secondary current have been computed for various values of load impedance. To validate the results, the proposed model has been compared to ATP-EMTP program. Second aspect of this paper is adequate CT sizing with new advance methodology consider KTD (Transient dimension) factor. CT selection has defined accuracy classes for perform kind of operation as like for metering, protection & special purpose.

Paper has also proposes advance CT sizing concept with KTD factor with transient performance analysis at asymmetrical current condition using Alternating Transient Programming (ATP) software. A very simple and effective model is presented for CT analysis. The main advantages of this proposed model is provided to following Information:

1) Selected type of CT & Selection of function
2) Selection of correct CT ratio according to system current & required type of class.
3) System Burden & resistance and inductance value impact on CT saturation.
4) Accuracy class of CT can be justifies with help of model for metering & more adequate operation.
5) It includes proper computing speed and accuracy. In this paper, modelling is done by ATP-EMTP programs.

KEYWORDS: Accuracy Class, Asymmetrical Current, CT Burden, CT Saturation, DC Offset and X/R ratio.

I. INTRODUCTION

To accurate performance of the Current transformer with metering & protection system, an accurate model for current transformer is needed. When a fault occurs in system high current flow with system, the current transformer approaches saturation region and this may lead to the secondary current distortion. Hence, it affects the protective relays operation and as a result, miss-operation will occur for the protective relays. Thus, this requires an accurate model of current transformer under short circuit in order to analyse the protective relays operation.

In this paper, an appropriate model is developed to predict the transient behaviour of a current transformer with a burden consisting of inductance and resistance, taking saturation into account. First, the sizing has to be proposed in advanced method of KTD & analysis saturation limit of CT. In the proposed CT sizing equation has including the KTD factor for adequate CT operation at fault condition. During fault condition system has produced DC offset current due to resistance & inductance in system. The results show the accuracy of this numerical integration method.

Paper has described KTD factor & there importance in adequate CT sizing. Previously, an ANSI/IEEE relay current transformer (CT) sizing criterion was based on traditional symmetrical calculations usually discussed by technical

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articles and manufacturers' guidelines. In 1996, IEEE Standard C37.110- 1996 [1] formalized some of this prior work by introducing (1 + X/R) offset multiplying factor for determine the CT saturation voltage, current asymmetry and current distortion factors; officially changing the CT sizing guideline on the basis for sizing CTs. In C37-1 10.1996 has recognizes primary current asymmetry and CT saturation due to the DC offset current component, it is no longer acceptable to use symmetrical primary current as the basis when performing CT calculations. A critical concern is the performance of fast protective schemes (instantaneous or differential elements) during severe saturation of low ratio CTs. Will the instantaneous element operate before the upstream breaker relay trips?
At the previously in CT sizing has using network maximum fault current & burden of the CT but in advance sizing has considered K_D and (1+X/R) factor for correct operation in transient condition and reduced the impact of DC offset current. X/R ratio is directly impacted on CT saturation now in a long distance transmission line & advance protection scheme has using many electronics device in system as like invertors, chopper, and other Facts device SSSC, UPFS, excitation panel etc that's why system has incising inductance value. DC offset current is related to X/R (time constant) value. In asymmetrical and symmetrical fault condition CT will saturate due to large DC off set current.

In I part of in this paper review modern CT sizing calculations using (1+X/R) to determine the CT saturation voltage if the results are practical and if standard CTs can be used. To augment the 1 +X/R consideration, a waveform approach is introduced. Because modern industrial electrical power systems are typically resistance grounded, ground relaying is considered beyond the present scope of this paper. Although the paper focuses on minimum ratio CT sizing and the concept of KTD factor & effect of Asymmetrical and symmetrical current of the system.

Alternative Transients Program (ATP) version of EMTP is an inexpensive, powerful tool for evaluating CT performance. The II part of in this paper briefly describes ATP software, provides instructions for constructing a CT model using ATP, and presents the CT performance analysis in transient condition. The paper uses the CT models to demonstrate:

- Construct a CT model & plot Primary & secondary excitation current.
- Impact of X/R ratio on CT saturation & role of transient dimension factor
- CT accuracy
- Analysis of current transformer saturation level with & without considering Transient Dimension Factor

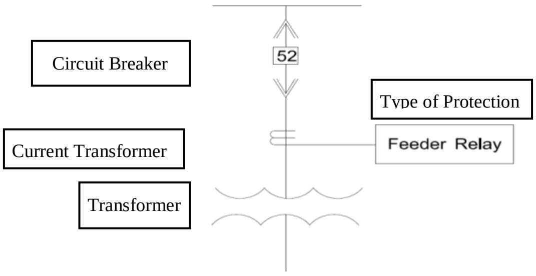

Fig.1 Single Line diagram & CT connection Indication

A critical concern is the performance of the relay's instantaneous element during severe saturation of low ratio CTs. Will the instantaneous element operate before the upstream main breaker relay trips? It is obvious the instantaneous element will eventually trip, but will it trip in an anticipated, repeatable manner before the upstream main breaker relay operates? Typical applications that involve either non-operation or nuisance tripping concerns are as follows (Fig. 1):

1) Feeder instantaneous overcurrent (ANSI 50) relay
2) Motor self-balancing differential (ANSI 87M) instantaneous relay
3) Generator differential (ANSI 87G) protection relay

This paper focuses on traditional CT sizing criteria during fault conditions for instantaneous element (ANSI device 50) only.
In Fig. 2 has shown the equivalent circuit of a current transformer with load impedance and details of parameter in CT. Basic working principle of the CT is same as the traditional transformer so no more difference in CT equivalent circuit as compare to traditional transformer. As show in fig 1 the CT secondary voltage V_S not should be saturate and exciting

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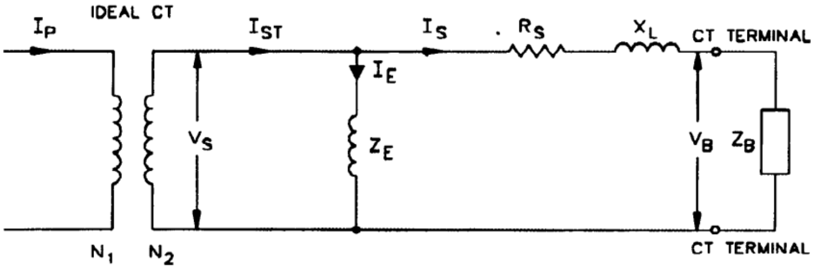
current should be low for better protection & measurement. When the voltage developed across the CT burden is low, the exciting current is low. The waveform of the secondary current will contain no appreciable distortion. As the voltage across the CT secondary winding increases because either the current or the burden is increased, the flux in the CT core will also increase. Eventually the CT will operate in the region where there is a disproportionate increase in exciting current.



V_S	is the secondary exciting voltage
V_B	is the ct terminal voltage across external burden
I_P	is the primary current
Z_E	is the exciting impedance
I_{ST}	is the total secondary current
R_S	is the secondary resistance
I_S	is the secondary load current
X_L	is the leakage reactance (negligible in Class C cts)
I_E	is the exciting current
N_2:N_1	is the ct turns ratio
Z_R	is the burden impedance (includes secondary devices and leads)

Fig.2 Equivalent circuit of a current transformer with load impedance

The CT core is entering the magnetically saturated region; operation beyond this point will result in an increasing ratio error and a distorted secondary current waveform. The Alternative Transients Program (ATP) version of EMTP is an inexpensive, powerful tool for evaluating CT performance. This paper briefly describes ATP software, provides instructions for constructing a CT model using ATP, and presents a method of CT X/R ratio & Burden effect of CT in saturation condition.

II. CALCIFICATION OF CT ACCORDING TO CLASS

1. **PS Class CT** – This type of CT is use for where the current balance is precisely required to be maintained. In the Overall differential protection, Transformer, Generator protection needs PS class CT. The developed voltage in ct core is less than the knee voltage of the CTs.
2. **PROTECTION CLASS CT –** They are used for over current & instantaneous & IDMT Relay. As like 5P10, 5P20 are the protection class ct. It means the 5 is the significant the % limit of composite error 20 & 10 is the ALF it means the fault current of CT is in range of 10 & 20 time of the rated primary current of CT with ±5 % of defined % of composite error.
3. **METERING CLASS CT -** The core of ct should be low cross section area low saturation means with stand at high current or fault current condition. According to the accuracy the CT will be selected as like 0.5, 0.2 ,0.2s & 1.

   Note-
   - 0.2 & 0.2S class CT are used for the voltage above the 33 KV level.
   - 0.5 &0.5S class CT are used up to 33 KV level.

III. TRADITIONAL CT CALCULATION SIZING APPROACH

Protective relaying has always combined art and applied physics, with the goal of issuing tripping commands during abnormal electrical system conditions. Protective relaying systems are typically straight forward with current transformers, wiring and relays. Fig. 2 shows the equivalent circuit of a current transformer with a load impedance [2].

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Traditionally, manufacturers' literature and industry standards provided calculation analysis guidance to ensure CTs were adequately sized for both ratio and accuracy class.

One author's professional development of performing CT saturation calculations began with (1) to determine the minimum CT Accuracy class.

IV. DYNAMIC CHARACTERISTICS

A.FLUX CHANGE WITH ASYMMETRICAL PRIMARY CURRENT

The dc component of an asymmetrical current greatly increases the flux in the ct. When the dc offset is at a maximum, the CT flux can potentially increase to 1 + X/R times the flux resulting from the sinusoidal or non-offset component, where X and R are the primary system reactance and resistance to the point of the fault [B11]4. The difference between the non-offset and offset flux is illustrated in figures 3 & 4. In figure 3, there is remanent flux but no offset in the primary current. The CT core does not go into the saturated region of operation so the secondary current is undistorted. Figure 4 shows the resulting flux and secondary current when the primary current is fully offset. The increase in flux is not instantaneous, indicating that saturation does not occur instantaneously but takes time. This time is called the time to-saturation.

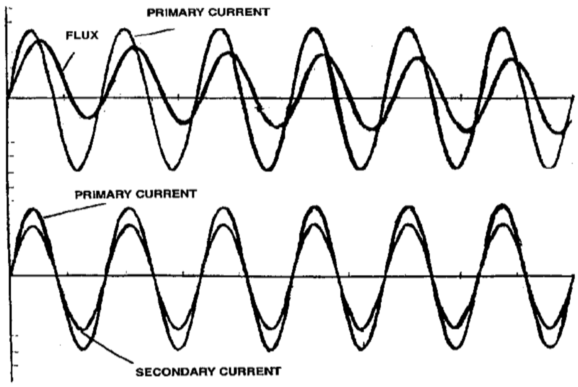

Fig.3 Relationship between primary current and flux and between primary current and secondary current for a non-saturated current transformer

1. Saturation factor and time-to-saturate

If practical, the effects of saturation can be avoided by sizing the CT to have a knee-point voltage above that required for the maximum expected fault current and CT secondary burden, with suitable allowance for possible dc component and remanence. The knee-point voltage may be 50% to 75% of the standard accuracy class voltage rating of the CT (e.g.,C 400). Saturation can be avoided by observing the following:

a) To avoid ac saturation, the CT shall be capable of a secondary saturation voltage, Vs :

$$Vs > Is \times Zs$$

Where I_S is the primary current divided by the turns ratio, and Z_S is the total secondary burden ($R_S + X_L + Z_B$).

b) To avoid saturation with a dc component in the primary wave and with a pure resistive burden, the required saturation voltage Vs is

$$Vs = I_S \times Z_S \times \left(1+ \frac{X}{R}\right)$$

Where X and R are the primary system reactance and resistance up to the point of fault.

If the CT burden is also inductive, the required saturation voltage to avoid saturation caused by primary dc is

$$Vs > Is \times Zs \times \left(1+ \frac{X}{R} \times \frac{Rs + R_b}{Zs}\right)$$

To also account for possible pre magnetization (in the worst direction)

$$Vs > \frac{Is \times Zs \times (1+X/R \times (Rs + R_b)) / Zs}{1 - \text{Per unit remanence}}$$

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These requirements generally result in impractically large CTs and hence compensating steps must be taken to minimize saturation effects on the relay protection plan. Some high speed instantaneous relays can operate before saturation has time to occur.

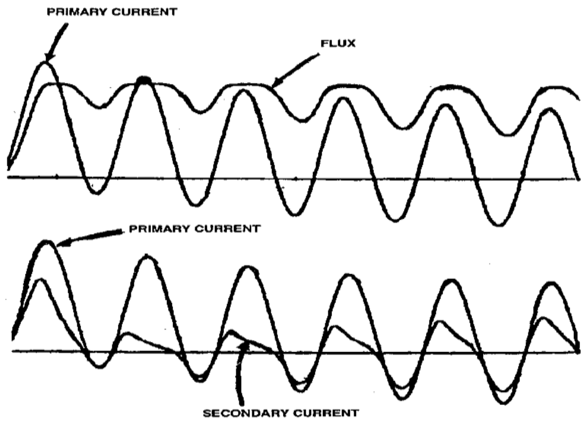

Fig.4 Relationship between primary current and flux and between primary current and secondary current for a saturated current transformer

V. CONSTRUCTING A CT MODEL USING ATP

The ATP version of EMTP is the basic software tool for electric system transient modelling. ATP Draw is a graphical, mouse-driven pre-processor to ATP on the MS Windows platform and uses a standard Windows layout. The Alternative Transients Program (ATP) version of EMTP is an inexpensive, powerful tool for evaluating CT performance. Fig no. 5 is the excitation test circuit with 1200/5 CT ratio & 1 phase saturation transformer form ATP library and connected suitable load with voltage source and set the required parameter of saturated transformer and test the model by recreating the CT excitation curve using ATP Draw circuit in Fig.6.

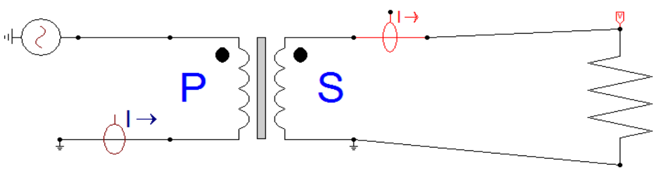

Fig.5 CT Test Circuit in ATP Draw

In the fig no. 6 has shown the excitation current curve of the CT and Knee point voltage. According to the CT will be saturate at 928.7 Volt.

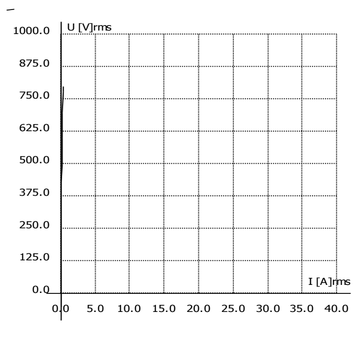

Fig.6 Excitation Current Curve

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Fig. 7 is CT excitation current curve has secondary current magnitude is 0.12 at 707.5 volt of source voltage. Now compare with Fig. 6 the current & voltage level of CT is approximate equal it means constructed Saturable Current Transformer is Adequate. Basically this analysis has to be is done for analysis of CT accuracy class.

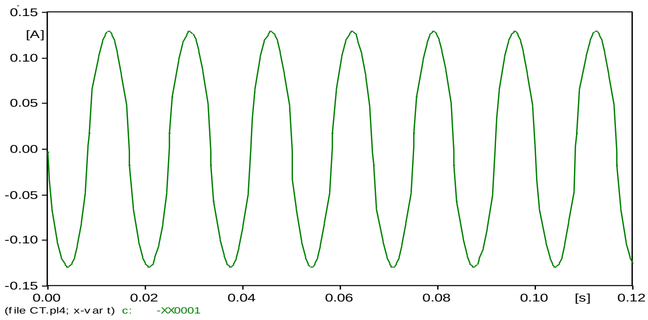

Fig.7 CT sec. excitation current at 707.5 volt

Now for the analysis of X/R ratio and burden effect on the CT the model is constructed with the help of previous CT model. Fig. 8 has connected RLC branch in series and playing with X/R ratio & burden value of the CT now the results are shown in Fig 9.

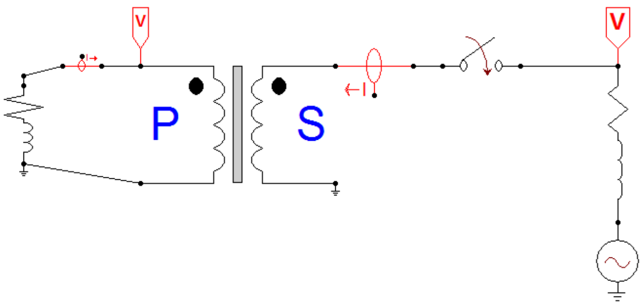

Fig. 8 Test circuit in ATP Draw

Fig. 9 is output response of the CT. In this curve has shown the impact of X/R ratio at starting condition current is rise due to high DC offset current. CT will saturated if X/R (Time Constant) ratio is to high then the decay of current is long and CT will saturate at that time. If CT primary & secondary current has no deviation in magnitude only current level is reused then CT is not saturated and selection of X/R is adequate

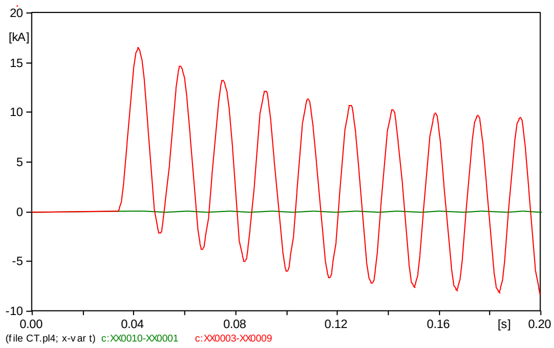

Fig. 9 CT Secondary Voltage & Load Current

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1. CT primary & Secondary has fully DC offset current due to the X/R (Time constant) value. If X/R ratio is high in network than slop of current is high. Magnitude of secondary current(in red line) is very low as compare to primary current that's why current is not plot in fig no.9
2. Compare both CT primary and secondary current level there is some deviation in secondary side curve due to high burden connected in secondary side with constant X/R ratio it means CT is saturated.
3. CT is saturated due to higher burden at secondary side. During the first 3 cycle CT is not sense current level so it will saturate for that time.
4. It means due to incising of Burden CT will be saturated so selection of CT Burden should be within the limit of CT than CT sizing is adequate

VI.SUMMARY

Modern IEEE Standard C37.110-1996 & according to manufacture detail & type of relay sizing the current CT should sized according to consider the transient dimension factor & CT saturation calculations include a (1+X/R) multiplier that significantly increases the required CT accuracy class during fault conditions in medium-voltage industrial power feeder circuit applications, particularly when low-ratio CT's are implemented so the secondary voltage of the current transformer. The KTD factor are using according to IEC standard and minimum ratio CT sizing. In general ct ratios are selected to match the maximum load current requirements, i.e., the maximum design load current should not exceed the ct rated primary current. The highest ct ratio permissible should usually be used to minimize wiring burden and to obtain the highest CT capability and performance in transient condition. As ATP model analysis we can summarised the role of the KTD factor and the performance analysis of CT

VII.CONCLUSIONS

According to current transformer sizing & used application it shall be all factor related to & for correct operation. When IEEE Standard C37.110-1996 formally introduced the (1+X/R) multiplier for CT saturation calculations, CT accuracy class requirements significantly increased for heavy industrial applications with low-ratio CTs on typical medium voltage feeder applications because the X/R ratio is 'high" (14 or greater). The DC offset voltage value is more in DC component where the inductance value is more. As like in near to excitation system of transformer and minimum in Transmission line because there are low DC component. This did not appreciably affect utility transmission applications because the utility industry X/R range is "low" (4 to 8). Because the (1+X/R) multiplier may require significant CT accuracy requirements, a modem method is needed to confirm the CT ratio and accuracy class and relay response during fault conditions. Multiplying (1+X/R) ratio is better & more safe in transient condition but sizing voltage is incising much more & cost also but the KTD factor has approx. minimum voltage CT sizing.
ATP, ATP Draw, TOP, and MathCAD are effective, inexpensive tools for power system transient analysis and relay simulation. ATP is very effective for modeling particular power systems and equipment configurations. Using ATP derive an accurate relay model from public information such as conference papers and instruction manuals. Use the model to understand relay transient performance in your system to improve applications and settings.

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