TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 8165 - 8169

Current Transformer Saturation & Impact Analysis of CT Saturation on Healthy System & Distance Protection in Power Network

Manish Mishra[1], Swakantik Mishra[2]
Department of Electrical and Electronics Engineering
Centurion University of Technology and Management
Ramachandrapur,Bhubaneswar-752050 Khurda, Odisha, India
[1]Email: 180303140001@cutm.ac.in, [2]Email: swakantik.mishra@cutm.ac.in

Article Info
Volume 83
Page Number: 8165 - 8169
Publication Issue:
May - June 2020

Article History
Article Received*: 19 November 2019*
Revised*: 27 January 2020*
Accepted*: 24 February 2020*
Publication*: 18 May 2020*

Abstract:

Live wire Power system faces many difficulties during normal & abnormal operating conditions. Disturbance like imbalance loading & faults hampers the dynamics of the system.Maintaining voltage to frequency ratio is crucial in power network, for this instrument transformers & protective device plays a vital role. So for accurate function of any protection scheme current transformer reliability is essential. The major issue with any current transformer is its saturation. In modern power system optical fiber CTs are being replaced with conventional CTs, but it has its own challenges. Even in present date conventional CTs are being used for protection of system. In this paper we have analyzed & discussed about CT saturation & its impact on distance protection on power system

Keywords: *CT Saturation, Knee Point Voltage, Distance Protection, Impedance measurement, Saturation Flux.*

I. INTRODUCTION

In modern Power System protection & measurement plays an important role in stability of grid. This can only be achieved through accuracy & speed of operation. With state-of-the art development in electrical manufacturing sector the texture of instrument transformer is also modernize to fulfill the requirement, looking to recent development optical fiber CTs are replacing conventional CTs, but it has its own challenges. As the process of development is gradual, the presence of conventional CT cannot be ruled out. So for a healthy system operation fast & accurate CT operation is critical.

Current transformer is a type of instrumentation transformer which is used to convert higher level current up to a level workable for protection, measurement and control setting. It produces a secondary current which is proportional to the current in the primary.

Current transformer insulates the secondary side from the high voltage of the primary side so that the secondary side is not exposed.When saturation occurs due to fault in the transmission line, the relay that is connected to the transformer cannot operate properly.

The secondary current is mainly used for the purpose of metering and protection.For protection less accuracy in CT is required as compared to the metering. In this paper distance protection system is connected with CT. So, accuracy of the current transformer not a major factor as the metering.

II. THEORY OF CT SATURATION

To understand CT saturation, first we have to know about the concept of working of CT, why does it saturate and what is happening after the saturation.

A. Working of CT

CT consists of two windings, secondary winding is around the core and the primary winding acts as a primary conductor passes through secondary. When current flows in the primary winding,alternating

May – June 2020
ISSN: 0193-4120 Page No. 8165 - 8169

magnetic field is generated. This leads to the generation of alternating magnetic flux around the transformer core that passes throughthesecondarywinding.If a burden is connected in secondary, analternating voltage is created by the magnetic flux across the secondary. This generates analternating current to flow in the secondary side, which creates its own alternating magnetic field and alternating magnetic flux that oppose which created by the primary. This results in cancelation of fluxes and leaving a net flux of negligible amount in the core.

So, basically CT is a type of transformer that produces a current in its secondary which is proportional to the current in the primary.

Figure (1) shows an equivalent circuit diagram of CT. Where I_p(the primary current), I_s(the secondary load current), I_0 (the magnetizing current) N1 and N2 represent the turns ratio of the CT, and the ratio current $I_{st}$is the primary current divided by this ratio.

The resistance R_{ct}represents the secondary winding resistance of the CT and R_{load}represents the resistance of the load. Here R_{ct}value is constant whereas the value of R_{load}varies according to the load.

In CT the constant currentsource $I_p$drives the total secondary current $I_s$as determined bythe turns ratio. $I_s$is the current that is measured by the load ifthe CT is ideal.

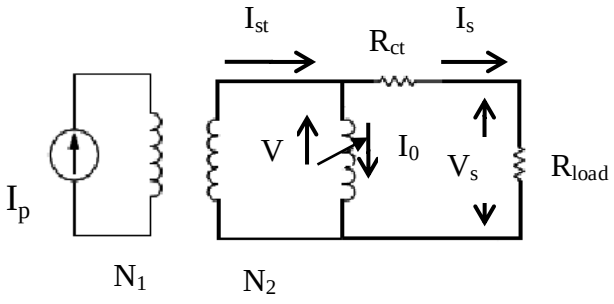


Fig.1.Equivalent Circuit diagram for Current Transformer

B. Current Transformer Saturation

If an open circuited condition occurred on the secondary of CT, in thesecondaryside very high alternating voltage flows due to the alternating magnetic flux.This results in high burden on the secondary side, creates a low impedance path due to fault conditioncauses a very high primary current, which leads to the saturation of the current transformer.

When CT gets saturated they can no longer maintain the current ratio between the primary and the secondary winding. Saturation may leads to malfunction of the protection devices as the measured current does not correspond to the current on the system.

III. SIMULATION OFCURRENT TRANSFORMER SATURATION

Figure (2) represents the MATlab simulation of a current transformer where there is connection between the source and output voltage and current. A voltage source of 120 KV is connected to the primary side of the current transformer through a circuit breaker. The rated current of the current transformer iss 2000/5.

The turns ratio of the transformer is repsented by,

$N_1 I_P = N_2 I_S$ (1)

Where N_1= primary turns and N_2 = secondary turns

The primary of the current transformer is taken as 1 turn. That means seconadary current is fixed as 5A and so accornding to equation (1) , the secondary turns is 80 turns and 400 A current is flowing in the primary side.

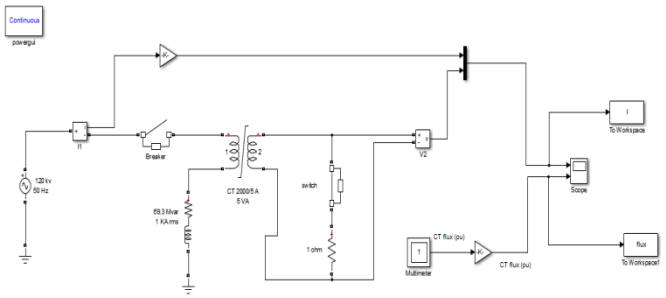


Fig. 2. Current Transformer Simulation Block

The output current and the flux can be represented by using the scope connected in the Simulink block. By using this block we can observe the behavior of current transformer for both normal and saturation condition.

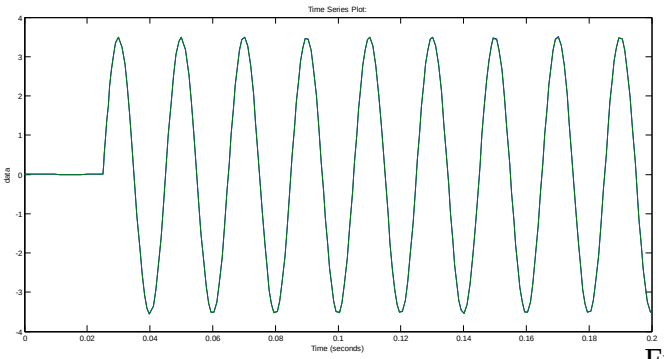
May – June 2020
ISSN: 0193-4120 Page No. 8165 - 8169

Figure (3) explains the generated secondary current of the transformer without saturation. It can be observed from the graph that the variation in curve is synchronized with time which indicates that ratio transformation is occurring in a smooth way, i.e. as per the current level in the line, the replication in reduced level as per ratio is availed for protection & measurement

Figure (4) explains the generated flux of the transformer due to the secondary current and can be measured by using the multi-meter. It can be observed from the curve that the envelope reduction is gradual with diminishing margin in positive and negative quadrant. With diminishing marginal shifting there will cause heavyfluctuation of current, this will lead to unnecessary relay actuation & circuit breaker triggering.

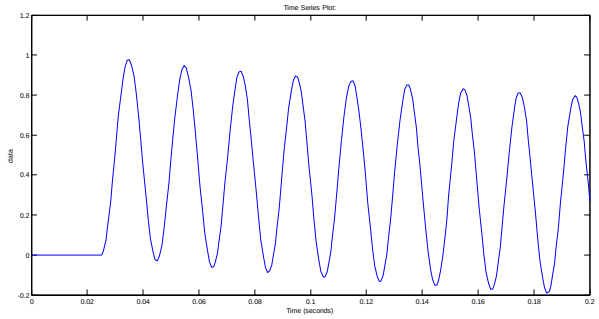
Figure (5) explains the influence of current saturation on the secondary current of the transformer. It clearly indicates that during saturation the peak current value reduces drastically and varies in-uniformly w.r.t. time. That is in spite of standing ratio the current value does not change accordingly as it should be.

Figure (6) explains the effect of current saturation on the flux. It indicates that the exchange of flux becomes constant after excitation flux reaches knee point voltage as shown in graph the flux increases to peak value as remains constant in positive quadrant w.r.t. time period without any variation or negligiblevariation, for which there will be no mutual exchange of flux form Ct core to secondary. Which will leads to excess accumulation of charge in CT core, resulting in heating of the core.



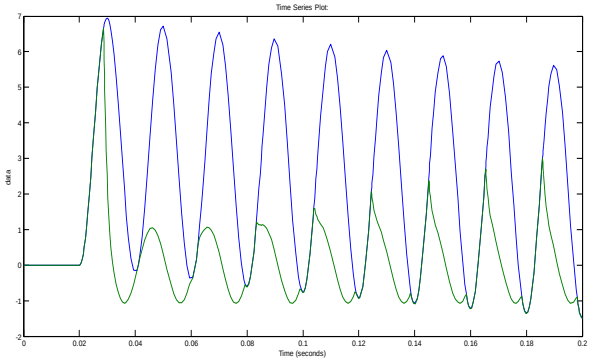
Current Vs Time

Fig. 3. Secondary current of transformer without CT Saturation



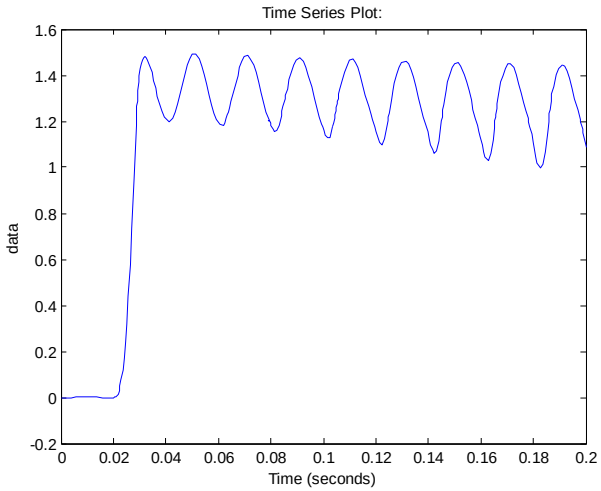
Flux Vs Time

Fig.4. Current Transformer Flux without CT Saturation



Current Vs Time

Fig. 5. Secondary current of transformer with CT Saturation



Flux Vs Time

Fig.6. Current Transformer Flux with CT Saturation

May – June 2020
ISSN: 0193-4120 Page No. 8165 - 8169

IV. Power system And Current Transformer with Distance protection Simulation Block

This block consists of a 120 KV line-to-line sourcevoltage, transmission line and a CT with current saturation effect on power system and distance protection system.

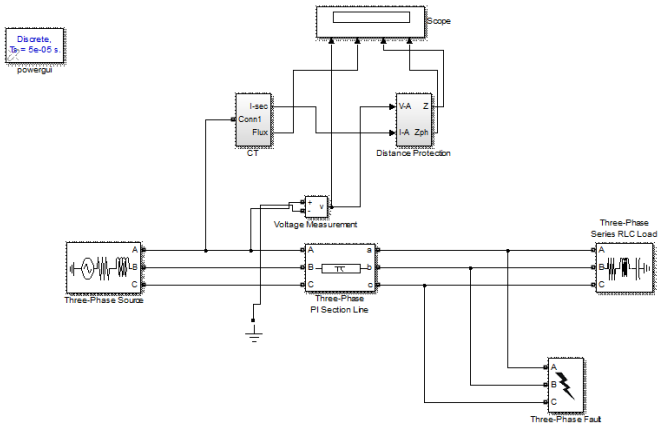


Fig.7. **Power system simulation**

This paper explains the behavior distance protection system under the influence of CT saturation. The simulation of the power system contains the source and the CT. The current signal moved from the CT to the distance protection block. Its simulation graph is given in figure (9,10).

A. Distance Protection Block

Distance protection is designed to detect the faults which occurred in the transmission lines.The main functions included in the digital relay model aredetection of faults, measurement of impedance and Zone protection.

1. Detection of faults

The relay allows the direct detection of the faulty phase and tripping of the appropriate distance measuring zone. Without phase selection under reach or over reach problem might occur.

2. Impedance Measurement Block

The impedance measurement block consists of subsystem used to calculate the fault impedance of single phase fault. The block uses an algorithm for the fault detection shown in equation (2).

$$Z_{slg} = \frac{VA}{IA+3KoIo} \qquad (2)$$

$$K_0 = \frac{Zo-Z1}{KZ1} \qquad (3)$$

$$I_0 = \frac{Vs}{Zo+2Z1} \qquad (4)$$

Where,

Z_{slg}= single line to ground Fault impedance
A = phase where fault occurs
VA= phase voltage
IA = phase current
Io = zero- sequence current
Zo = zero-sequence impedance (75 ohm)
Z1 = positive-sequence impedance (50 ohm)
K = residual compensation factor (taken as 0.9)
Vs = phase voltage during the phase to ground fault

Figure (8) shows the subsystem of the impedance measurement block.

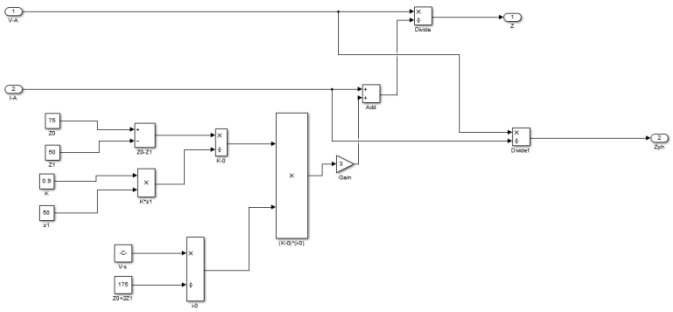


Figure 8.Apparent impedance model for SLG Fault

3. Zone protection

The distance protection system divides the transmission line in to different zones. Zone1 covers up to 80 percent of the first section of transmission line. The setting of the next zones depends on the length of the remaining sections of the line. Zone 2 covers up to 120 percent (Zone1+20%)and Zone3 covers up to 240 percent(zone1+zone2+20%) of the first section of the transmission line.

(Simulation graph of Fig. 7)

TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 8165 - 8169

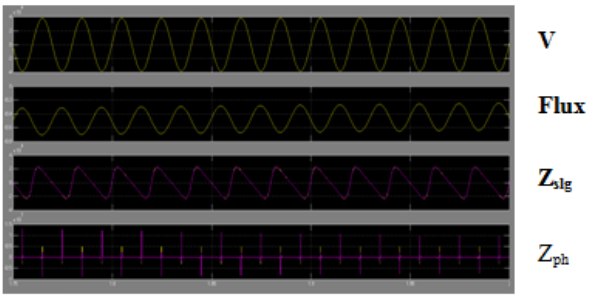


Fig. 9. Parameters with distance protection without CT saturation

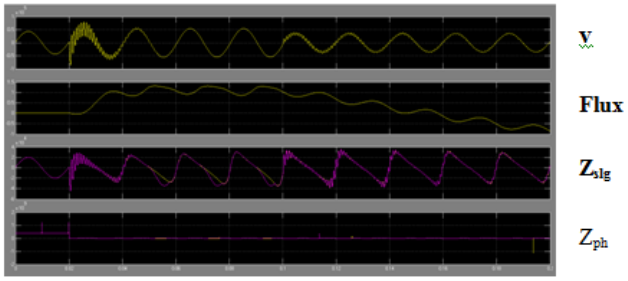


Fig. 10 Parameters with distance protection with CT saturation

V. RESULT AND DISCUSSION

Fig.9 and Fig 10 show the parameters of the designed distance protection which cover different parts of transmission line under study. The figure (9) explains the behavior of different parameters in a power system where distance protection is connected and the CT is operated without saturation. The figure 10 shows the behavior of the parameters when the CT connected to the power system in under the influence of saturation. Current saturation leads to an error in the calculated fault impedance (Zslg) and also there is an error occurred in the algorithm which is used to calculate the fault impedance. Due to this error, the distance protection is not working as it should.

VI. CONCLUSIONS

The CT saturation could force the distance protection, because of the algorithm which is used for the calculation of fault impedance in the protection system. This algorithm is using both the current and voltage signals. The saturation effect in CT has resulted in a failure in the calculation. This error leads to the problems in functions of the protection. So the CT saturation boost the measured impedance in the system.

REFERNCES

[1] A. Hargrave, M. J. Thompson and B. Heilman, "Beyond the knee point: A practical guide to CT saturation," 2018 71st Annual Conference for Protective Relay Engineers (CPRE), College Station, TX, 2018, pp. 1-23.

[2] K. Wannous and P. Toman, "The impact of current transformer saturation on the distance protection," 2016 17th International Scientific Conference on Electric Power Engineering (EPE), Prague, 2016, pp. 1-5.

[3] J. Mooney, "Distance Element Performance Under Conditions of CT Saturation," 2008 61st Annual Conference for Protective Relay Eng College Station, TX, 2008, pp. 491-497.

[4] Muhd, Hafizi&Idris, muhdhafizi&Hardi, Surya &Mohd, Zamri&Hasan, Syafruddin. (2013). Teaching Distance Relay Using M nulink Graphical User erface. PharmaceuticalEngineering. 53. 10.1016/j.proeng.2013.02.035.

[5] Mrehel, Omar &Elfetori, Hassan &H dallah. (2020). Implementation and n a SIMULINK Model of a Distance Relay in MATLAB/SIMULINK. 2020/3/25, pp. 1-6.

AUTHORS PROFILE

Mr. Manish Mishra is a Research Scholar Centurion University of Technology and Management, Bhubaneswar. He has two years experience as a junior lecturer at JITM,BALANGIR

Mr. Swakantik Mishra is an Assistant Professor in Centurion University of Technology and Management, Bhubaneswar; He has more than 10 years of experiences in industry & academia. His research interests are electricity market, electricity pricing, operational issue in power system.