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EFFECT OF CURRENT TRANSFORMER SATURATION ON DISTANCE RELAY IN 220KV POWER TRANSMISSION LINE

B.V.Chakradhar[1],Y.Mohan[2], CH.Kalyan[3], P.Sai Krishna[4]

#1,2,3,4 Student of Electrical and Electronics Engineering, Geethanjali Institute of Science and Technology, Nellore, Andhra pradesh, India,

Abstract -The distance protection relay measures the line voltage and line current at the relay location and evaluates the ratio between these quantities. Distance relays are widely used on transmission, and even distribution systems. Current transformers (CT) are the very important part of the power system protection. The main purpose of a CT is to transform the primary current in a high voltage power system to single level that can be handled by delicate electronic device. This paper deals with the influence of CT saturation on distance digital relay. Saturation of the CT is evaluated for fault close to the relay location.

Keywords: Solar energy, Photovoltaic, Solar tracking, Microcontroller, Power

1. INTRODUCTION

The electrical power system has many elements which are important to ensure security and protection of the system.current transformers are applied in high voltage transmission systems The current transformer is a device which is connected to the power system and is used to produce low current that is possible to use in protection devices. The current transformer has two parts (primary and secondary). The primary side has few coil turns and the secondary side has a large coil turns. This structure is used to obtain low current on the secondary side; the current which is produced in secondary side is used for several functions in power system such as metering and protection, therefore, the output current of the current transformer becomes the input for the protection device, however, the ratio between the primary winding and the secondary winding have caused the current saturation during faults which occurs in the transmission line. In this case, the relay which is connected to the current transformer cannot respond or trip in right way [5]. The current transformer is used for different functions as was mentioned above (metering and protection), however, the level of accuracy depends on the operation type. There is a relationship between the accuracy of the CT and rated current and the good accuracy is important for metering. In this paper the current transformer is connected to the distance protection, consequently, the current transformer which is required for this test doesn't require the accuracy level as good as for metering [11].

2. Transient Monitor:

The concept of transient motor is generallyintroduced to improve the phasar estimation process.The transcient monitor is nothing but the difference between the original input signal and reconstructed signal ad=fter phasor estimation.During CT saturation the presence of decaying DC component is the main cause for this difference so for the transcient monitor using least squares techniques approach the mathematical formulation is provide below

$$i_k = I_m \sin(k\omega_0 t_s + \varphi) + A_0 e^{-kt_s/\tau}$$

Where "I_m" is the peak value of the fundamental component, 'k' is the sampling instant, "ω_0 is the fundamental frequency, "t_s" is the sampling interval, "φ" is the phase angle of the fundamental frequency component, "A_0" is the magnitude of the dc component at the instant $t = 0$, and "τ"is the time constant of the decaying dc component. Suppose N is

the number of samples per cycle. By varying the value of k from 1 to N, the fundamental component of current can be estimation as

$$[A][x] = [B] \quad (2)$$

where

$$[A] = \begin{bmatrix} \sin(\omega_0 T_s) & \cos(\omega_0 T_s) & 1 & -T_s & T_s^2 \\ \sin(\omega_0 2T_s) & \cos(\omega_0 2T_s) & 1 & -2T_s & (2T_s^2) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \sin(\omega_0 NT_s) & \cos(\omega_0 NT_s) & 1 & -NT_s & (NT_s^2) \end{bmatrix}$$

The state vector is given by

$$[X] = \begin{bmatrix} I_m \cos\varphi & I_m \sin\varphi & A_0 & \frac{A_0}{\tau} & \frac{A_0}{2\tau^2} \end{bmatrix}^T$$

and the current measurement vector

$$[B] = \begin{bmatrix} i(t_0 + t_s) & i(t_0 + 2t_s) \cdots\cdots i(t_0 + Nt_s) \end{bmatrix}^T$$

The unknown vector $[X]$ can be represented as

$$[X] = A^{\dagger}[B] \quad (3)$$

where $A^{\dagger}$ is the left pseudo inverse of [A].

The fundamental components of current signal can be regenerated using the estimated unknown vector given in (3) and can be articulated as

$$[B'] = [A][X] = [A](A^{\dagger}[B]) \quad (4)$$

The difference between $[B']$ and $[B]$ can be computed as

$$[\varepsilon] = [B'] - [B] = \left[\left[[A](A^{\dagger}[B])\right] - I\right][B] \quad (5)$$

where, $[\varepsilon] = [\varepsilon_1, \varepsilon_2, \varepsilon_3 \ldots \varepsilon_k]$. The transient monitor index (TMI) is defined as sum of the absolute values ε_k over one cycle and can be represented as

$$\text{TMI} = \sum_{k=1}^{N} |\varepsilon_k| \quad (6)$$

III. Proposed Method

As the value of TMI is computed using (6) is based on recursive window, it will be nonzero till the CT saturation continues. So, in a system CT saturation is detected using the proposed method if in any phase

$$\text{TMI} > \zeta \quad (7)$$

where ζ is the threshold value and practically it is set at zero. For worst case scenario like for different system configuration or based on short circuit current level any threshold setting can be provided. The flow diagram of the proposed method is provided in Fig.1. According to the proposed logic, relay computes the local end current information for each phase a, b and c. Using least square approach the current phasors for each phase is then calculated using (3). The current samples are than recomputed using (4).

Using (5) the error or difference in samples i.e. the original and reconstructed samples can be estimated using one cycle estimated errors the TMI is computed considering the relation (6). If the value of TMI is more than the threshold than it is considered as a CT saturation condition.

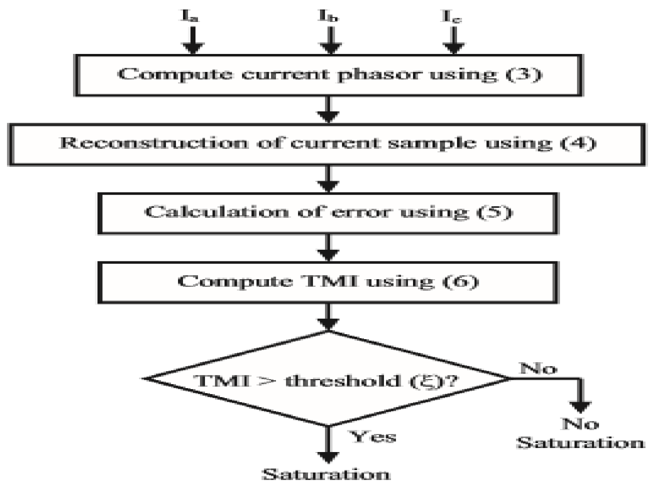

Fig. 1. Flow diagram of the proposed detection algorithm.

4. THE EXCITATION CURVE OF CTS

A.. Characteristics of current transofrmer The current transformer primary winding is connected in

series with the device in which the current is to be measured. Since current transformer is fundamentally a transformer, it transmits the current from the primary to the secondary side, inversely proportional to the turns so as (1)

$$I_p = nI_s \qquad (1)$$

where n is the ratio of turns between the secondary and primary winding. The equation (1) explains the normal transformer with a different number of windings between the primary and secondary side. Figure (1) explains the equivalent circuit for a current transformer. Reactance Xm explains the magnetizing current; the secondary current which is generated in secondary side is divided into internal current and magnetizing current.CurrentIs represents the internal winding current.

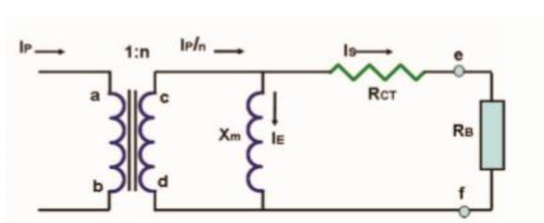

Fig. 1. Equivalent Circuit for a Current Transformer[10] B. Saturation Test The current transformer can be tested as connected the secondary side to the voltage source then measured the current which produced on the secondary side, taking into consideration that the primary side remains open without load during the test. The voltage is increased gradually with measuring the current until reach to the saturation point which is started when the voltage is increased 10 % and the secondary current is increased 50%. After this point, any small increase in voltage has resulted in large increases in current that supposed to mean the saturation is started [3]. Thane test starts with decreased the voltage value gradually and writing the current value for all voltage values until the voltage value becomes at the end is equal zero to make sure that core. Demagnetization after that we can draw the magnetic curve.

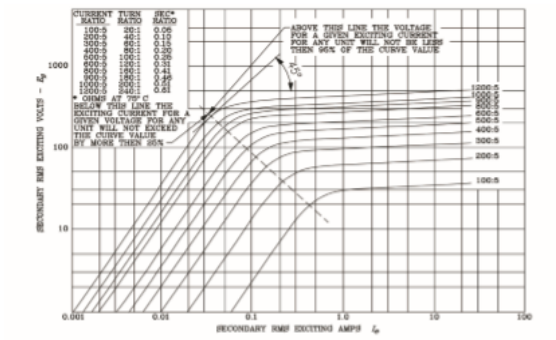

Fig. 2. Secondary excitation curve example

TABLE I. EXCITATION CURVE VALUES [13]

V_e (volt)	I_e (ampers)	Z_e (ohms)
3.0	0.001	3000
7.5	0.002	3750
12.5	0.003	4167
18	0.004	4500
60	0.010	6000
150	0.020	7500
200	0.025	8065
300	0.050	6000
400	0.200	2000
447	1.0	447
486	10	49

BY SIMULINK:

The Simulink explains the connection between the current transformer with source and output current and voltage. voltage source 120 Kv is connected to breaker then to the current transformer on the primary side and the

current transformer has rated current 5.CURRENT TRANSFORMER SATURATION 2000/5 .

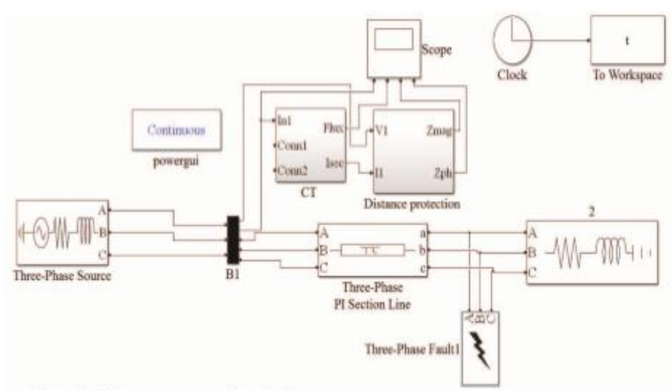

Fig : power system simulation

The model consists of one source operating at 120 kV line-toline rating voltage, 100 km transmission line, load, current transformer block which includes the influence of current saturation on power system and distance protection [1].

Figure (4) explains the secondary current which is generated in secondary side of the current transformer .This current inside the range of magnetic curve which is without saturation.

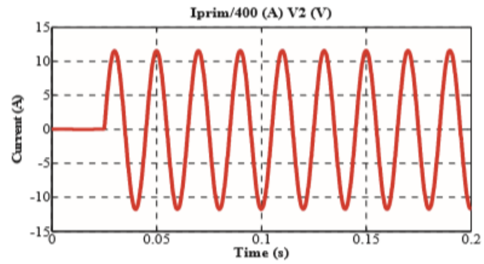

Fig. 4. Secondary current of transformer without CT Saturation

Figure (5) explains the current transformer flux which is generated by AC secondary current .the flux can be measured by using the multimeter that is allowed to measure all contents inside the current transformer (primary current, secondary current and flux) [3].

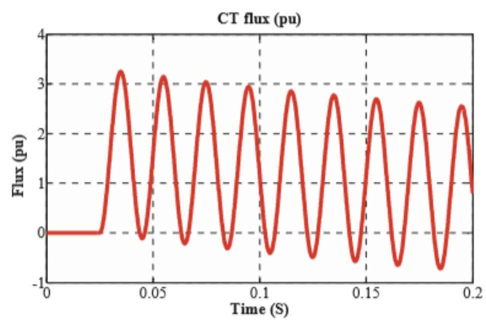

Fig. 5. Current transformer flux

We can see the effects of saturation in the waveforms of primary current and secondary current with current saturation influence (Fig.6). A large ration of the A-phase ratio current has gone to magnetizing current. This wave is an input for protection system. Digital relays are affected by current saturation of current transformer, especially, when this relay measures the magnitude of the input current, voltage and ratio between current and voltage pfsuch as distance protection [6].

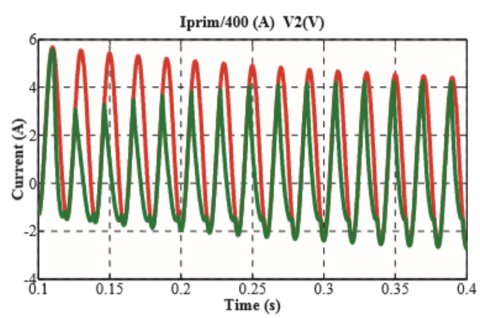

Fig. 6. Secondary current of transformer with CT Saturation

This paper explains the impact of CT saturation on the distance protection. As we mentioned above the power system simulation contains first of all the source then the CT block inside this block there is current transformer also the saturation parameters for this specific system. After the CT block the current signal is moved to the distance protection block which is used this signal with many functions starting from the filter, sampled values and discrete Fourier transformer [1]. The current waveform as shown in (Fig.8) illustrates fault current and healthy phase currents. The fault was started from 0.2s and at 0.5s the phase A current comes back to steady state. Figure 8 shows the fault current without the influence of CT saturation.

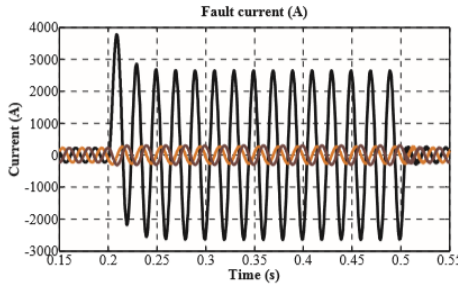

Fig. 8. Secondary current of transformer without

The simulation results are presented for fault in phase A. Time development of impedance measured and calculated by relay is in Fig. 10. The results for the remaining faults can also be determined using the formula (4). It presents how the distance protection has detected the fault with current saturation.

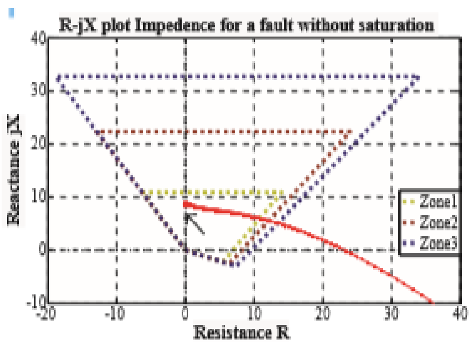

Fig. 10. R-jX plot impedance for a fault with current saturation

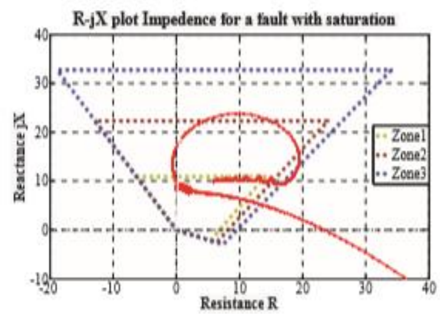

Fig. 11. R-jX plot impedance for a fault with/out current saturation

Fig.10 and Fig 11 show the three zones of the designed distance protection which cover different parts of transmission line under study. The figure 10 explains where the fault occurs without impact of current saturation (from the Simulink without CT block). The result fault impedance is 9 ohms. It means the fault occurred in the first zone. The figure 11 shows the fault impedance under the impact of current saturation (as mentioned above that the first block is simulated the current transformer). Current saturation had resulted in an error in the calculated fault impedance, Moreover, there is an error of the algorithm which is used to calculate the fault impedance. Due to this error, the distance protection is not working as it should. Discrete Fourier Transform (DFT) is used to obtain magnitude and phase components in the time domain of input signal.

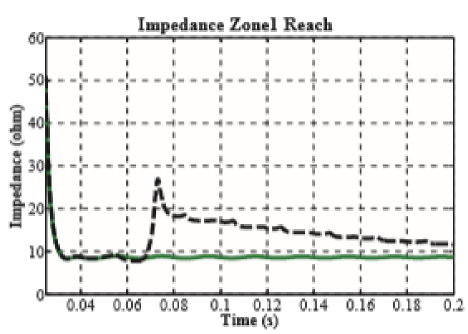

Fig. 12. Impedance plot for Zone 1 reach

The Fourier block is used to extract the fundamental frequency components from the distorted fault signals by eliminating decaying DC components. Fig. 13 shows the magnitude waveform obtained for current signal with/out saturation. The brown line is the current without saturation and the black one with saturation.

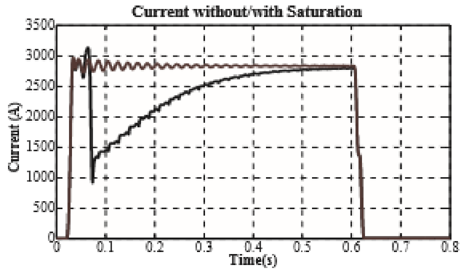

Fig. 13. Current signal magnitude from FFT

CONCLUSIONS

The distance protection could be impacted by the saturation of current transformer; especially tripping time could delay, because the algorithm which is used for calculation of the fault impedance in the protection relay. This algorithm is using both current and voltage signals.A method for detecting CT saturation from the computed magnitude of transient monitor index (TMI) using least square techniques is presented in this work.The saturation effect in current has result in a failure of the calculation. This error lead to the problems in functions of the protection. So the distance element is under reach and has slower operation time and CT saturation increases the measured impedance in the distance element.

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