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A Novel Method to Analyse the Effects of Geomagnetic Induced Current on Transformer

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Abstract

Geomagnetic induced currents are generated on the power system by solar storms and solar flare, which causes damages to power transformer. GIC (DC) current when enter the power grid through the neutral point of transformer causes saturation of the transformer and the transformer gets damaged hence a novel hardware model was fabricated and the effects were analyzed. A software simulation was done using MATLAB and the effects on power transformer were observed to be increase in reactive power consumption and fluctuating harmonics in neutral current and the excitations current. Were analyzed which has got significance in the practical field to give warnings before the occurrence of the damage to the transformer and the subsequent interruption of power supply.
Keywords: Geomagnetially Induced Current (GIC), Transformer, power system, harmonics

I. Introduction

Normally power transformers are designed to operate with a sinusoidal voltage. Due to solar activity on Earth Surface and ESP Earth surface potential is induced which distorts the input voltage of the power grid and cause superimposition of DC current on transformer and causes various damages to the system.

In power system, neutral points of transformer are generally grounded for providing protection to the system. Therefore, due to variation in geomagnetic field it will produce potential difference and induce current between neutral point of transformer. This current is known as Geomagnetically induced current.

Flow of current between neutral is known as geomagnetically induced current (GIC) and causes instability issues and equipment damage in power systems during geomagnetic storms. The transformer are designed to operate close to the knee of the magnetization characteristics and when DC enters it causes the transformer to enter into the saturation region in the half cycle of input supply. This is known as half cycle saturation of transformer.

Due to half cycle saturation transformer draws large exciting current and result in increased reactive power consumption heating of the transformer and distortion of the alternating current waveform and harmonic generation in currents.

During GMD, the saturation of transformer depends on the magnitude of DC current and on the core. The level of half cycle saturation determines the nature of waveform of magnetizing current and reactive power consumption of transformer. The simulation is carried out to analyze the effect of GIC (DC) on transformer. This paper presents the simulation results to show the effects of GIC on the waveform of neutral current of transformer. The simulation model and results of transformer are presented in section

II. Hardware Implementation To Analyze The Effect of DC on Transformer

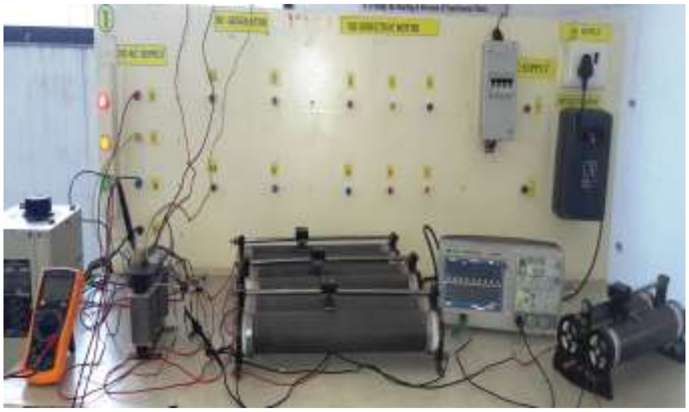

Fig. 1: Hardware Implementation of Transformer with injection of DC Current

In real high voltage power transformer, it is difficult to conduct test due to high magnitude of the currents and power. This problem was resolved by using reduced scale transformer. Thus, effect and investigation of it is done in a laboratory setup by injecting DC currents into a three-phase transformer.

Three phase AC voltage in the range of (0-440V) is applied to three phase transformers with the help of autotransformer and digital multimeter. A three-phase transformer of 440V/12V, 12VA, with primary winding delta and secondary winding star connected and neutral grounded so as to measure the effect of GIC on transformer and power system. For injection of DC current into the secondary winding of the transformer a half wave rectifier is used in series with three phases of the secondary winding.

The DC source injects a current which depends upon the three-phase resistive load. As the maximum secondary voltage is 12V a maximum DC current of 1 A can be injected into the star point, hence 0.333 A per phase. As the secondary side magnetization current of the transformer is about 1A the DC source is able to deliver a current that is half of the magnetization current.

This leads to saturation effects within the transformer core material. For monitoring of the primary and secondary side voltage to ground a digital storage oscilloscope (DSO) is used. The primary side and secondary side current are metered with the help of clamp meter. The waveform of voltage before and after DC current injected is shown in figure 2 and figure 3

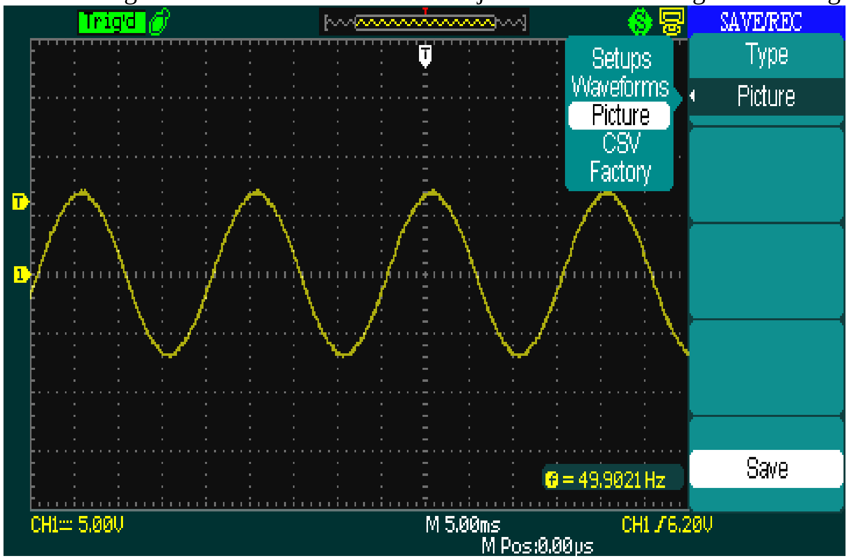

Fig. 2: Waveform on Primary Side of Transformer before DC Current is injected

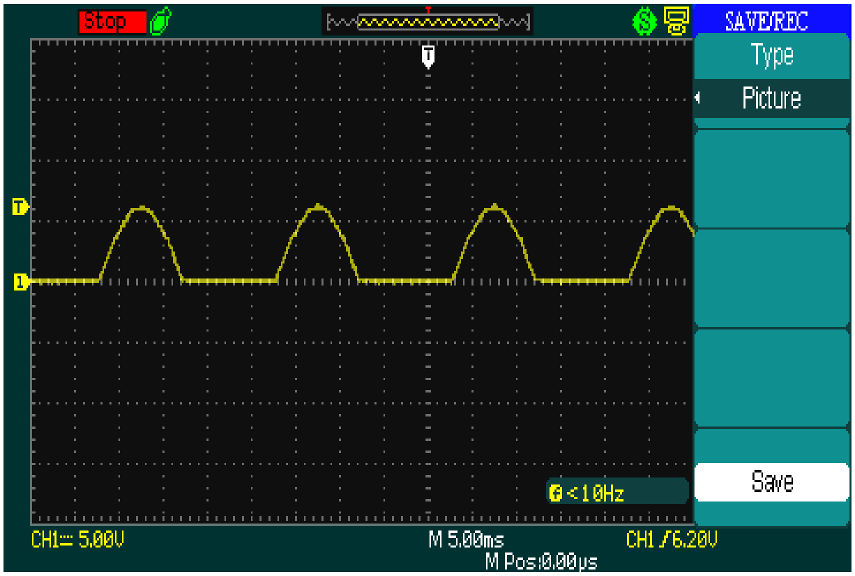

Fig. 3: Waveform on Secondary Side of Transformer after DC is injected into Transformer

III. Simulation and Result to Analyze The effect of GIC (DC) Current on Three Phase transformers

The simulink model consist of a transformer with three phase saturable transformer, resistive load, Bus bar B1and B2, current and voltage measurement meter to measure current and voltage in respective phase, DC voltage source to produce DC current in order to simulate GIC effect.

Figure 4 shows simulation model to analyze the effect of GIC (DC) on transformer using simulation on MATLAB. Three phase saturable transformer is designed with a voltage of 440V in the primary and the secondary voltage of 12V, and a resistive load.

The aim of this is to evaluate the effect of GIC with the transformer operating with DC. The rating of three phase transformers is a 12VA, 50 Hz. The line voltage of primary winding is 400 V & line voltage of secondary winding is 12V.

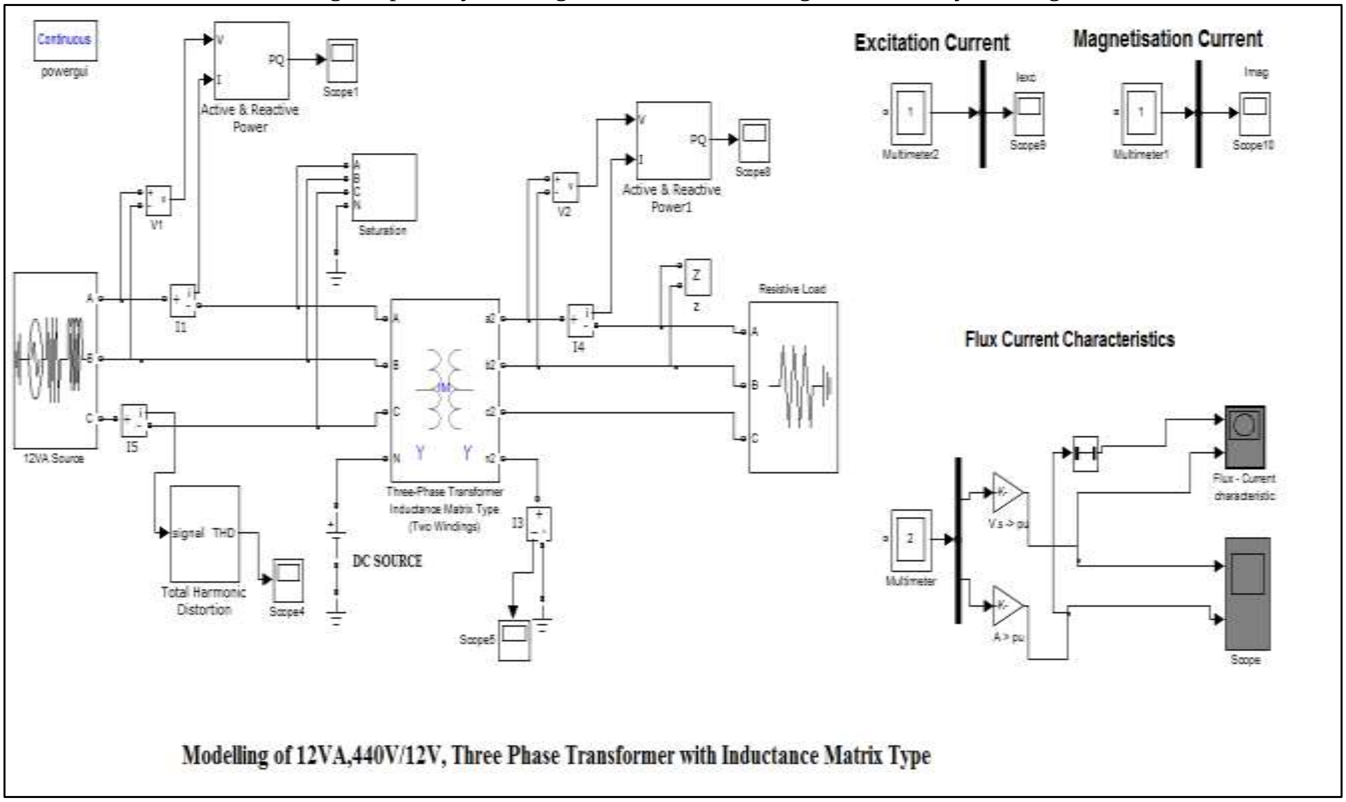

Fig. 4: Simulink Model of Transformer with effect of GIC (DC)

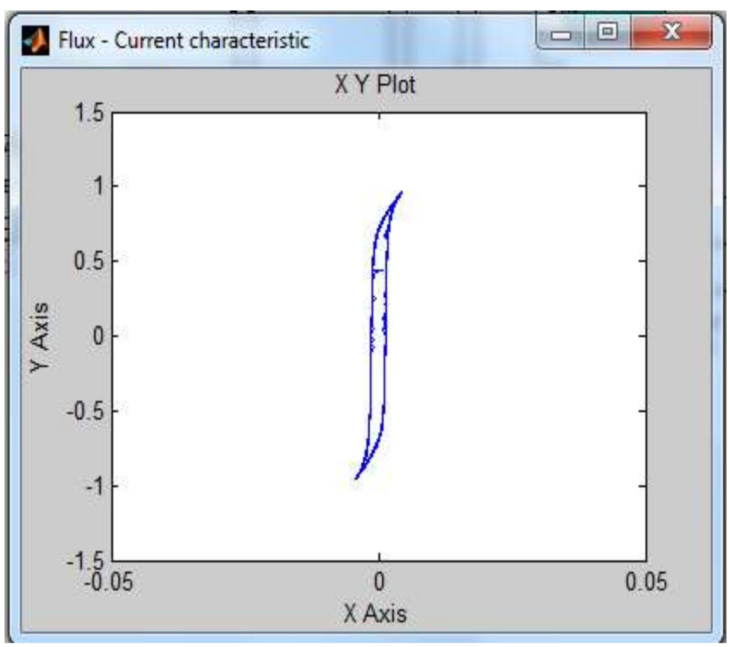

Fig. 5: Flux-Current Characteristics of Transformer

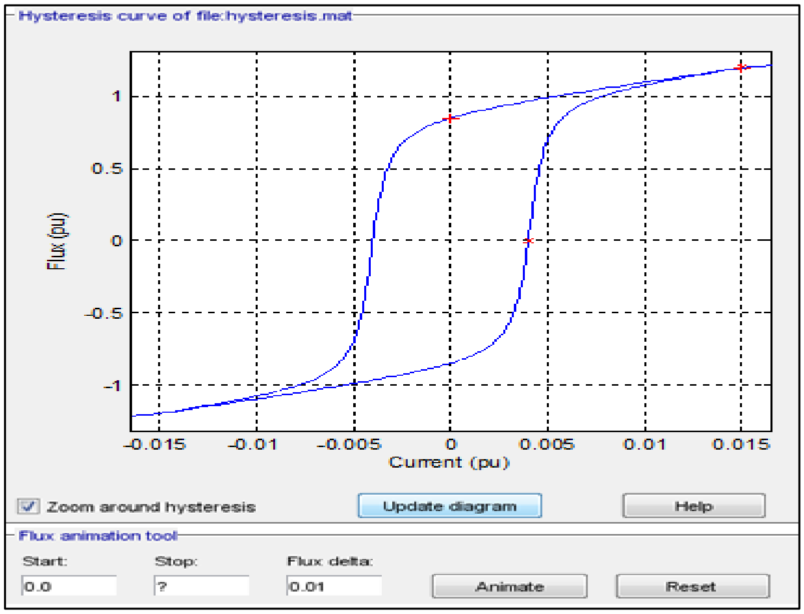

Fig. 6: Hysteresis Curve of Transformer When DC current is induced in Transformer by Power GUI Tool

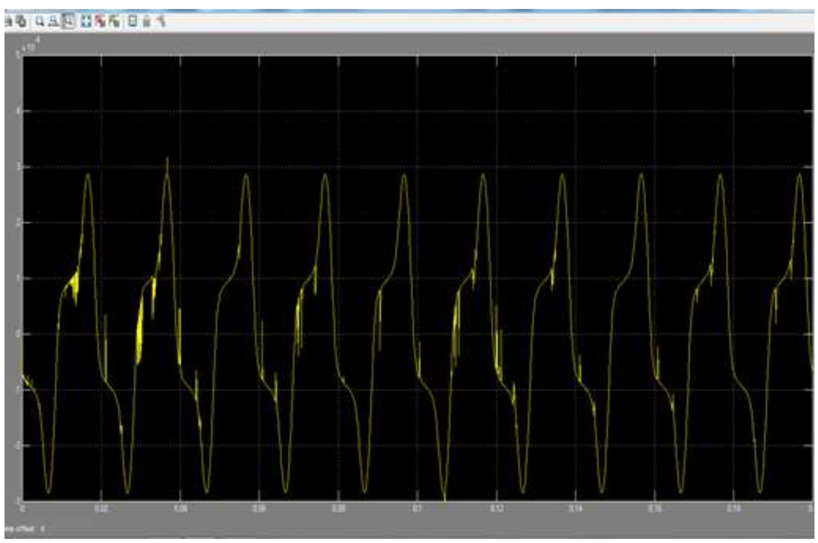

Fig. 7: Iexc Saturation Current of Transformer

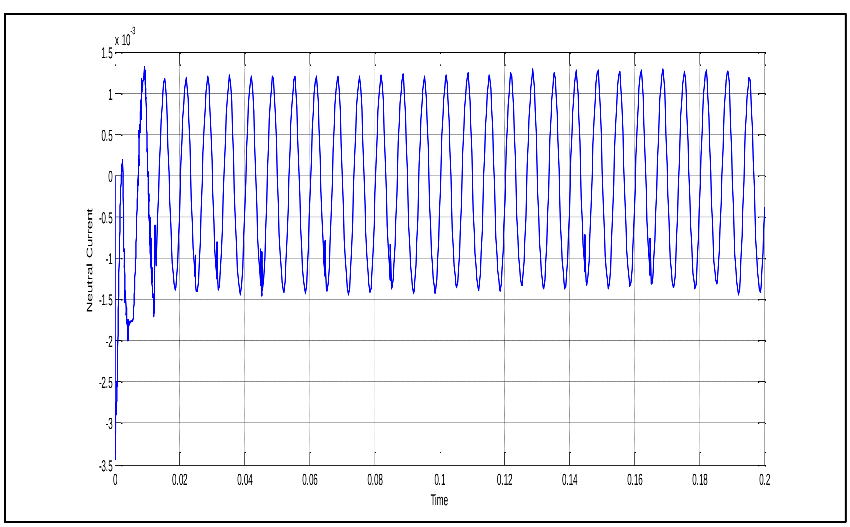

Fig. 8: Neutral Current When DC is induced at Secondary Side of Transformer

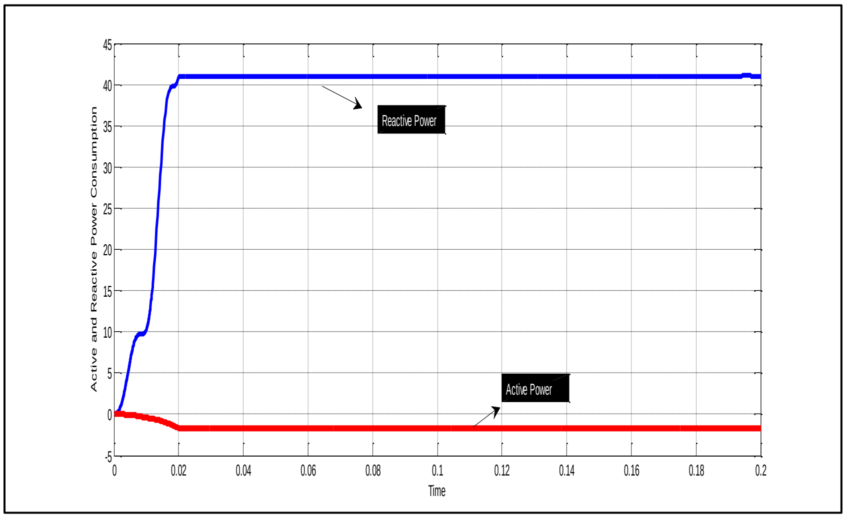

Fig. 9: Active and Reactive Power Compensation of Transformer

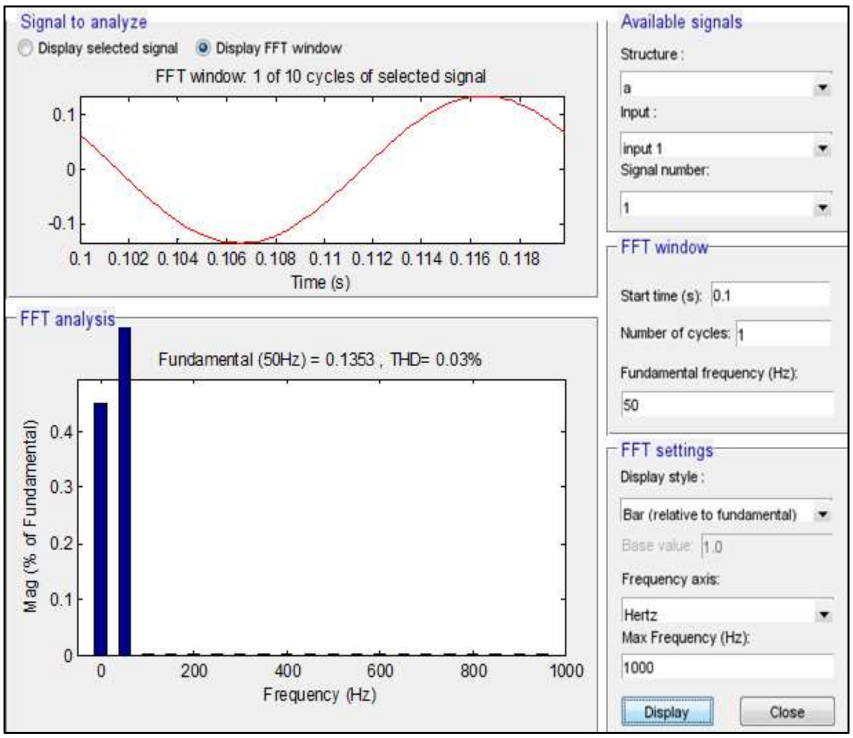

Fig. 11: FFT Analysis in Current when DC is Induced in Secondary Star connected Transformer

IV. CONCLUSION

The simulations of GIC using a three phase saturable transformer model shows

1) Reactive power consumption is increasing from 0 to 0.02 m sec and after 0.02 m sec it becomes constant while the active power of transformer decreases from 0 to 0.02 m sec and thereafter it becomes constant.
2) The neutral current fluctuations are observed predominantly as the DC is injected into the neutral of the saturable transformer.
3) The fluctuating harmonics in neutral current using power GUI FFT tool is found to be 0.03%.
4) The fluctuating harmonics is also found in the excitation current of transformer.
5) The B-H curve is also plotted and the area of the curve increases which shows the hysteresis losses are proportionally increasing as DC current is being increased.

The hardware and simulation model has given the results which will be of immense importances to the practical field engineers. Further studies could observe effects which happen in a bigger scaled power transformer leading to damages of the insulation or even to failures occurring after GIC events. Further investigations about these phenomena on large scaled setups shall be followed and the scalability of the setup needs to be investigated.

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