ANALYSIS OF THE MITIGATION METHODS OF GEOMAGNETICALLY INDUCED CURRENT

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ABSTRACT

Plasma beams which are expelled from the sun induce geo-magnetically induced current in power system. The law on which this phenomenon depends is also explained in this paper. The purpose of this paper is to analyze the MATLAB simulation model of geo-magnetically induced currents. The results obtained are compared with actual system without geo-magnetically induced current. The geo-magnetically induced current produces harmonics in the transmission line current. This harmonics which is produced due to GIC is analyzed by using fast fourier transform (FFT). Harmonics which is produced pulsates the active and reactive power consumption in the transmission line and because of this pulsation various effects are seen in the transmission line performance. These effects are also studied in this paper. This paper presents a novel mitigation technique to reduce the effects of geo-magnetically induced currents (GICs) on high-voltage power systems.

Keyword: -Geomagnetically Induced Current, Power System, Harmonics , Mitigation

1. INTRODUCTION

The intense plasma flares expelled from the sun directly heats earth's Magnetosphere. This causes geomagnetic storms and thus charged particles are produced in Magnetosphere. These charged particles in magnetosphere then follow magnetic field Ionosphere then follows magnetic field in Ionosphere. Thus magnetic field of earth changes.

This disturbed magnetic field links with the transmission line and transformer. According to Faradays first law of whenever the conductor placed in a magnetic field, an EMF induced in it. Thus voltage gets induced in transmission line. Thus, a very large current called GIC flows through the neutral of transformer.

GIC is nothing but a dc current having a very low frequency of about 0.01 hertz to 0.001 hertz. This dc current saturates the transformer core. Thus the magnetizing current increases largely and heavy losses occurs inside the transformer and thus transformer gets heats up and transformer may get damage. Because of the saturation, the harmonics are produced in transmission line current. This harmonics increases the root mean square value of line current. Thus relay mal-operates and whole system is hampered.

2. GIC SIMULATION MODEL

Simulation model consist of source voltage source. GIC is introduced in the system by using RAMP signal whose slope .is taken as 100 and starting time is 0.1.This means that GIC will comes in picture .Control voltage source is used to control the amplitude of GIC.As magnitude of GIC is very much small thus to analyze the GIC in proper way two three phase programmable voltage source is considered.

The amplitude of this programmable voltage source is taken 1.004.Instead of using 1 we have taken 1.004 to compensate the voltage drop in transmission line. So that whole 400KV will be supplied to the transformer. As we have analyzed the GIC on large network thus, we have taken the rating of transformer as 200MVA.

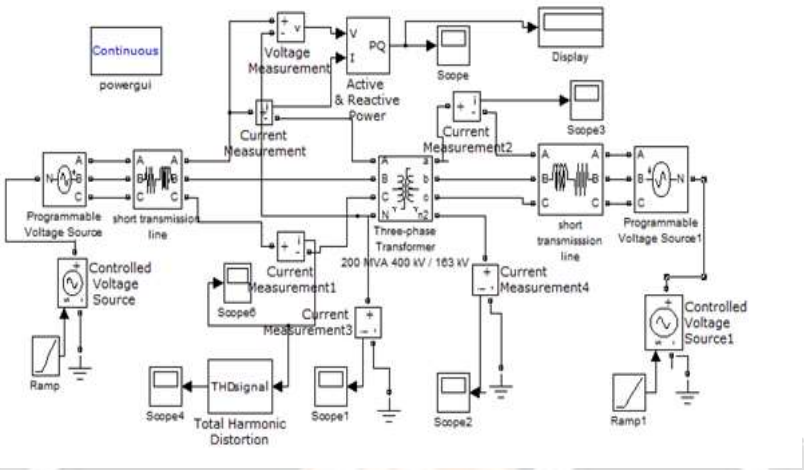


Fig.1 Simulation Model of GIC

3. ANALYSIS OF THE MAIN MODEL

The starting time of ramp signal is taken at 0.1 second. Thus GIC is introduced in the circuit after 0.1 seconds. As GIC is equivalent to DC current and thus because of this DC offset current, the line current shifts away from its original axis.

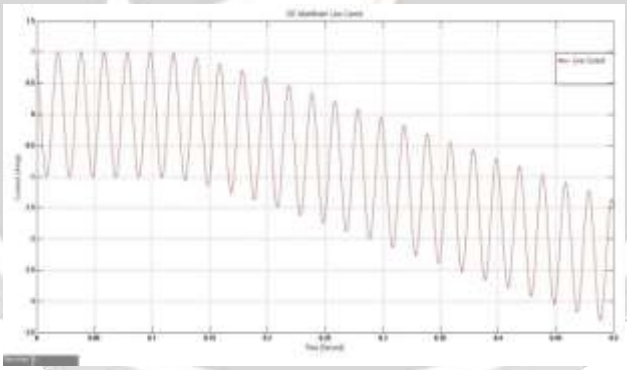


Fig.2 Line Current Waveform

Due to GIC, the system became unbalanced, thus current will starts flowing through neutral of transformer.

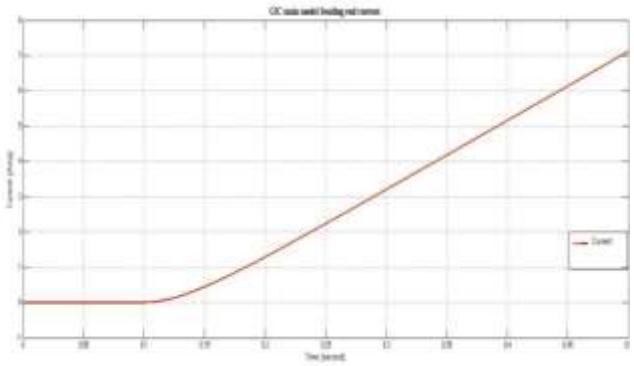


Fig. 3 Sending End Neutal Current

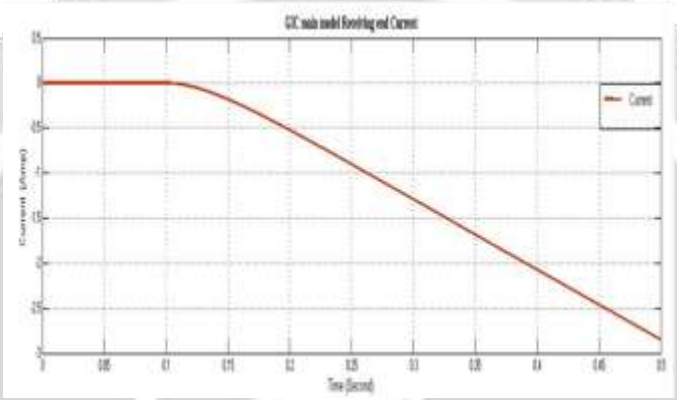


Fig.4 Receiving End Neutal current

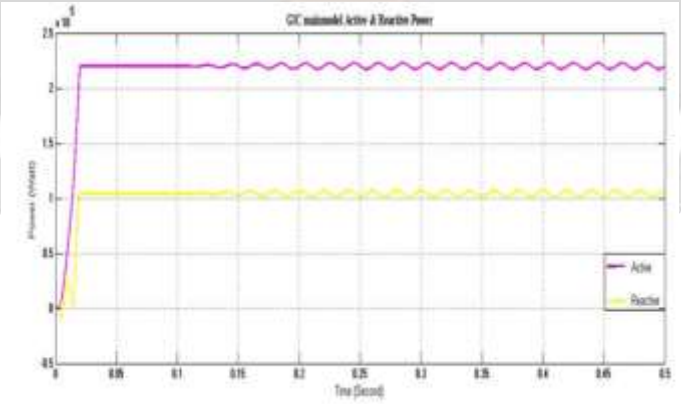


Fig .5 Active Reactive Power

Due to GIC, there is fluctuation in active and reactive power. Thus due to increase in reactive power, the root mean square value of current increases and thus relay mal-operates and thus whole system may get blackout.

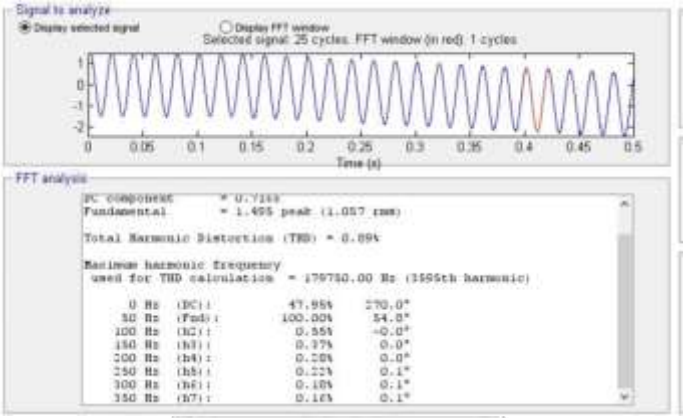


Fig.6 FFT Analysis

Due to GIC, the harmonics will be produced in the transmission line. This harmonics will be analyzed by using total harmonics distortion block. By using fast fourier transform, harmonics are analyzed.

Thus by result obtained, we found that dc components are about 47.95%.

4. MITIGATION METHODS

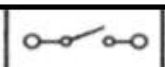
1.		Disconnect at Neutral
2.		Inductor at Neutral
3.		Resistor at Neutral
4.		Capacitor at Neutral
5.		Capacitor with by-pass at Neutral

Table 1 Various GIC Mitigation Methods

- **Disconnect at neutral**: The most obvious way to block the GIC is to disconnect the neutral from the ground where the GIC enters. But opening the neutral causes unpredictable voltage transients, hinders the ground fault detection, and may result in safety and insulation problem especially under single-phase-to ground faults.
- **Inductor at the neutral**: Inductors are generally used in the neutral to reduce the ground fault current levels. Since the GIC frequency is very low, such an inductor has very little effect on reducing the GIC.
- **Resistor at the neutral**: Resistor in neutral does not eliminate the GIC although it can substantially reduce it at the cost of loss in protection sensitivity and size of the equipment.
- **Solidly connected capacitor at the neutral**: Capacitors in neutral totally eliminate the GIC but may cause ferroresonance.

- **Capacitor at neutral with bypass:** This method allows switching the capacitor to neutral only during the GIC event; therefore, it limits the possibility of ferroresonance.

4.1 REDUCTION OF GIC BY USING RESISTANCE

Resistance is connected to neutral of transformer to reduce GIC. But in circuit 1000 ohms is taken, thus there will be large power loss in circuit and again resistance will not reduce GIC completely. Thus resistance is not a satisfactory method.

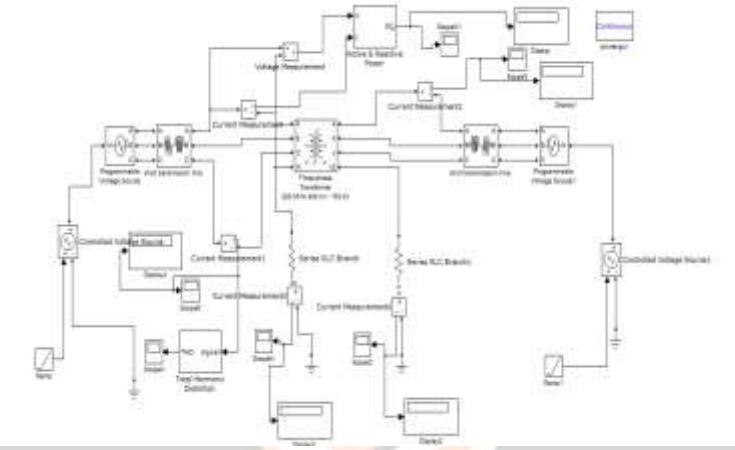


Fig .7 GIC Model with Resistance in Neutral

R value	Total Harmonic Distortion
0.2	0.83%
10	0.18%
50	0.05%
100	0.04%
1000	0.04%
2000	0.04%

Table 2 FFT Analysis by Using Resistor

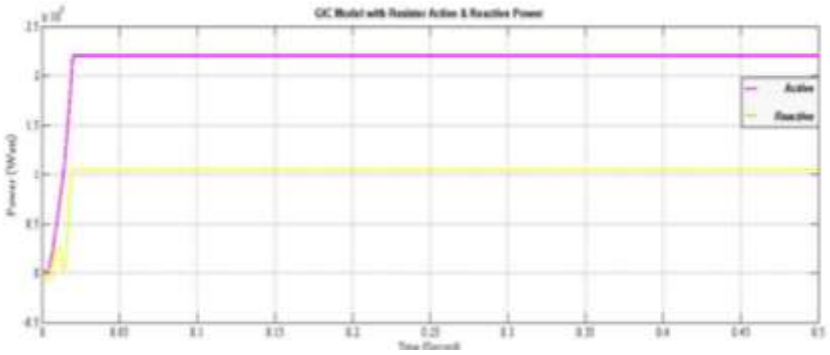


Fig. 8 Active and Reactive Power

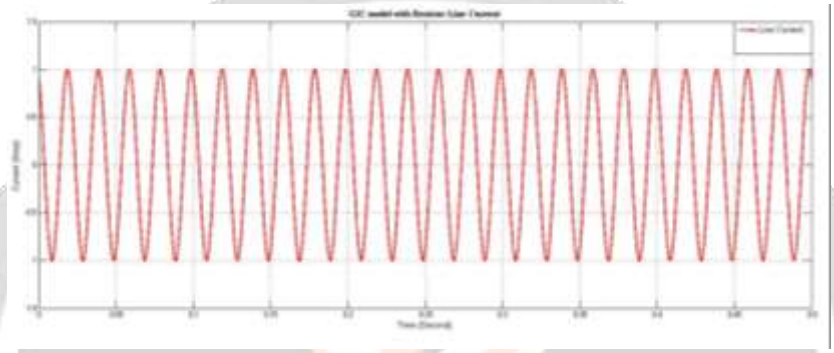


Fig. 9 Line Current

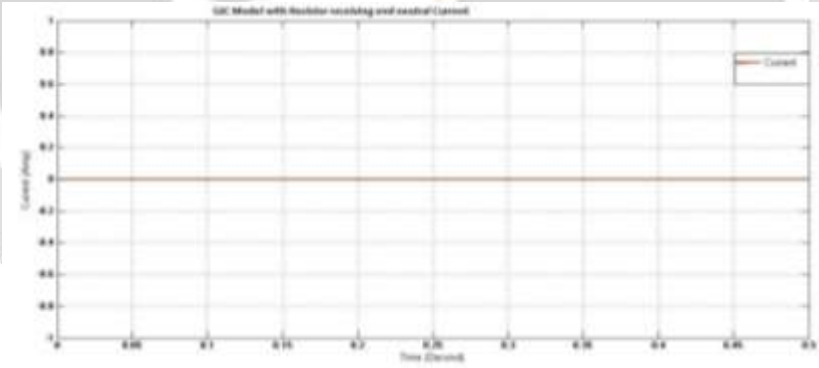
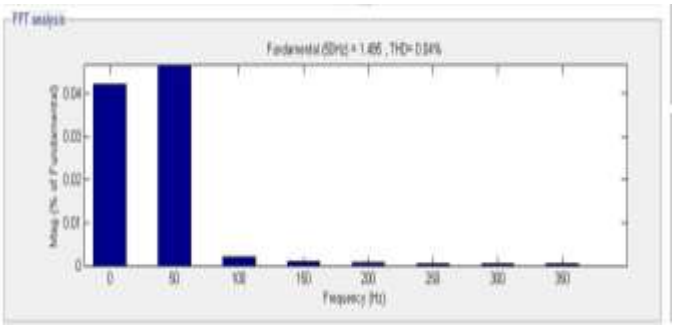


Fig. 10 Receiving End Neutral Current



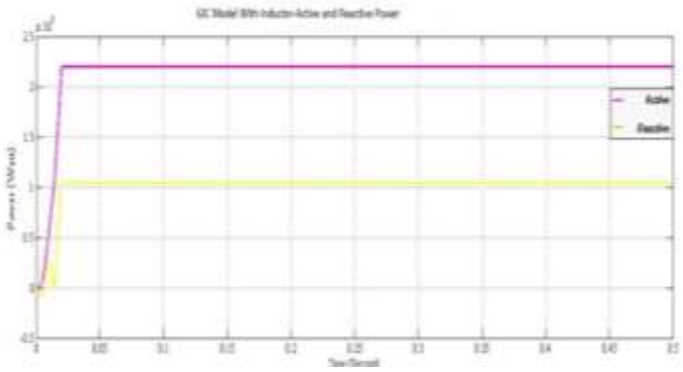


Fig. 11 FFT Analysis

4.2 REDUCTION OF GIC BY USING INDUCTOR

Reactance of inductor is equal to XL=2πFL, but as GIC frequency is very low about 0.01hz to 0.001hz,thus XL will be very small and thus inductor will act as short circuit. Thus inductor will not reduce GIC satisfactorily.

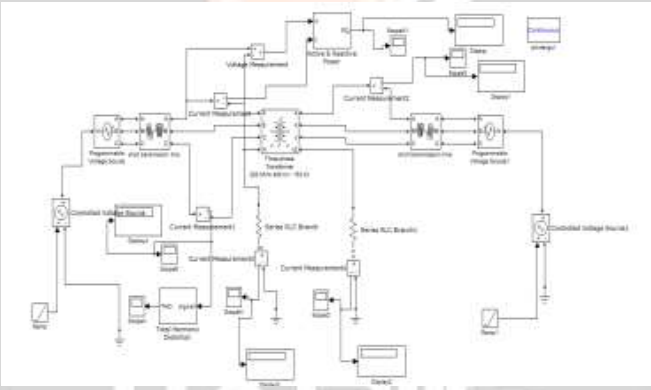


Fig. 12 GIC Model with Inductor in Neutral

L value (H)	TotalHarmonic Distortion
1	**0.43%**
5	**0.38%**
10	**0.06%**
20	**0.04%**

Table 3 FFT Analysis by Using Inductor

Fig. 13 Active and Reactive Power

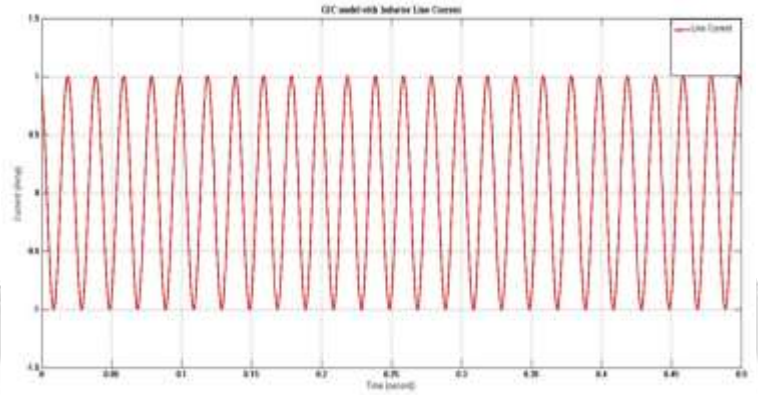


Fig. 14 Line Current

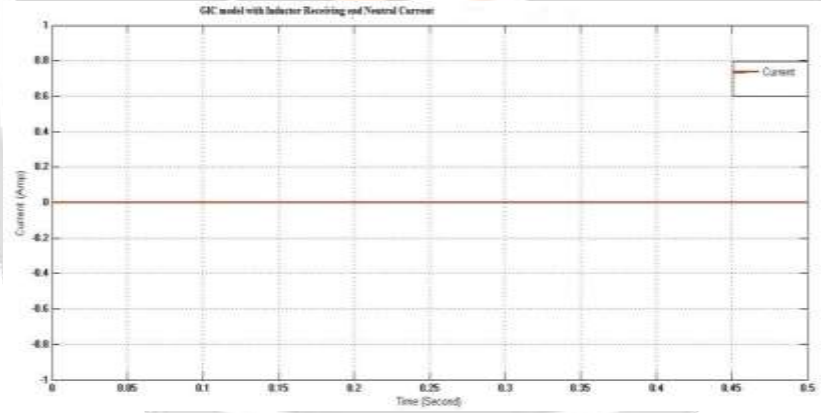


Fig 15 Receiving End Neutral Current

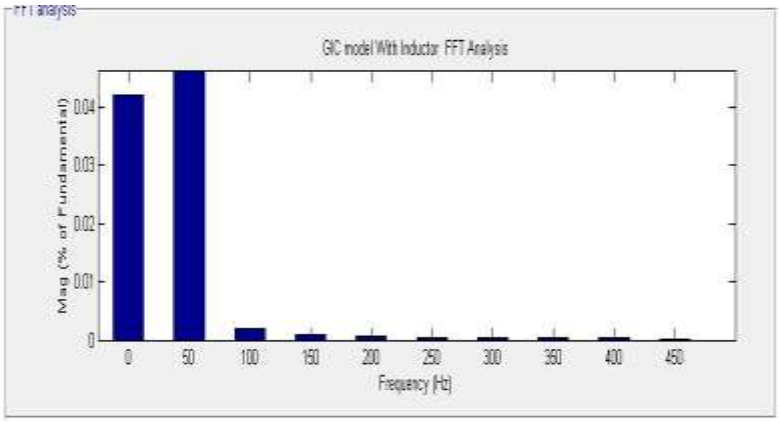


Fig. 16 FFT Analysis

4.3 REDUCTION OF GIC BY USING CAPACITOR

Reactance of capacitor is given by $Xc = 1/2\pi fC$. Now, frequency of GIC is very low and thus XC will be very large and thus capacitor will act as open circuit. Thus capacitor is not a satisfactory method.

R	C(micro farad)	Total Harmonic Distortion
1e^3	1	0.04%
1e^3	2	0.04%

Table 4 FFT Analysis By Using Capacitor

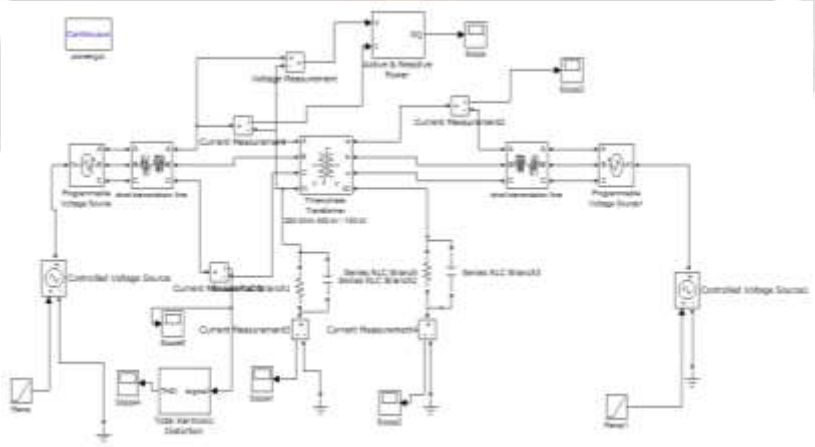


Fig. 17 GIC Model with Capacitor in Neutral

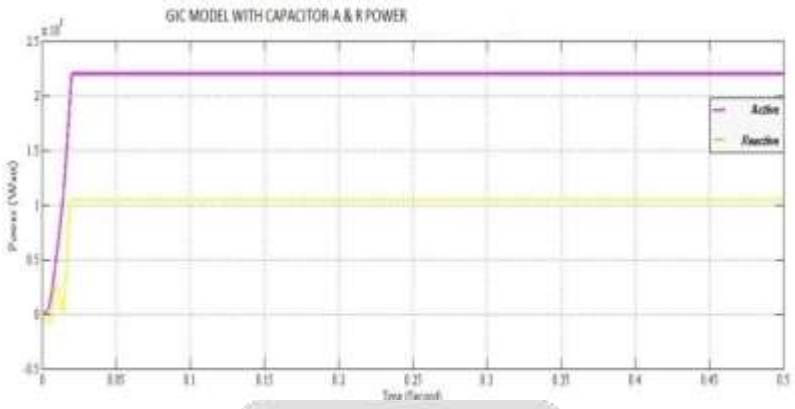


Fig 18 Active and Reactive Power

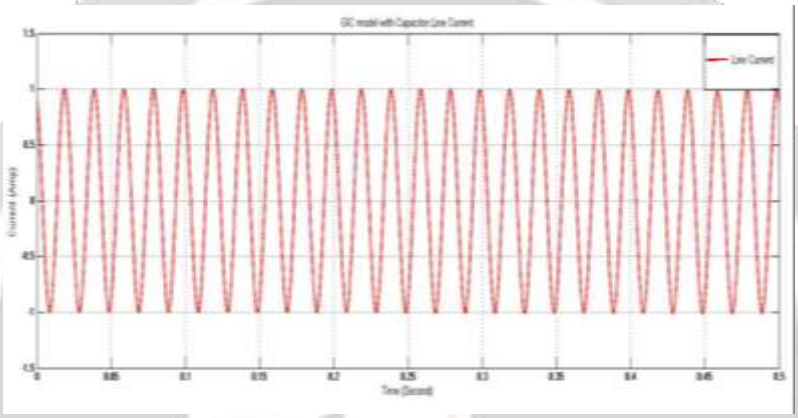


Fig 19 Line Current

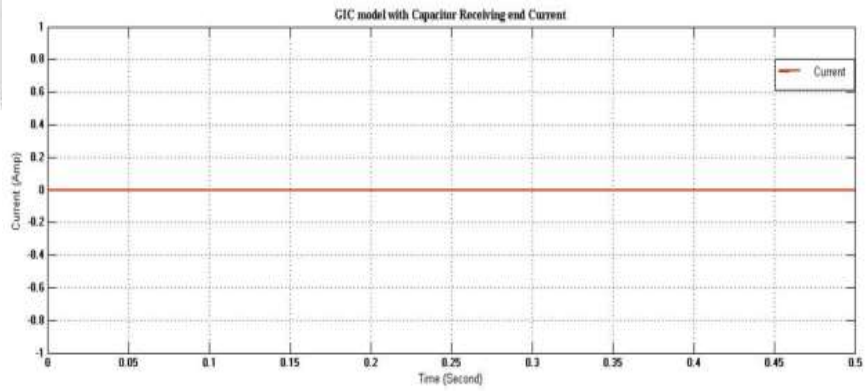


Fig.20 Receiving End Neutral Current

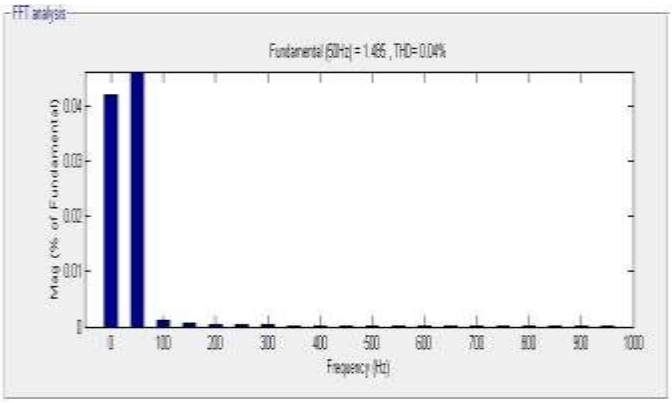


Fig. 21 FFT Analysis

5. CONCLUSIONS

Geo-magnetically induced current is a small phenomenon. But it may hamper the whole system. GIC may cause total blackout of the whole system by increasing the reactive power consumption.

A novel method to mitigate GIC has been introduced in this paper. By using the various electrical parameters like resistor, inductor and capacitor, the GIC which flows through neutral of transformer can be reduced.

The various mitigation methods mentioned above is simulated in MATLAB software. By using above methods, though GIC is reduced, but it may content some amount of harmonics and this harmonics is analyzed by using Fast Fourier Transform (FFT) analysis.

6. REFERENCES

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