Analysis & Mitigation of Geomagnetic Induced Current on Power System
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Abstract— Solar storms is a condition that effects various systems and power equipment’s. During solar storms a geomagnetic induced current (GIC) starts flowing through long conductor such as power cables and system. When this Geomagnetic Induced Current flows through a transformer it saturate the core, which then leads to increase in reactive power consumption and harmonics in the power system and heating of the transformer. Harmonics levels can cause protective relays to sense wrong and trip the circuit this can lead to a problem such as loss of production, blackouts. Heating of transformers can also lead to permanent damage to parts and replacement of it. A mitigation technique to reduce the effects of geomagnetic induced currents (GICs) on high-voltage power systems. The method consists of connecting switching devices at the neutral grounding connection point of transformer banks. Only one transformer bank needs to be grounded through a switch.

Key words: Solar Storm, Power System, GIC, Transformer, Harmonics

I. INTRODUCTION
Solar activity has maximum approach to earth and therefore it investigates solar storm and risks & problems related for power systems. An overview of solar storm related risks & problems related to geomagnetic induced currents in transformers.

Due to the interaction between the space weather and Earth’s magnetic field the current is produced at the ground level this current is called Geomagnetic induced current(GIC). This interaction is created due to the coronal mass ejections (CME) from the solar storm. The electro jet is produced by coronal mass injection, which passes through the magnetosphere. This process of production of electro jet is called geomagnetic disturbance (GMD). GMD is a phenomenon which is initiated by solar process on earth. Sunspots give rise to solar flares and coronal mass ejections. CME carries its own currents and magnetic fields that are capable of affecting the Earth’s magnetic field. Charged particle increase the current flows in electro jets above the Earth’s surface. These currents induce quasi-dc voltages in transmission lines due to which GIC flow in the system.

II. TECHNIQUES TO MITIGATE GIC
Earlier there was no power grid but today due to increase in energy demand power system role is increasing. Due to GIC flow in transmission lines it damages the power system and lead to power grid collapse and blackout. So to reduce this effects power industry has started to produce solutions to mitigate GIC. Addition to neutral blocking, series capacitor in phase of the transmission line, it prevent flow of GIC in the line also it can be used for series compensation.

Also a mitigation technique consisting of installing semiconductor switching devices between the transformer neutral and ground. When GIC is detected, the semiconductor GIC reducer (SGICR) opens and closes the connection to ground at 1 kHz. The switching action reduces dc current but does not completely block it. Thus, the disadvantages of completely disconnecting the neutral are eliminated.

A. Ways to Reduce GIC
Devices that can be used for the purpose of mitigating GIC flow in the network some techniques are used and are as follows.
1) Disconnect Neutral
The way to block the GIC flow is to disconnect neutral from ground where GIC current enters the network. When neutral connections are not properly disconnected then it can lead to problem like voltage transients and faults problems especially under single-phase-to-ground faults.
2) By connecting Inductor at neutral
Inductors at neutral are generally used to reduce the ground fault current. As the frequency of GIC is very low so inductors have little effect of reducing GIC.
3) **By Connecting Resistance at neutral**
   As resistance in neutral does not reduce the GIC flow in the network but in some amount it reduces the damage to equipment’s.

4) **By connecting capacitor at neutral**
   Capacitors are used at the neutral side to completely eliminate the flow of GIC in the power system.

### III. EFFECTS ON POWER TRANSFORMER

Grounded part of the system from where GIC enters the system and effects by DC flow. Effects of GIC flow in the power system can lead to saturation of power transformers.

#### A. Power Transformer

Principle of power transformers is to transfer electric energy from one AC voltage system to another via magnetic energy. This can be done by Faraday’s law, which states that a time varying magnetic field will induce an electromotive force, much like a voltage.

Transformer consists of two electrical conductors wound around a core of ferromagnetic material such as iron or steel. These two windings, called primary and secondary winding, are electrically insulated from each other and are only connected by the magnetic field in the core material.

![Fig. 5: Single Phase Transformer](image)

Simply put this means that an AC on the primary side, with emf, will induce an alternating magnetic flux in the core material. This flux will flow through the core and through the windings on the secondary side where it will induce the emf. It is the magnetic flux in the core that may be affected by GIC. To understand this we have to know a little bit more about what happens in the core. The transformer core is in other word designed to provide a path of low magnetic reluctance for the magnetic field much in the same way as an electric conductor is meant to form a low resistive path for an electric current. This analogy can be helpful for the understanding of how a transformer works even though there are important difference between the permeability and conductivity.

One very important difference is that the core can become saturated with magnetic flux in a way we do not see in electric conductors. Once the core has become saturated it cannot hold any higher magnetic field and additional magnetic flux will have to find other paths. Leakage flux is quite common in transformers even under normal operation and affects voltage regulation and power losses.

Under normal operating condition a transformer will operate within the linear region below the saturation limit. Power transformers are built to operate with alternating current, direct current superimposed on the AC, which makes the transformer core to saturate. This also happens when GIC enters into the transformer through the neutral point.

![Fig. 4: Transformer Saturation](image)

### IV. TRANSFORMER CONSEQUENCES

When GIC starts to flow through a transformer winding it will DC bias the transformer and cause the core to start to saturate. This saturation will cause:

- (a) production of both even and odd harmonics,
- (b) a substantial increase in reactive power consumption and
- (c) increased heat production and an increase of transformer losses.

The severity of these effects depends on the strength of the geomagnetic disturbance. Here follows a more detailed description of each of these effects and their consequences.

![Fig. 6: GIC flow in transformer under normal condition indicated by green line and red line indicate during saturation period](image)

### V. SIMULATION AND RESULT

![Fig. 7: GIC Simulation Block Diagram](image)
Figure 6 shows simulation model of GIC and its effects on transformer using MATLAB software. Ramp input is applied to the controlled voltage source which acts as a GIC input to the three phase programmable voltage source. Programmable voltage source is connected to active & reactive power block through voltage measurement & current measurement block and system. The THD block is used to measure waveform distortion due to GIC.

A. Reactive Power Consumption

Reactive power consumption increases as the value of GIC increases. As seen in figure that after time of 0.02 sec reactive power consumption reaches its maximum value and after sometimes it become linear. Active power flow also increases but there is decrease in GIC. Hence it can lead to instability in the power system and voltage collapse.

Fig. 6: Simulation model of GIC and its effects on transformer using MATLAB software

Fig. 8: Active and Reactive Power consumptions

Fig. 9: Powergui Output

Fig. 10: Reactive Power Consumption

The total harmonic distortion of transformer current is about 71.44% and harmonic order increases as GIC increases. When GIC reaches to a certain value only DC and fundamental Components are present and magnitudes of other harmonics are so small that they are neglected in the transformer.

VI. CONCLUSION

GIC creates flux in transformer and due to these current increases and hence transformer core saturates. As core saturates it lead problems to power system like power system instability, blackout. Because of increase in current the heating loss the primary and secondary windings may get burnt and damage.

GIC can also cause overloading problems in HVDC system. The distortions in AC voltage waveforms make DC power transmission difficult & power loss occurs.

REFERENCES


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