Master Thesis "GIC Distribution"

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Abstract- GICs are currents generated by Geomagnetic Disturbances that flow along the electric system and may modify the performance of some elements in it. This can disturb the normal functioning of electric systems.

I. INTRODUCTION

Electricity is nowadays necessary, and therefore the system must be reliable in order to provide energy to the consumers. The aim of this project is to study the distribution of Geomagnetic Induced –currents along the system.

II. THEORETICAL BACKGROUND

Solar GIC are currents with a frequency close to 0 Hz, therefore, they can be considered as direct current. When a solar storm occurs, it disturbs the magnetosphere of the earth and, according to the Faraday's law [1] an electromotive force across a conductor is created when it is exposed to a varying magnetic field.

Induced currents flow through the lines along with the AC current that is being supplied as normal operation; this may affect certain elements such as transformers and can disturb the proper functioning of the electric system.

Direct currents flowing through transformers cause a vertical shift on the B-H curve of the transformer, it moves the normal point of operation closer to saturation. If the transformer reaches its saturation point it will not work and it may lead to a blackout.

III. Material

In this study the most important devices to be taken into account are transformers and blocking devices. Transformers change the voltage and the current maintaining the same power at both sides of it, P=V*I. The core of the transformers can be formed as a three-legged core, five-legged core or in the shape of a shell core transformer, this will affect the way that the transformers behave.

Blocking devices are divided between grounding resistance or capacitors. Capacitors installed in the grounding of the transformers impede the flow of DC currents through them; this will stop the GIC from flowing to soil. Grounding resistances can also be installed at the grounding of the transformers; increasing the resistance the induced current will be lower.

IV. Modelling GIC

Geomagnetic Induced currents flow along conductors, the magnitude of them depends on the electromagnetic field, the direction, the length of the line and the resistance of it. To calculate the GMD-induced voltage on transmission line k, Uk, the electric field is just integrated over the length of the transmission line [2].

$$U_k = \oint_C \vec{E} \cdot \overrightarrow{dl} \quad (2)$$

This field can be split into two terms according to its coordinates.

$$U_K = E_{k,N} \cdot L_{k,N} + E_{k,E} \cdot L_{k,E} \quad (3)$$

V. PARAMETRIC ANALYSIS

Two models have been used in order to study the distribution of induced currents. The first model is a PowerWorld 4 bus model, in which different conditions have been tested such as different fields, directions or use of blocking devices. In the first model three different studies will be carried out, the first one being different cores of transformers and the use or not of blocking devices. After the study it can be proved that the three legged transformer is the one with less reactive losses and less voltage drop; a priori this one will be the more convenient and the most suitable for all situations. It has been proved that the use of blocking devices diminishes the induced current, in the case of grounding resistance; or eliminates the induced current in case of the capacitor.

VI. TEST IN A MORE REALISTIC SYSTEM

Several tests in a more realistic system, such as the 21 bus system provided by PowerWorld presented below.

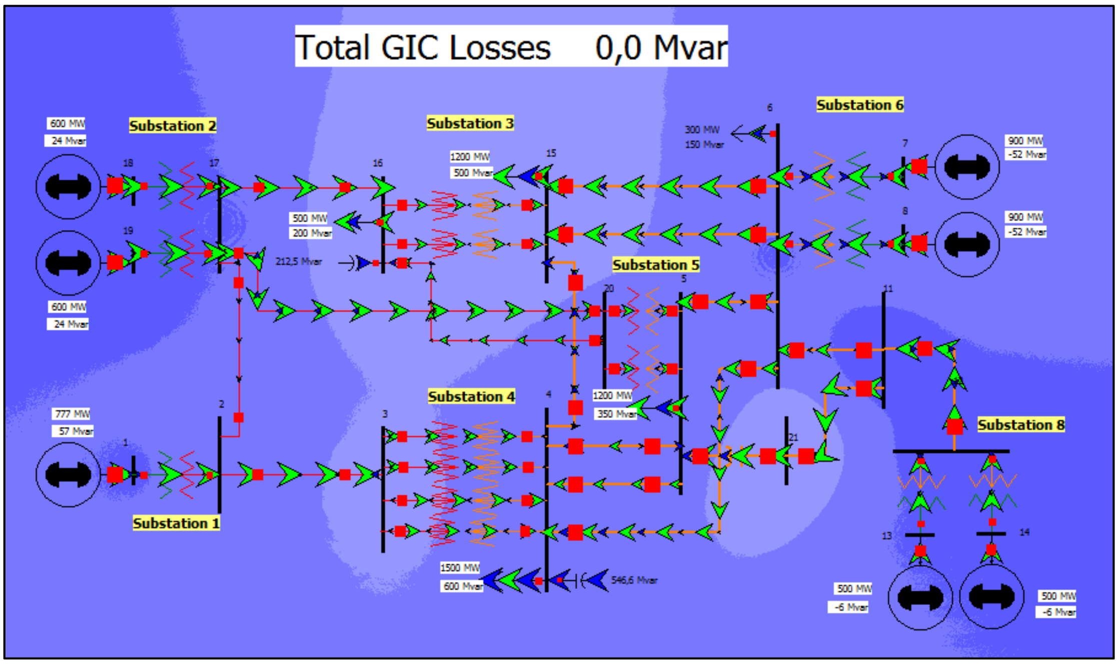

Figure 1 21 bus test system with no GIC.

This system will be used to test the different blocking devices and study the distribution of GIC under different conditions. This system is more realistic and the results can be applied in real systems.

VII. RESULTS

After studying the different blocking devices for all conditions; it can be concluded that both capacitors and grounding resistance diminish the flow of GIC along the system. Capacitors protect the bus where they are located but grounding resistances are expected to diminish the current in the whole system.

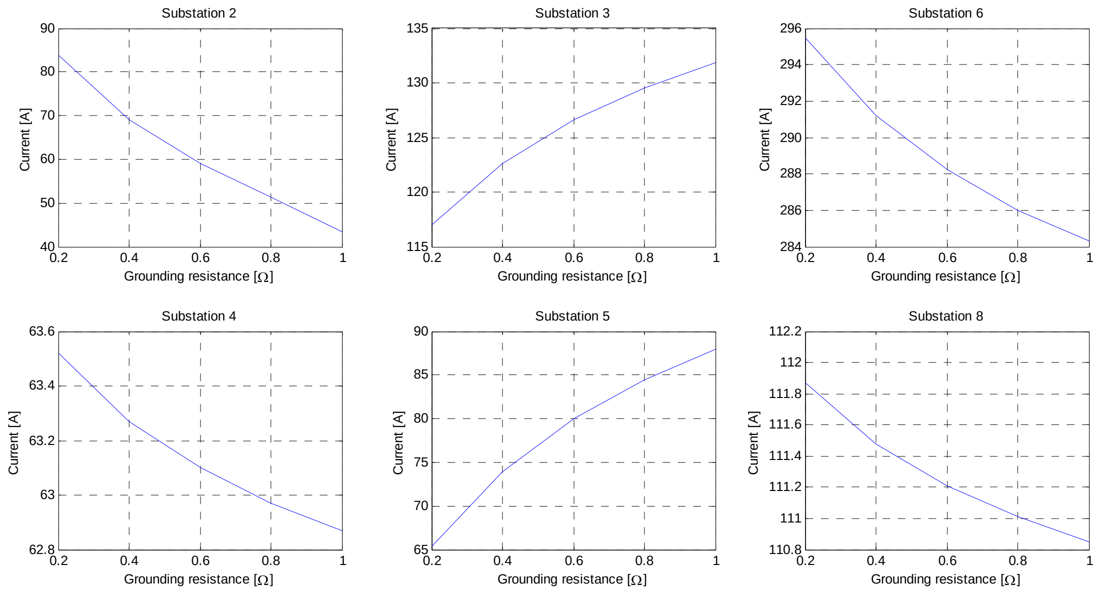

Figure 2 Induced currents in different busses when changing grounding resistance in bus 2 under a 5V/km GIC field.

As can be seen in the previous graph the induced currents can increase when increasing grounding resistance in a certain substation. This is due to the different loops of the net, in some of them increase in order to compensate the loss of current in the first substation. However overall the GIC currents are lower and also the reactive losses.

VIII. CONCLUSIONS.

The main conclusion of this study is that both capacitors and grounding resistance are applicable to assure the system against GIC currents. Grounding resistances are a better solution overall because they protect the whole system, not only the substation where they are installed. It is shown however, that while a grounding resistance decreases the overall GIC, it also increases GIC at some locations. There must be a compromise in the grounding resistance, if it is too large the voltage during asymmetrical faults is too large; therefore the grounding resistance must not be too large.

IX. REFERENCES

[1] T.R. Hutchins, T.J. Overbye "The effect of geomagnetic disturbances on the electric grid and appropriate mitigation strategies", (2012).

[2] T. J. Overbye, Komal S. Shetye, T. R. Hutchins, Q. Qiu, J. D. Weber, "Power Grid Sensitivity Analysis of Geomagnetically Induced Currents" (2013).