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Comparative Study of Various Filtering Techniques to Reduce Harmonics in HVDC Converter Transfomer Due to GIC

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Abstract: *The Geomagnetically induced current adversely effects the power system. Main impact of geomagnetically induced current is on power transformer and also HVDC converter transformer. Because of the interaction of the solar storm on earth, there is a occurrence of DC bias current. Many harmful effects are observed in the HVDC converter transformer. The invasion of geomagnetically induced current into the converter transformer is through neutral wire which will result into the saturation of converter transformer core saturation. This leads to the production of harmonics in the power system. Because of the harmonics, many other adverse effects are seen to be occurring which includes heating of transformer core, windings may burn, etc. This paper presents the techniques to inhibit the invasion of Geomagnetically induced current into the converter transformer neutral. Furthermore, it gives a comparative study of the various techniques by examining it in MATLAB/SIMULINK.*

Keywords: *Geoamagnetically induced current(GIC),Converter transformer, DC bias, Filtering techniques*

I. INTRODUCTION

There is an interaction between the space weather and Earth's magnetic field. Because of this interaction, the current is produced at the level of ground. This current which is produced is known as geomagnetically induced current (GIC). The reason for this interaction is because of coronal mass ejection (CME) from the solar storm. There is a production of electro jet by the coronal mass ejection, which passes through the magnetosphere. The process of production of electro jet is geomagnetic disturbance (GMD). At the ground level, a geoelectric field is induced due to the electro jet which id DC current. Geomagnetically induced current flows in the direction of this field. Because of the change in geoelectric field with respect to time, this current is produced. The electric power system uses 50Hz frequency, which is very high as compared to the geomagnetic variations which are slow in low frequency range of about mHz. Therefore, whenever there is a flow of geomagnetically induced current through the converter transformer neutrals, it affects as the DC current. The range of magnetizing current pulses is in the range of about 1/10th to 1/12th of the operating cycle due to the short duration of the high peaks of geomagnetically induced current which is only about 1-2 minutes. GIC occurs because of the geomagnetic storm which may lead to dangerous effects on geophysical exploration surveys, oil and gas drilling operations. Geomagnetically induced current endangers the electrical power system all over the world [9].

The occurrence of the saturation of the converter transformer core is due to the flow of DC current through it. The harmonic production takes place due to the saturated core which becomes a reason to damage the transformer. Other effects of invasion of geomagnetically induced current are excessive heating of transformer because of which winding of transformer may get burned. The exciting current of the converter transformer rapidly increases. The path of flow of geomagnetically induced current is from high resistance to low resistance path. The neutral wire of converter transformer is the starting point of the geomagnetically induced current to flow and through the neutral wire of converter transformer; it leaves the power transmission system. In HVDC transmission system, there are long span AC and DC transmission lines and also the three phase converter transformer consists of three single phase transformers. Therefore, the magnetic circuit permeability is very large and the saturation of core material magnetization curves occurs on a large extent. Hence the converter transformer is more vulnerable to the invasion of geomagnetically induced current. Moreover, overloading of *Sample IJERD Paper for A4 Page Size* 2 filter in HVDC transmission system and switching problems are other adverse effects of geomagnetically induced current. Some of the blackouts had occurred in the past years due to the invasion of geomagnetically induced current into the transformer neutral. On 13th March, 1989 the largest electrical system blackout had occurred. The reason was the high magnitude of geomagnetically induced current in the entire zone of Quebec. A large step up transformer on the generating side was damaged (at a nuclear plant on east coast of United States). In the South of England, the first largest event due to geomagnetically induced current was observed, where because of earth currents, all telegraph lines were stopped in Great Britain in 1847. The largest blackout occurred in the Toronto area of Canada on 22nd September, 1957 and 11th February, 1958.

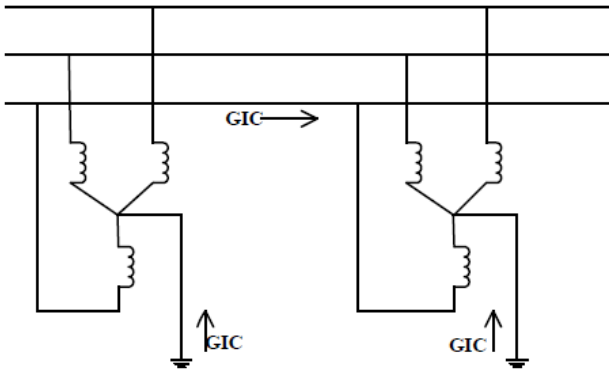

Fig.1. Geomagnetically induced current flowing along the transmission line between two transformers [1]

High Voltage Direct Current is one of the most efficient alternatives for the transmission of huge amounts of electricity over long distances. Converter transformer plays an integral role in HVDC. Basic HVDC transmission system is shown in Fig.2 [1, 2]

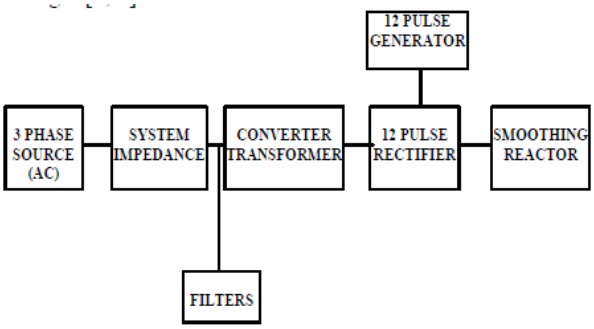

Fig. 2 Block diagram of HVDC system

A. Effects of Geomagnetically induced current

1. Production of the harmonics which may lead to mal-operation of protection relays.
2. Results in increased requirement of reactive power because of the operating point being shifted to the saturation region.
3. Leads to the increased corrosion of pipeline steel.
4. Causes damage of high voltage power transformers.
5. Individual transmission circuits may trip which results into system collapse.
6. Overloading of reactive power compensation devices may result due to the flow of extra harmonic currents into the capacitor bank. This makes the system to demand more voltage support.
7. DC bias may occur and also it may cause the saturation of converter transformer core to a great extent. When the DC current enters into the neutral of HVDC converter transformer, it results into geoelectromagnetic disturbances. The DC current entering into the AC system is a very serious problem in HVDC transmission system. The adverse effect which is caused due to DC bias is that it leads to make a transformer a source of harmonic. DC bias disturbs the symmetry of exciting current which leads to the production of both even and odd harmonics. This asymmetry causes the HVDC system to become unstable [3, 5, 12].

II. DESCRIPTION OF HVDC SYSTEM

The system consists of the complete HVDC transmission system. A 3 phase AC supply is given. The line side winding of three phase HVDC converter transformer is connected to the AC supply. The converter is connected to the valve side winding of the HVDC converter transformer. The converter is triggered with the help of PWM generator (12 pulse unit). The Geomagnetically induced current invades into the converter transformer neutrals. The Geomagnetically induced current is inhibited by using various filters.

A. Converter transformer

The HVDC converter transformers are those connected in between the AC busbars and the converter valves. A three phase converter transformer consists of three single phase transformers. The requirements of a 12 pulse unit that it should be connected to 3 phase 2 winding converter transformers. One of the two converter transformers is connected as star-star and the other as star-delta. It prevents the DC potential to enter into the

AC system, thus it behaves as a galvanic barriers between the DC and AC system. The transformation of the voltage between the AC system and HVDC system is done with the help of converter transformer.

B. Synchronised 12 Pulse Generator

The Synchronized 12-Pulse Generator is used to trigger the converter bridge. The Synchronized 12-Pulse Generator block generates two vectors of six pulses synchronized on the twelve thyristor commutation voltages. The first set of pulses, denoted PY, is sent to the six-pulse bridge connected to the wye (Y) secondary winding of the Y/Y/Delta converter transformer. The second set of pulses, denoted PD, is sent to the six-pulse bridge connected to the delta secondary winding of the converter transformer.

C. 12 Pulse Unit

12 pulse unit comprises of two units of 6 pulse bridges which are connected in series. One of the 6 pulse bridges is connected to star-star converter transformer and the other to star-delta converter transformer. System parameters: ±500kV one pole, 1000MW, 2kA, converter transformer wiring for YN, Y and YN, D, variable ratios for (345/1.732)/(213/1.732) and (345/1.732)/213 [2,11, 13]

III. TECHNIQUES TO INHIBIT GIC

The voltages and currents which have the tendency to emerge in the electrical power system because of the non-linear electric loads are termed as harmonics. Harmonics distort the voltage and current waveforms. The harmful effects of these distortions leads to tripping of the circuit components of protection circuit, increase in the thermal stress of equipment, magnetization of the HVDC converter transformers, etc. [6, 7]. There are many methods which are used to reduce harmonics which are as follows:

A. Active filter

The active filter is not economical for usage but it has high controllable characteristic that results in meeting the demand of dynamic filtering.

B. Passive filter

It reduces the fixed order harmonic current. The passive filters have the ability to extract the harmonic currents by using the tuned circuits.

C. Shunt Active filter

These are implemented in the novel hybrid filter configuration.

D. Inductive Filtering Technology

Ampere turn balance action is made in between the windings of the couplings of the converter transformer, thus blocking the flow of harmonic currents into the primary winding. [4, 8, 10].

In order to block the harmonics due to the GIC, following methods are used for the inhibition of the geomagnetically induced current.

a) Neutral Series Resistance

With the help of a current limiting resistor, the geomagnetically induced current can be significantly lowered. The current limiting resistor is connected in between the HVDC converter transformer neutral point and the ground. The inhibition of geomagnetically induced current is done by using the isolation characteristics of capacitor using neutral series resistance. Neutral series resistance can be implemented as shown in fig.3.

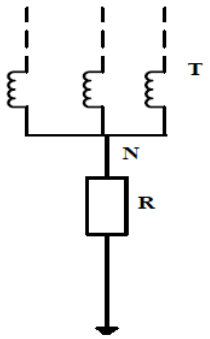

Fig. 3 Neutral series resistance [2]

b) Neutral Series Capacitance

The neutral series capacitor blocks the flow circuit of geomagnetically induced current. The flow of AC current is no way disturbed because of the blocking of the flow circuit of geomagnetically induced current as shown in fig.4.

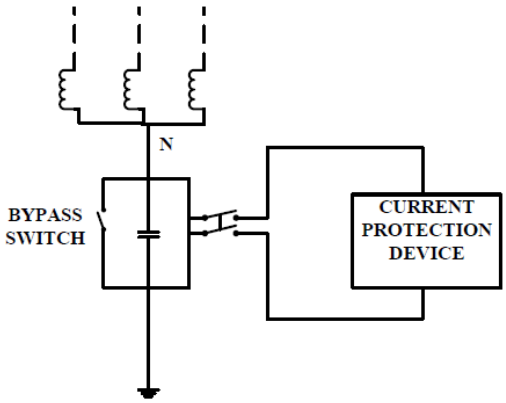

Fig. 4 Neutral Series Capacitor [2]

c) AC Line Series Capacitor

Geomagnetically induced current can be blocked in any of the AC systems by using the capacitors on the AC transmission line as shown in fig.5. In order to block the DC current flowing in the power transmission lines, it uses the capacitor's isolation characteristics. It results in the cut off of the flow loop of DC current. [2]

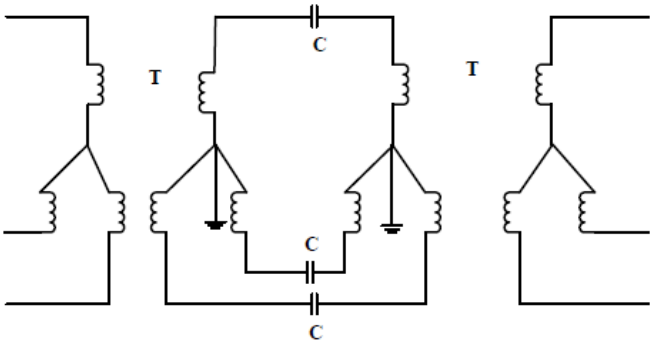

Fig. 5 AC Line Series Capacitor [2]

IV. SIMULATION AND RESULTS

The Geomagnetically induced current is represented by ramp input. The controlled voltage source is being applied by the ramp input which acts as a GIC input to the linear transformer. The linear transformer is then connected to the HVDC converter transformer block through the current measurement block and the voltage measurement block. The MATLAB simulation is done and the total harmonic distortion (THD) is measured using each of the techniques which are used to inhibit the geomagnetically induced current.

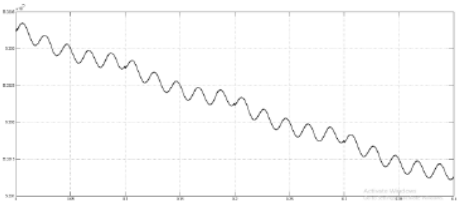

Fig.6 Harmonics in the line winding of HVDC converter Transformer without filter

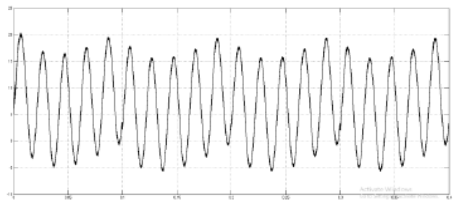

Fig.7 Harmonics in the line winding of HVDC converter transformer using neutral series resistance

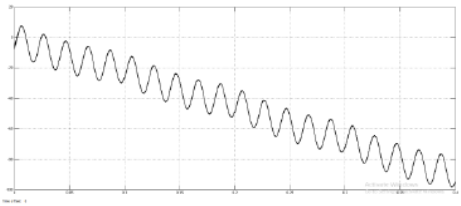

Fig.8 Harmonics in the line winding of HVDC converter Transformer using neutral series capacitor

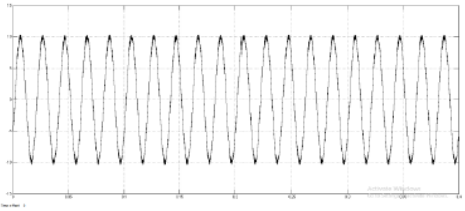

Fig.8 Harmonics in the line winding of HVDC converter transformer using AC line series capacitor

V. CONCLUSION

The invasion of geomagnetically induced current into the electrical power system has many harmful effects. In this paper, more focus is given on the effects of invasion of geomagnetically induced current into the HVDC converter transformer. Due to the geomagnetically induced current, it causes the rated converter transformer core bias. The phenomenon of DC bias occurs as the geomagnetically induced current enters into the neutrals of the converter transformer. In general, only odd harmonics occur. But when there is an occurrence of DC bias, even harmonics also come into action. This results into increase in the harmonic losses in the HVDC transmission system. Due to the harmonics occurring because of the invasion of geomagnetically induced current into the converter transformer, it is important to reduce the impact of geomagnetically induced current into the HVDC transmission system. Various filtering techniques are given to inhibit the geomagnetically induced current from entering into the neutrals of converter transformer. Neutral series resistance, neutral series capacitor and AC line series capacitance are the methods of filters which can used to inhibit the geomagnetically induced current and decrease the total harmonic distortion. This paper describes a comparative study of the different filtering methods using MATLAB/SIMULINK. It is observed that the least total harmonic distortion (THD) is obtained with the help of AC line series capacitance. With the help of the calculated total harmonic distortion it is concluded that AC line series capacitance is the best method which can be used for the inhibition of geomagnetically induced current.

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