SIMULATION OFMULTIGRID HVDC SYSTEM USING STATCOM

Ms. Jagruti Metiya[1], Prof.Vaishali .Y. Patel[2]
[1]P.G. Scholar, [2]Assistant Professor
Electrical Department, Merchant College of Engineering, Visnagar, Mehsana, Gujarat, India

Abstract: In modern technical era, Flexible Alternating Current Transmission System (FACTS) devices are one of the popular controllers which can achieve and established a desired power condition at certain points. A FACTS device is used to enhance controllability and increases power transfer capability of the power system network. A FACTS device is used to enhance controllability and increases power transfer capability of the power system network. This Paper deals with the stability problem at either end of rectifier and inverter of a HVDC link with STATCOM (Static Compensator), when connected to a weak AC system which has the stability enhancement for power instability and commutation failures.

In this Paper the authors proposed shunt controller is based on the voltage source converter topology as it is conventionally realized by VSC that can generate controllable current directly at its Output terminal. The performance and behaviour of this shunt controller is tested in power transmission network as well as it is compared in the test systems with and without STATCOM in MATLAB/Simulink. Simulation results prove that the modelled shunt controller is capable to improve the Performance of system significantly.

Keywords: HVDC, STATCOM, PQ, Fault Analysisetc.

I. INTRODUCTION

As we see modern civilization heavily depends on consumption of electrical energy for commercial, industrial, domestic, agricultural and social purposes. HVDC is most economical way to transmit bulk power over longer distances, complexity in controlling of the power flow, asynchronous power grid interconnections and renewable energy integration due to its flexible power control. Among the numerous techniques concerning HVDC system, DC transmission line protection is one of the important unit thus it provides fast fault clearance and guarantees the operation security of the entire HVDC transmission system. In modern era, increasing demand of power supply and improving transmission capabilities is important issues. HVDC transmission network is better than HVAC transmission for long transmission system. Due to the significant progress in power electronics technology during the past two decades, the use of High Voltage Direct Current (HVDC) power transmission is becoming more and more attractive. HVDC transmission offers significant advantages for the transfer of bulk power over a long distance transmission. But HVDC transmission connected converters inherently consume large amounts of reactive power; typically, the reactive power demands of the converter are 50% - 60% of the DC power being transferred. There are important concerns for the proper design and safe operation of HVDC thyristor converters, when it is connecting to weak AC systems such as low frequency resonances, high temporary over voltages (TOVs), risk of voltage instability, harmonic instability, long fault recovery times and increased risk of commutation failure.

With the growing demand for bulk power transmission over long distances, there is increase in demand of HVDC transmission systems in power systems. As a result, situations are and will be more common where several HVDC links located in the vicinity supply power to increase the reliability of the overall system. The HVDC system consisting of two or more such HVDC links is called multi grid HVDC system. The potential problems arising from multi grid HVDC systems are:

- Small signal instability due to control interactions among constituent HVDC links
- Voltage instability and collapse
- Increased commutation failures in one constituent HVDC link due to AC faults occurring in the vicinity of the neighboring one
- Transient AC voltage depression due to simultaneous recovery of constituent HVDC links after AC faults

Many of these concerns are closely related to the AC voltage regulation at the converter bus. Generally, the associated reactive compensators and HVDC systems are operated and controlled independently and the interaction between them considered only under steady state condition. If the control become coordinates between the HVDC system and reactive power compensator, the performance in transient state and dynamic performance of HVDC system will be improved. The transient performance of HVDC system is very important. Since, the increasing demand of power in industries forced integration of HVDC system with AC system. After the development of FACTS controllers, the transmission capability becomes improved. These controllers improve the controllability and stability of power networks. STATCOM (Static Synchronous compensator) is one of the most important Flexible AC transmission system (FACTS) devices because of its ability to regulate voltages in transmission lines, to improve transient stability and to compensate variable reactive power.

In this paper the topology which is considered is that the characteristics of the line-commutated HVDC with a STATCOM at the inverter end. This proposed system comprises a black start function and a HVDC- STATCOM coordination control scheme. Furthermore, this paper investigates the advantages of cost reduction of the HVDC link filter design, overvoltage control and performance of HVDC system connected with STATCOM and without

STATCOM. This paper also presents the analysis of voltage instability of Multi grid system consisting of two HVDC links interconnected through an AC tie-line. The voltage instability problem is more acute when one or both HVDC links terminates in a weak system [1].

In this paper a LCC (Line commutated Converters) based Multi grid system is considered and its large disturbance voltage stability is analyzed for various operating control modes. Since LCCs always consume reactive power, the possibility of voltage instability or collapse is quite high. The dynamic reactive power support at any one of the AC buses is provided using STATCOM (Static Synchronous Compensator). It is also shown in [1] that dynamic analysis provides more accurate results as compared to that of static analysis of the voltage instability problem. Finally, the effect of location of STATCOM, location of disturbance and various control modes on voltage stability at both the AC commutation buses are investigated.
The various terms used for discussion of results are SCR (Short circuit ratio) at an AC bus for the Multi grid system is defined by Eqn.1 [3]

$$SCR = \frac{1}{z} \ldots\ldots\ldots\ldots (1)$$

Where z is the equivalent Thevenin impedance seen from the AC commutation bus without including susceptance of the shunt capacitor banks at AC bus.

Also, Effective Short circuit ratio (ESCR) is used if the shunt capacitor banks at the AC bus are also included in equivalent Thevenin impedance. The critical SCR (CSCR) is defined as the SCR below which the voltage instability occurs for a given DC power level. However, when the power levels of the connected HVDC links are very much different, the voltage stability in multi grid system is not represented accurately by individual SCR values but by MSCRs (Multi grid Short circuit ratio) [3].

II. CHALLENGES AND RESEARCH OBJECTIVES

This paper deals with the stability problem at either end of rectifier and inverter of a HVDC link with STATCOM (Static Compensator), when connected to a weak AC system which has the stability enhancement for power instability and commutation failures. In this paper, the proposed shunt controller is based on the voltage source converter topology as it is conventionally realized by VSC that can generate controllable current directly at its Output terminal. The performance and behavior of this shunt controller is tested in power transmission network as well as it is compared in the test systems with and without STATCOM in MATLAB/Simulink. Simulation results prove that the modelled shunt controller is capable to improve the Performance of system significantly.

Research Problem

- ✓ Small signal instability due to control interactions among constituent HVDC links
- ✓ Voltage instability and collapse
- ✓ Increased commutation failures in one constituent HVDC link due to AC faults occurring in the vicinity of the neighboring one
- ✓ Transient AC voltage depression due to simultaneous recovery of constituent HVDC links after AC faults

Objectives…

- The main aim of this presentation is to justify the importance of FACTS devices in HVDC.
- We improve the stability of multi grid HVDC system using STATCOM device.
- The modelling and simulation of Multi grid HVDC system with STATCOM device.
- Different Fault Conditions Analysis with HVDC-STATCOM system.

III. HVDC SYSTEM

The electric power is generated, transmitted and distributed as an AC power. From the generating stations, power is transmitted to the end user via transmission and distribution lines. Transmission lines are long and operates at high or extra high voltages.

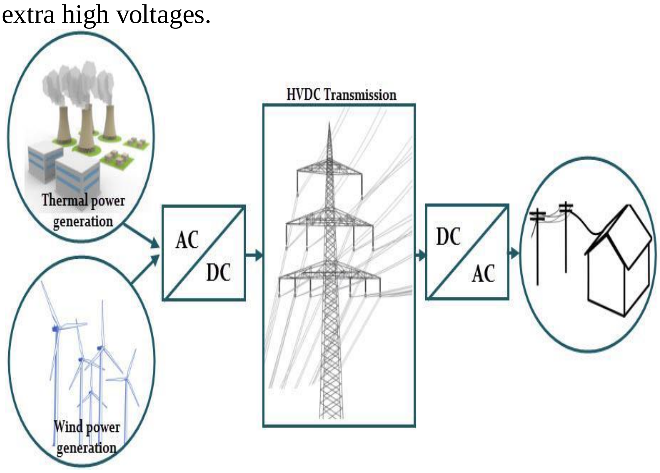

Figure 3. 1 HVDC System

At the end of the DC power system, DC power is inverted to the AC power and synchronizes with succeeding AC network. So the entire HVDC consists of three sections, namely converter station, transmission portion and an inverter station. The sending end or converter station consists of 6, 12, or 24-pulse thyristor bridge rectifier while the receiving end or inverter station consists of a similarly configured thyristor bridge but which operates in inverter mode.

Advantages of HVDC over HVAC Transmission Systems
A long distance point to point HVDC transmission scheme generally has lower overall investment cost and lower losses than an equivalent AC transmission scheme. HVDC conversion equipment at the terminal stations is costly, but the total DC transmission line costs over long distances are lower than AC line of the same distance. HVDC requires less conductor per unit distance than an AC line, as there is no need to support three phases and there is no skin effect. Depending on voltage level and construction details, HVDC

transmission losses are quoted as less than 3% per 1,000 km, which are 30 – 40% less than with AC lines, at the same voltage levels. This is because direct current transfers only active power and thus causes lower losses than alternating current, which transfers both active and reactive power.

In DC transmission, only two conductors are needed for a single line. In case of AC transmission, at least three conductors are needed and six conductors would be needed for double circuit line. It can transport power economically and efficiently over long distances with reduced transmission lines compared with losses in AC transmission.

Components of an HVDC Transmission System

The essential components in a HVDC transmission system are 6/12/24 pulse converters, converter transformer with suitable ratio and tap changing, filters at both DC and AC side, smoothening reactor in DC side, shunt capacitors and DC transmission lines.

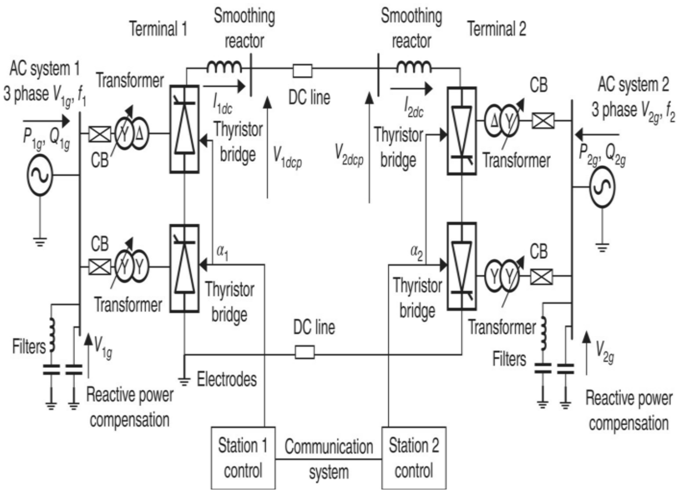

Figure 3. 2 Component of HVDC system

IV. PROPOSED WORK

HVDC-STATCOM Model

Statcom is one of contrivance of FACTS family. Figure 4.1, shows high voltage Dc transmission utilizing STATCOM connected at the inverter side. It shows a property of mitigation of sag, swell and notches. It provides better power flow control. And additionally ameliorate the potency of transfer capability in a high voltage transmission line [1]. Customarily due to line charging, and withal due to thyristor switching at converter end, certain harmonics and voltage sag, swell takes place. So it directly affects the puissance quality, and reaches to the receiving end, and this poor quality power is given to the load, which leads to the malfunctioning and inefficient performance of the system.

If STATCOM is connected at the receiving end afore the load then in case of any voltage instability or any fault. The astringency and quality is mitigated. So there by incrementing the puissant quality. And in today's arena power quality is main concern. In this Figure firstly AC supply is provided by alternator, and by designates of (customarily three phase) transformer voltage level is rectifier converter, so afore alimenting to the rectifier it is called HVAC (high voltage AC transmission). And by rectifier DC output is taken, and it is called as a Dc link. This Dc supply is inverted by betokens of Inverter (which is a 6pulse arrangement of thyristor). And after getting Ac output from inverter, this is again alimented to the STATCOM for mitigation.

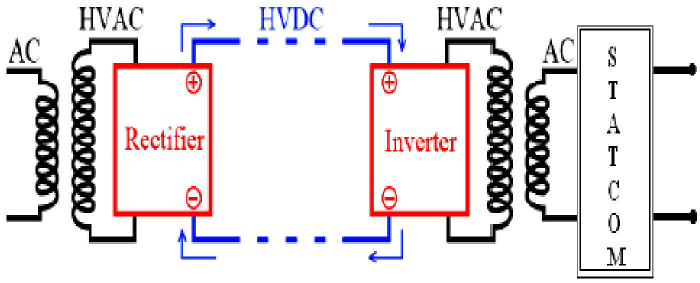

Figure 4.1: Statcom with HVDC system

Afore restarting the system, it will be compulsory to disconnect the load from the HVDC inverter. The STATCOM is pre-charged to supply the puissance to HVDC system through the small generator and a rectifier. The DC capacitor to be fed by the auxiliary power supply until the HVDC converter commences. When the DC capacitor is plenary charged, the STATCOM output voltage is ramped up (giving smooth energization of the transformer) and then the HVDC converter can be de-blocked to commence transmitting active power. After HVDC system has recuperated, the disconnected switch is opened to isolate the auxiliary power supply to the DC capacitor of the STATCOM. Short term active power variation can be buffered and together with the reactive power perturbation to the main grid can be mitigated efficaciously.

STATCOM Modelling

A STATCOM is a modern reactive power compensator that is based on the voltage source converter technology. Although it is made of power electronic circuits like an SVC, its behavior is more like that of an SC. It is actually a fully controllable active compensator, as shown in Figure 4.2 (a). A STATCOM works as a controllable voltage source that holds the bus voltage before its limits are reached. The limit of a STATCOM is the current limit that it allows to flow through its power electronic circuit. Figure 4.2 (b) shows the voltage-current (VI) characteristics of a STATCOM. It should be noted that a STATCOM can provide its maximum current even if the voltage is dropped to a very low value. Its reactive power output beyond its controllable value is proportional to the bus voltage instead of proportional to the square of the bus voltage, as is the case with an SVC. This feature gives a STATCOM more capability to support the system voltage and improve the system voltage stability. The current limit of a STATCOM is normally imposed in the control system, for example limiting the Iq order in the DQ decoupling control. The current limits of the steady state and transient state are usually implemented with the same mechanism. Although they can be designed to allow a certain short-time over current in some circumstances, the difference between the limits of the steady state and the transient state would not be very large.

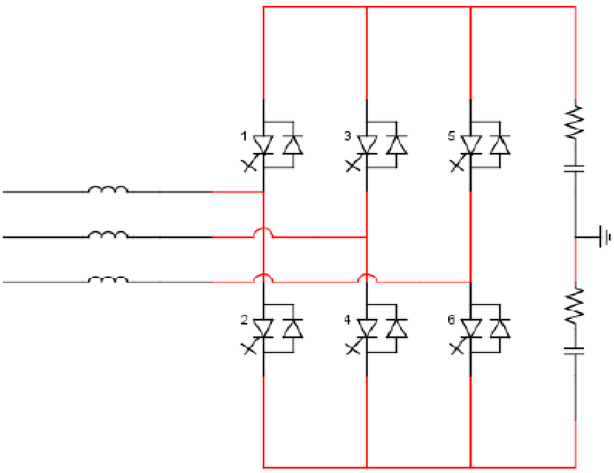

Fig (a)

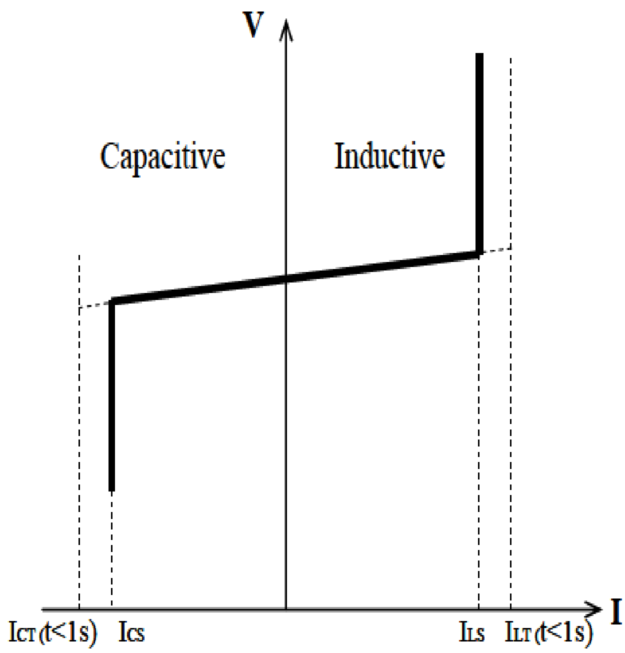

Fig (b)

Figure 4.2: STATCOM Circuit and VI Characteristic

Benefits and Power System Enhancements by HVDC and FACTs

Due to a dramatic growth of power demand in densely populated areas, the enormous amounts of power must be transmitted to large load centers with overhead lines and cables. The higher voltage levels are required to optimize the transmission losses. Using power electronic devices – HVDC and FACTS – provides the necessary control features to enhance the power system. In HVAC applications the power transmission capability is limited by the load dependent phase shift along the transmission line, the voltage drop of the line and the thermal limits of its conductors. In long overhead lines a key factor to limit the power transfer is the SIL (Surge Impedance Loading). During normal operations the transmission line can transmit a certain amount of active and reactive power without exceeding a specified voltage tolerance band, typically ±5%.

V. MODELLING AND SIMULATION

Proposed HVDC-STATCOM System

The rectifier and the inverter which are gate-pulse based IGBT converters connected in series. The converters are interconnected through a 75-km line and smoothing reactors as shown in Fig 5.1. The converter transformers (Wye grounded/Wye/Delta) are modelled with Three Phase Transformer (Three-Winding) blocks. The Matlab simulation of HVDC system with VSC control is shown in fig 5.1 below.

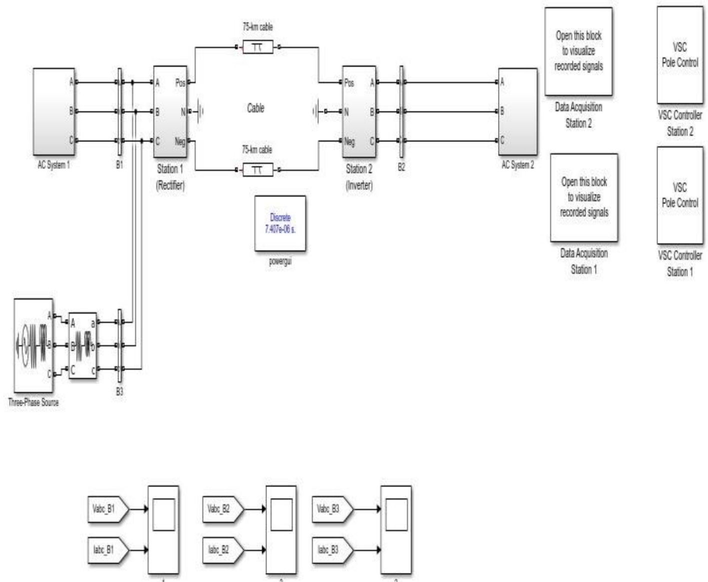

Figure 5.1: Simulink Model of HVDC with VSC control

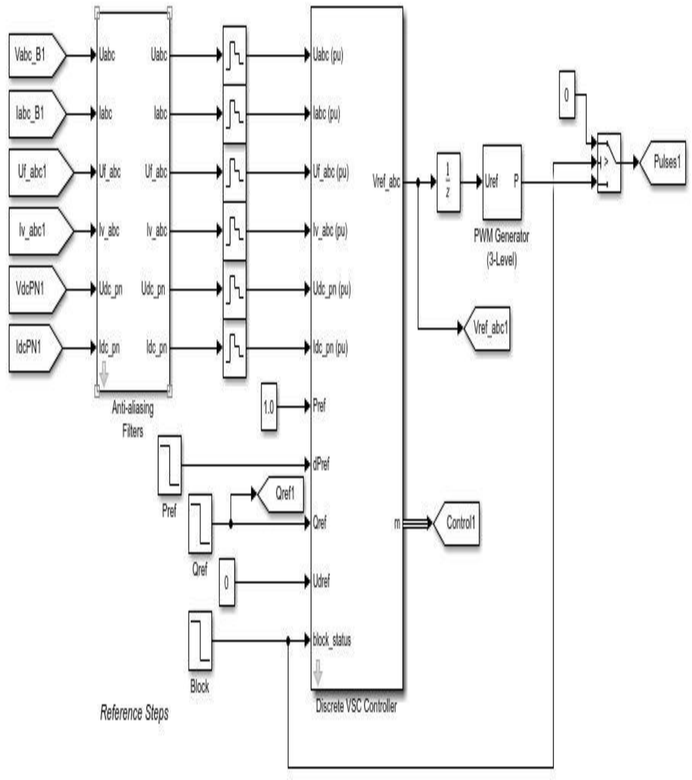

Fig 5.2- VSC controlling subsystem

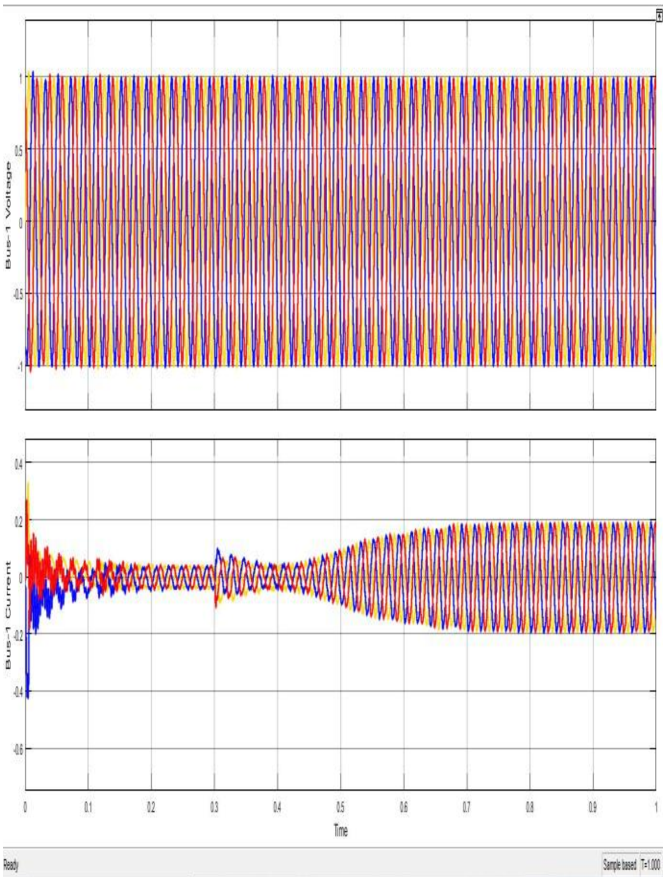

Fig 5.3- Bus-1 Voltage and Current without STATCOM

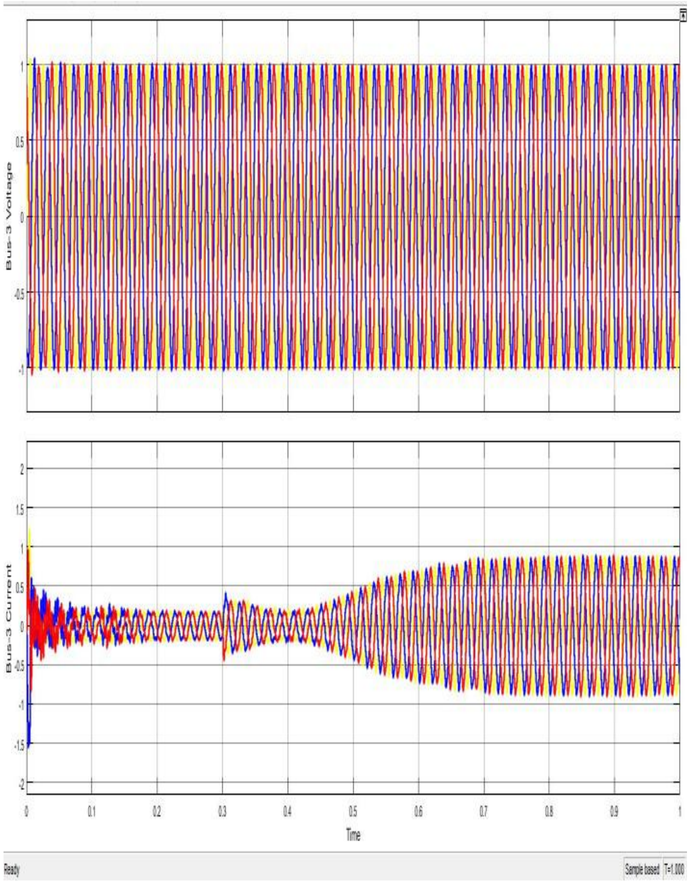

Fig 5.5- Bus-2 Voltage and Current without STATCOM

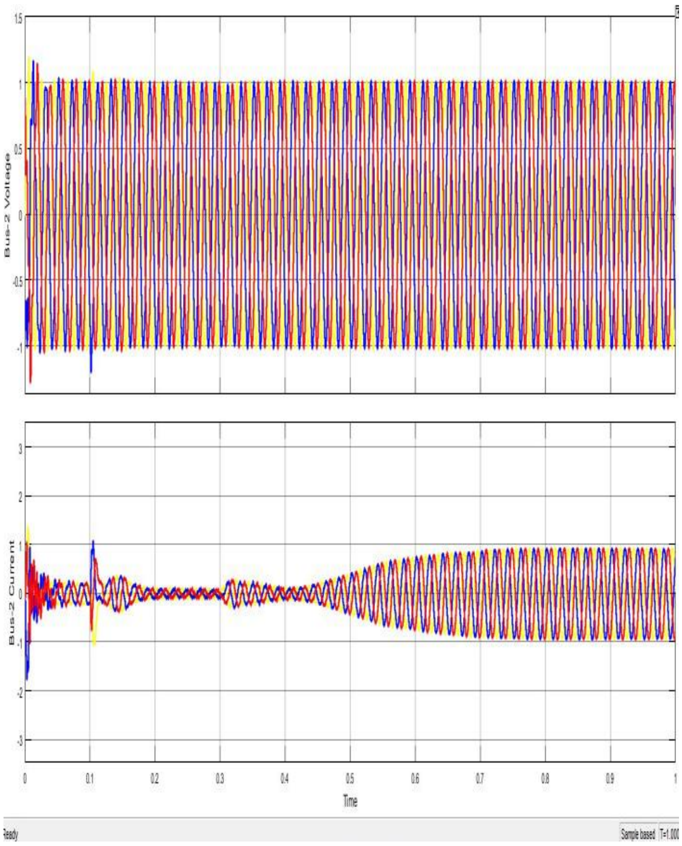

Fig 5.4- Bus-2 Voltage and Current without STATCOM

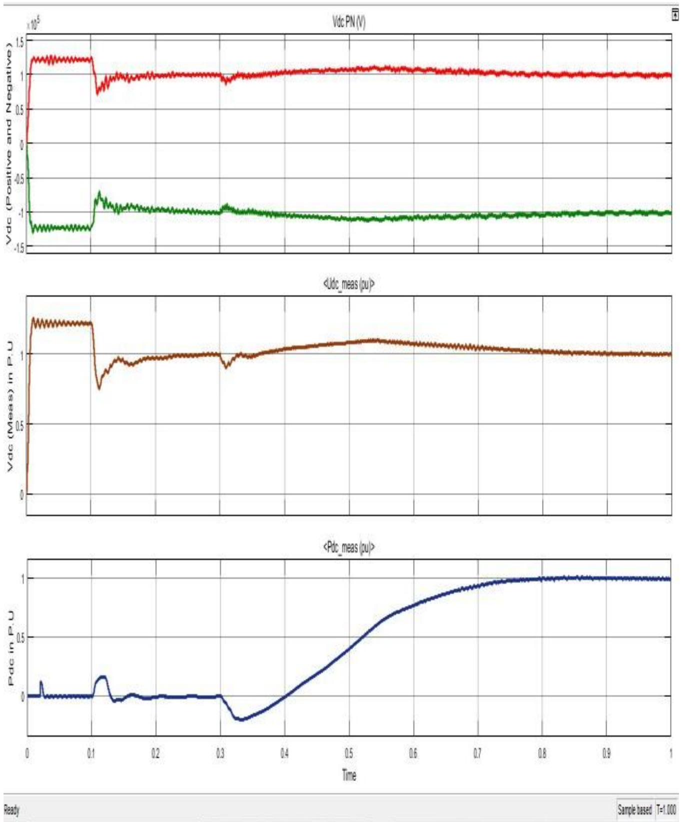

Fig 5.6- Converter Side-1 Output Parameters

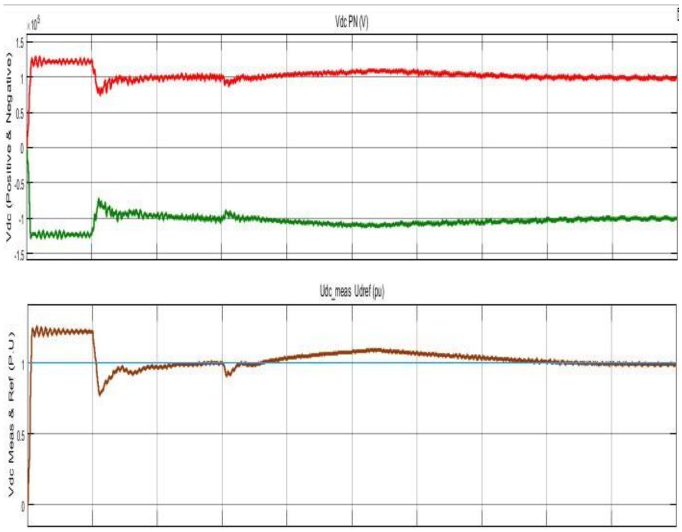

Fig 5.7- Converter Side-2 Output Parameters

The firing-angle control system is configured using pulse generator in series, one of which is operated as a modified HVDC bridge. The HVDC power converters with thyristor valves will be assembled in a converter bridge of twelve pulse configuration. This is accomplished by star-star connection and star-delta connection. Reduction of harmonic effects is another factor of investigation.

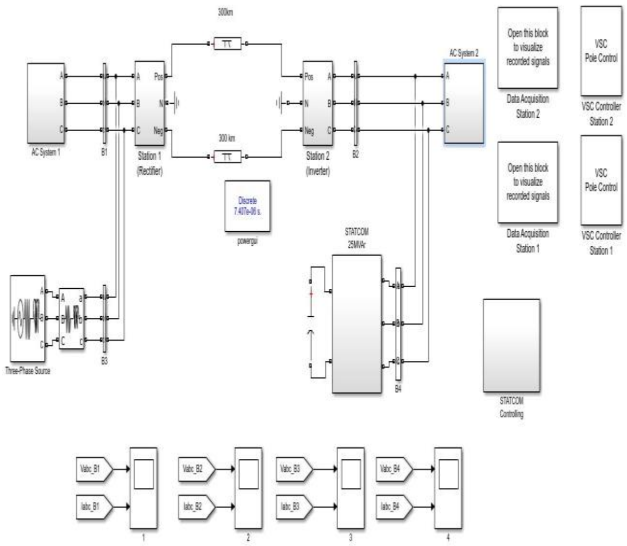

Fig 5.8- HVDC system with STATCOM integration

Here, MATLAB/SIMULINK program is used as the simulation tool. The firing angles are always maintained at almost constant or as low as possible so that the voltage control can be carried out. Three level IGBT bridges are the best way to control the DC voltage. Other bridges or convertors are not preferable of series due to the increase in harmonic content. The control of power can be achieved by two ways i.e., by controlling the current or by controlling the voltage. It is crucial to maintain the voltage in the DC link constant and only adjust the current to minimize the power loss. The rectifier station is responsible for current control and inverter is used to regulate the DC voltage. Firing angle at rectifier station and extinction angle at inverter station are varied to examine the system performance and the characteristics of the HVDC system. The voltage and current waveform are shown in figure. The output is get with STATCOM in HVDC network system.

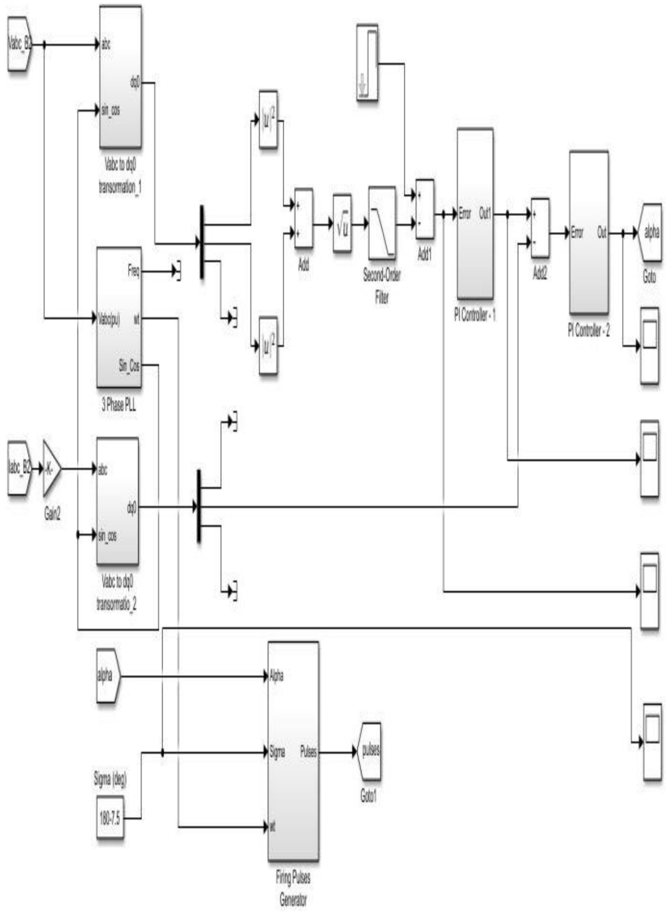

Fig 5.9- STATCOM controlling subsystem

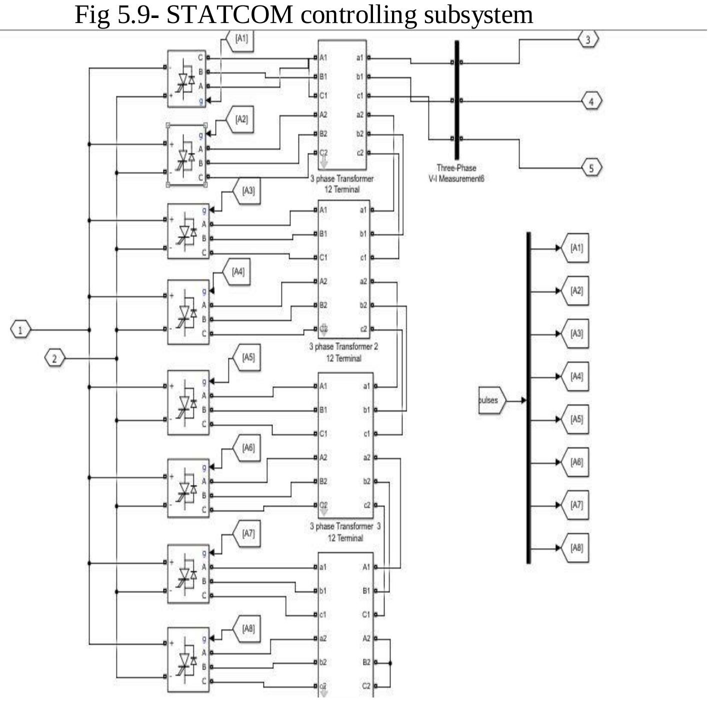

Fig 5.10- VSC converter STATCOM subsystem

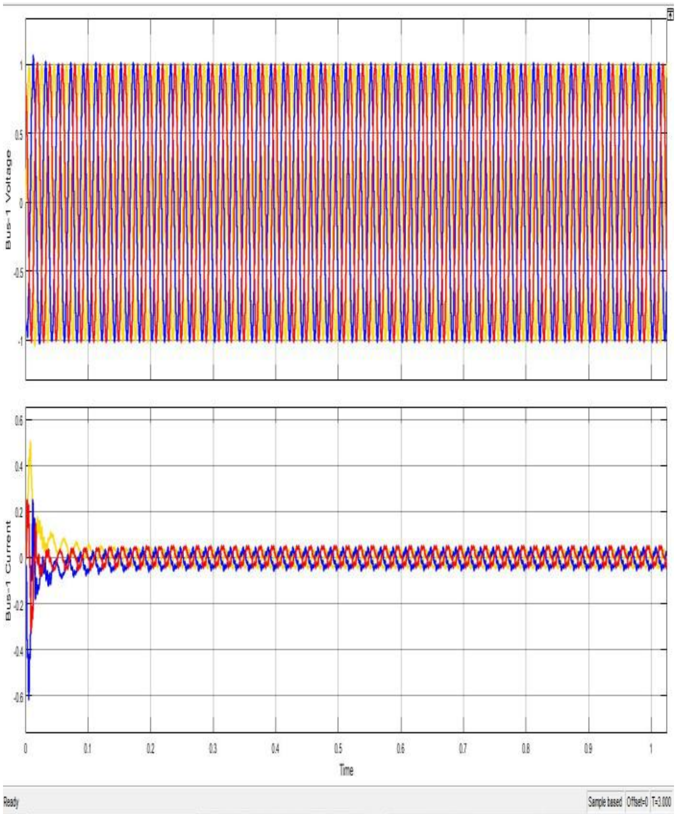

Fig 5.11- Bus-1 Voltage and Current with STATCOM

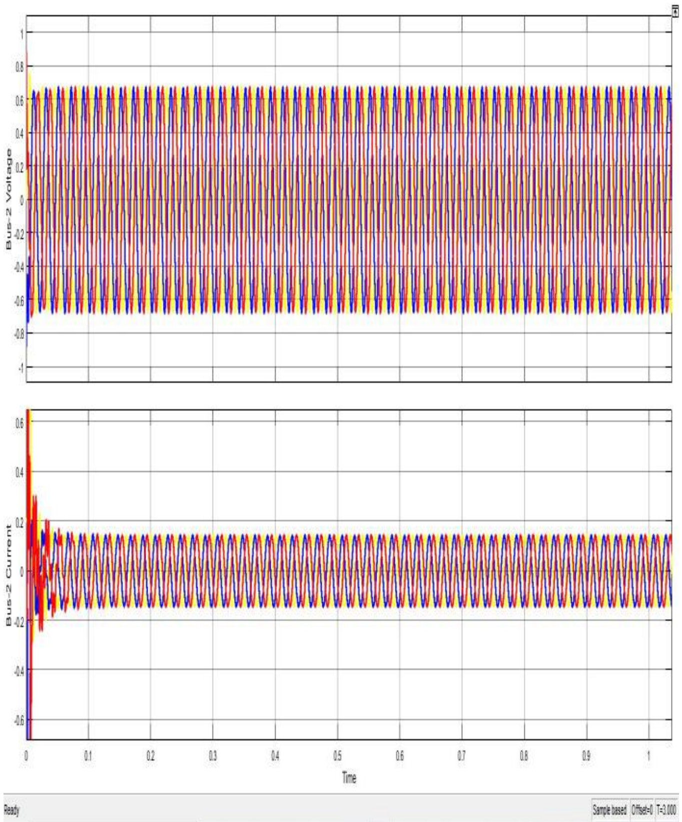

Fig 5.12- Bus-2 Voltage and Current with STATCOM

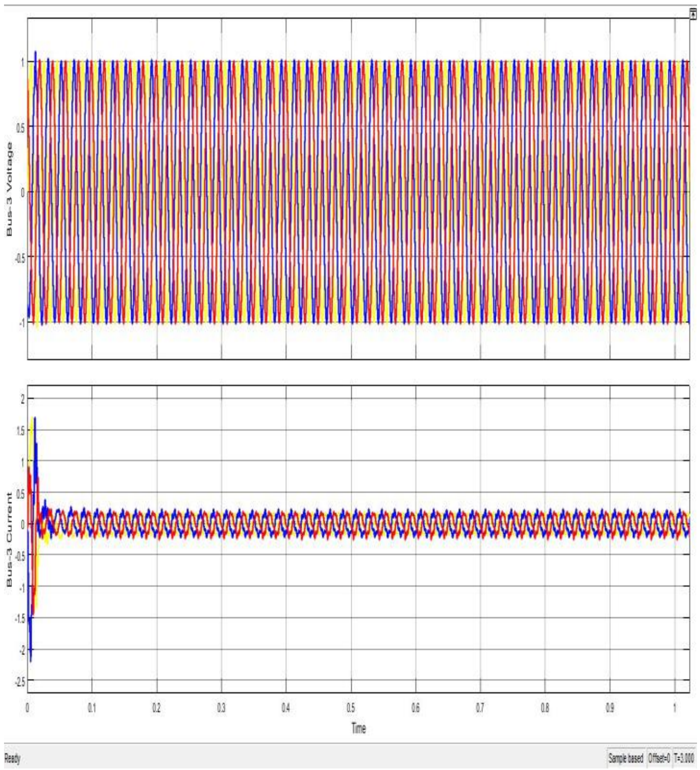

Fig 5.13- Bus-3 Voltage and Current with STATCOM

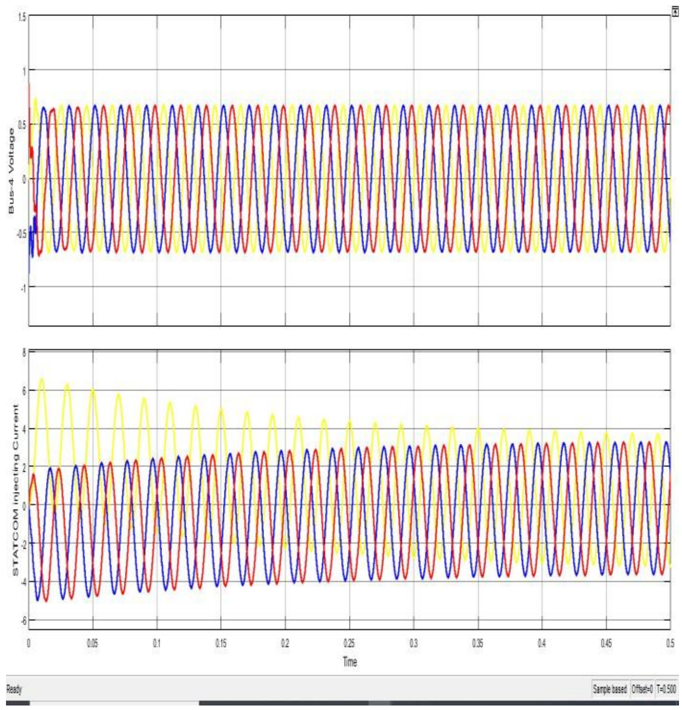

Fig 5.14- Voltage and Current across STATCOM at Bus-4

VI. CONCLUSION

This paper proposes a HVDC System and its problem of power quality mitigation scheme using STATCOM device. The STACOM integrated with HVDC system shows the improvements in power quality problems like voltage distortions, Harmonics, etc. After the Simulation results we can see that STATCOM integration with HVDC System is successful and useful for large power system Network. This paper describes about the widespread of this paper which has enlisted all aspects for High voltage direct current (HVDC) transmission. Good HVDC design begins with a thorough understanding of the basic concepts, their, and operation and control of HVDC system. There are many bases for operation and control before acting on them, but for High voltage direct current (HVDC) transmission there are many constraints. After the Simulation results we can see that STATCOM integration with Multi grid HVDC System is successful and useful for large power system Network.Hence it is required to test the systems for different condition, and checking the system for limit violations by using features of Power Flow. The Simulation of HVDC with STATCOM is successfully done with voltage and current waveform improvement.

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