Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 4, Issue 12, December -2017

OPERATION AND REVIEW OF HVDC SYSTEM WITH STATCOM DEVICE FOR MULTIGRID SYSTEM

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Abstract:- *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.*

Overview

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 neighbouring 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 project 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].

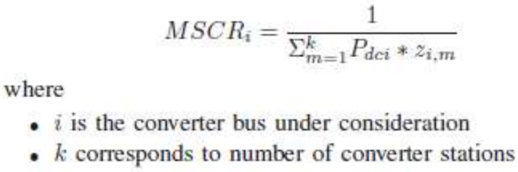
In this paper a LCC (Line commutated Converters) based Multi grid system is considered and its large disturbance voltage stability is analysed for various operating control modes. Since LCCs always consume reactive power, the possibility of voltage instability or collapse is quite high. The dynamic reactive 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]

$$SCR=\frac{1}{z} \text{ ………… } (1)$$

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]. MSCRs unlike individual SCRs consider the power levels of the each connected HVDC link and hence gives more accurate description of the voltage stability in MIDC system. MSCRs also indicate how strongly the individual HVDC links participate in the voltage stability of the multi grid system.



$$MSCR_i = \frac{1}{\Sigma_{m=1}^{k} P_{dci} * z_{i,m}}$$

where

- i is the converter bus under consideration
- k corresponds to number of converter stations

………… (2)

HVDC SYSTEM

Historical Perspective on HVDC Transmission It has been widely documented in the history of the electricity industry, that the first commercial electricity generated (by Thomas Alva Edison) was direct current (DC) electrical power. The first electricity transmission systems were also direct current systems. However, DC power at low voltage could not be transmitted over long distances, thus giving rise to high voltage alternating current (AC) electrical systems. Nevertheless, with the development of high voltage valves, it was possible to once again transmit DC power at high voltages and over long distances, giving rise to HVDC transmission systems.

➢ The HVDC technology

The fundamental process that occurs in an HVDC system is the conversion of electrical current from AC to DC (rectifier) at the transmitting end, and from DC to AC (inverter) at the receiving end. There are three ways of achieving conversion:-

- Natural Commutated Converters. Natural commutated converters are most used in the HVDC systems as of today. The component that enables this conversion process is the thyristor, which is a controllable semiconductor that can carry very high currents (4000 A) and is able to block very high voltages (up to 10 kV). By means of connecting the thyristor in series it is possible to build up a thyristor valve, which is able to operate at very high voltages (several hundred of kV).The thyristor valve is operated at net frequency (50 Hz or 60 Hz) and by means of a control angle it is possible to change the DC voltage level of the bridge. This ability is the way by which the transmitted power is controlled rapidly and efficiently.

- Capacitor Commutated Converters (CCC). An improvement in the thyristor-based commutation, the CCC concept is characterized by the use of commutation capacitors inserted in series between the converter transformers and the thyristor valves. The commutation capacitors improve the commutation failure performance of the converters when connected to weak networks.

- Forced Commutated Converters. This type of converters introduces a spectrum of advantages, e.g. feed of passive networks (without generation), independent control of active and reactive power, power quality. The valves of these converters are built up with semiconductors with the ability not only to turn-on but also to turn-off. They are known as VSC (Voltage Source Converters).

The components of an HVDC transmission system To assist the designers of transmission systems, the components that comprise the HVDC system, and the options available in these components, are presented and discussed. The three main elements of an HVDC system are: the converter station at the transmission and receiving ends, the transmission medium, and the electrodes.

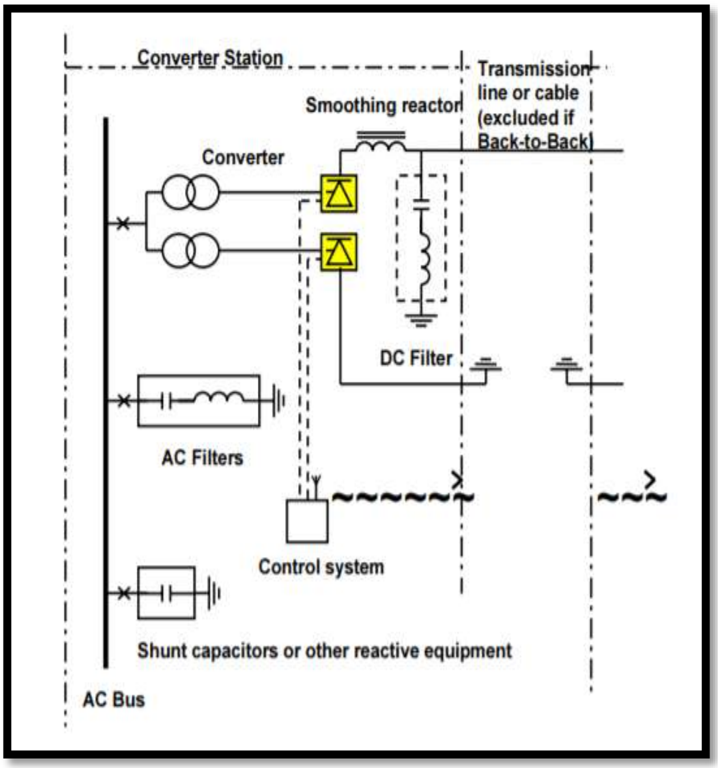


Fig 3.1- Block Diagram of HVDC System

STATCOM Overview

This shunt connected static compensator was developed as an advanced static VAR compensator where a voltage source convertor (VSC) is used in-stead of the controllable reactors and switched capacitors. Although VSCs require self-commutated power semiconductor devices such as GTO, IGBT, IGCT, MCT, etc (with higher costs and losses) unlike in the case of variable impedance type SVC which use thyristor devices, there are many technical advantages of a STATCOM over a SVC.

The principal benefit of the STATCOM for transient stability enhancement is direct through rapid bus voltage control. In particular, the STATCOM may be used to enhance power transfer during low-voltage conditions, which typically predominate during faults, decreasing the acceleration of local generators. An additional benefit is the reduction of the demagnetizing effects of faults on local generation. STATCOM behave analogously to synchronous compensators, except that STATCOM have no mechanical inertia and are therefore capable of responding much more rapidly to changing system conditions. When compared to synchronous machines, they do not contribute to short circuit currents and have no moving parts. However, the system has a symmetric lead-lag capability and can theoretically go from full lag to full lead in fraction of cycles.

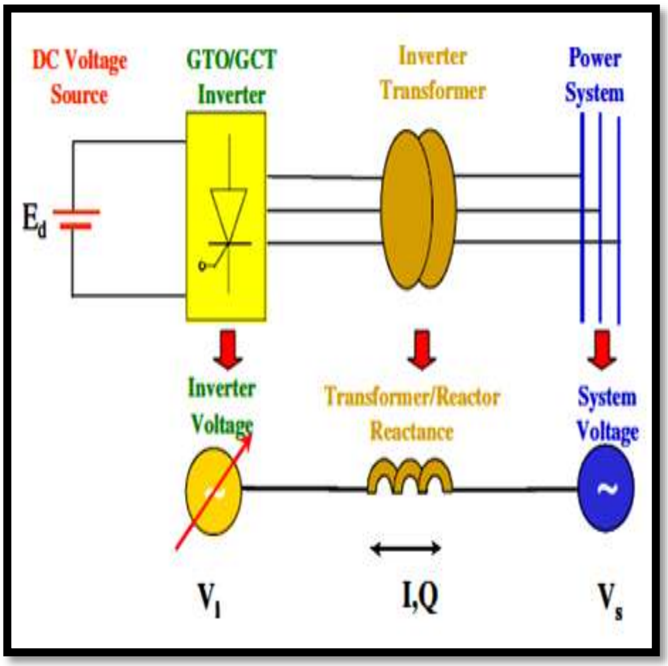


Fig. 4.1 STATCOM arrangement in power system

A STATCOM, connected in shunt, with the system is capable of improving transient stability by compensating the reactive power at the point of common connection. The ultimate objective of applying reactive shunt compensation in a transmission system is to increase the transmittable power during transients.

This is achieved by increasing (decreasing) the power transfer capability when the machine angle increases (decreases).

The key benefits of Statcom

(a) Faster response

(b) Requires less space as bulky passive components (such as reactors) areeliminated

(c) Inherently modular and relocatable

(d) It can be interfaced with real power sources such as battery, fuel cellor SMES (superconducting magnetic energy storage)

(e) A STATCOM has superior performance during low voltage condition as the reactive current can be maintained constant (In a SVC, the capacitive reactive current drops linearly with the voltage at the limit of capacitive susceptance). It is even possible to increase the reactive current in a STATCOM under transient conditions if the devices are rated for the transient overload. In a SVC, the maximum reactive current is determined by the rating of the passive components – reactors and capacitors.

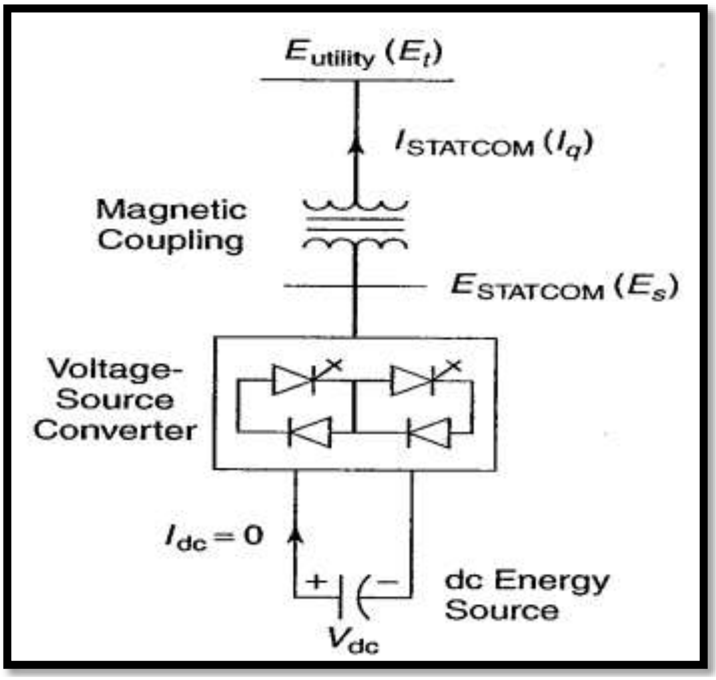


Fig. 4.2 Single Line Diagram of STATCOM

Figure 4.2 shows the single line diagram of a STATCOM. In this configuration the VSC is connected with utility system through magnetic coupling. By controlling the converter output voltage E_s, the reactive power exchange from converter to ac system can achieve easily. That is if the amplitude of output voltage is increased above that of the utility bus voltage, E_t, then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system.

If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system. If the output voltage equals the ac system voltage, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state. If the DC capacitor voltage, V_{dc}, is increased from its nominal value, the STATCOM is “overexcited” (capacitive mode) and generates reactive power. If the voltage of the DC capacitor bank is decreased below the nominal value, the STATCOM is “under excited” (inductive mode) and absorbs reactive power from the system. This is completely analogous to increasing or decreasing the field voltage of a synchronous compensator.

PROPOSED SYSTEM

HVDC STATCOM SYSTEM

Statcom is one of contrivance of FACTS family. Figure 4.3, 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 (thyristor commutation, in this thesis 6 pulse is adopted), 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.

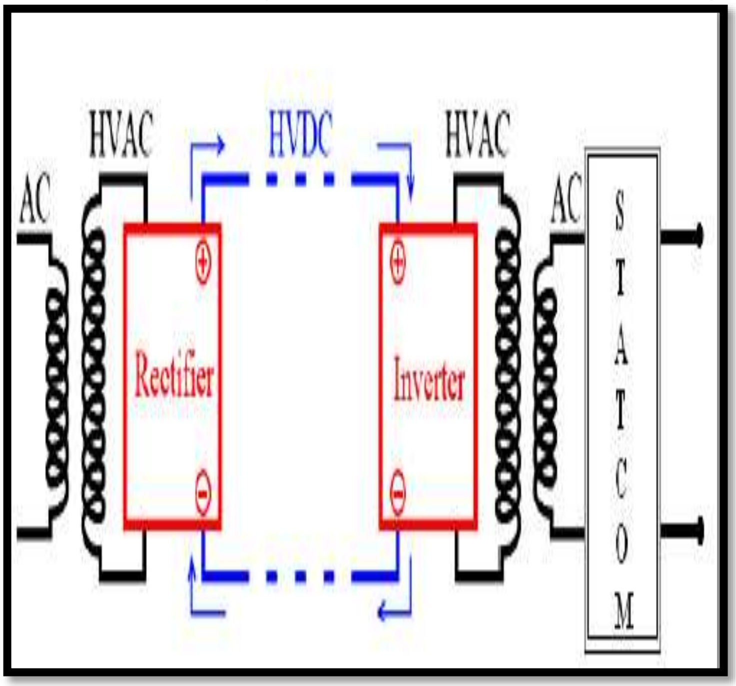


Figure 4.3: Statcom with HVDC system

After restarting the system, it will be compulsory to disconnect the load from the HVDC inverter. The STATCOM is precharged 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 deblocked 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.

MODELLING AND SIMULATION

Matlab Model of HVDC system with internal Fault:-

The Matlab model of the HVDC proposed system with internal fault is shown in the fig below. The simulation results of Voltage and Current also shows the unbalancing due to internal fault in HVDC system.

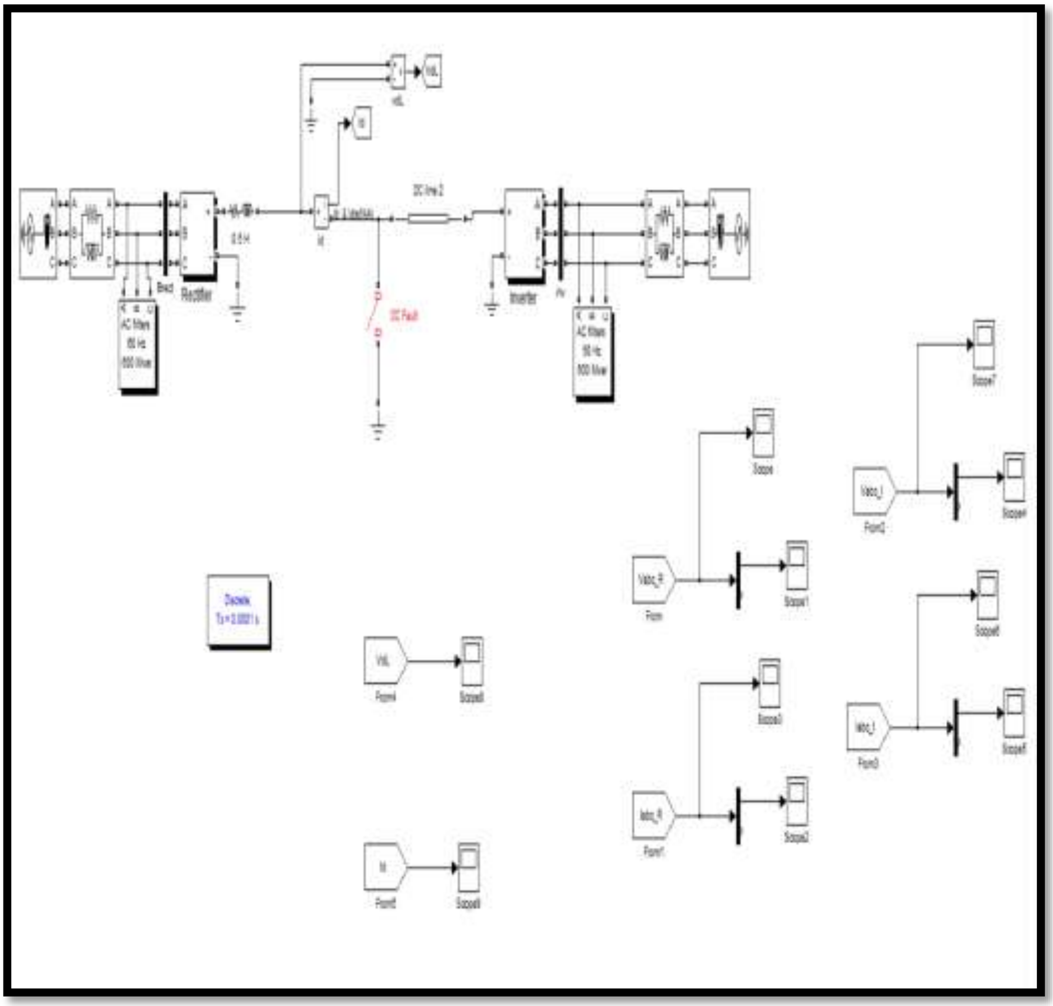


Fig 5.1- Matlab Model of HVDC System with Fault

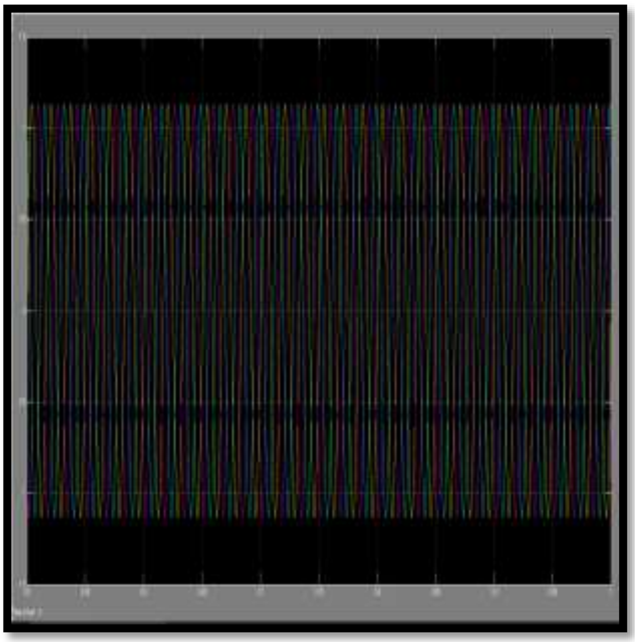


Fig 5.2- Source side voltage

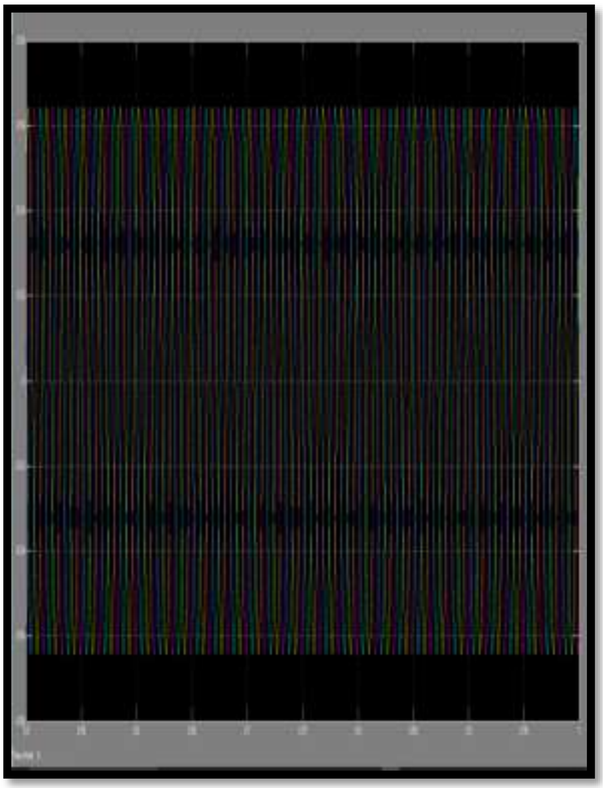


Fig 5.3- Source side current

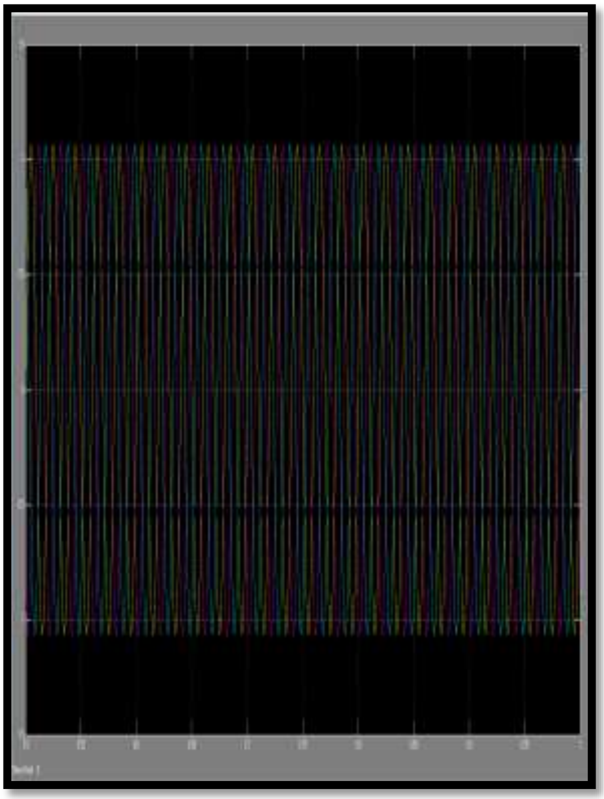


Fig 5.4-Inverter side voltage

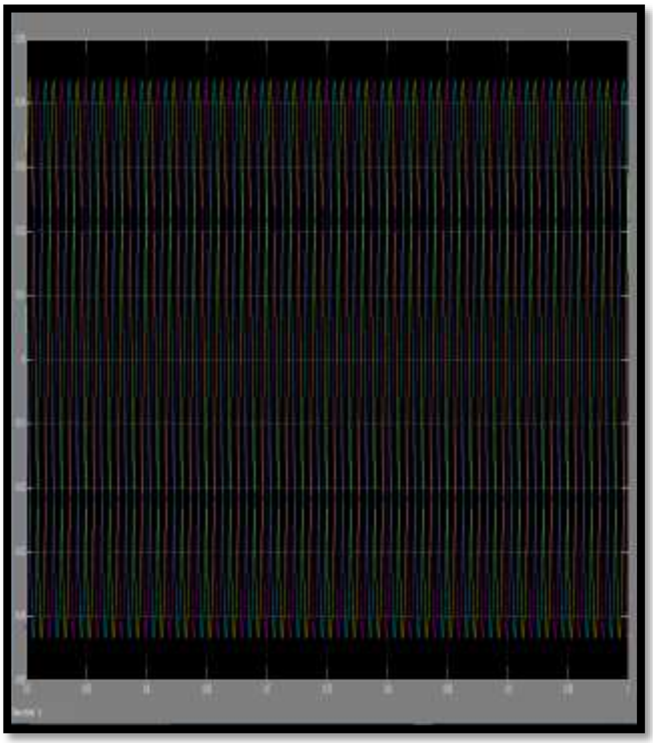


Fig 5.5- Inverter side current

HVDC System with STATCOM

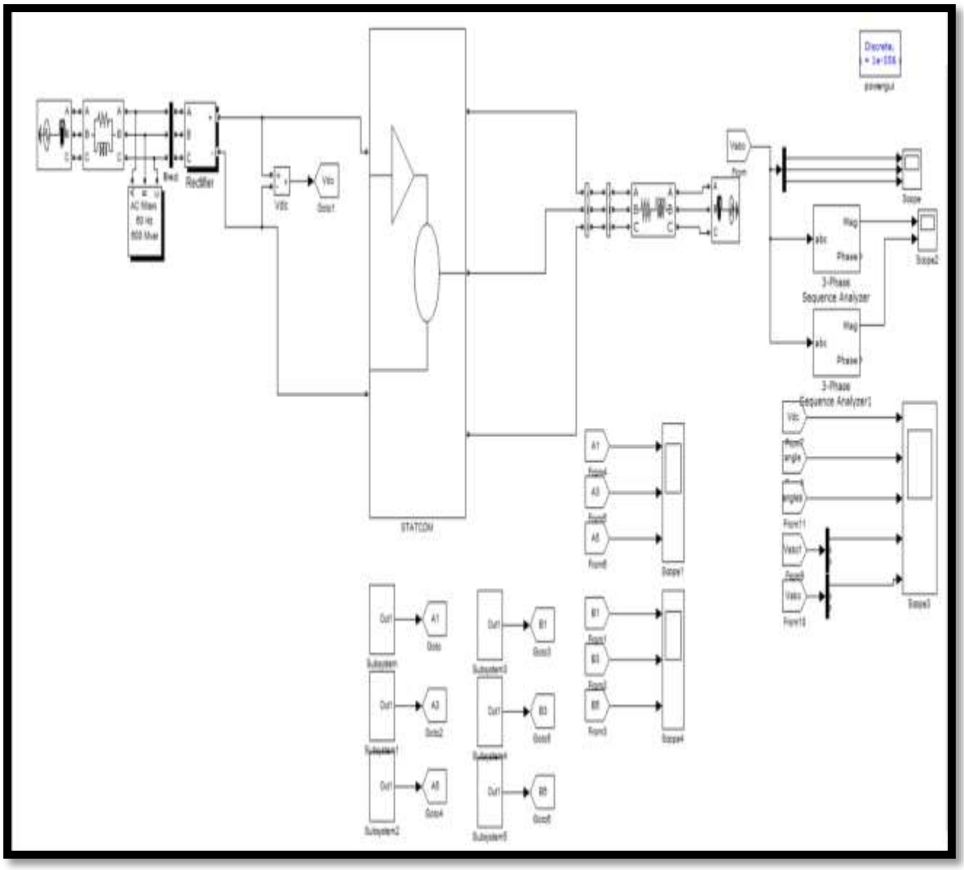


Fig 5.6- Proposed HVDC System with STATCOM

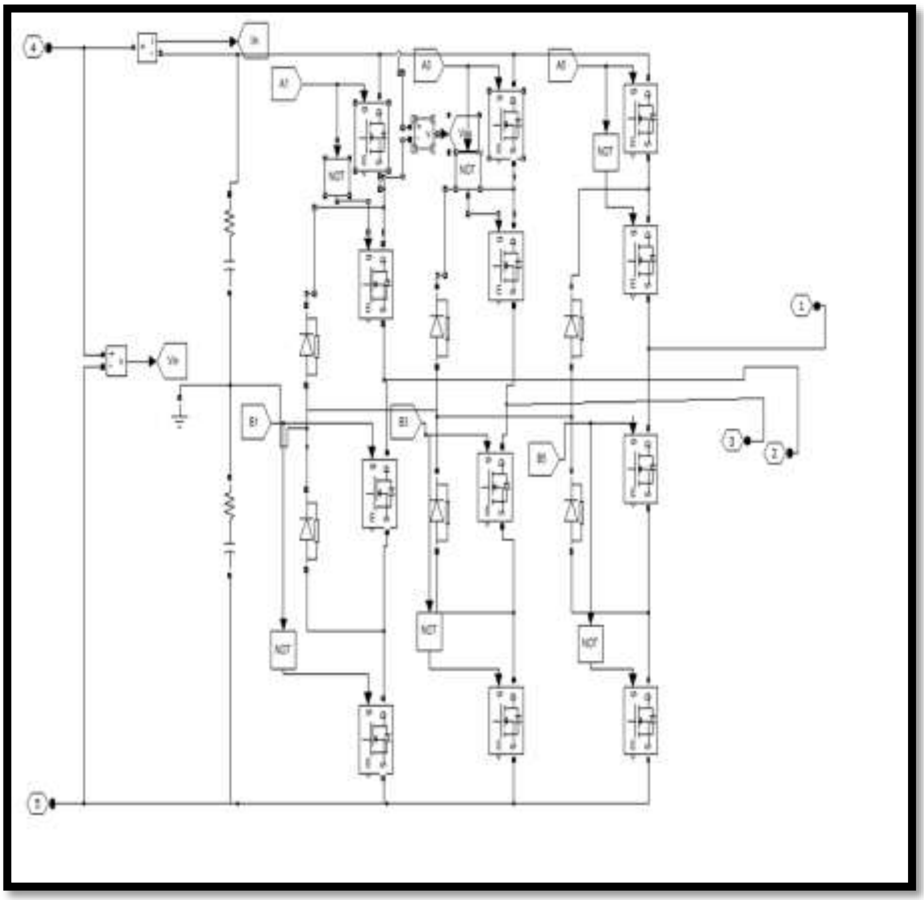


Fig 5.7- STATCOM Subsystem

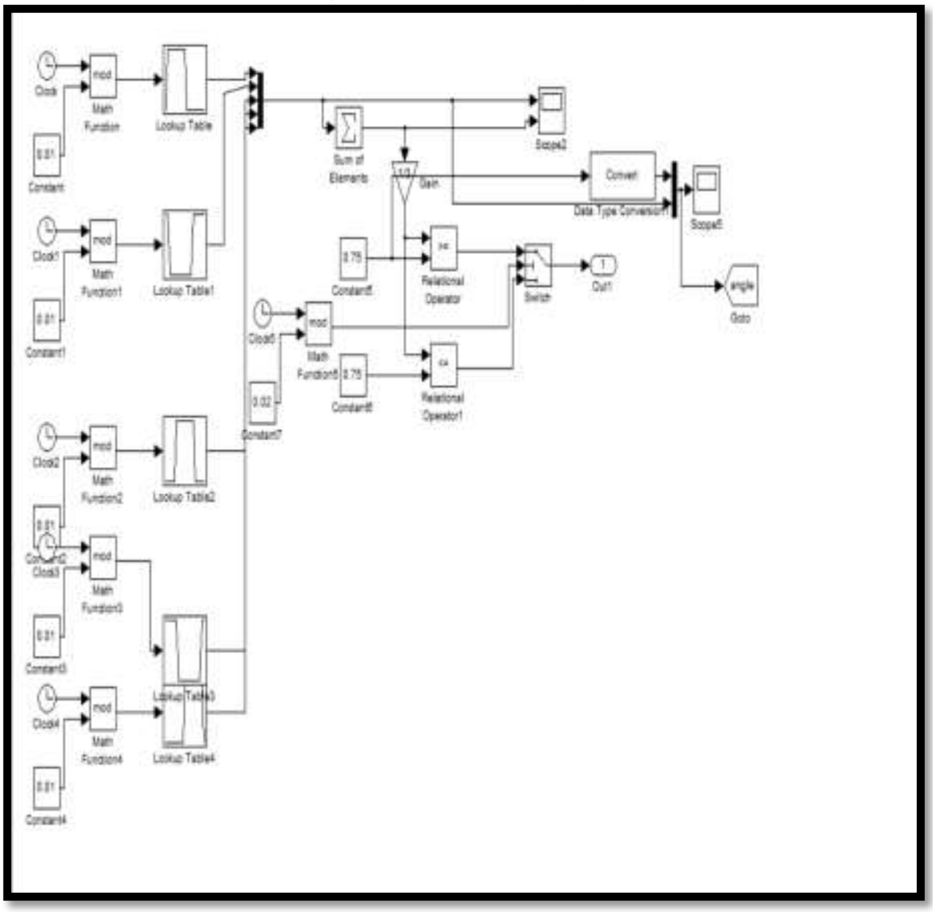


Fig 5.8- Control Subsystem for STATCOM Operation

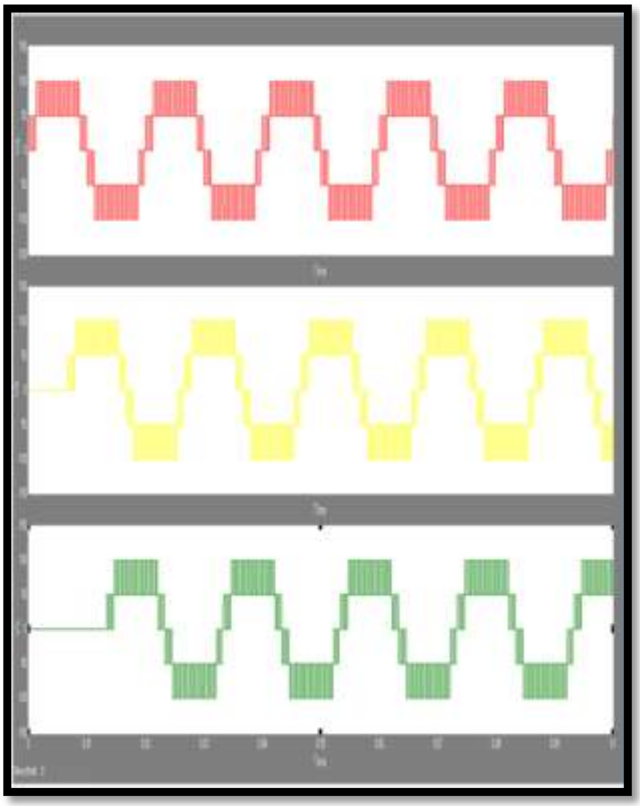


Fig 5.9- Inverter controlled output

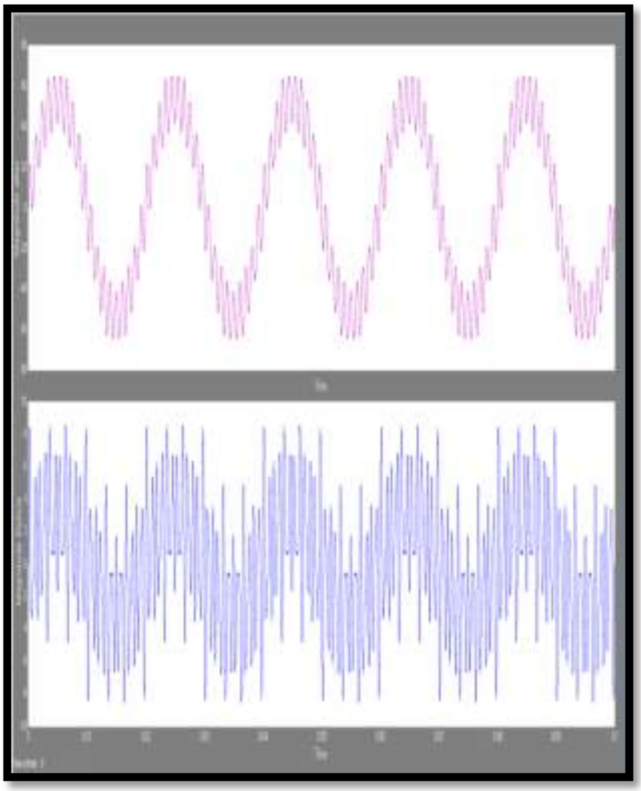


Fig 5.10- Magnitude variation

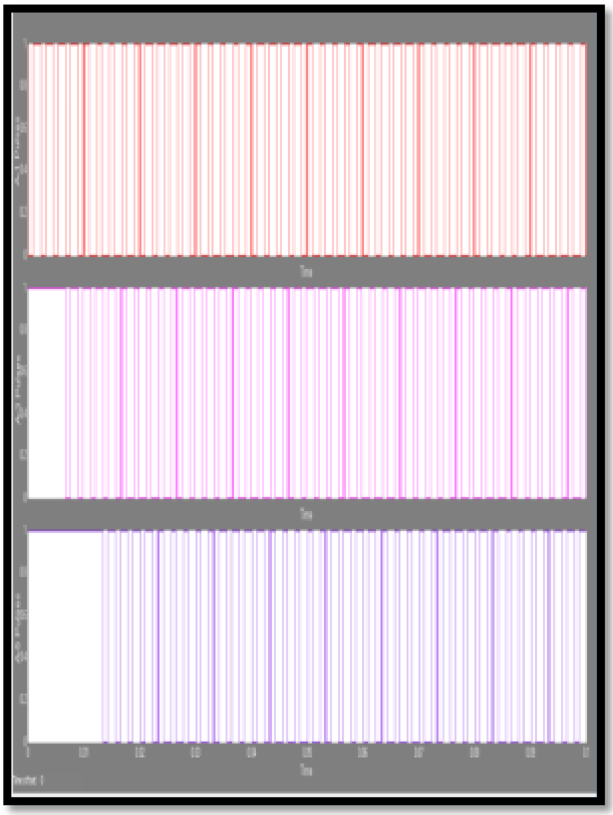


Fig 5.11- Triggering pulses for A1, A3, A5

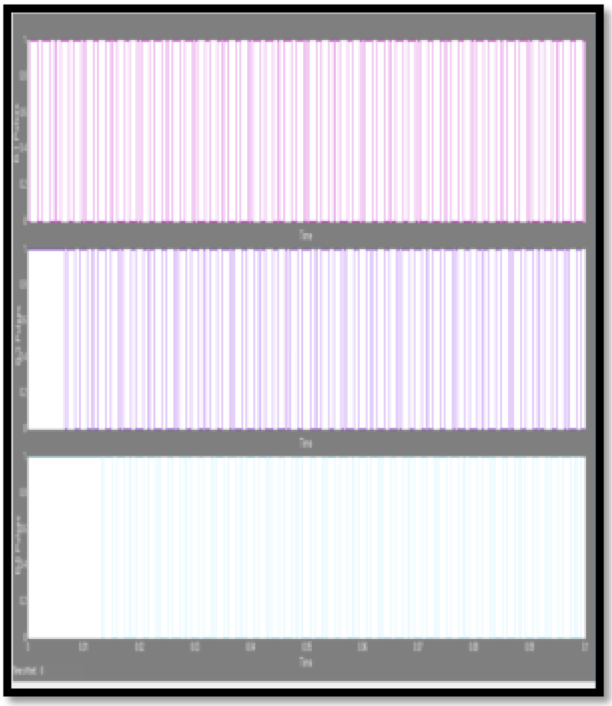


Fig 5.12- Triggering pulses for B1, B3, B5

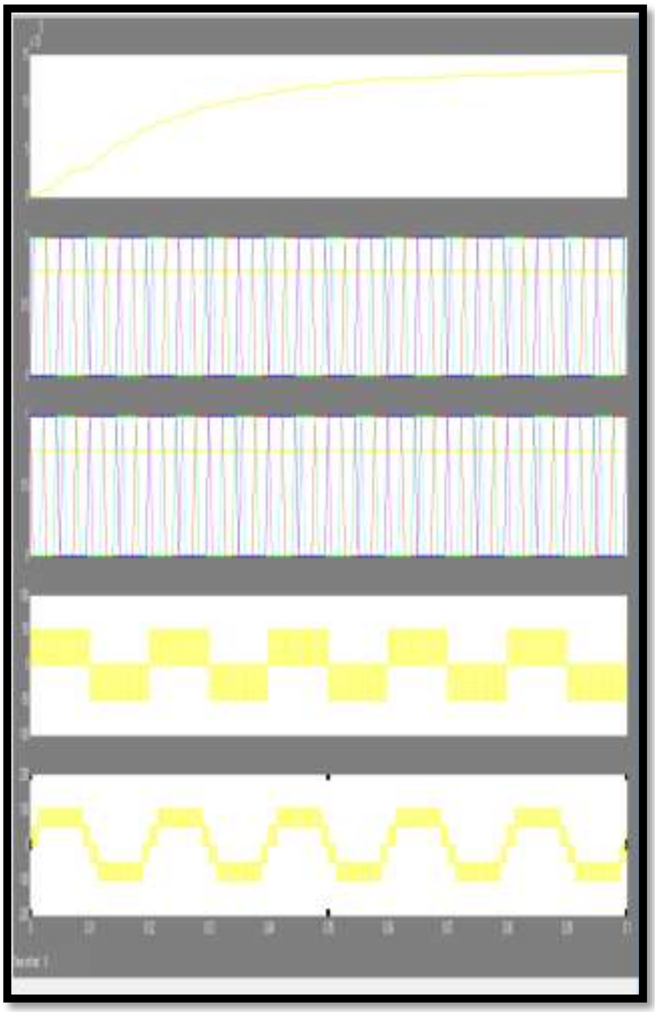


Fig 5.13- Final Controlled output of Proposed System

Conclusion

This project 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 also useful for large power system Network.

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