

SIMULATION OF HVDC SYSTEM WITH STATCOM DEVICE FOR POWER QUALITY ENAHNCEMENT IN 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 coordinatates 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 near the neighbouring one
- ✓ Transient AC voltage depression due to simultaneous recovery of constituent HVDC links after AC faults

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].

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.

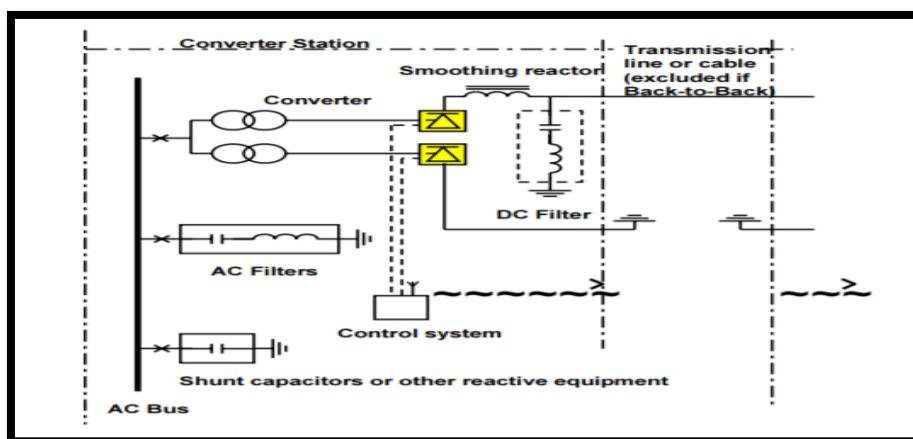


Fig 3.1- Block Diagram of HVDC System

STATCOM Overview

This shunt connected static compensator was developed as an advanced static VAR compensator where a voltage source converter (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. 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.

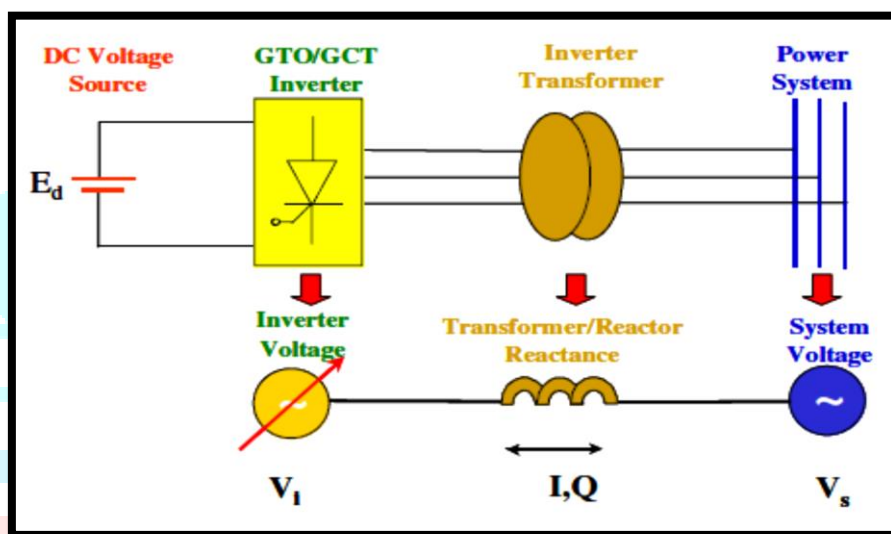


Fig. 4.1 STATCOM arrangement in power system

A STATCOM, connected in shunt, with the system can improve 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.

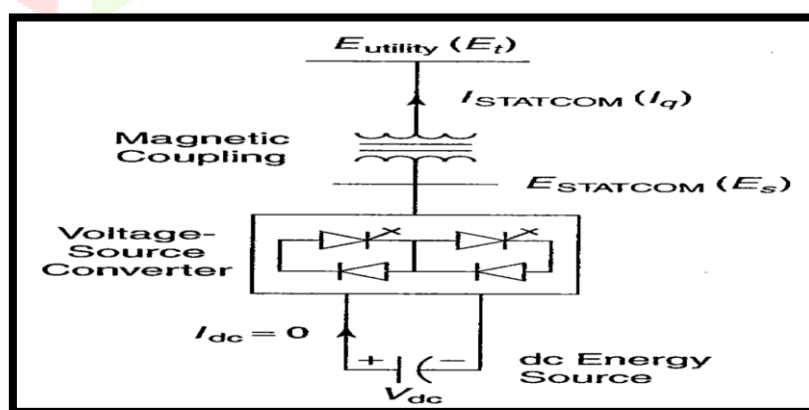


Fig. 4.2 Single Line Diagram of STATCOM

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 flow through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system.

PROPOSED 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 are 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.

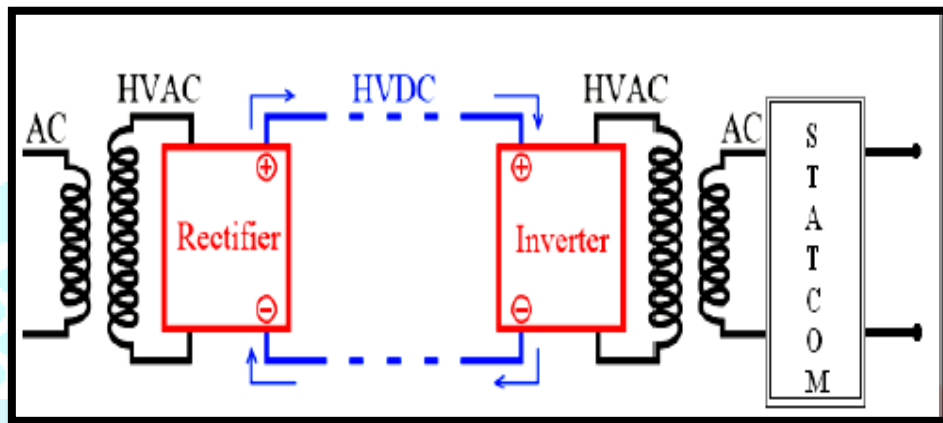


Figure 4.3: Statcom with HVDC system

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.

MODELLING AND SIMULATION

HVDC System with STATCOM

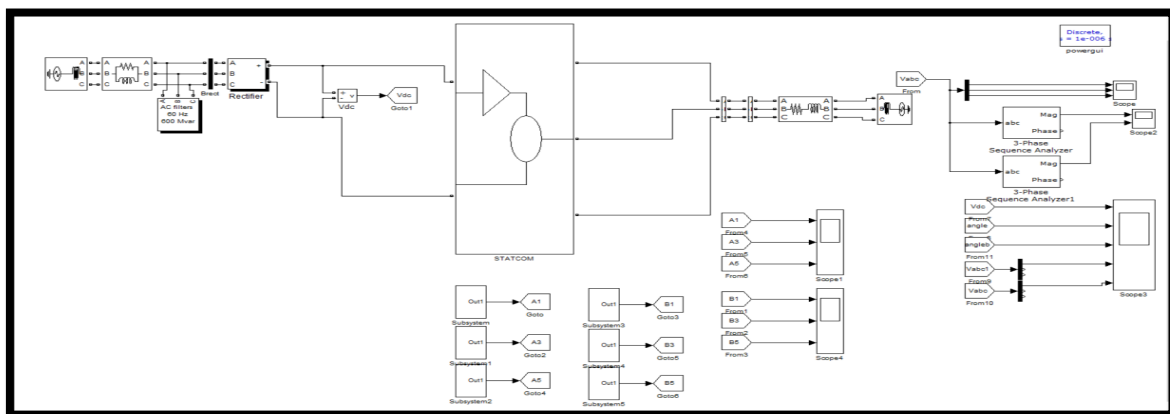


Fig 5.1- Proposed HVDC System with STATCOM

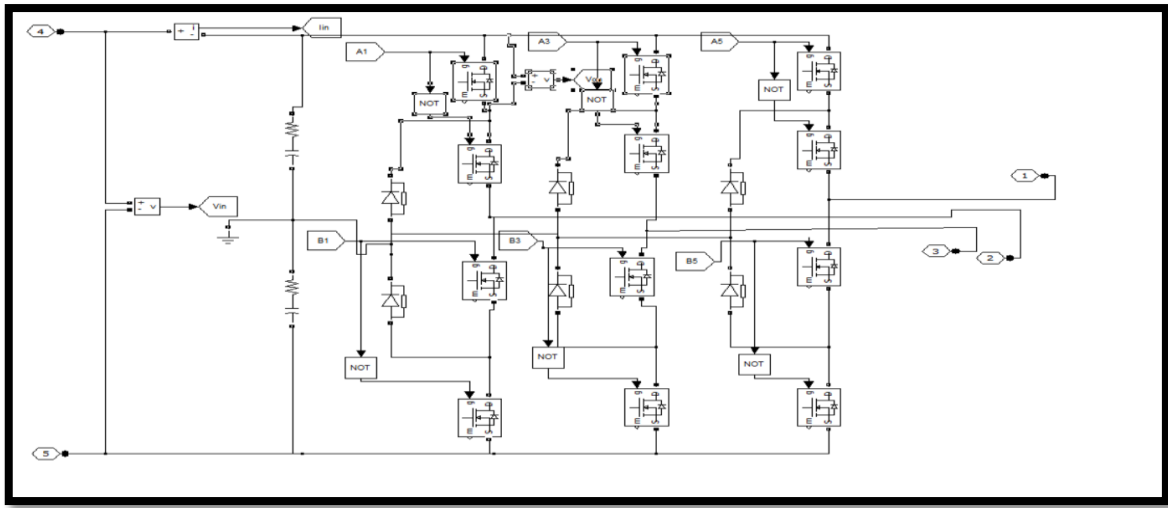


Fig 5.2- STATCOM Subsystem

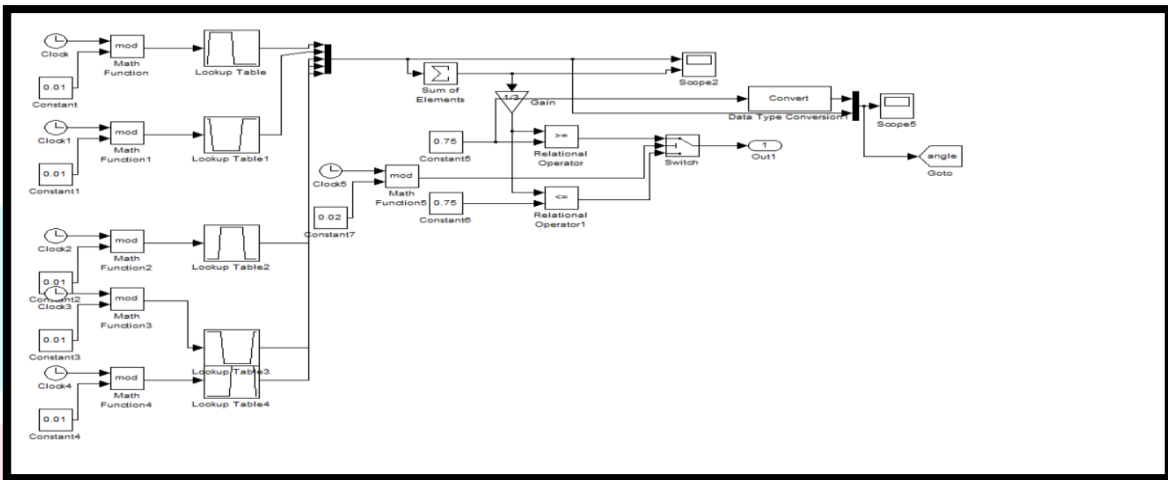


Fig 5.3- Control Subsystem for STATCOM Operation

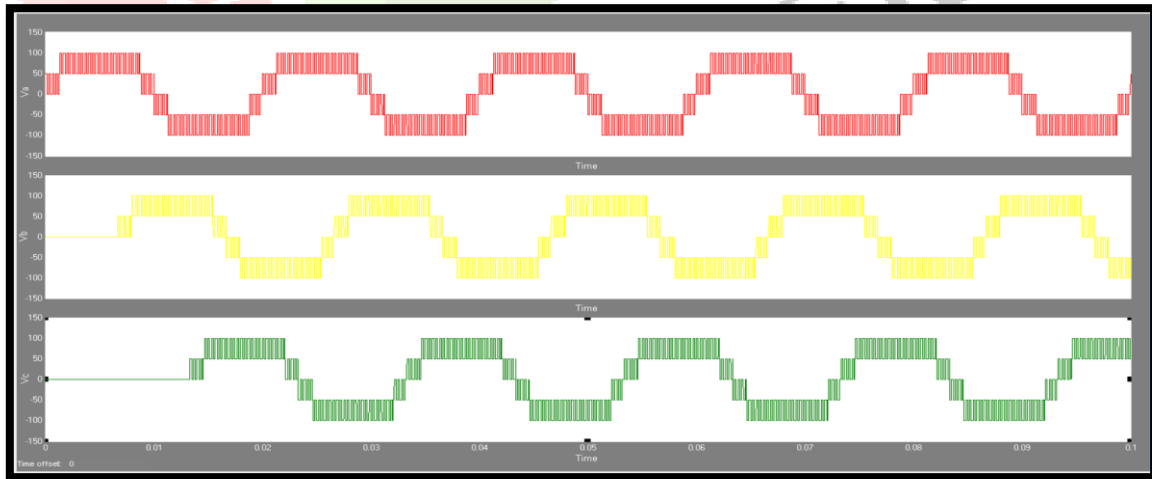


Fig 5.4- Inverter controlled output

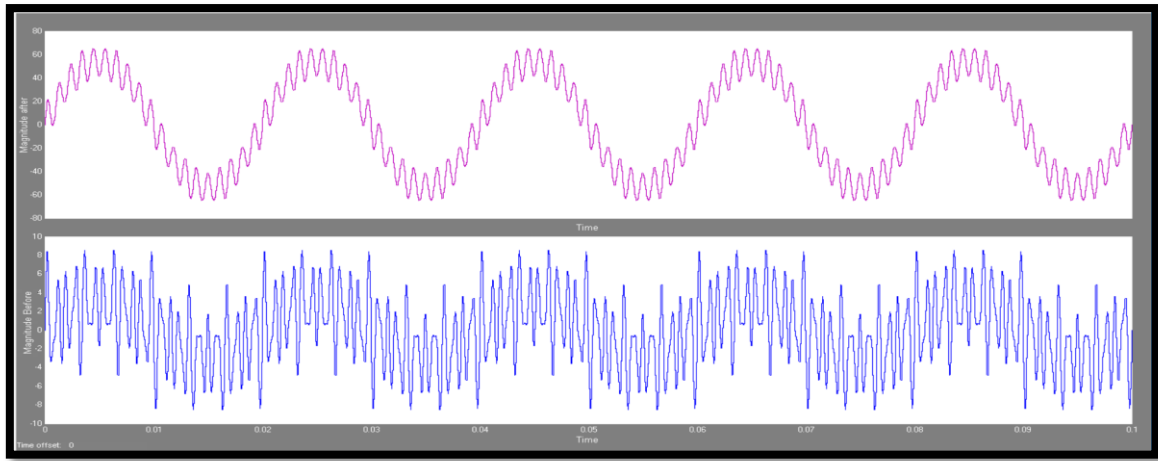


Fig 5.5- Magnitude variation

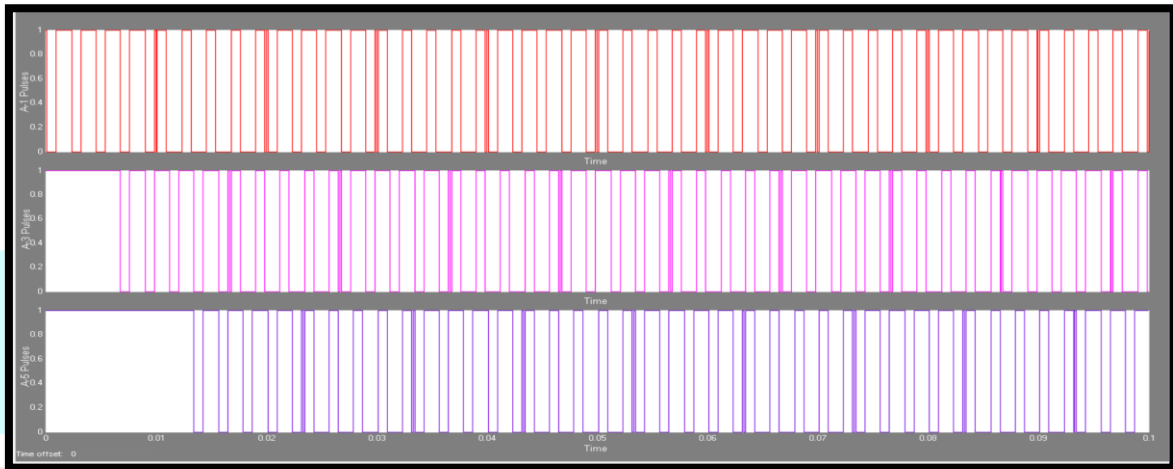


Fig 5.6- Triggering pulses for A1, A3, A5

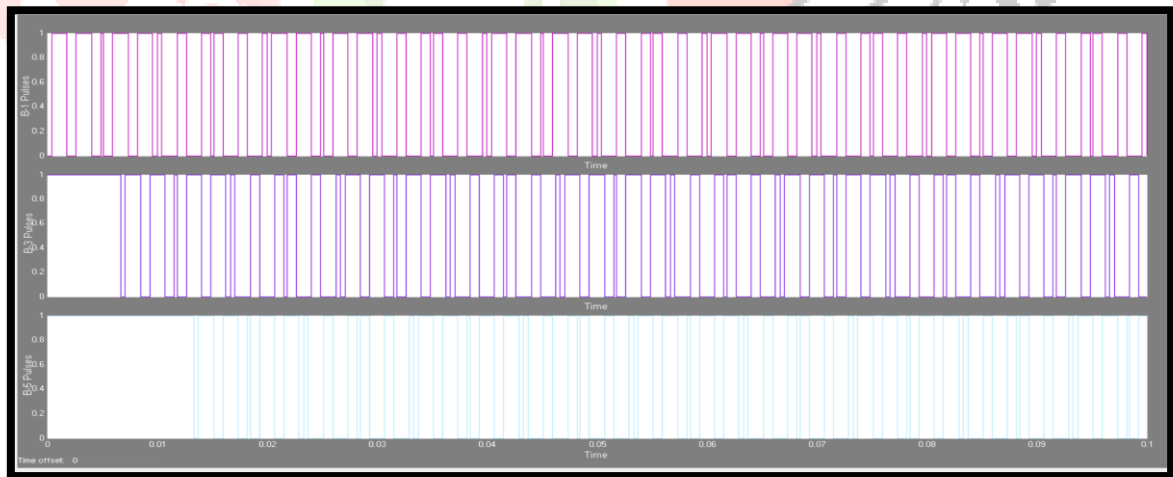


Fig 5.7- Triggering pulses for B1, B3, B5

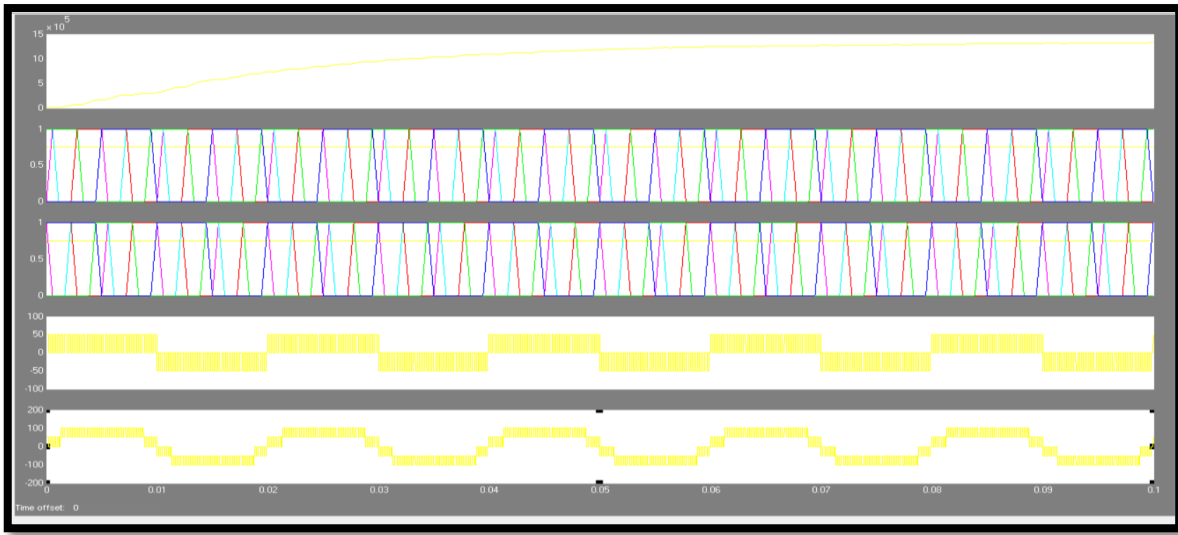


Fig 5.8- Final Controlled output of Proposed System

Multi Grid HVDC System with STATCOM

In the below section the above proposed system has been integrated with multi-grid and it is consider with variable input parameters in the Multi-grid HVDC system. But Due to use of STATCOM the output parameters have been controlled and successful operation has been done in this project.

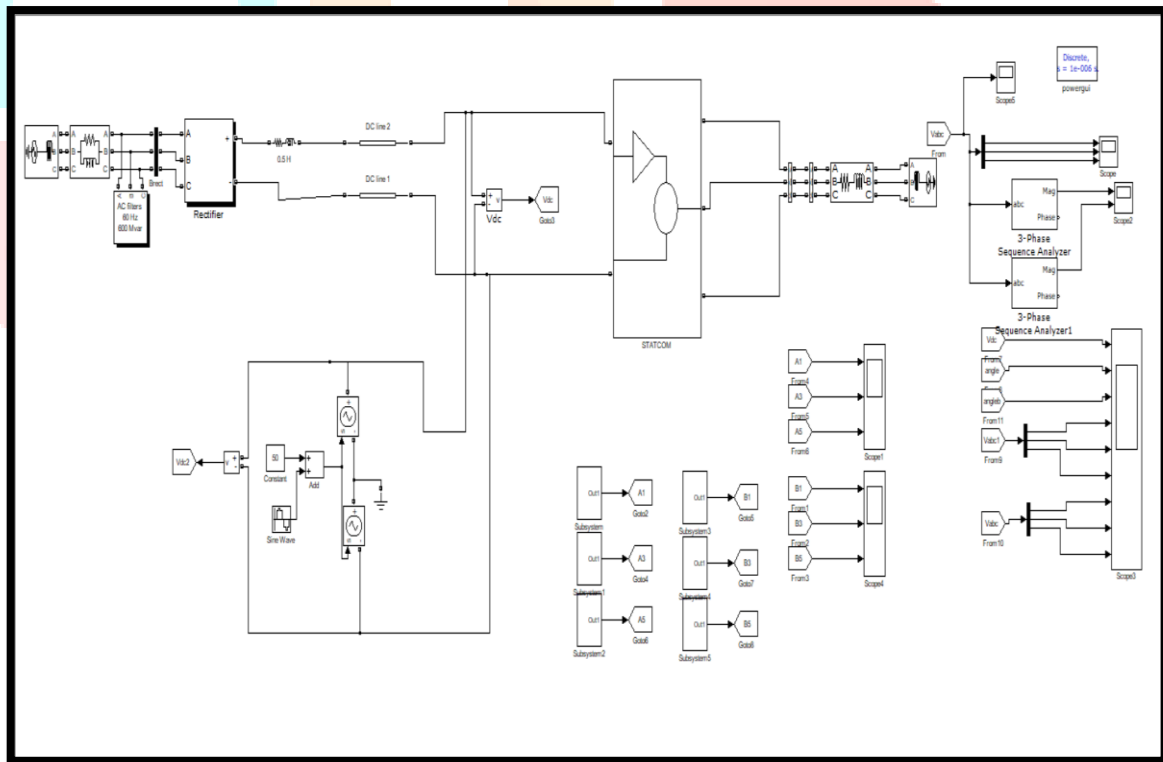


Fig 5.9 Proposed Multi-Grid HVDC System with STATCOM



Fig 5.10- Inverter controlled output

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.

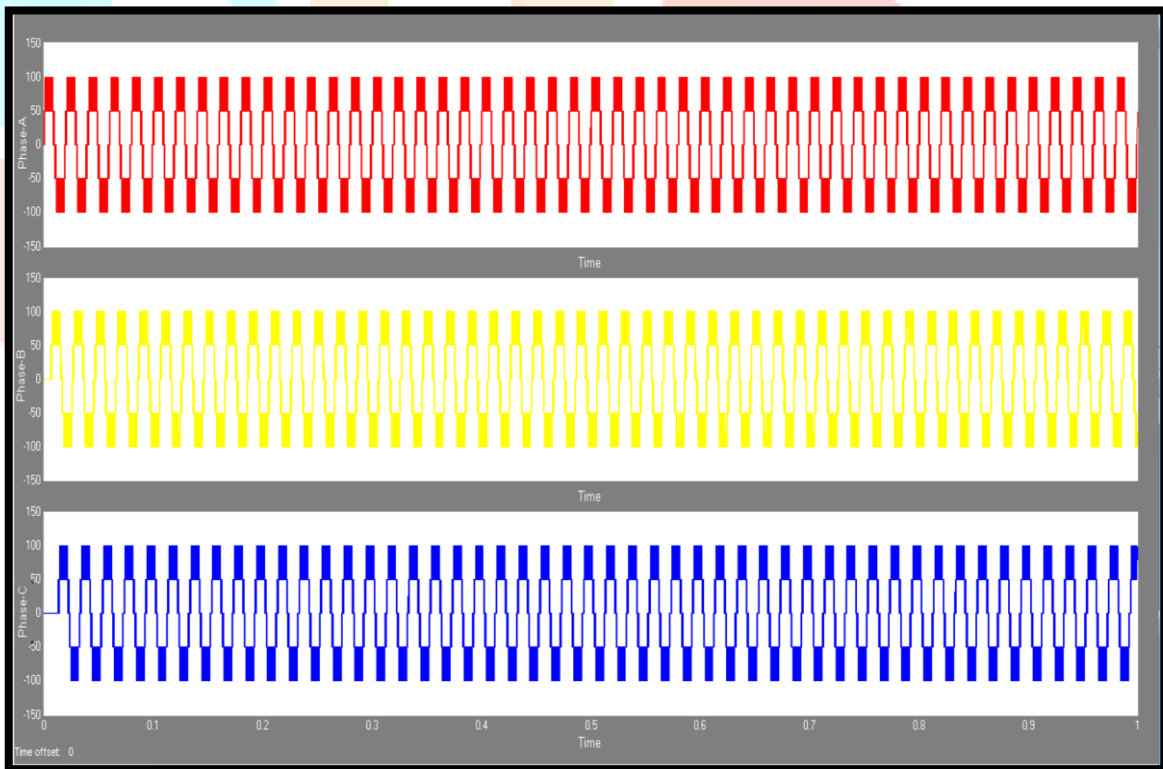


Fig 5.11- Inverter controlled output (each phase output)

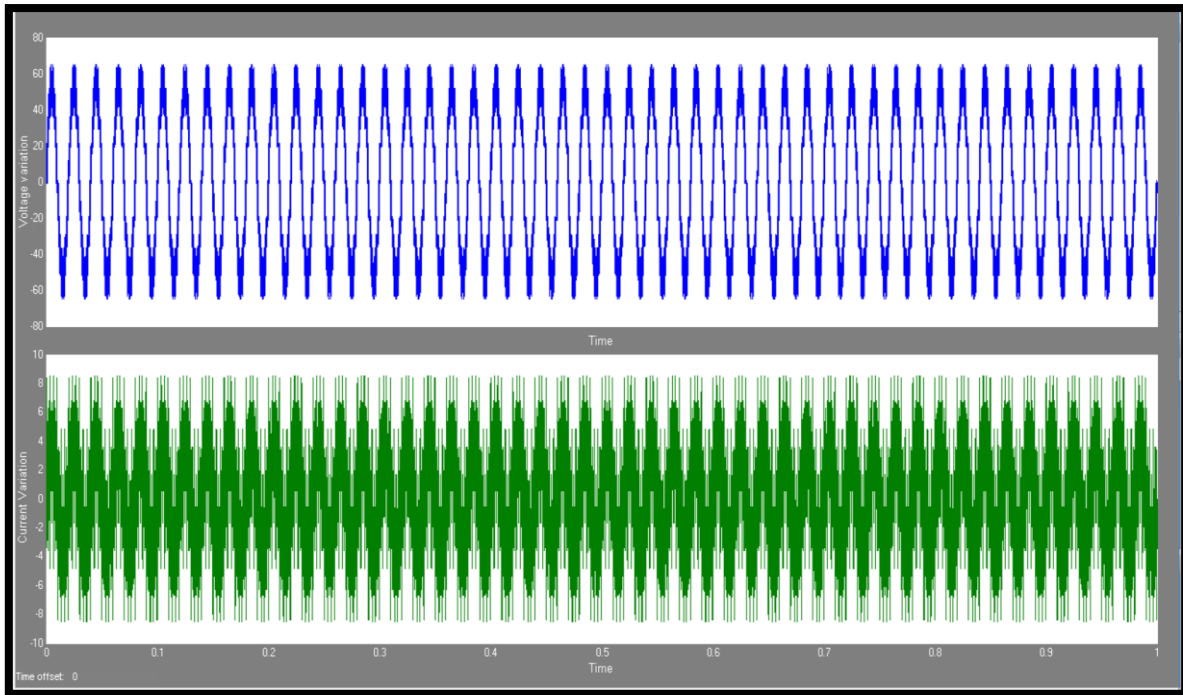


Fig 5.12- Magnitude variation (Voltage & Current)

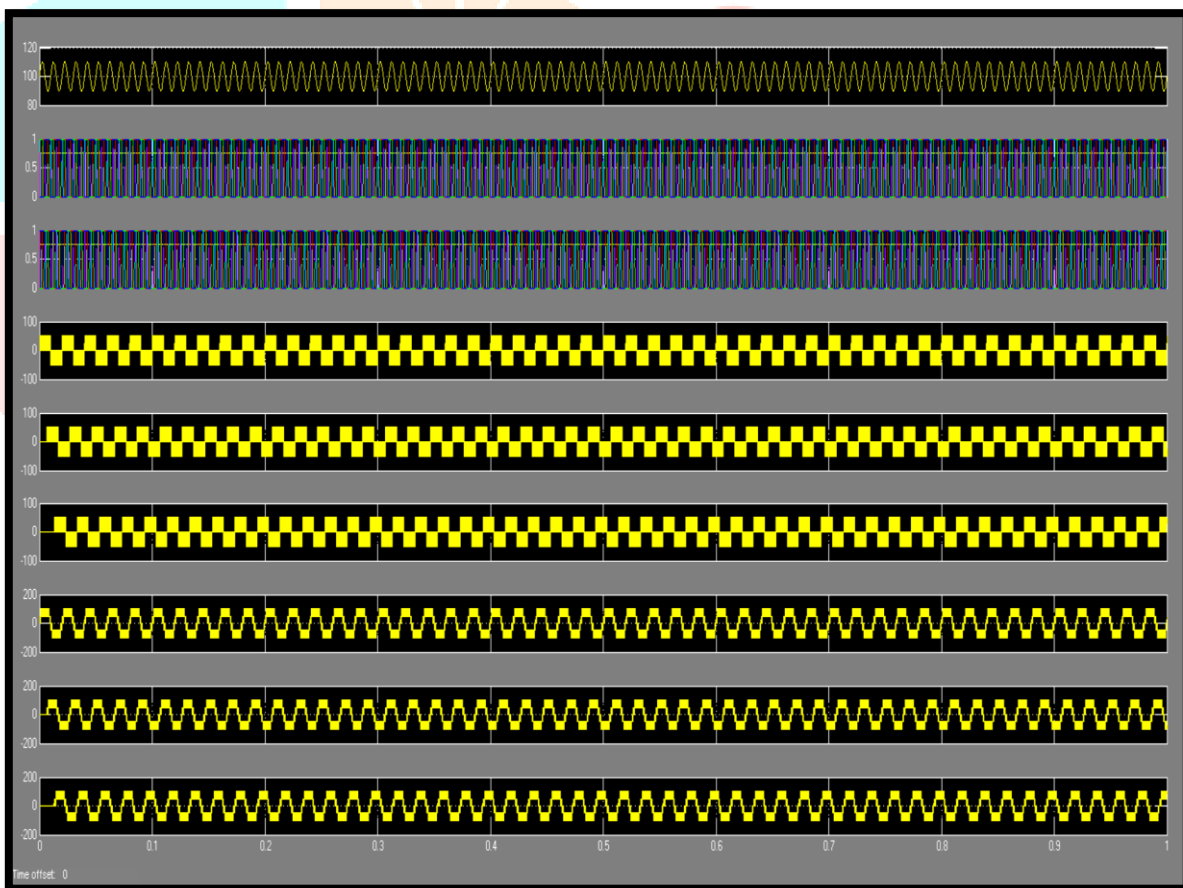


Fig 5.13- Final Controlled output parameters of Proposed System

Comparison & Analysis of without and with STATCOM of Proposed System

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 converters 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.

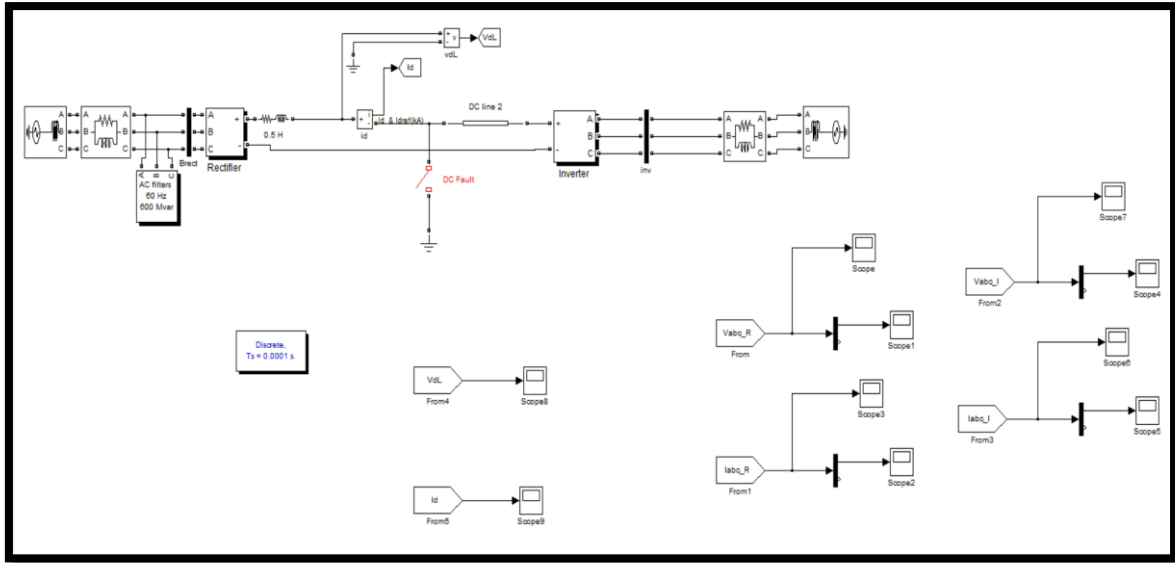


Fig 5.14- Without STATCOM proposed System

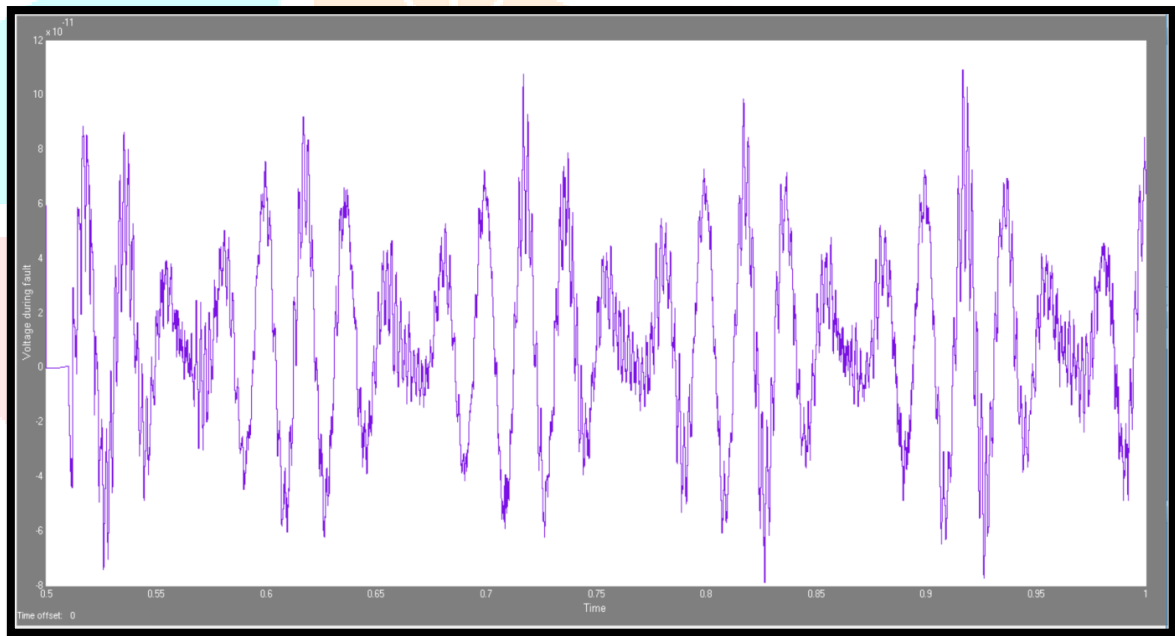


Fig 5.15- Voltage fluctuation

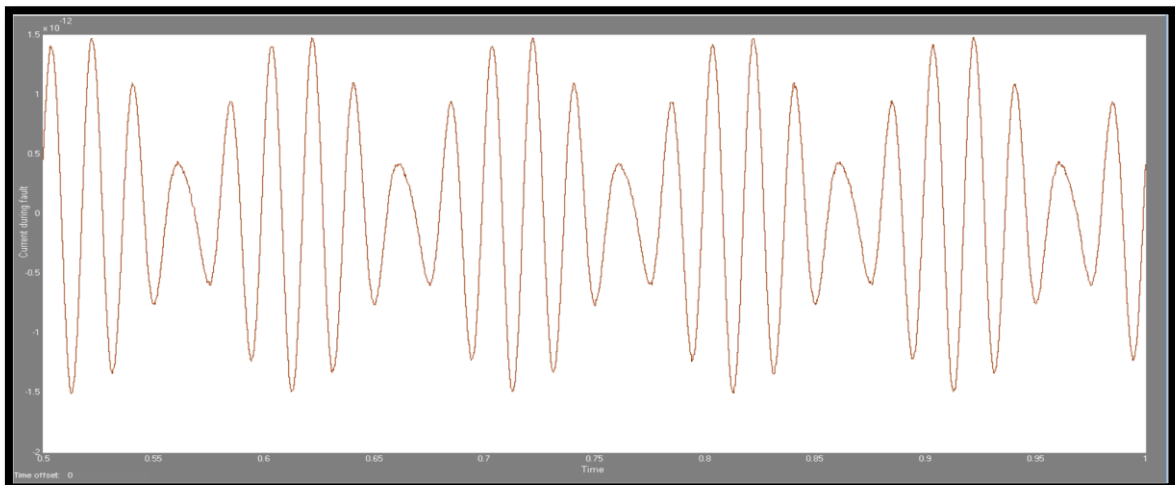


Fig 5.16- Current fluctuation

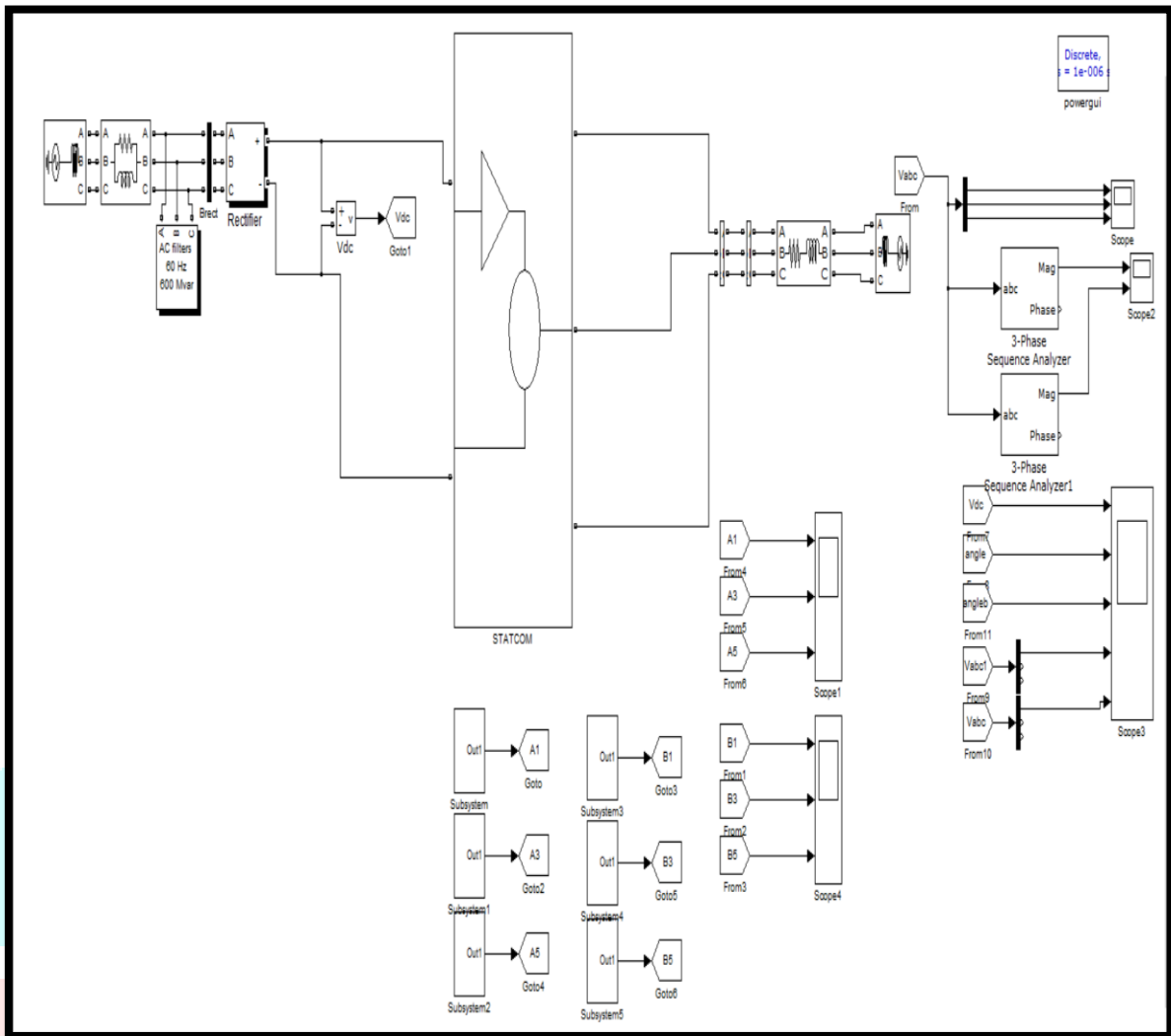


Fig 5.17- Proposed HVDC System with STATCOM

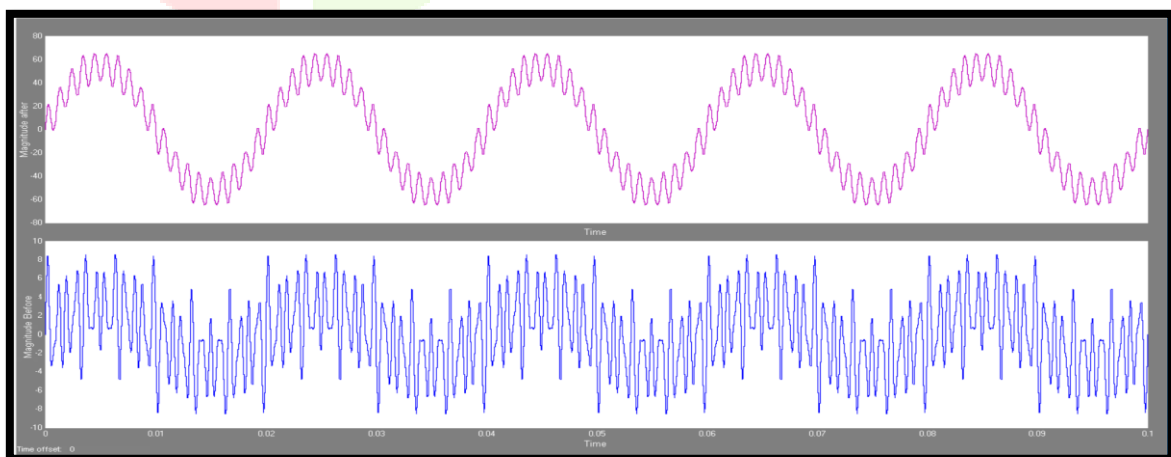


Fig 5.18- Magnitude variation

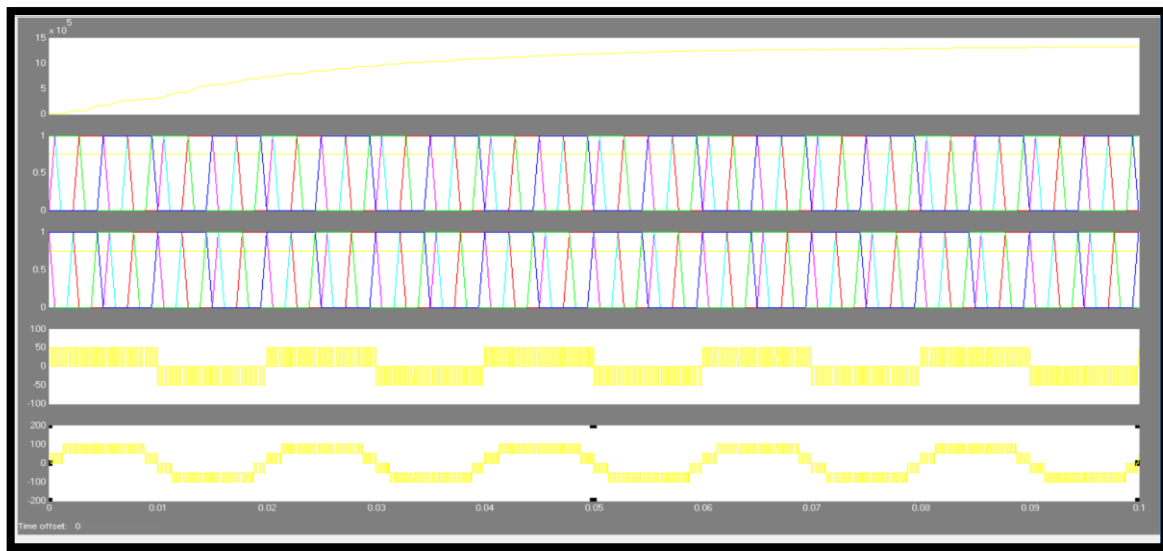


Fig 5.19- Final Controlled output of Proposed System

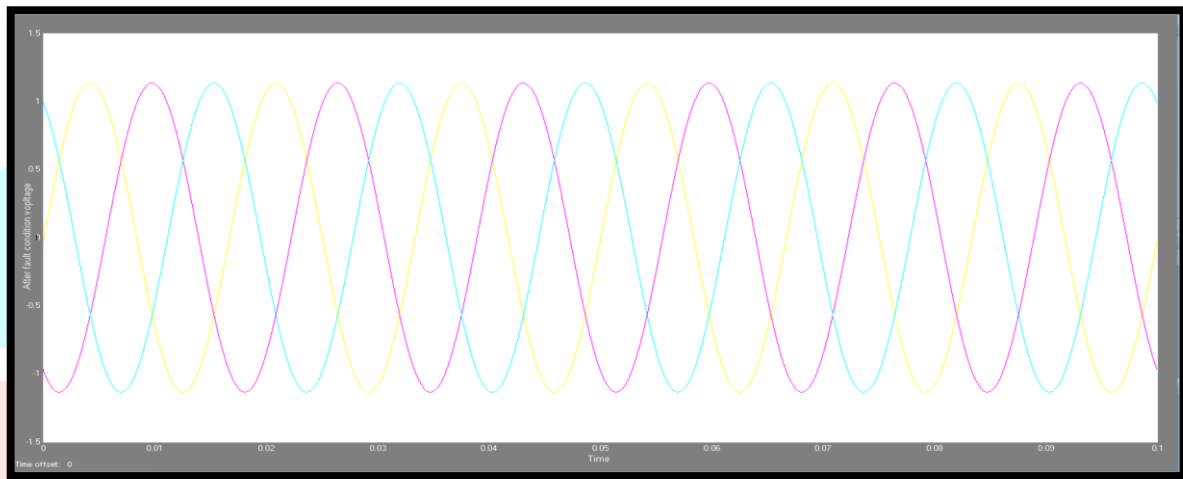


Fig 5.20- controlled Voltage after STATCOM Integration

STATCOM integrated with Multi-Grid HVDC system in shunt connection

The proposed scheme may be a good solution for connecting island loads, offshore oil platforms, or off-shore wind farms. The proposed solution can be used with both cables and overhead lines. Second, with the reactive power coordination between STATCOM and HVDC systems, it offers a robustness for recovery from a commutation failure, and other faults on the system. Third, with the ability of the STATCOM to act as an active filter, the design of the passive filters of the HVDC system can be eased somewhat; this will enable recouping some of the costs incurred in installation of the STATCOM. In this paper, the coordinated control strategy for the STATCOM-HVDC has been described.

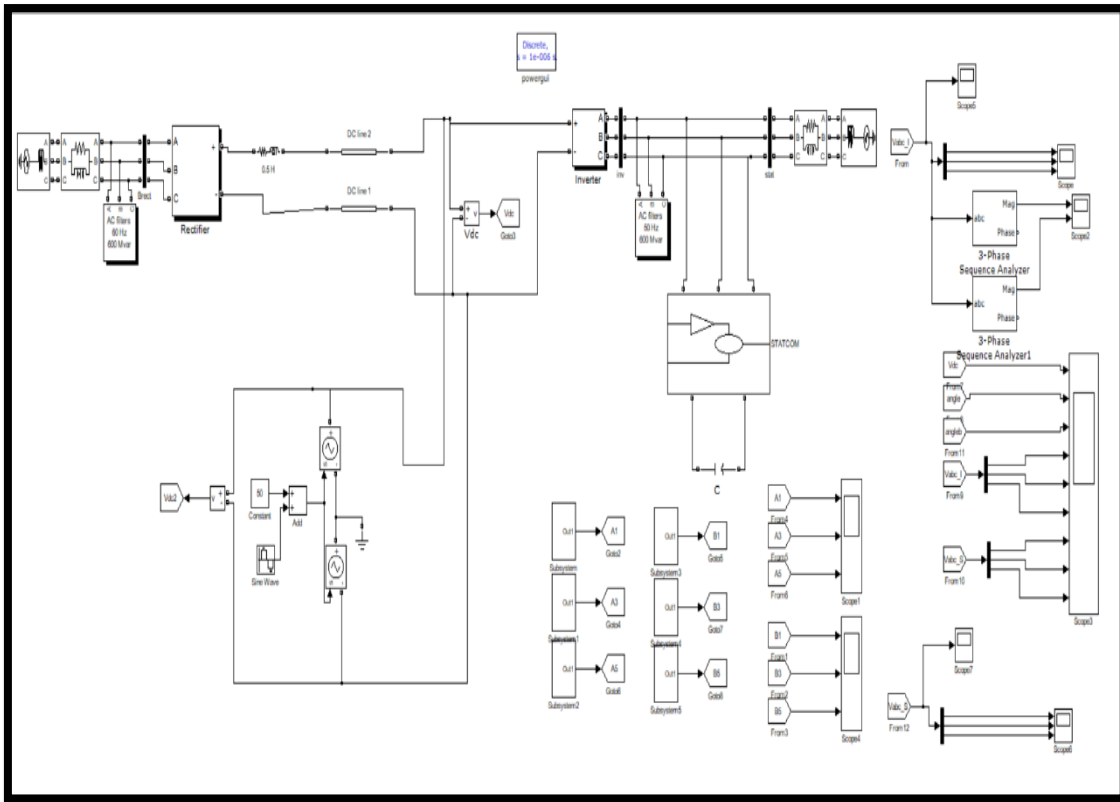


Fig 5.21- STATCOM integrated with Multi-Grid HVDC system in shunt connection

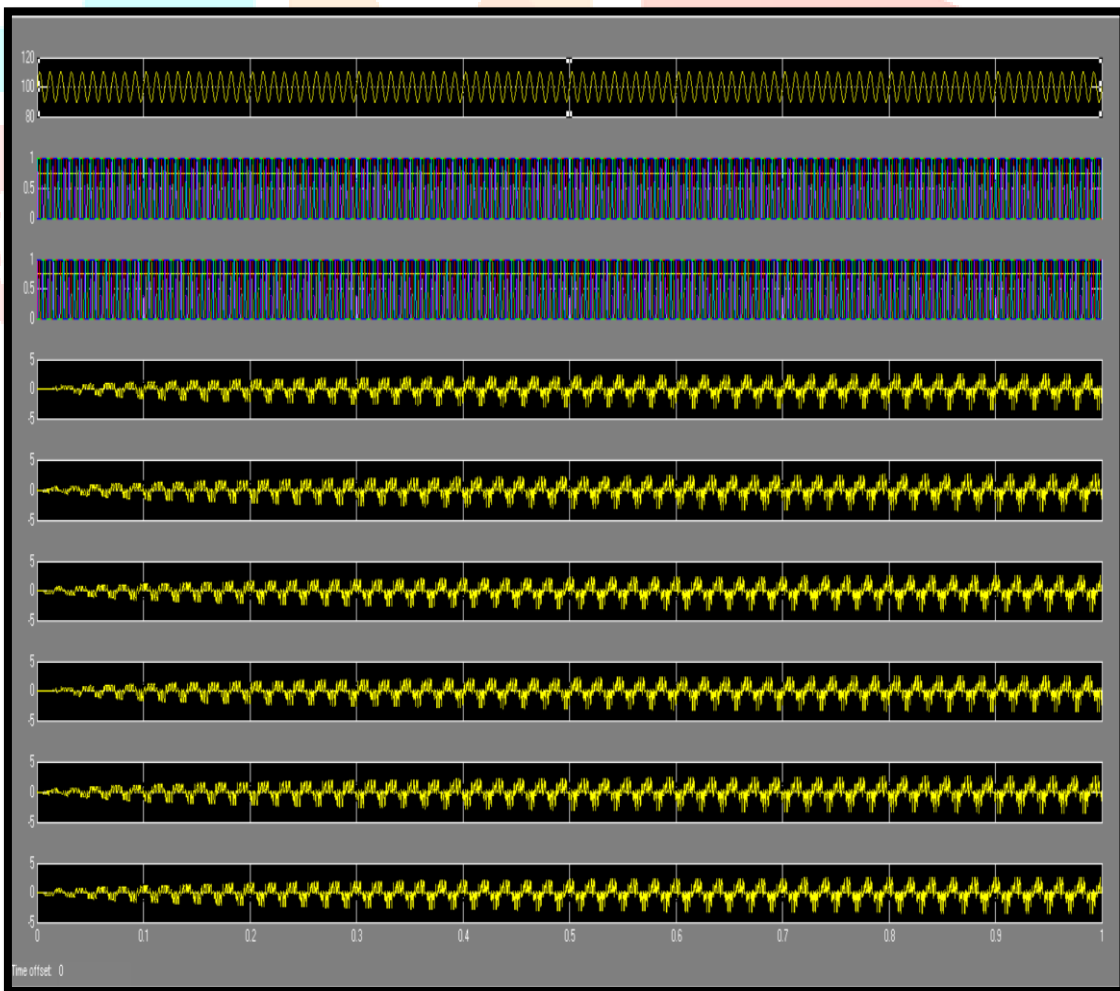


Fig 5.22- Output Controlled Parameters for power quality Improvement

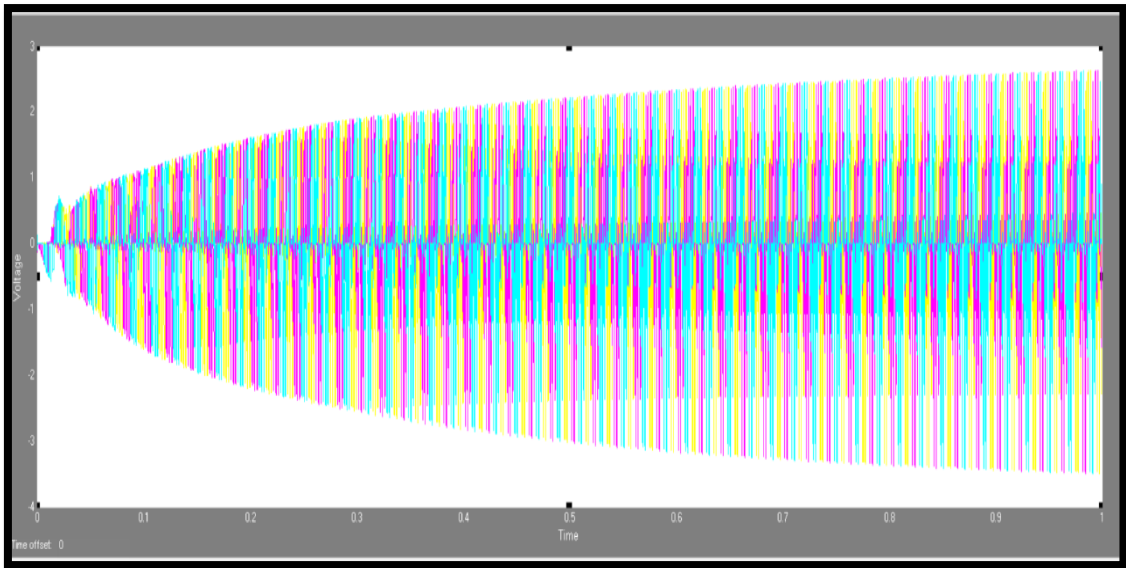


Fig 5.23- Inverter side output voltage waveform

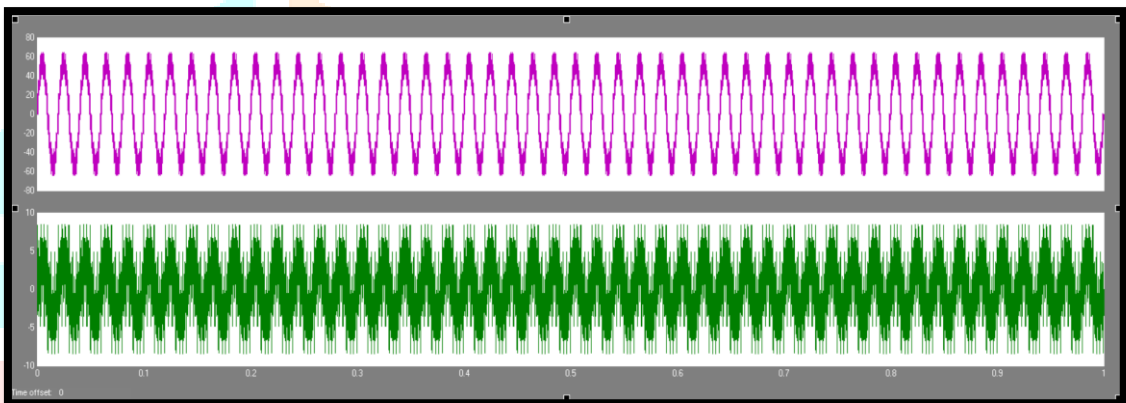


Fig 5.24- Voltage and Current Waveform Improvement

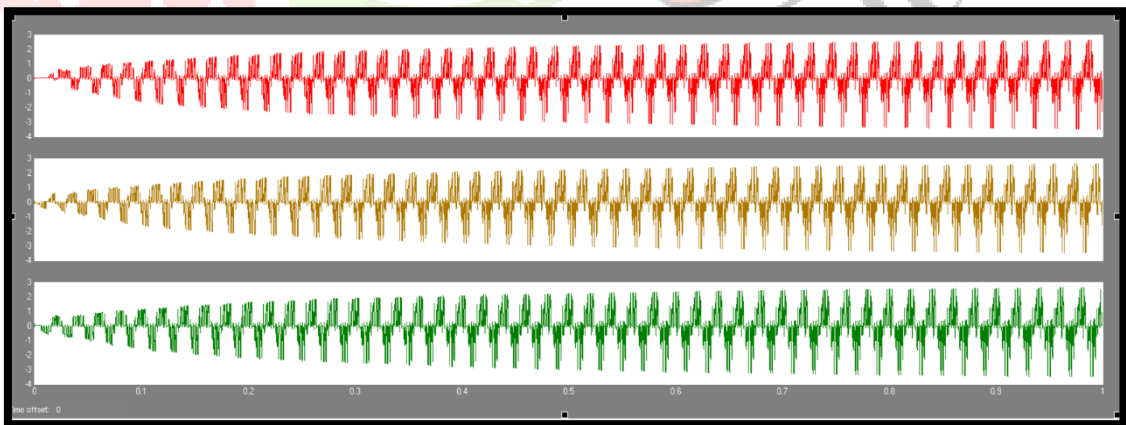
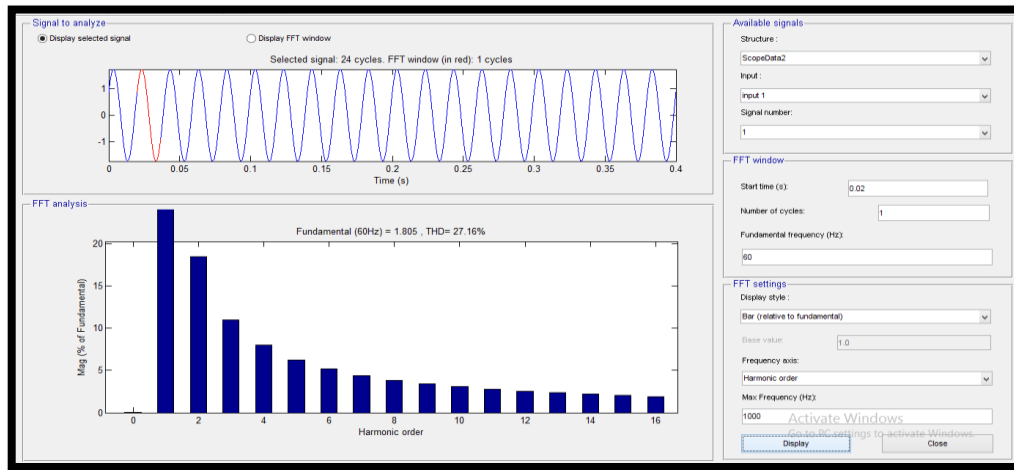


Fig 5.25- Three Phase A.C voltage output waveform improvement

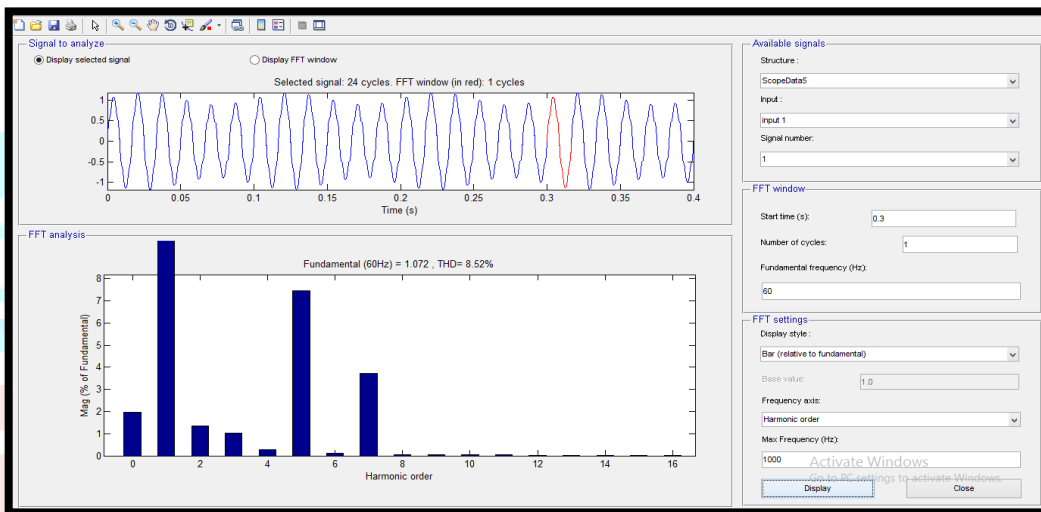
THD ANALYSIS

The THD Analysis of above two different cases is shown in below section: -

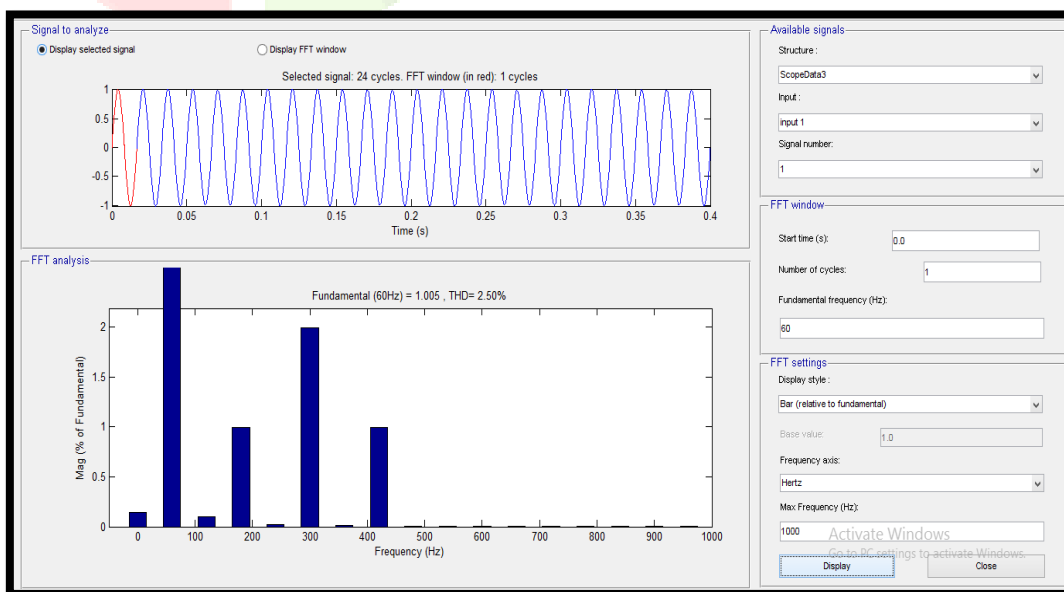
1. THD without control device in the System: -



2. THD with 6-pulse STATCOM device in the proposed system: -



3. THD with 12-pulse STATCOM device in the proposed system: -



THD Comparison: -

Sr.No	FACTS device	THD %
1	Without device	27.16%
2	With 6-Pulse STATCOM	8.52%
3	With 12-Pulse STATCOM	2.50%

Conclusion

This paper proposes a HVDC System and its problem of power quality mitigation scheme using STATCOM device. The STATCOM 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. The comparison for without STATCOM and with STATCOM for HVDC proposed system has been also successfully done in this paper. After the Simulation results we can see that STATCOM integration with Multi grid HVDC System is successful and useful for large power system Network. The THD level of the output side or load side waveform is reduced from 27.16% to 2.50%.

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