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Comparison of Nine Level And Eleven Level Based DSTATCOM Systems for Distribution System

K. Balaji Nanda Kumar Reddy[1], Dr. V. C. Veera Reddy[2]
[1](Research Scholar, Rayalaseema University, Kurnool, Andhra Pradesh, India)
(Department of EEE, Annamacharya Institute of Technology & Sciences, Tirupati, Andhra Pradesh, India)

Abstract: DSTATCOM is capable of improving the voltage of weak buses in the distribution systems. The objective of this research work is to reduce the THD in the output of STATCOM using multilevel concept. This paper deals with design, modeling and simulation of Ten Bus System using Matlab Simulink. Modeling of DSTATCOM and control of THD using multilevel DSTATCOM becomes an important issue. Ten Bus Distribution Systems (TBDS) with nine and eleven level STATCOM's are modelled, simulated and the results are presented here. The simulation results indicate that the THD with eleven level-based STATCOM is observed to be less than that of nine level based STATCOM.

Keywords: TBDS - Ten Bus Distribution System
NLSS - Nine Level STATCOM System
ELSS - Eleven Level STATCOM System
THD - Total Harmonic Distortion
SPWM -Sinusoidal Pulse Width Modulation

I. INTRODUCTION

Customary consistent state steadiness studies and transient solidness considers the dynamic power stream and power edge; most importantly expecting steady receiving and sending end transport voltage. The receptive power stream and voltage fall amid overwhelming current stream are ignored. This approach could not explain several blackouts in USA, Europe, and Japan etc. during the last quarter of the twentieth century. Blackouts were due to voltage collapses. During voltage collapses, the bus voltage starts falling and as a result power transfer through the transmission line starts reducing resulting in ultimate voltage collapse and loss of system stability of the entire network. That is the reason voltage security ponders have got more consideration and have obtained a fundamental place in power framework. Voltage fall wonders occur where receptive power administration is lacking.

The application of power electronics in the electric power transmission plays an important role to make the system more reliable, controllable and efficient [1]. Because of de-regulation, natural enactments and cost of development it is ending up noticeably hard in constructing new transmission lines. Thus it is essential to fully utilize the capacities of the existing transmission system. Flexible AC Transmission System (FACTS) has become a popular solution to our large/over extended power transmission & distribution system. FACTS devices are proving to be very effective in using the full transmission capacity while increasing the power system stability, transmission efficiency, maintaining power quality and reliability of the power system. These devices are mainly based on either Voltage Source Converters (VSC) or Current Source Converters (CSC) and have fast response time. As an important member of FACTS devices family, STATCOM has been the center of attention and the subject of active research for many years. STATCOM is a shunt-associated gadget that is utilized to give receptive power remuneration to a transmission line.

This controller can either absorb or inject reactive power whose capacitive or inductive current can be controlled independently to the AC line voltage. Thus, STATCOM can enhance the transmission line load ability by extending the MW margin and improves the oscillation of voltage transients through efficient regulation of the transmission line voltage at the point of connection [1]-[3].

The device is connected to a load bus with a converter transformer. The displaying of shunt controller and testing is reproduced in MATLAB/Simulink. The controller is a piece chart that presents the earth electronic model of shunt controller. PID controller is used to control the current injection at the connection point by varying the desired parameters, one is Modulation Index (AM) and another is the power angle (δ). Mainly there are four loop tuning methods for a PID controller; those are manual tuning, Ziegler-Nichols, Software Tools and Cohencoon Method. Firstly, Ziegler-Nichols method is chosen for loop tuning and then manual tuning is applied to the PID controller by trial and error method to take its performance at optimum level. Actually, there are four diverse control procedures for a STATCOM controller i.e. coordinate control, decoupling control, cross control and framework control. The immediate control strategy is utilized here to control the yield of the shunt associated FACT device.

II. BASIC CONFIGURATION AND PRINCIPLE OF OPERATION

Basically, shunt connected FACTS device can be realized by either a VSC or a CSC [4]. But the VSC topology is preferred because CSC topology is more complex than VSC in both power and control circuits. In CSC such as GTO (Gate Turn-Off Thyristor) is used, a diode has to be placed in series with each of the switches. This almost doubles the conduction losses compared to the case of VSC. The DC link energy storage element in CSC topology is an inductor whereas, in VSC topology it's a capacitor. Thus, the efficiency of a CSC is expected to be lower than that of the VSC [6]-[9]. The modelled STATCOM using VSC topology is being used in the test system to supply reactive power to increase the transmittable power and to make it more compatible with the prevailing load demand. Thus, the shunt connected FACTS device should be able to minimize the line over voltage under light load condition and maintain voltage levels under a heavy load condition. Two VSC technologies can be utilized for the VSC. One of them where VSC is constructed with IGBT/GTO-based SPWM inverters.

This type of inverter uses Sinusoidal Pulse-Width Modulation (SPWM) technique to synthesize a sinusoidal waveform from a DC voltage source with a typical chopping frequency of a few kilo hertz. Harmonic voltages are cancelled by connecting filters at the AC side of the VSC. This type of VSC uses a DC link voltage Vdc. Output voltage is varied by changing the modulation index of the SPWM modulator. Thus modulation index has to be varied for controlling the reactive power injection to the transmission line. In another type VSC is constructed with GTO-based square-wave inverters and special interconnection transformers. Typically four three-level inverters are used to build a 48-step voltage waveform. Special interconnection transformers are used to neutralize harmonics contained in the square waves generated by the individual inverters. In this type of VSC, the fundamental component of output voltage is proportional to the voltage V_{dc}. Therefore V_{dc} has to be varied for controlling the reactive power.

The shunt controller is like a current source, which draws from or injects current into the system at the point of connection. The shunt controller may be a variable impedance, variable source or a combination of these [10]. Variable shunt impedance associated with the line voltage causes a variable current stream and thus speaks to infusion of current into the line. For whatever length of time that the infused current is in stage quadrature with the line voltage, the shunt controller just supplies or devours receptive power. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). When the system voltage is high, it absorbs reactive power (STATCOM inductive).

The variation of reactive power is performed by means of a VSC connected on the secondary side of a coupling transformer. The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V2 from a DC voltage source. Any other phase relationship will involve handling of real power as well [11]. So, the shunt controller is therefore a good way to control the voltage at and around the point of connection through injection of reactive current (leading or lagging) alone or a combination of active and reactive current for a more effective voltage control and damping of voltage dynamics [12].

The above literature does not deal with a comparison of nine and eleven based on STACOMs in ten bus radial distribution system. This work proposes eleven level STATCOM for power quality improvement of ten bus system. The real power (P) and reactive power (Q) is expressed as follows:

$$P = \frac{E.V}{X} Sin\delta \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$Q = \frac{E_2}{X} - \frac{EV.}{X} Cos\delta \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

III. SIMULATION RESULTS

Ten bus system with nine level STATCOM is shown in Fig 1.1. Each line is represented as a series combination of R & X. Each load is represented as a shunt impedance. The Voltage at bus-5 is shown in Fig 1.2 and its peak value is 1.5 $*10^4$V. The real and reactive powers at bus-5 are shown in Fig 1.3 and real power is 4.5 MW and reactive power is 1.2 MVAR. The current frequency spectrum at bus-5 is shown in Fig 1.4. The THD content is 3.5%. The circuit of nine level STATCOM is shown in Fig 1.5. The output voltage of STATCOM is shown in Fig 1.6 and its peak value is 400V. The voltage at bus nine is shown in Fig 1.7 and its peak to peak value 2.5 $*10^4$ V. The real & reactive power at bus nine is shown in Fig 1.8 and real power is $10*10^6$VARand reactive power $4*10^6$ watts. The current frequency spectrum at bus nine is shown in Fig 1.9. The THD content is 3.9%.

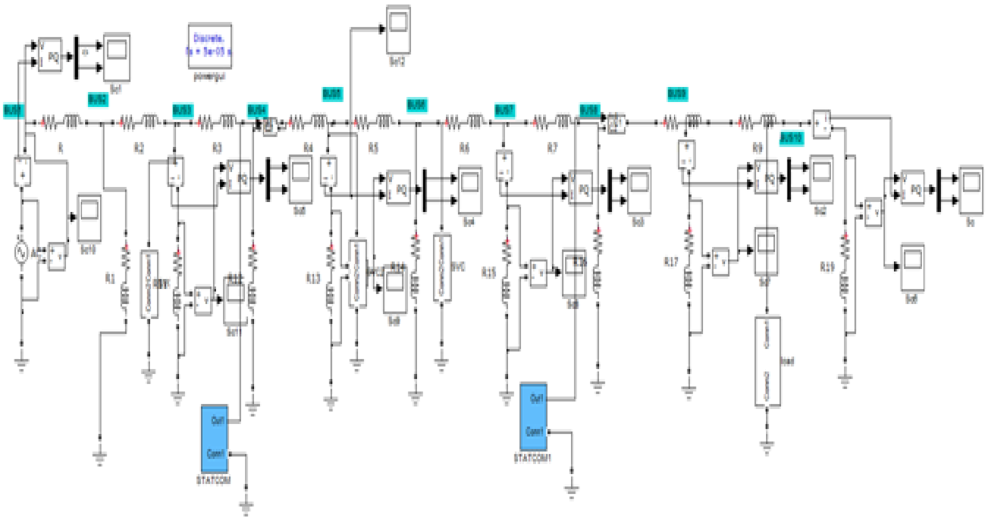

Fig 1.1 Tenbus system with nine level STATCOM

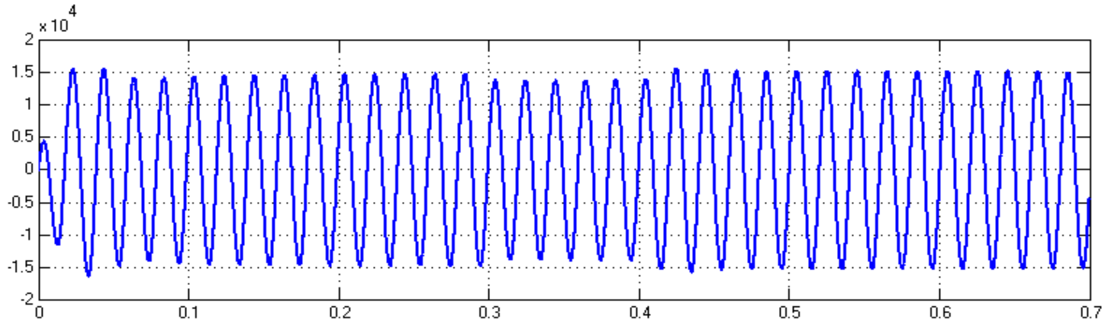

Fig 1.2 Voltage at bus-5

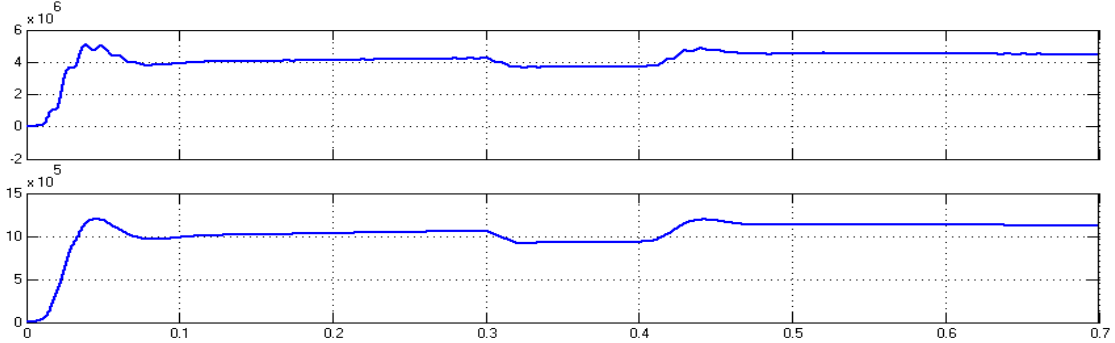

Fig 1.3 Real & reactive power at bus-5

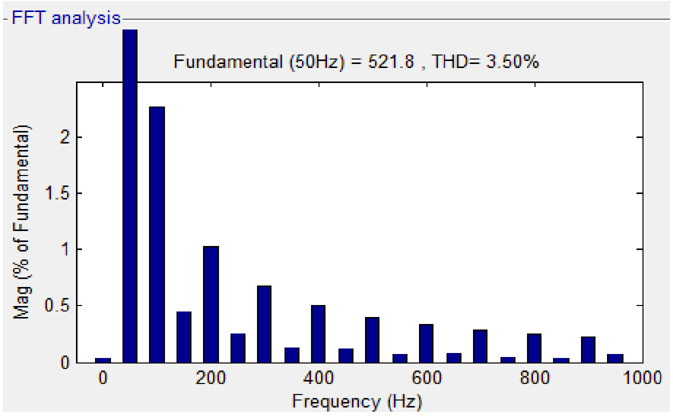

Fig 1.4 Frequency spectrum for current at Bus-5

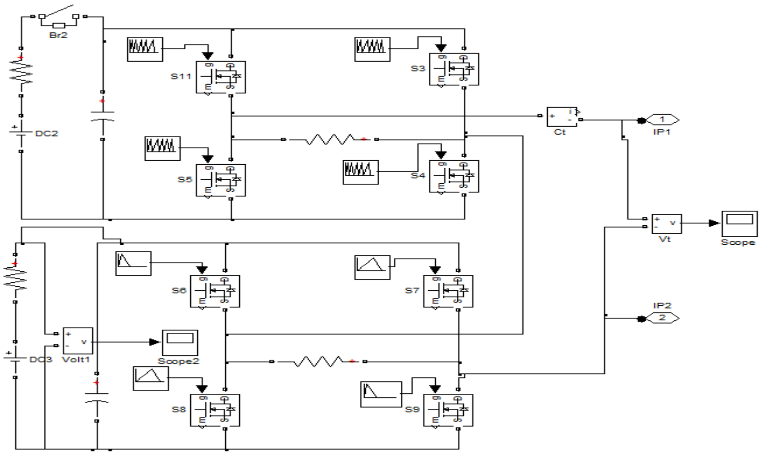

Fig 1.5 Circuit of Nine level STATCOM

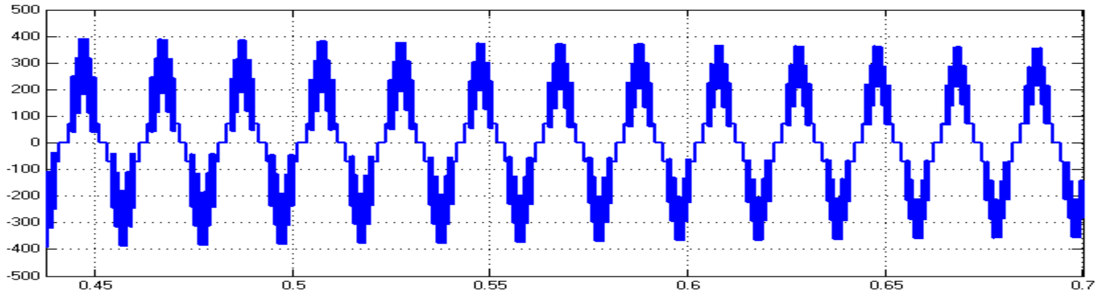

Fig 1.6 Output voltage of STATCOM

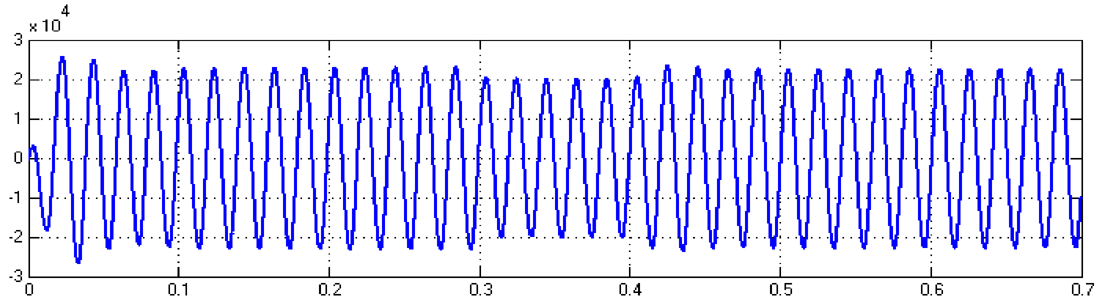

Fig 1.7 Voltage at bus-9

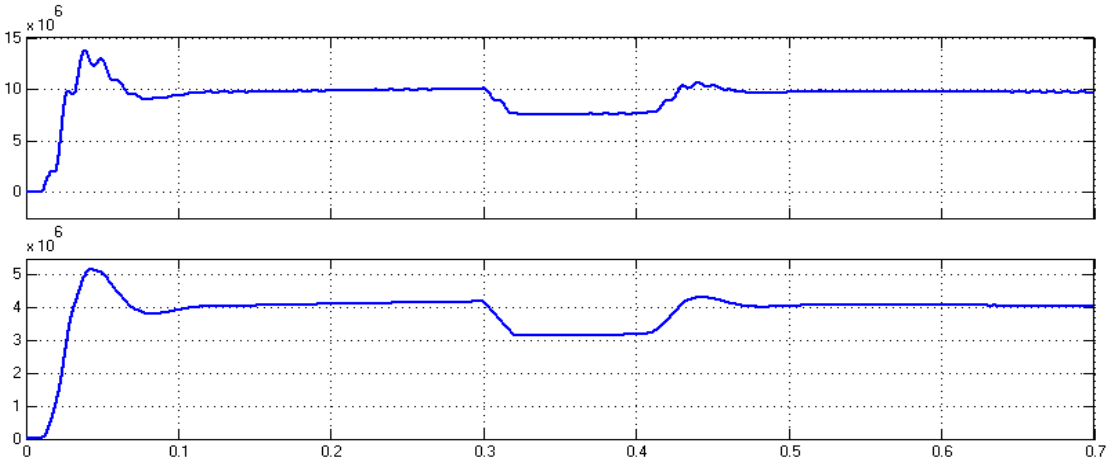

Fig 1.8 Real & Reactive power at bus-9

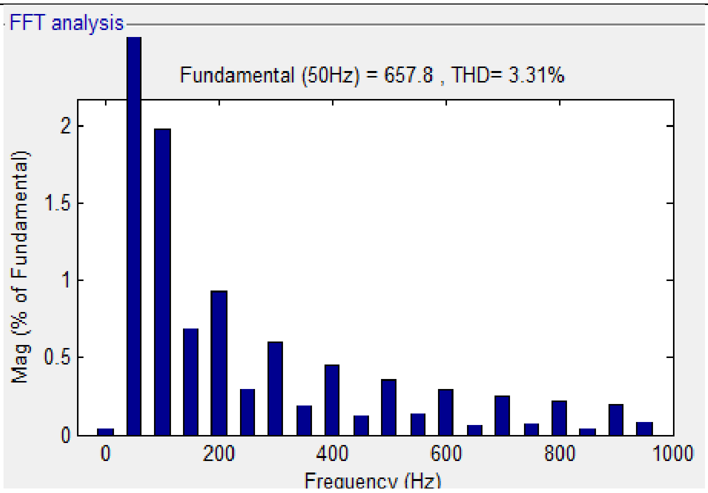

Fig 1.9 Frequency spectrum for Current at bus nine

Ten bus system with eleven level STATCOM is shown in Fig 2.1. The voltage at bus five is shown in Fig 2.2 and its peak value is 2*10^4V. The real and reactive powers at bus-5 are shown in Fig 2.3 and real power is 7*10^6 watts and reactive power is 2*10^6 VAR. The current frequency spectrum for bus-5 is shown in Fig 2.4. Eleven level STATCOM circuit is shown in Fig 2.5. The output voltage of STATCOM is shown in Fig 2.6 and its peak value is 500 V. The voltage at bus nine is shown in Fig 2.7 and its peak value is 3.5 *10^4 V.

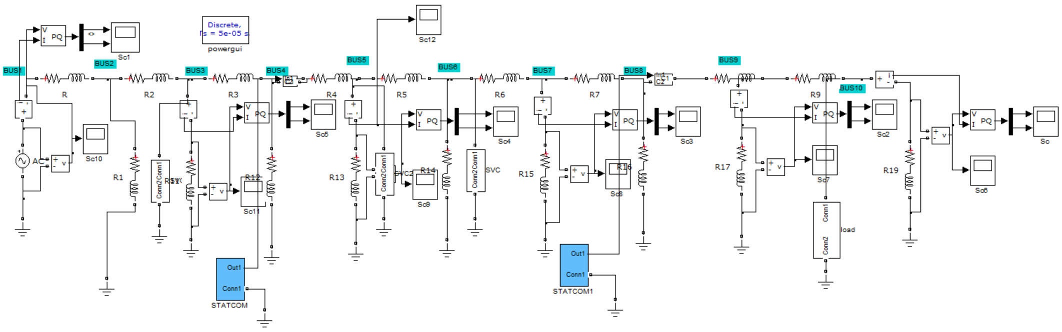

Fig 2.1 Tenbus system with 11- level STATCOM

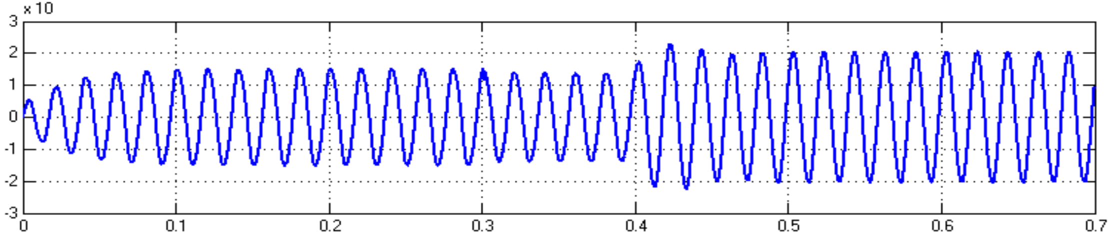

Fig 2.2 Voltage at bus-5

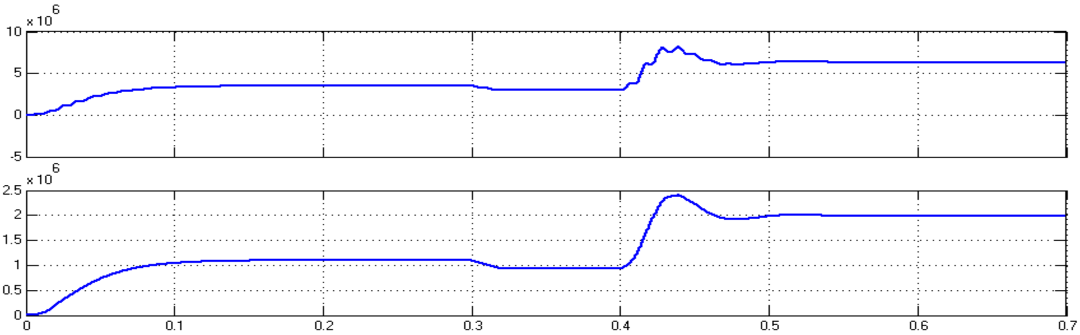

Fig 2.3 Real & reactive power at bus-5

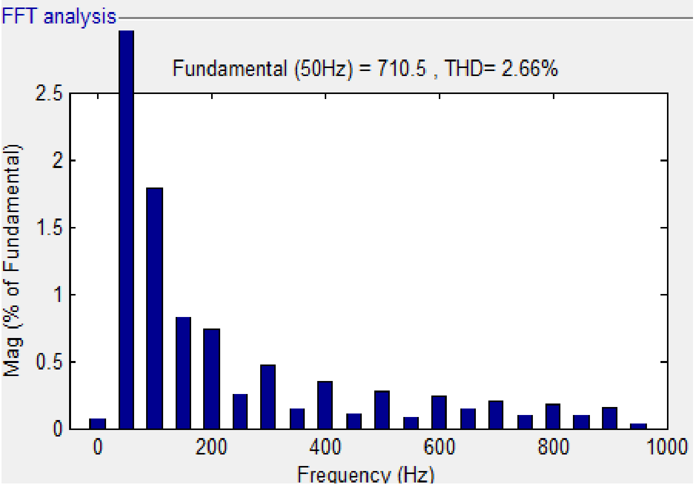

Fig 2.4 Frequency spectrum for current at bus 5

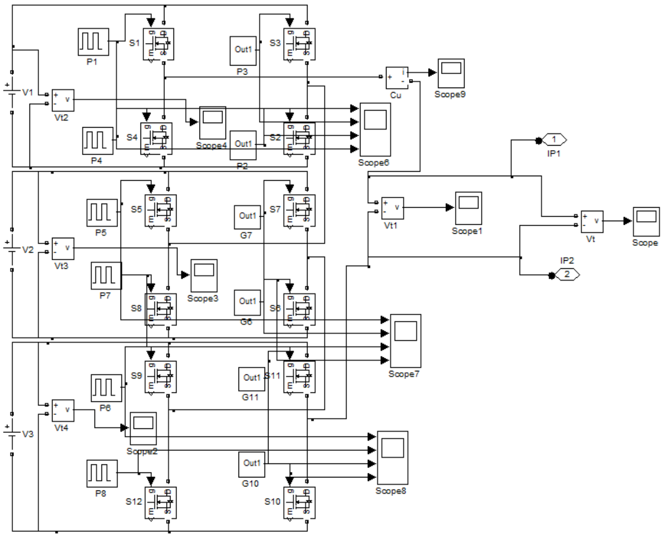

Fig 2.5 Circuit of Eleven level STATCOM

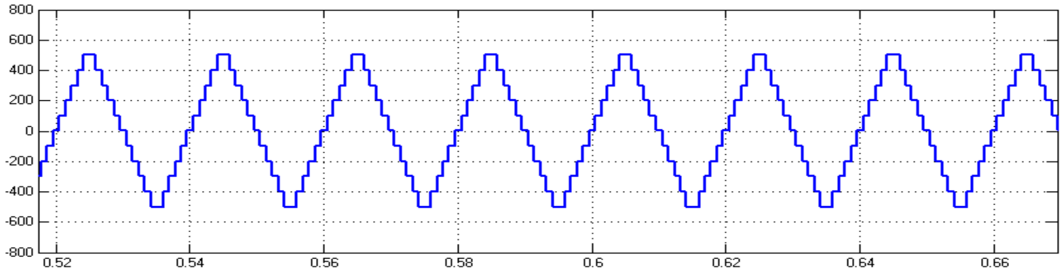

Fig 2.6 Output voltage of STATCOM

The real & reactive power at bus nine is shown in Fig 2.8 and real power is $12*10^6$ Watts and reactive power $4.8*10^6$ VAR. The current frequency spectrum at bus nine is shown in Fig 2.9. The THD content is 2.66%. The comparison of real and reactive power at bus five is given Table-1. The comparison of real and reactive power at bus nine is given in Table-2. The real and reactive powers increase by 20% by replacing nine level STATCOM with eleven level STATCOM.

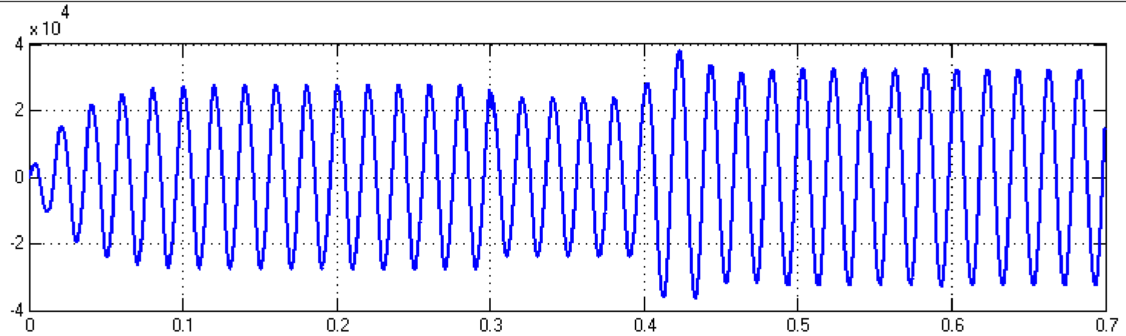

Fig 2.7 Voltage at bus-9

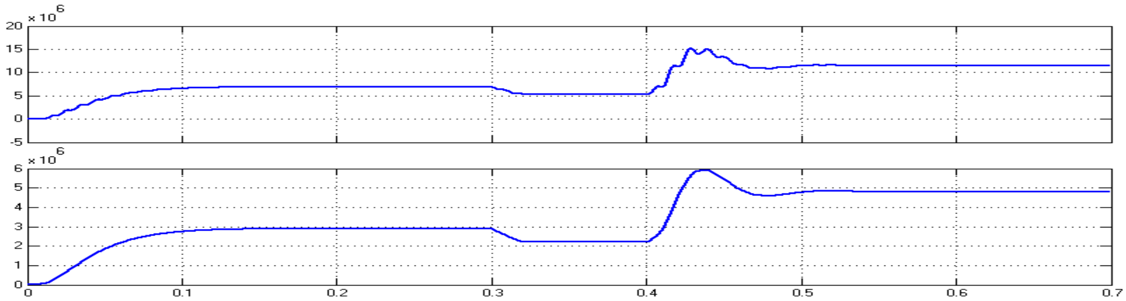

Fig2.8 Real & Reactive power at bus-9

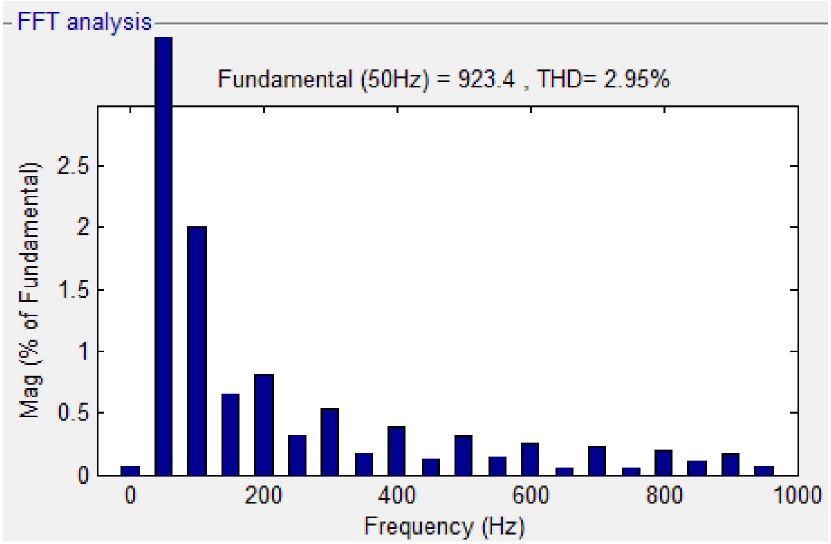

Fig 2.9 frequency spectrum for Current at bus Nine

Table-1
Comparsion of Real & Reactive Power at Bus-5

STATCOM	THD	Real power (MW)	Reactive power(MVAR)
9-level	**3.50%**	**4.562**	**1.739**
11-level	**2.66%**	**5.678**	**2.051**

Table-2
Comparsion of Real & Reactive Power at Bus-9

STATCOM	THD	Real power (MW)	Reactive power(MVAR)
9-level	**3.31%**	**10.015**	**4.056**
11-level	**2.95%**	**11.472**	**4.850**

IV. Conclusion

The conclusions derived from simulation work on NLSS &ELSS presented in previous section has been summarized. Ten Bus Distribution System was successfully modelled and simulated using the blocks of Simulink and the results are described. Voltage Sag was created by adding an extra load and it is compensated by using STATCOM. The THD is reduced by 1 percentage by replacing Nine level STATCOM with Eleven level STATCOM. The real and reactive powers delivered to the load increase by 10% by using ELSS instead of NLSS. The results obtained in this paper are clear example of improvement in power quality using multilevel STATCOM. The advantages of proposed system are reduced heating of distribution lines and improved voltage profile. The disadvantage of STATCOM is that it requires large DC Capacitor at the input and eight switches per phase.

The scope of the present work is to study the performance of ELSS in ten bus system. The performance of ELSS in thirty bus system will be studied in future. Closed loop controlled ELSS to extend control capability will be studied in future.

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