International Journal of Engineering Research and Reviews ISSN 2348-697X (Online)
Vol. 2, Issue 2, pp: (15-21), Month: April 2014 - June 2014, Available at: www.researchpublish.com

Design of Multi Level Converter for Power Quality Enhancement

Vishakha Tiwari

ME Control System, Department of Electrical Engineering, Jabalpur Engineering College, Jabalpur, INDIA

Abstract: **The multilevel converter has drawn tremendous interest in the power industry. The general structure of the multilevel converter is to synthesize a sinusoidal voltage from several levels of dc voltages. Multilevel voltage source converters are emerging as a new breed of power converter options for both medium and high power applications. This paper deals with the design and implementation of a five level cascade H bridge converter (CHB) based static synchronous compensator (STATCOM) employing an effective modulation control technique simulated in a MATLAB Simulink environment. The main object of this paper to maintain the voltage profile by compensating the reactive power. Relative Harmonic analysis is also discussed in this paper based on the total harmonic distortion (THD) calculations.**

Keywords: **Reactive power compensation, STATCOM, multilevel converter topology, pulse width modulation (PWM), harmonics.**

I. Introduction

Modern power systems are of complex networks, where hundreds of generating Stations and thousands of load centers are interconnected through long power transmission and distribution networks. Even though the power generation is fairly reliable but the quality of power is not always so reliable. In Power distribution system power should provide with an uninterrupted flow of energy at smooth at the contracted magnitude level to their customers. In distribution network sinusoidal voltage required where consumer uses various non linear, inductive and capacitive load. These load distorted the power quality of the power system. Power quality depends on the voltage rather than current and power. To improve the power quality different approaches such as reactive power compensation have been implemented to meet the requirements. In order to overcome this poor quality some facts devices (STATCOM, SVC) were incorporated in power system but these devices leads generation of harmonics in power system. So, the converter used within the STATCOM should be able to withstand the increased power levels. So, in order to overcome this problem, the term multi level is brought out in 1981. The very important thing of multilevel inverters is that creating more output steps and to reduce the Total Harmonic Distortion (THD) [1]. An increased number of levels capable of eliminating the coupling transformer and replace it with cheap reactors to allow a power exchange with the power system.

II. Statcom configuration

The basic operating configuration of a **STATCOM** is given in Fig 1. It consists of a voltage source inverter (VSI), dc side equivalent capacitor(C) with voltage Vdc on it and a coupling reactor (LC).[2] STATCOM is a primary shunt device of the FACTS family, which uses power electronics to control power flow and improve voltage stability on power system [3]. The STATCOM regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. For purely reactive power flow in three phase voltages of the STATCOM must be maintained in phase with the system voltages. The variation of reactive power is performed by means of a VSC connected through a coupling reactor or transformer .The VSC uses forced commutated power electronics devices (MOSFET or IGBT's) to synthesize the voltage from a dc voltage source. [3]The operating principle of STATACOM is explained in Fig.1. It can be seen that if V C> V S then the reactive current flows from the converter to the ac system through the coupling transformer by injecting reactive power to the ac system. On the other hand, if V C< V S then current flows from ac system to the converter by absorbing reactive power from the system. Finally, if Vc = Vs then there is no exchange of reactive power. The amount of reactive power exchange is given by:

Q=Vs (Vs-Vc sin$\phi)/xl$…… (1)

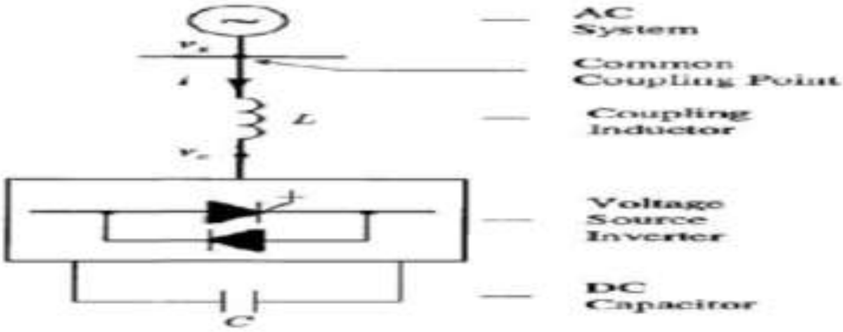

Fig. 1 Single lines diagram of Statcom

III. Multilevel Converter Configuration

The cascade multilevel inverter consists of number of H-bridge inverter units with separate dc source for each unit and is connected in cascade or series as shown in figure 2. Each H-bridge can produce three different voltage levels: +V dc, 0, and -V dc by connecting the dc source to ac output side by different combinations of the four switches S 1, S2 ,S 3, and S 4. The ac output of each H-bridge is connected in series such that the synthesized output voltage waveform is the sum of all of the individual H-bridges' outputs [1, 2] .By connecting the sufficient number of H-bridges in cascade and using proper modulation scheme, a nearly sinusoidal output voltage waveform can be synthesized, fig. 2 Five level h bridge inverter The magnitude of the ac output phase voltage is given by:[2]

Van = Va1+Va2+Va3+Va4+Va5. … (4)

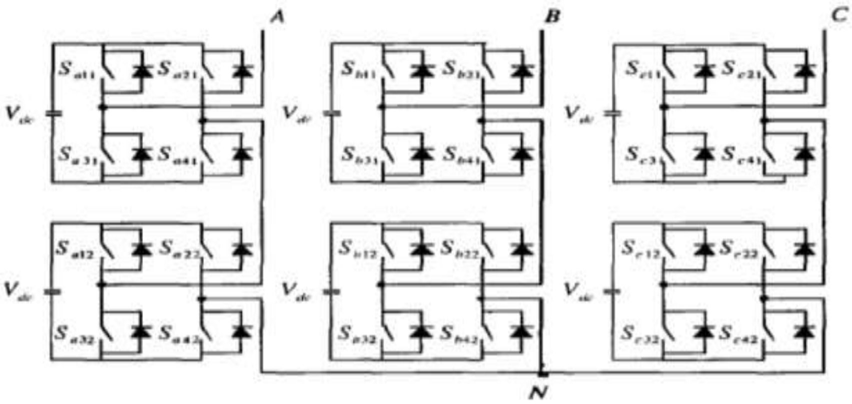

Fig. 2 Five Level H bridge converter

IV. Switching strategy

The output voltage waveform of the cascaded five level H bridge converters based STATCOM depends on the switching pattern that is controlled by the switching angles of the converters. Theses switching angles can be selected, but appropriate switching angles are required to achieve best quality of the output voltage waveform. By employing sinusoidal harmonic elimination method (SHEM) lower order harmonics can be eliminated in the output waveform. For a stepped waveform Fourier analysis by selective harmonic elimination reduction (SHEM):[4,5]

Vw(t) = $4vdc/\pi\sum$[cos($n\theta$1)+cos(nθ2)+---cosnθ5] sin($n\omega t)/n$….. (5)

Where, n=1,3,5,7------,

The magnitude of the Fourier coefficient when normalized with respect to Vdc :

H(n) = $4/\pi n[\cos(\theta)1+\cos(\theta 2)+$----- ---$\cos(\theta 5)]$….. (6)

Where n=1, 3,5The conducting angles, θ1, θ2, ..., θ5, can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are so chosen that predominant lower frequency harmonics, 5th, 7th, 11th, and 13, harmonics are eliminated.

V. SPWM (sinusoidal pulse width modulation technique)

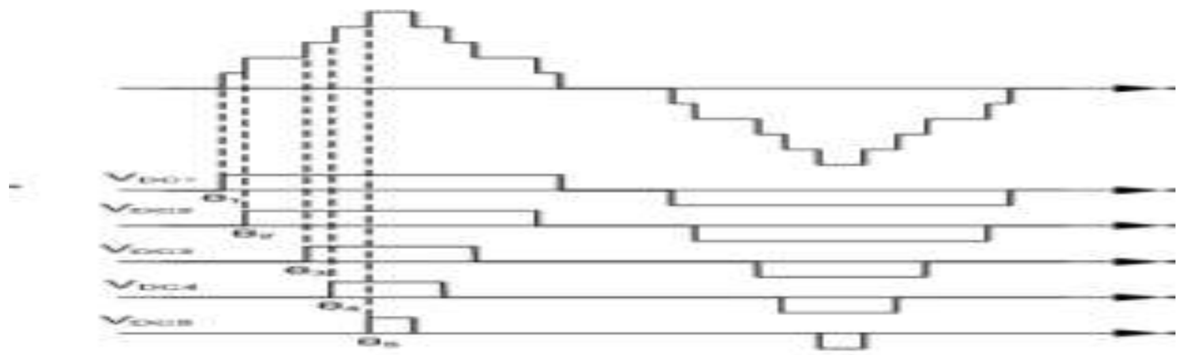

Fig. 3 Staircase wave form gained by 5 level inverter using SPWM technique

VI. Simulation

A basic power system model is designed consisting of 3 phase source of 100 MVA and a line voltage of 11 KV. Five levels H bridge inverter based statcom controller is connected to the power system as shown in fig. 4.

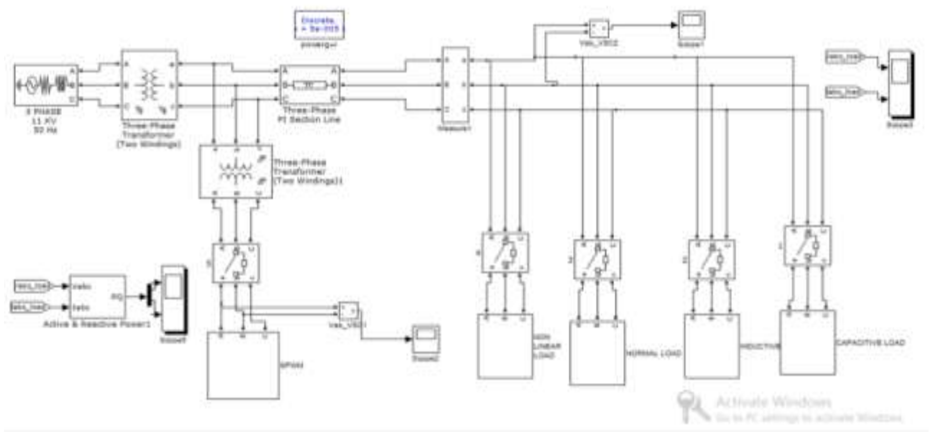

Fig. 4 Simulink model of a power system with STATCOM controller

The power is transmitted through a transmission line of 100 km to load centre. At load centre different loads are connected to the system at different duration of time as shown in fig. 4. The power is coming from the three phase source is transmitted through a step down transformer to a load center. Here step down transformer is used for the commercial industrial purpose. There is a subsystem contains multi-winding transformer next to the three phase step down transformer. This is used for injecting reactive power into the transmission line when the power deviation occurs.

There is another subsystem below to the multi-winding transformer is called STATCOM controller. The power is coming from a three phase source is step down by three phase step downtransformer. Statcom mainly used for injecting or absorbing reactive power from or to thesystem. In fig.4 , four different load (load centre) are connected to the three phase ac supply through a circuit breaker.Here Circuit breaker acts as a switch.Whenever power deviation occurs statcom controller will improve that power deviation and after compensation the power is transmitted to load centre.

VII. Simulation result

Case 1 : when non linear load connected to the 3 phase ac supply during time 0.0 to 0.2 second by circuit breaker (switch) it leads harmonics and distorted power quality .To minimize total harmonic distortion multilevel inverter with statcom topogy is used in this paper .Fast fourier transform analysis (FFT) is done for harmonic calculation. Fig 4 and 5, shows FFT analysis result with and without statcom.Witout statcom it found 16% and after compensation harmonic minimized up to 4.76%.

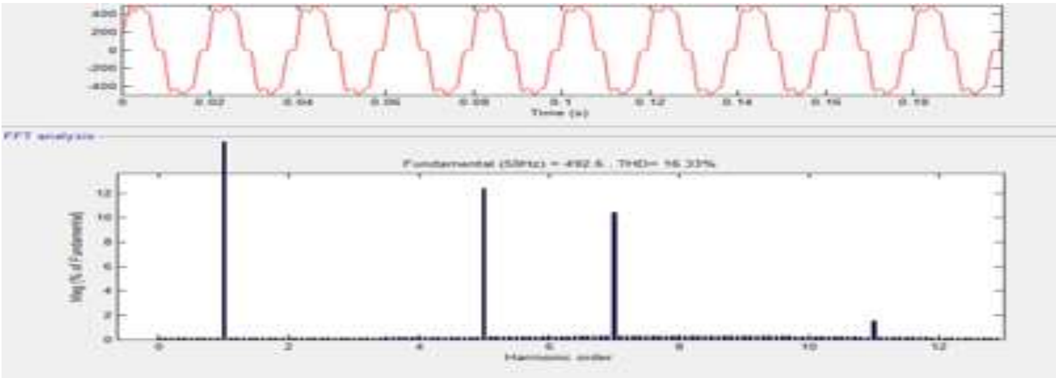

Fig.5 FFT analysis without compenstion

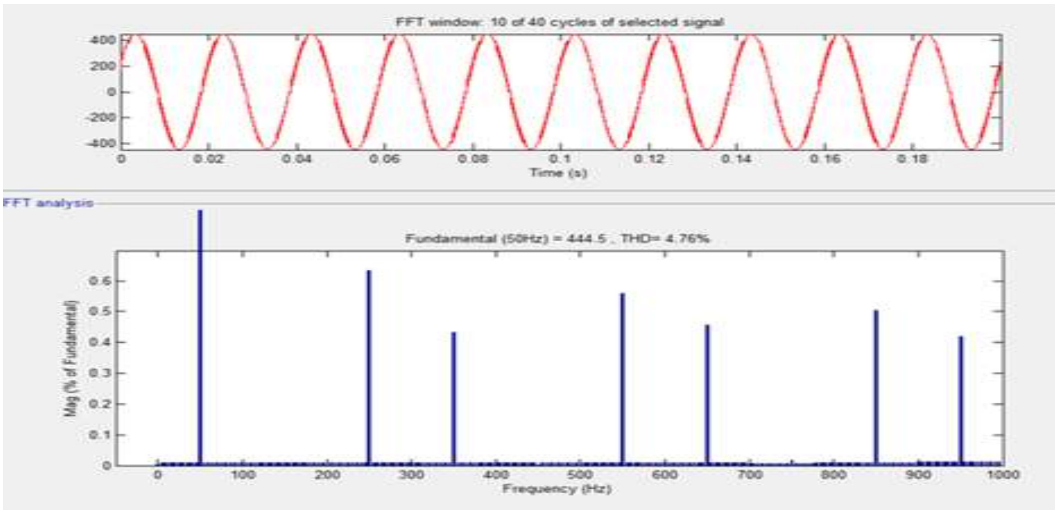

Fig.6 FFT analysis with STATCOM

Case2: When linear load connected to ac supply novoltage deviation has found because of pure linear load in simulation study.

Case3: At interval 0.4 to 0.6 second there is a voltage dip when inductive load connected to ac supply .voltage dip is shown in fig.6

Due to switching on of the load the source voltage become reduced from normal level .In that duration statcom injects the voltage to source and boost up that voltage up to the normal level.

Case4: At interval 0.6 to 0.8 second when capacitive load connected to ac supply ,due to switching on of the load there is a momentary increase in voltage .These fluctuation are not desirable in power system.

If voltage level rised due to switching on of capacitive load in that case statcom absorbs that voltage and maintain voltage up to normal level.Fig.7 shows voltage and current waveforme without statcom.Fig. 8 shows maintain voltage profile with statcom.

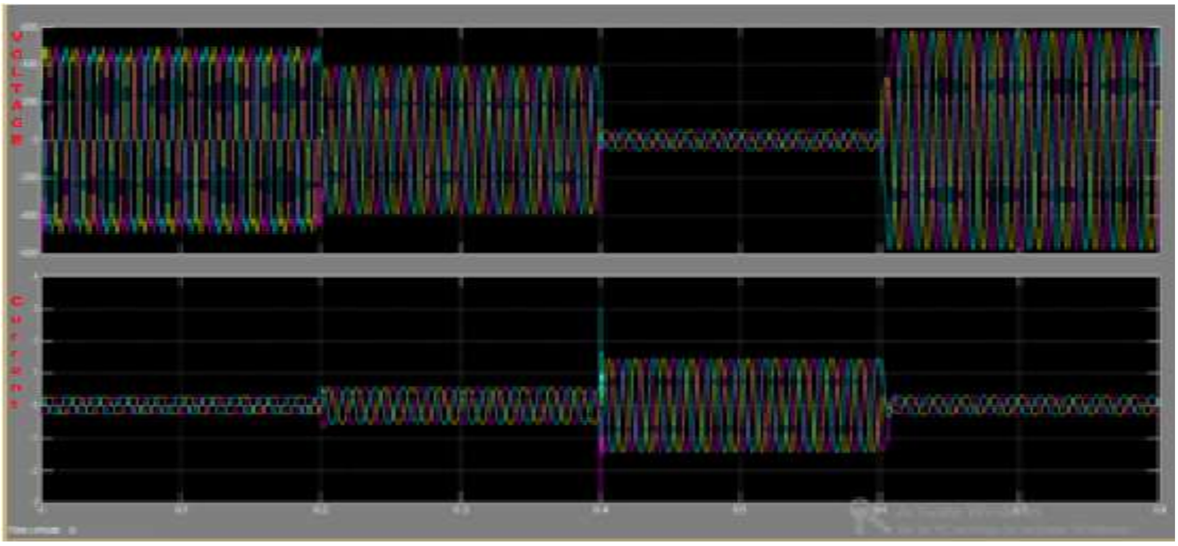

Fig.7 Voltage and current waveform without statcom

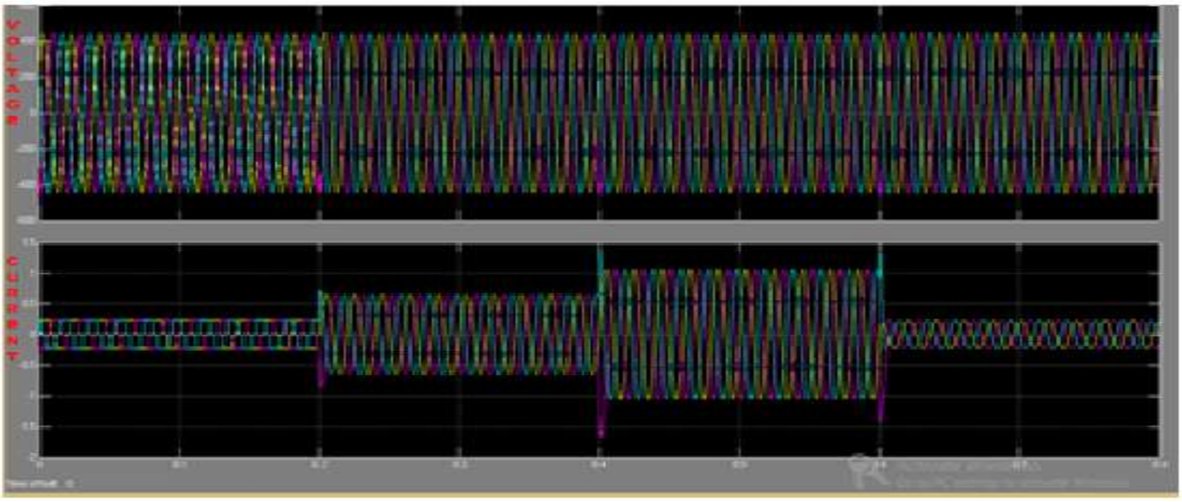

Fig.8 Maintain voltage profile with STATCOM

Total Harmonic Distortion:

For analyzing the quality of the voltage waveform of satcom total harmonic distortion calculation[7,8] are performed by using equation:

$$THD = \frac{\sqrt{\sum_{K=2}^{\infty}|V_k|}}{|V_1|} \ldots\ldots\ldots\ldots(6)$$

The total harmonic distortion of statcom output voltage of cascade three level inverter based STATCOM is found 41% after simulation as shown in fig10. Another output of Cascade 5 level inverter based STATCOM is found 33.73% as ahown in fig. 11.

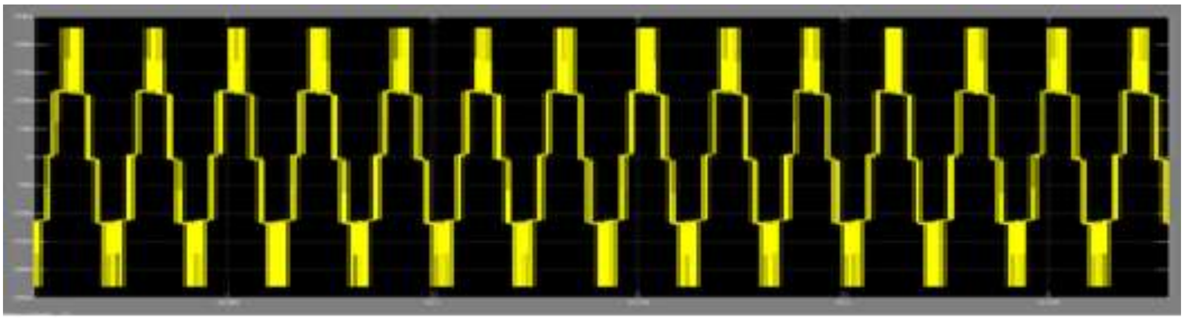

Fig.9 Statcom output voltage waveform

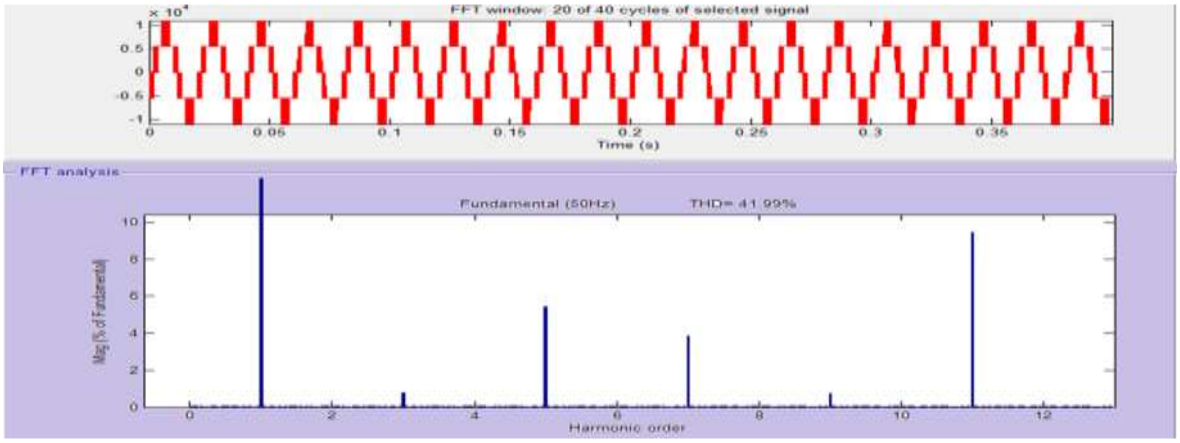

Fig.10 Total harmonic distortion analysis of

STATCOM output voltage:

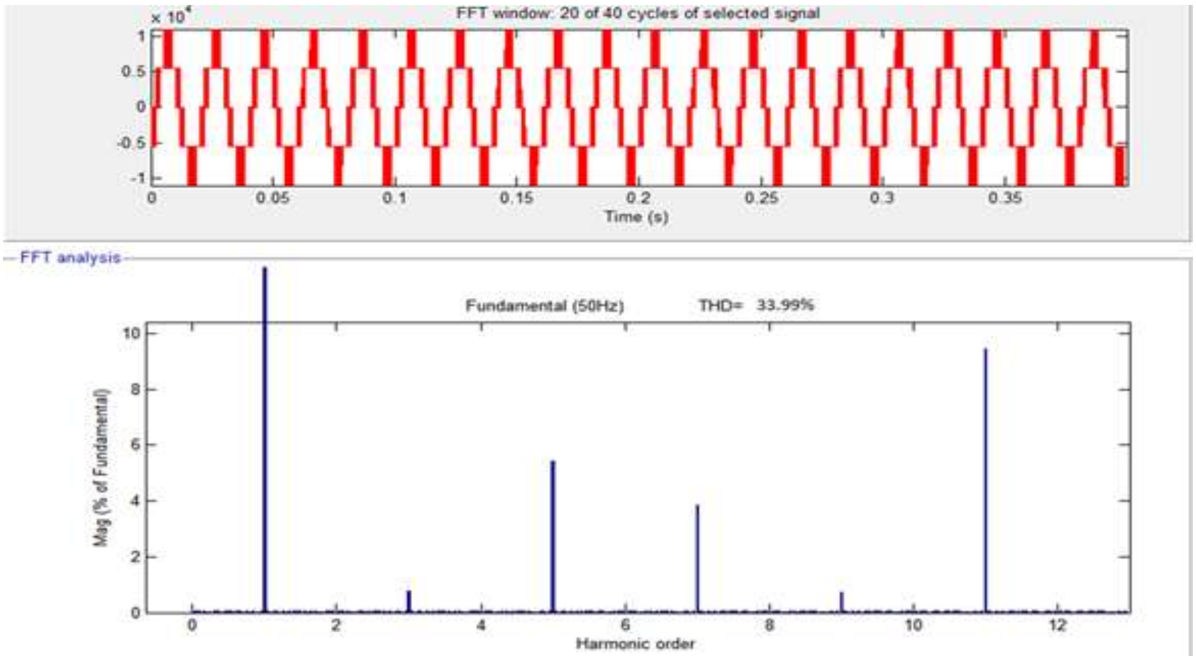

Fig.11 THD analysis of STATCOM output voltage

VIII. Conclusion

This work gives the solution ofreactive power compensation in power system.The statcom controller is designed for fiveLevel H bridge inverter . This control schemeregulates the capacitor voltage of the STATCOM andmaintain supply voltage for any load variationwith respect to the rated value. To verify the control performance, the proposed controller with the three-level cascaded inverter based STATCOM and five level cascaded inverter based statcom simulated. It has been observed that the five level inverter is able to reduce the THD values of statcom output voltage .Simulated result shows that statcom with multi level inverter is suitable for reactive power compensation and also for reduction of harmonics in output of STATCOM.

References

[1] Hirofumi Akagi (2011) "Classification,Terminology, and Application of the Modular Multilevel Cascade Converter (MMCC)" IEEE Transaction on Power Electronics, Vol. 26, No.11, pp: 3119-3130, August.

[2] Cee, Josep, (2003) "Circuit-Level Comparison of STATCOM Technologies" IEEETransaction on Power Electronics, Vol. 18,No.4, pp: 1081-1092, July. Vineesha (2012).

[3] "Simulated Control System Design of a Multilevel STATCOM for Reactive Power Compensation" IEEE Transactions on Industry Application, Vol. 35, No. 5, pp: 257-263, December.

[4] Jon Andoni Barrena (2008) "Individual VoltageBalancing Strategy for PWM Cascaded HBridgeConverter Based STATCOM" IEEETransaction on Industrial Electronics, Vol. 55,No. 1, pp: 21-30, Janury.

[5] Makoto Hagiwara (2008) "Control andExperiment of Pulsewidth Modulated ModularMultilevel Converter" IEEE Transactions onPower Electronics, Vol. 24, No.7, pp: 1737-1746, October.

[6] Chong Han, Zhanoning Yang, (2007) "Evaluation of Cascade Multilevel Converter Based ST ATCOM for Arc Furnace Flicker Mitigation" IEEE Transaction on Industry Applications, Vol. 43, No.2, pp: 378-385, March! April.

[7] Ben-Sheng Chen and Yuan-Yih Hsu," An Analytical Approach to Harmonic Analysis and Controller Design of a STa TCOM", IEEE Trans. Power Delivery, Vol. 22, No. I, Jan 2007.

[8] T. Manokaran, B.Sakthivel and Mohamed Yousuf,"Cascaded Multilevel Inverter Based Harmonic Reduction in Statcom" International Journal of Engineering Science and Technology, Vol. 2(10), 2010.

[9] Nitus Voraphonpiput, Teratam Bunyagul, and Somchai Chatratana, "Analysis and Performance Investigation of a Cascaded Multilevel STATCOM for Power System Voltage Regulation".

[10] Chunyan Zang, Zhenjiang Pei, Junjia He, Guo Ting, Jing Zhu and Wei Sun, "Comparison and Analysis on Common Modulation Strategies for the Cascaded Multilevel ST A TCOM" PEDS2009.

[11] Vineesha (2012) "Simulated Control System Design of a Multilevel STATCOM for Reactive Power Compensation" IEEE Transactions on Industry Application, Vol. 35, No. 5, pp: 257-263, December.

[12] N.G.Hingorani, L. Gyugyi, “Understanding FACTS, Concepts and Technology of Flexible AC Transmission systems”, IEEE Press 2000.

[13] K.R.Padiyar, “FACTS Controllers in power Transmission and distribution”. New age international publishers, first edition 2007.

[14] C.L.Wadhwa, “Electrical power system” New age international publishers ,first edition 1983.