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DESIGN AND ANALYSIS OF NINE LEVEL CASCADED MULTILEVEL CONVERTER BASED STATCOM FORWIND ENERGY CONVERSION SYSTEM

R Vibin[1] Shriraam S[2] Sudhanthira P[3]

[1,2,3]Assistant Professor , Department of EEE,CMS College of Engineering &Technology, Coimbatore, Tamil Nadu

Email: vibin.086@gmail.com[1] ksudhanthira85@gmail.com[3]

ABSTRACT

Grid connection of Fixed Speed Wind Turbines (FSWT) may cause power quality problem which tends to islanding of the generator from the grid. The performance of wind turbine and thereby power quality issues are determined on the basis of measurements and the norms followed according to guidelines specified in International Electro-technical Commission standard, IEC-61400.Voltage stability is a major issue to achieve the uninterrupted operation of wind farms equipped with FSWTs. In this paper the design of nine level Symmetrical and Asymmetrical Cascaded H-Bridge (CHB) – Multi Level Converter (MLC) based Static Synchronous Compensator (STATCOM) has been proposed. The dynamic behavior of both 9 level Symmetrical and Asymmetrical Cascaded Multilevel Converter based STATCOM is validated by simulation with MATLAB/SIMULINK. The performance of these STATCOM units is tested by connecting in shunt with the transmission line, along with the induction generator-based wind farm. The complete digital simulation of the STATCOM incorporated into the power system is performed using the MATLAB/SIMULINK environment and the results are presented to validate the feasibility of the proposed topology.

Keywords - Wind Farm, Induction Generator, Point of Common Coupling (PCC), Pulse Width Modulated (PWM) inverter, Multilevel Converter.

I. INTRODUCTION

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. Wind power is a source of voltage fluctuating and flicker. The need to integrate renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant [1]. The issues of power quality are of great importance to the wind turbine [2]. The dominating type of wind generators are induction generators, since they are robust and cost effective [6]. But they do not contribute to voltage regulation because they are substantial absorbers of reactive power. In the fixed speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations [13]. A Static Compensator (STATCOM) based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines [6]. The paper is organized as follows. The Section II introduces the power quality standards, issues and its consequences of wind turbine. The Section III describes the topology for power quality improvement. The Section IV, V, VI, VII and VIII discusses on the test system waveforms/results and

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conclusion respectively. The performance of the wind turbine and thereby power quality are determined on the basis of measurements and the norms followed according to the guideline specified in International Electro-technical Commission standard, IEC-61400. The power-electronic technology plays an important role in distributed generation and integration of renewable energy sources into the electrical grid and it is widely used and rapidly expanding as these applications become more integrated with the grid based systems [3].

II. POWER QUALITY STANDARDSAND ITS CONSEQUENCES

The various power quality standards and the consequences regarding the installation of fixed speed induction generator based wind farm at the Point of Common Coupling (PCC) are discussed below:

A. International Electro Technical Commission Guidelines

The guidelines are provided for measurement of power quality of wind turbine. The standard norms are specified in [4].

1) IEC 61400-21: Wind turbine generating system, part-21.Measurement and Assessment of power quality characteristic of grid connected wind turbine.

2) IEC 61400-13: Wind turbine measuring procedure in determining the power behaviour.

3) IEC 61400-3-7: Assessment of emission limit for fluctuating load.

B. Voltage Variation

The voltage variation results from the wind velocity and generator torque. The voltage variation is directly related to the real and reactive power variations. The voltage variation is commonly classified as under:

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.
- Long duration voltage variation.

The voltage flicker issue describes about dynamic variations in the network caused by the wind turbine or by cyclic loads.

C. Harmonics

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network.

D. Wind Turbine Location in Power System

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

E. Self Excitation of Wind Turbine Generating System

The self excitation of Wind Turbine Generating System (WTGS) with an asynchronous generator takes place after disconnection of WTGS with local load. The risk of self excitation arises especially when WTGS is equipped with compensating capacitor. The capacitor connected to induction generator provides reactive power compensation.

F. Consequences of the Issues

The voltage variation, flicker, harmonics causes the mal-function of equipments namely microprocessor based control system, programmable logic controller. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipments like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipments. Thus it degrades the power quality in the

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grid [12]. The power quality issues are to be taken into consideration before the installation of wind turbine induction generator at the PCC. The various issues affecting the performance of wind turbine induction generator should be highlighted to overcome the future problems [11].

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The performance of both Symmetrical Cascaded Multilevel Converter(CMC) and Asymmetrical Cascaded Multilevel Converter(ACMC) based STATCOM has been compared based on the Total Harmonic Distortion (THD) results and also ignore the need for the VSC based STATCOM [10]. The STATCOM injects the current into the grid in such a way that the source current are harmonic free and their phase angle with respect to source voltage has a desired value [15]. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. The proposed grid connected system is implemented for power quality improvement at PCC as shown in Figure 1.

A. Wind Energy Generating System

In this configuration, wind generations are based on constant speed topologies with pitch control turbine. The induction generator is used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. Fig.1, represents the grid connected system for power quality improvement.

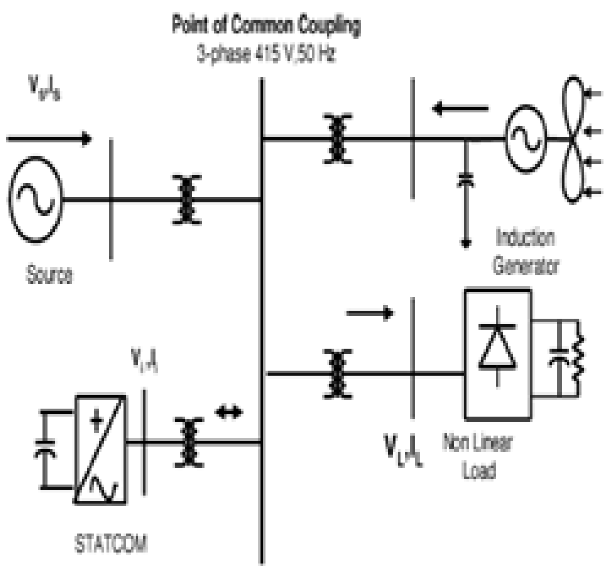

Figure 1 Grid connected system for power quality Improvement

B. System Operation

The shunt connected STATCOM is connected with the interface of the induction generator and non- linear load at the PCC in the grid system [9]. The STATCOM output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system [14]. A single STATCOM using insulated gate

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bipolar transistor is proposed to have a reactive power support, to the induction generator and to the nonlinear load in the grid system. The main block diagram of the system operational scheme is shown in Figure 2.

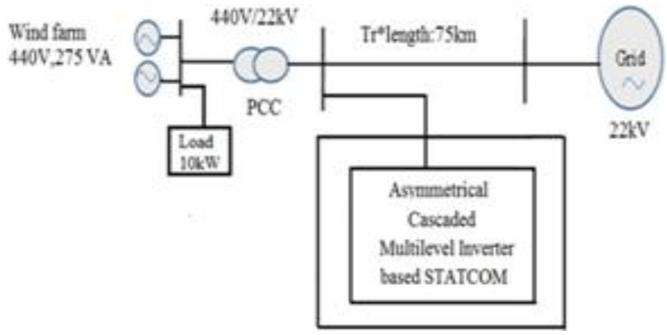

Figure 2 System operational scheme in grid system

C. Nine Level Output Based on Switching Angles

The output voltage developed across each phase is dependent upon the switching angle selection and thecorresponding waveform is shown below:

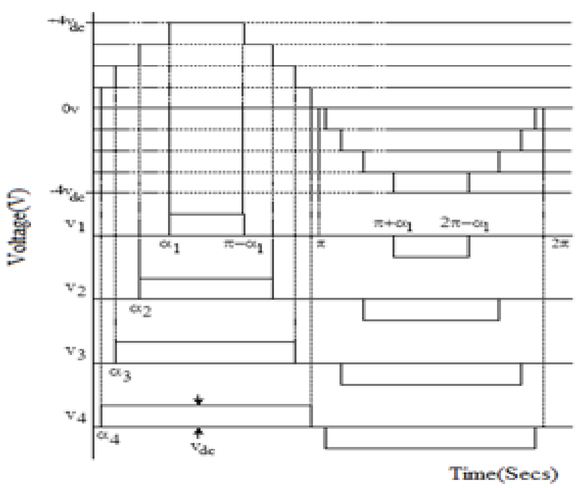

Figure 3 Nine level output waveform

IV. SIMULATION MODEL OF THECMC BASED STATCOM

The CMC based STATCOM interfaced with the test system is shown in Fig. 4,

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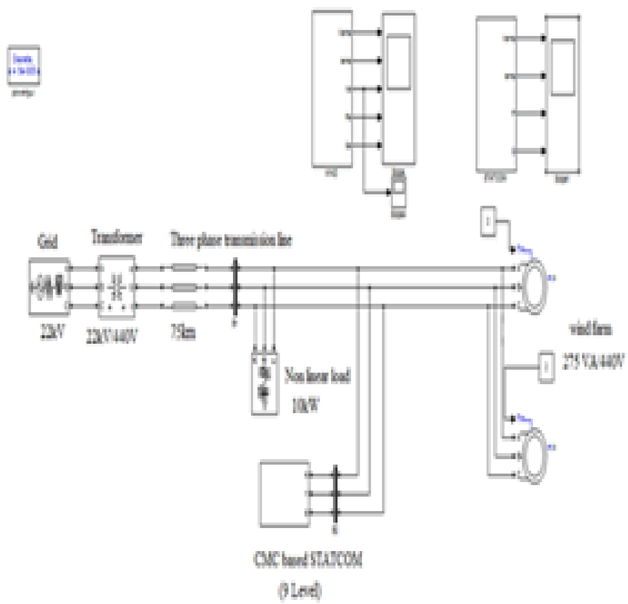
Figure 4 Simulation model of CMC based STATCOM interfaced with the test system

The CMC based STATCOM has been interfaced with the test system which has been designed for nine level with the aim of reducing the step up transformer at the output of the converter by cascading each of the H- bridges. Each phase uses four H-bridges to generate nine level output. The following parameters such as voltage, current, real power and reactive power being measured with respect to test system without induction generator, test system with induction generator and test system with both induction generator and CMC based STATCOM.

V. SIMULATION RESULTS FOR CMCBASED STATCOM

The load voltage, load current, real power and reactive power for the above test systems are been measured including the THD.

A. Load Voltage



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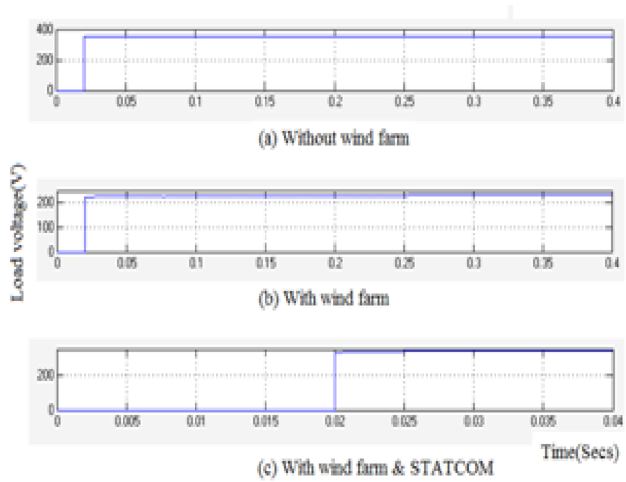

Figure 5 Load voltage

Load voltage with an induction generator connected to PCC there is a droop but with respect to STATCOM
there is an improvement in the voltage profile.

B. Load Current

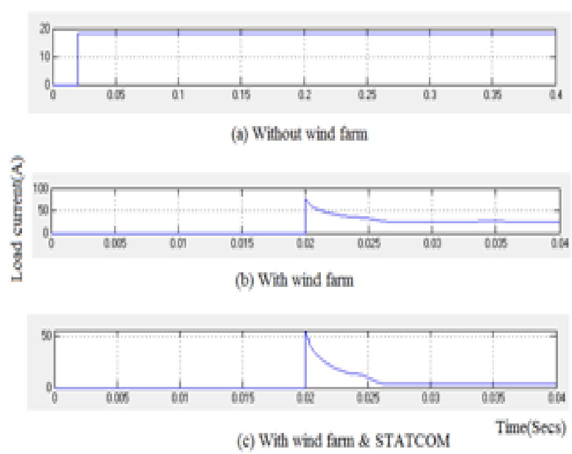

Figure 6 Load current

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C. Real Power

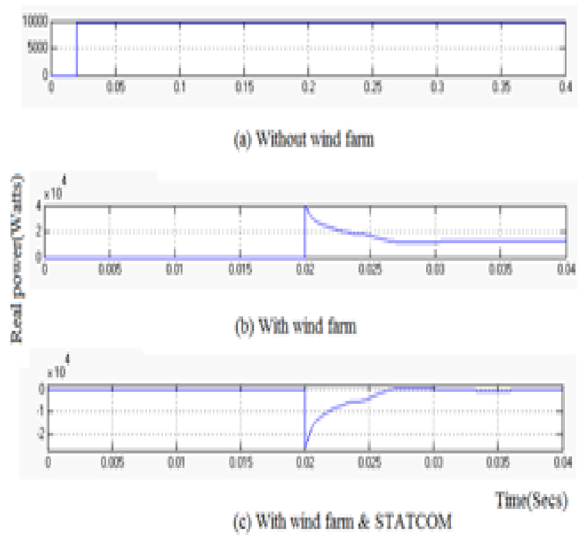

Figure 7 Real power at PCC

It has been inferred from the waveforms that there is a supply of real power to the grid from the induction generator initially but later on it decreases but afterthe STATCOM is been introduced into the PCC further there in an improvement in the real powerflows across the load.

D. Reactive Power

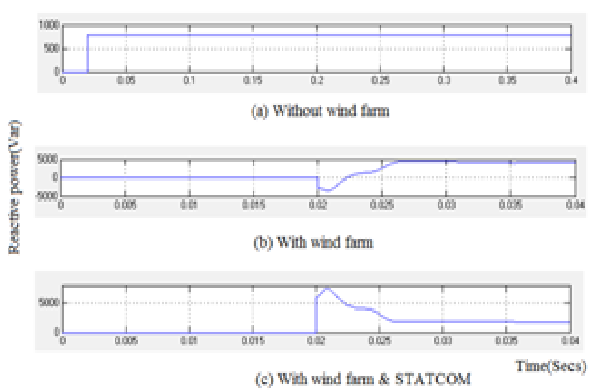

Figure 8 Reactive power at PCC

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E. Total Harmonic Distortion

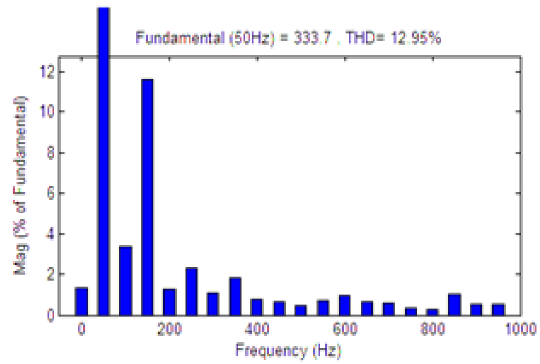

Figure 9 Total harmonic distortion for CMC based STATCOM

VI. SIMULATION MODEL OF ACMC BASED STATCOM

The ACMC based STATCOM interfaced with the testsystem is shown in Fig 10.

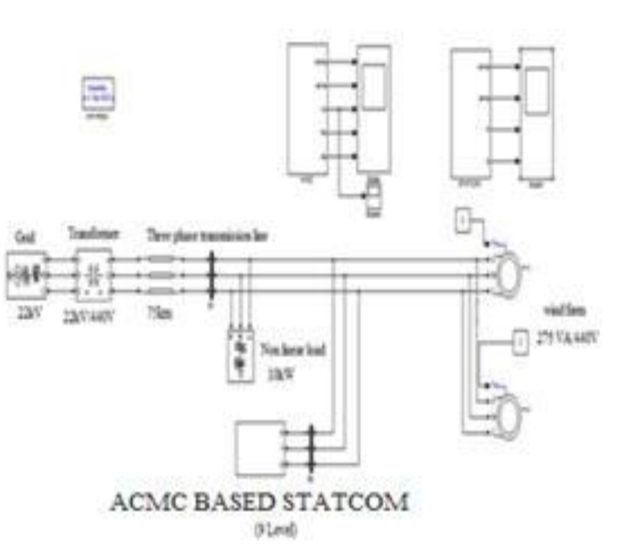

Figure 10 Simulation model of proposed system

VII. CONTROL DESIGN OFPROPOSED SYSTEM

The multicarrier based sinusoidal pulse width modulation control scheme has been developed with the aim of reducing the total harmonic distortion across the CMC based STATCOM output [5] and the simulation model is shown in Fig .10.

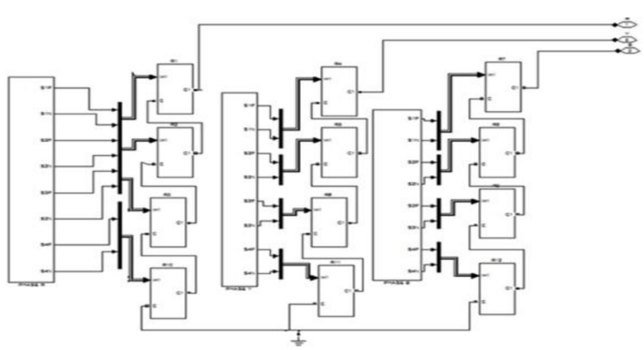

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Figure 11 Multicarrier based sine PWM generation (9level)

VIII. SIMULATION RESULTS FORACMC BASED STATCOM

The load voltage, load current, real power and reactive power for the above test systems are been measured including the total harmonic distortion.

A. Load Voltage

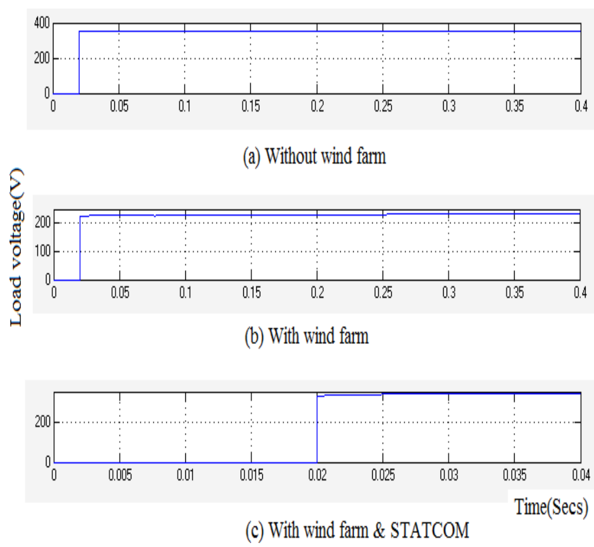

Figure 12 Load voltage

B. Load Current

F.

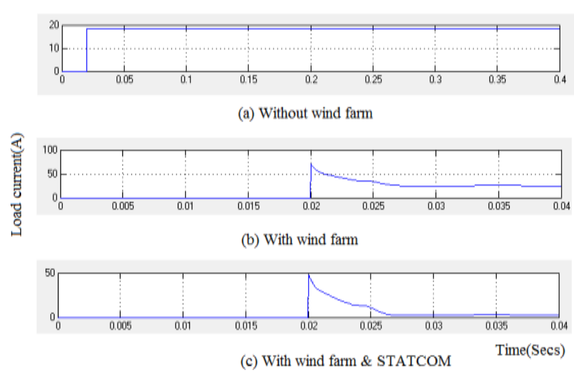

Figure 13 Load Current

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C. Real Power

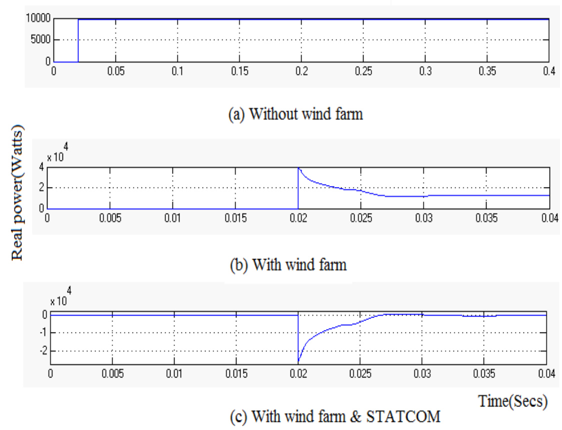

Figure 14 Real Power at PCC

D. Reactive Power

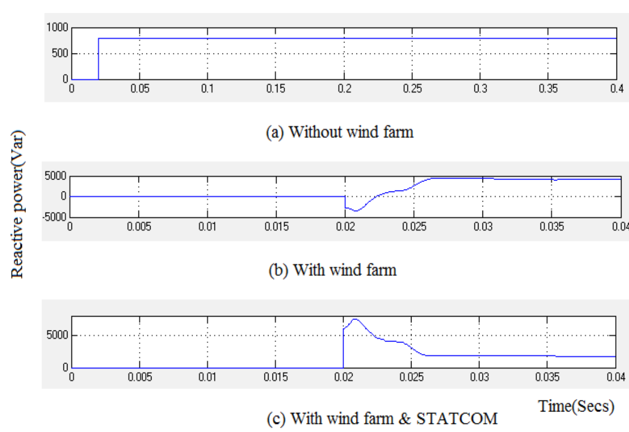

Figure 15 Reactive power at PCC

E. Total Harmonic Distortion

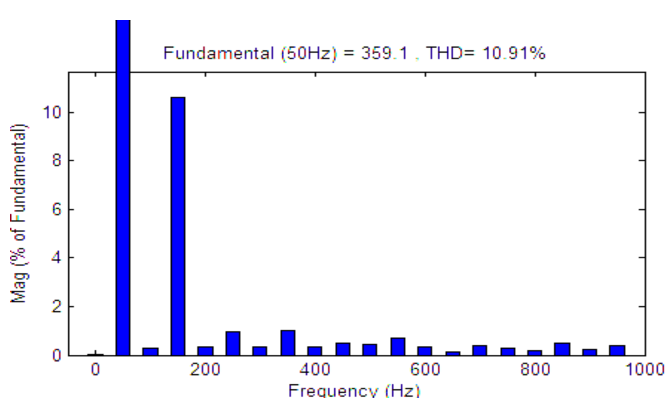

Figure 16 Total harmonic distortion for ACMC based STATCOM

F. Nine Level Inverter Line Output

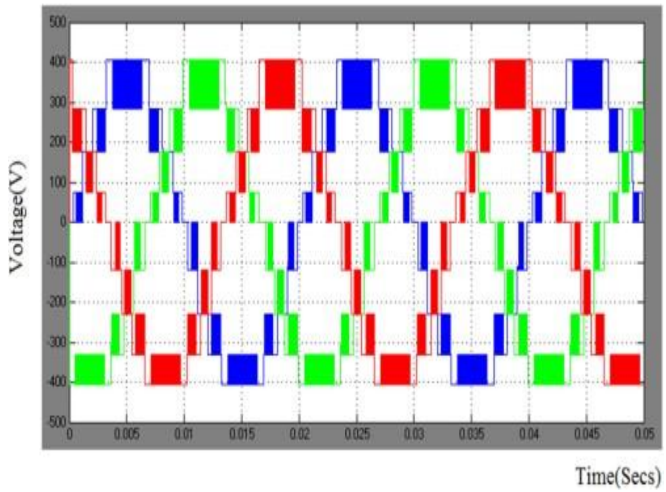

Figure 17 Asymmetrical cascaded Multilevel inverter output

IX. CONCLUSION

This paper compares both nine level CMC based STATCOM and ACMC based STATCOM control scheme for power quality improvement in gridconnected wind generating system and with non- linear load. The power quality issues and its consequences on the consumer and electric utility are presented. The integrated wind generation along with ACMC based STATCOM have shown the outstanding performance in compensating the reactive power consumed by the wind generator as well as there is an improvement in the voltage profile.

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