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Power Flow Control Scheme for Wind Energy Conversion System using FACTS Controller

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Abstract* - Injection of wind power into an electric grid affects the power quality. 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 influence of the wind turbine in the grid system concerning the power quality measurements are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation. The paper study demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATIC COMPENSATOR (STATCOM) is connected at a point of common coupling to mitigate the power quality issues. The STATCOM control scheme for the grid connected wind energy generation system is simulated using MATLAB/SIMULINK in power system block set.

***Index terms* – International Electro-technical Commission (IEC), power quality, wind generating system (WGS).**

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. 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 issue of power quality is of great importance to the wind turbine [2]. 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. A 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.

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, VIII and IX discusses on the control design as well as the test system waveforms/results and conclusion respectively.

II. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. *International Electro Technical Commission Guidelines*

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

1) IEC 61400-21: Wind turbine generating system, part 21. Measurement and Assessment of power quality charac- teristic of grid connected wind turbine.
2) IEC 61400-13: Wind turbine measuring procedure in determining the power behavior.
3) IEC 61400-3-7: Assessment of emission limit for flu- ctuating load.

B. *Voltage Variation*

The voltage variation issue results from the wind velocity and generator torque. The voltage variation is directly related to 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 dynamic variations in the network caused by wind turbine or by varying 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. The disadvantages of self excitation are the safety aspect and balance between real and reactive power [3].

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 degrade the power quality in the grid.

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The Conventional STATCOM comprises of Voltage Source Converter, DC link Capacitor and a Coupling Transformer is being connected to the Point of Common Coupling (PCC) to the grid. The STATCOM based Voltage Source Converter 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 [7]. 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 [3]. The proposed grid connected system is implemented for power quality improvement at PCC as shown in Fig. 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.

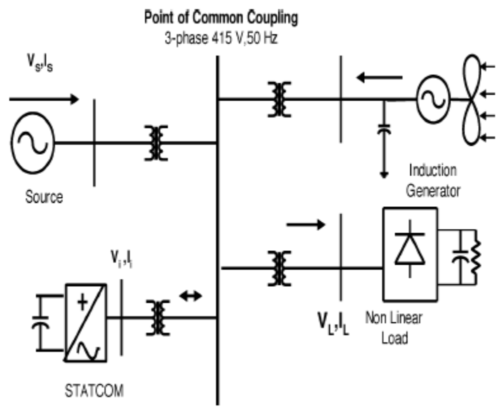

Fig.1 Grid connected system for power quality improvement

B. *System Operation*

The shunt connected STATCOM is connected in shunt with the induction generator and non-linear load at the PCC in the grid system [6]. The Static Synchronous compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system. A single STATCOM using insulated gate 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 Fig. 2.

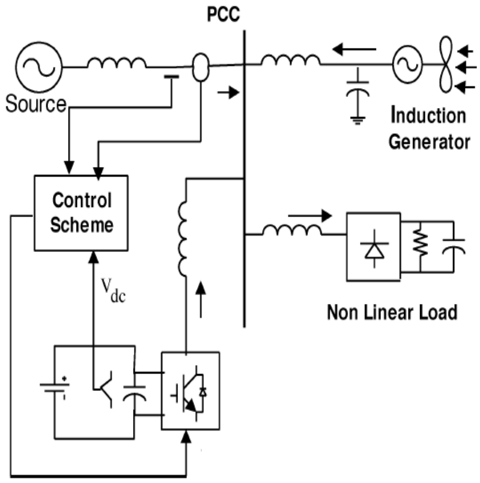

Fig.2 System operational scheme in grid system

IV.SIMULATION MODEL OF THE CONVENTIONAL SYSTEM

The conventional based STATCOM is shown in Fig 3.

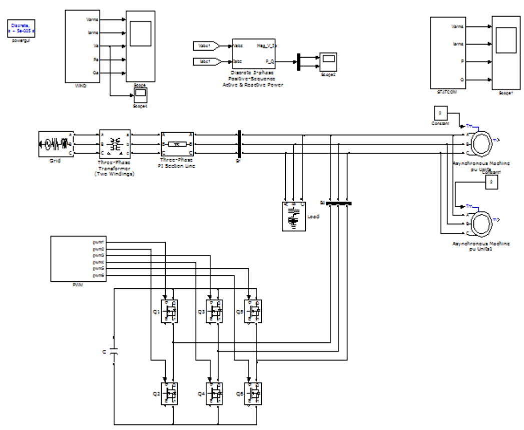

Fig.3 Simulation model of conventional system

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 STATCOM.

V. SIMULATION RESULTS FOR THE CONVENTIONAL SYSTEM

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*

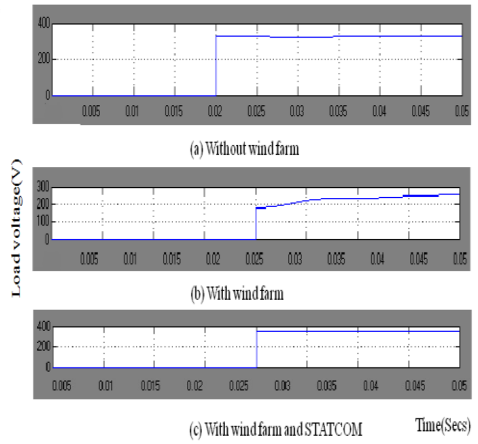

Fig.4 Load voltage

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*

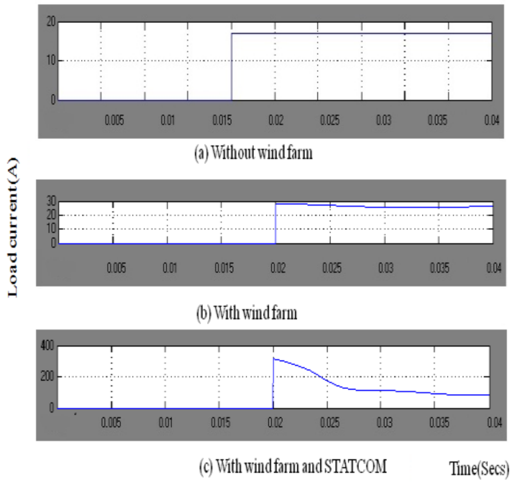

Fig.5 Load current

C. *Real Power*

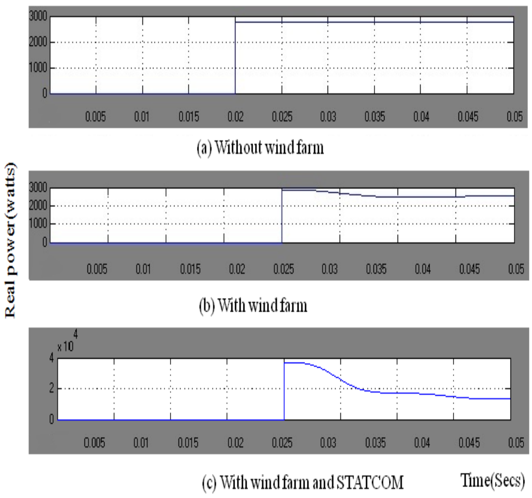

Fig.6 Real power at PCC

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 after the STATCOM is been introduced into the PCC further there in an improvement in the real power flows across the load.

D. *Reactive Power*

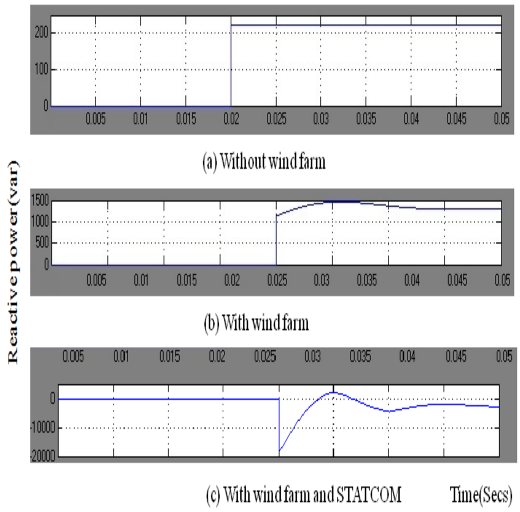

Fig.7 Reactive power at PCC

It has been inferred from the above waveforms that the reactive power is drawn from the grid by the induction generator in order to magnetize the stator and later on there is a gradual improvement in reactive power across the load from the induction generator but when the STATCOM is been connected to the grid, reactive power drawn by the induction generator is been compensated by injecting reactive power at the PCC and as a result the flow of reactive power has been controlled to a large extend and are maintained between the limits.

E. *Total Harmonic Distortion*

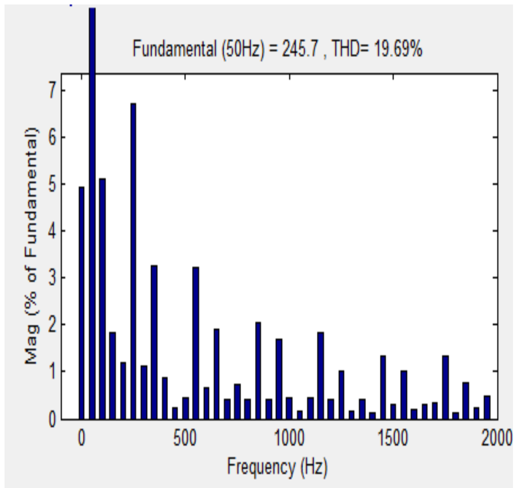

Fig.8 Total harmonic distortion for conventional STATCOM

VI. SIMULATION MODEL OF THE PROPOSED SYSTEM

The Cascaded Multilevel Converter (CMC) based STATCOM is shown in Fig 9.

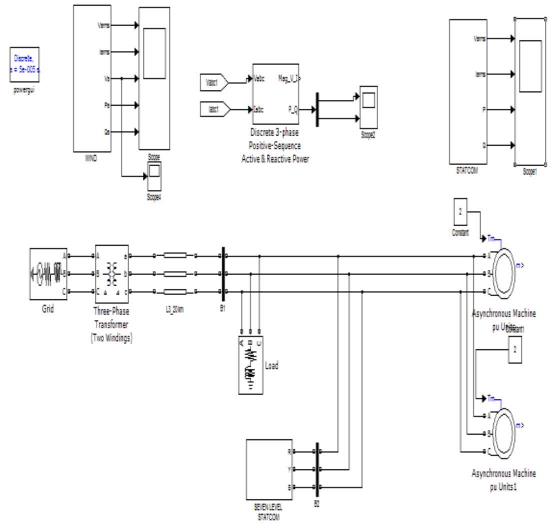

Fig.9 Simulation model of proposed system

VII. CONTROL DESIGN OF THE PROPOSED SYSTEM

The multicarrier based sinusoidal pulse width modulation control scheme has been developed in [5] with the aim of reducing the total harmonic distortion across the CMC based STATCOM output with the carrier frequency of 10kHZ, modulation index of 0.9 and the corresponding simulation model is shown in Fig 10.

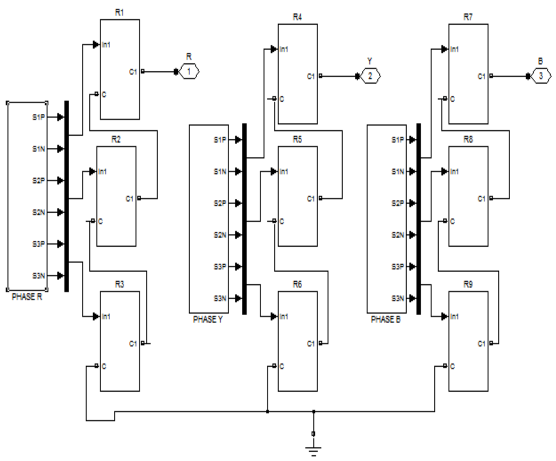

Fig.10 Multicarrier based sine PWM generation

VIII. SIMULATION RESULTS FOR THE PROPOSED SYSTEM

The parameters such as Load Voltage, Load Current, Real Power and Reactive Power for the above test system had been measured including the total harmonic distortion.

A. *Load voltage*

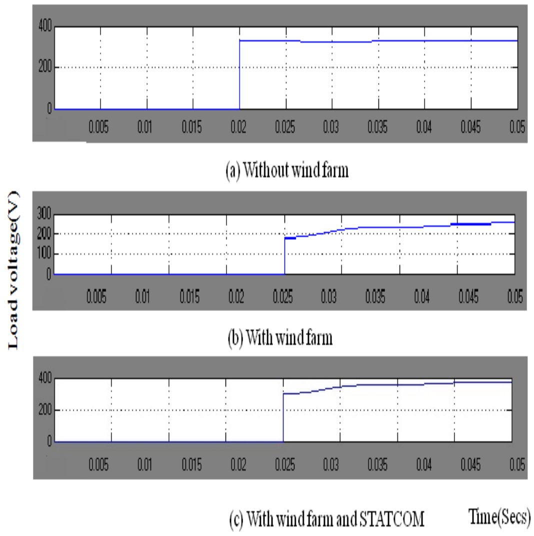

Fig.11 Load voltage

B. *Load Current*

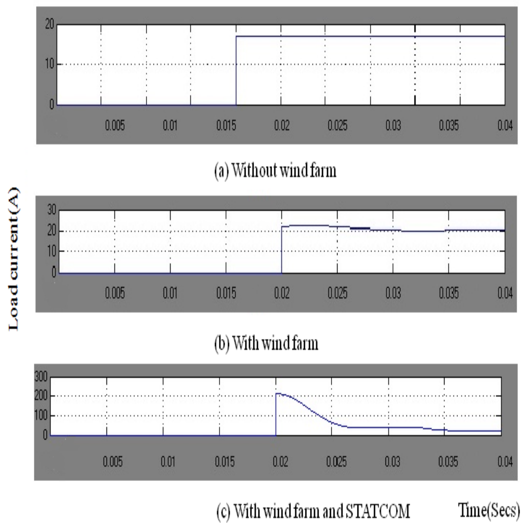

Fig.12. Load current

C. *Real Power*

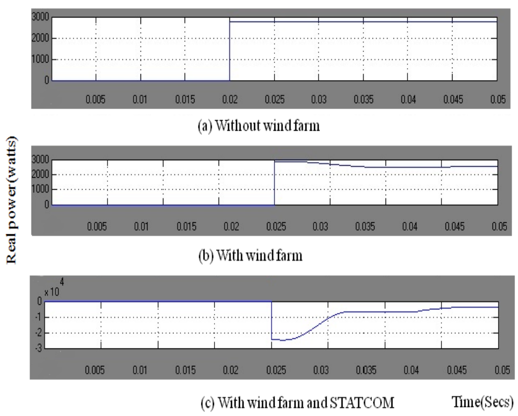

Fig.13 Real power at PCC

D. *Reactive Power*

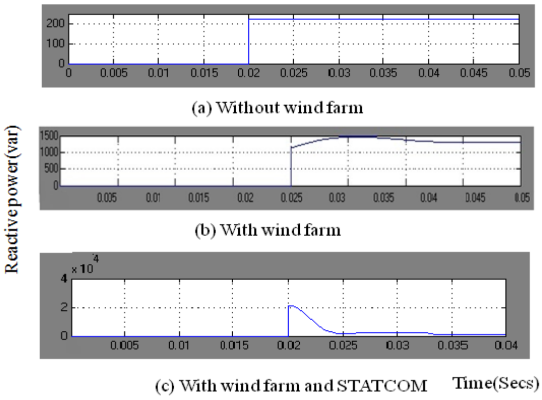

Fig.14 Reactive power at PCC

E. *Total Harmonic Distortion*

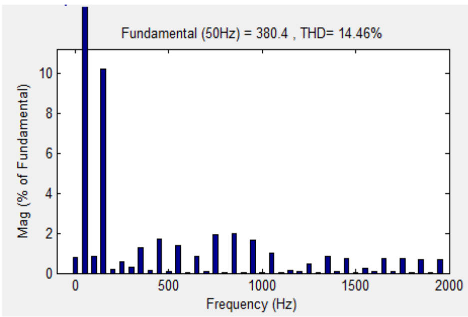

Fig.15 Total harmonic distortion for CMC based STATCOM

IX. CONCLUSION

This paper compares both conventional STATCOM and CMC based STATCOM control scheme for power quality improvement in grid connected 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 CMC based STATCOM have shown the outstanding performance in compensating the reactive power consumed by the wind generator.

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