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Power Quality Improvement in Grid Connected Wind Energy System Using STATCOM

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Abstract: *This paper deal with the performance analysis and operating principles of power electronics based FACTS device static synchronous compensator for power quality improvement at the point of common coupling for the grid connected wind energy system. A three phase three wire system is assumed in this study. An IGBT based three phase inverter circuit with PWM control strategies supplied by a DC storage capacitor called STATCOM is connected in shunt with the PCC. When the inverter output voltage is greater than the bus voltage, STATCOM will act as a capacitor i.e. it will inject reactive power into the bus. When the inverter output voltage is less than the bus voltage, STATCOM will act as a inductor i.e. it will absorb reactive power from the bus. Power Quality Improvement in Grid Connected Wind Energy System Using STATCOM is simulated using MATLAB/SIMULINK in power system block set.*
Keywords: *Permanente-magnet synchronous generator, Pulse width modulation (PWM), Static synchronous compensator (STATCOM), Voltage source converter (VSC).*

I. Introduction

The demand of electrical energy is increasing in whole world day by day. Due to less availability of conventional sources, renewable energy resources like wind, solar; biomass etc. has been fast developed in whole world. Here we discussed about wind energy system. When we integrate wind energy into existing power system, it will present a technical challenges and it causes the power quality issues. One of the power quality issues is flicker which is induced by voltage fluctuation. In the normal operating condition wind turbine produces the continuous variable output power.

To mitigate the voltage flickers and power quality issues a fact device static synchronous compensator is connected at the point of common coupling.

II. STATCOM

A static synchronous compensator is a shunt device of the flexible AC transmission system (FACTS) family. It consists of an inverter circuit with capacitor as the dc input source as shown in Fig 1. Its name (STATCOM) indicates its operational components [2].
First operational component is static.
Second operational component is synchronous. Third operational component is compensator.

STATICS operational component denotes solid state switching devices. SYNCHRONOUS operational component shows it is analogous to an ideal synchronous machine with three sinusoidal phase voltage at fundamental frequency. COMPENSATOR operational component shows reactive power compensation.

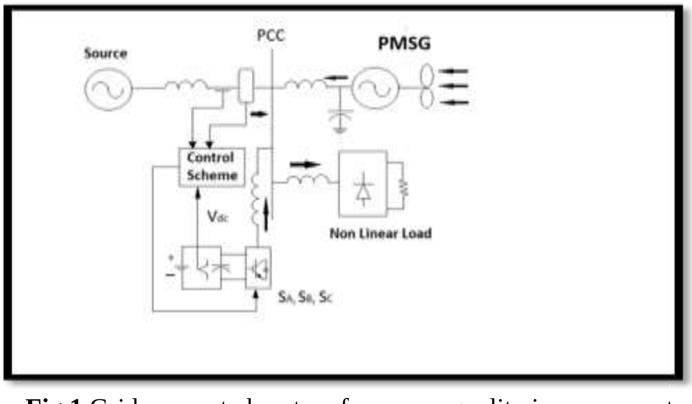

Fig.1 Grid connected system for power quality improvement

A. Basic Operating Principle Of STATCOM

The basic operating principle of a STATCOM is similar to synchronous machine [3]. The synchronous machine will provide lagging current when under exited (E_X< V) and leading current when over exited (E_X > V).

STATCOM can generate and absorb reactive power similar to the synchronous machine. If the output voltage of voltage source inverter is greater than the bus voltage then the STATCOM will act as a capacitor and generate reactive power means it provide leading current to the bus. If the output voltage of the inverter is less than the bus voltage than STATCOM will act as a inductor and absorb reactive power means it provide lagging current to the bus.

B. Controlling circuit of the STATCOM

The controlling scheme of the STATCOM is based on the unit vector template and hysteresis current controller technique [1], [4], [7],[11].

a. Unit Vector Template Generation:

For generating unit vector template Phase locked loop is used (PLL) [1]. PLL generate reference angle θ to generate the unity voltage vector. For generating reference angle θ, grid voltage is sensed and taken to the PLL block as shown in Fig. 2

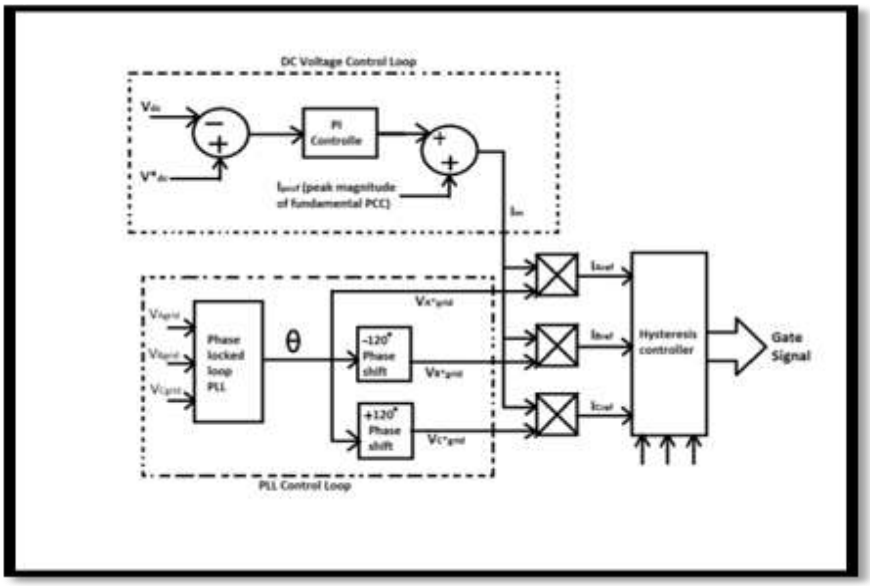

Fig 2 STATCOM controller

The output of PLL block with proper phase shift is unit vector template and given by equations shown below

$$V^*_{grid}\,A = Sin\,\theta \quad (1)$$
$$V^*_{grid}\,B = Sin\,(\theta - 120^o) \quad (2)$$
$$V^*_{grid}\,C = Sin\,(\theta + 120^o) \quad (3)$$

b. Reference current signal generation

For generating reference current signal DC voltage control loop is used. In dc voltage control loop measured value of dc voltage is compare with the reference value of dc voltage and error will give to the PI controller. The output of the PI controller is the peak amplitude of fundamental input current (I_m)

The peak amplitude of fundamental input current is multiplied with the unit vector and output of multiplier become reference current signals

$$I_{Areff} = I_m * V^*_{gr}$$
$$I_{Breff} = I_m * V^*_{gr}$$

$id\,A$ (4)

$id\,B$ (5)

$$I_{Creff} = I_m * V^{*}_{grid\,C} \quad (6)$$

c. Hysteresis Current Controller (HCC)

In this technique PCC current is compare with the reference current signal and error signal is proceed by using HCC [1],[7] as shown in Fig 3 Switching pattern of the STATCOM will decided by the suitable band of the HCC.

$$I_{Aerror} = I_{Areff} - I_{Apcc} \quad (7)$$
$$I_{Berror} = I_{Breff} - I_{ACpcc} \quad (8)$$
$$I_{Cerror} = I_{Creff} - I_{Cpcc} \quad (9)$$

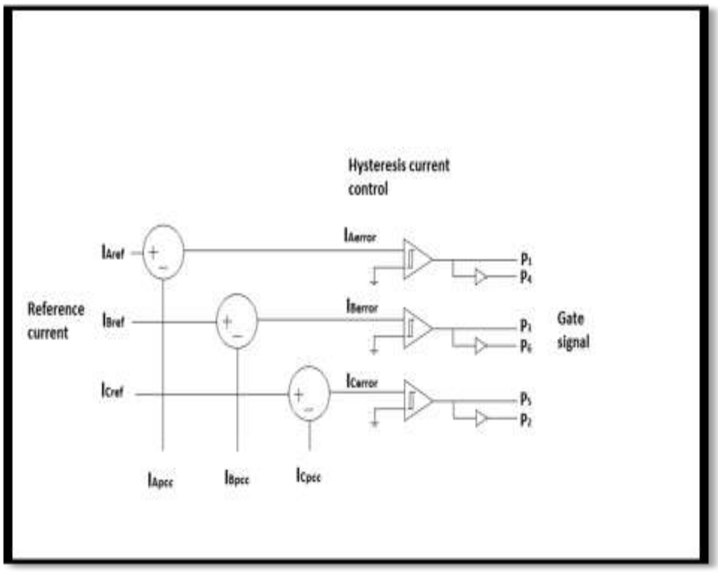

Fig. 3 Hysteresis current controllers

d. Smiulation result of the controlling circuit

Fig.4 shows switching pattern of each IGBT inside inverter.

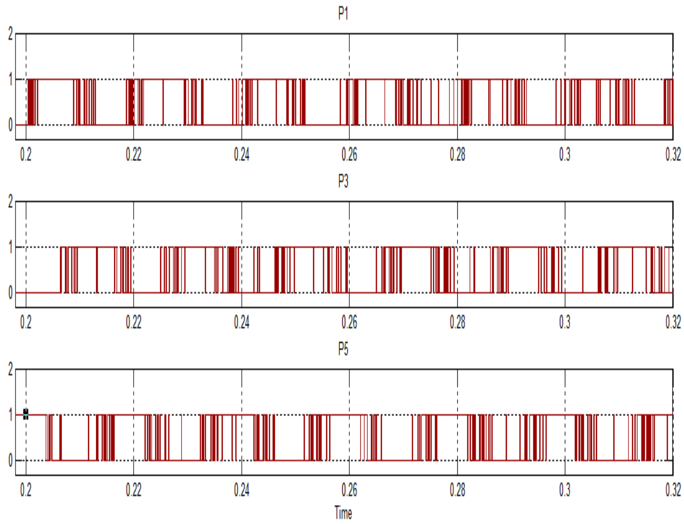

Fig.4 (a) Output of the controlling circuit for upper positive group of inverter

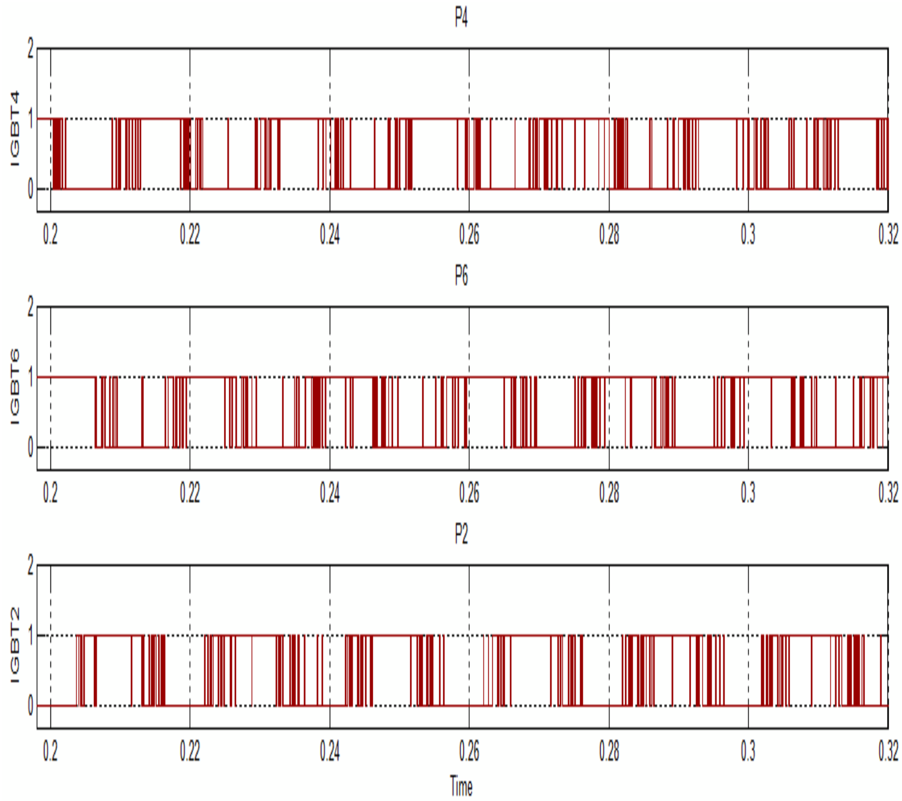

Fig.4 (b) Output of the controlling circuit for lower negative group of inverter

Wind Energy System

In wind energy system we use PMSG. By using wind turbine the kinetic energy of the wind is converted into mechanical torque as shown in Fig.5. Mechanical energy is converted into electrical energy by using salient pole permanent magnet synchronous generator [9],[10]. PMSG cannot be interface directly to the grid [8]. We use rectifier and inverter for making constant frequency.

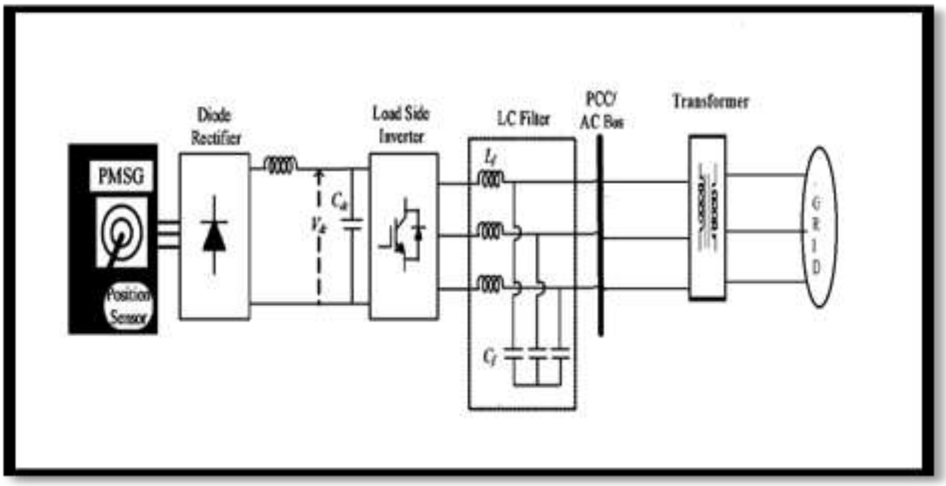

Fig.5 wind energy system

A. Simulation resuls of the wind energy system

Fig.6 shows instantaneous active and reactive power waveform of WEGS, Three phase output voltage waveform of grid connected WEGS,RMS power, electromagnetic torque and mechanical torque.

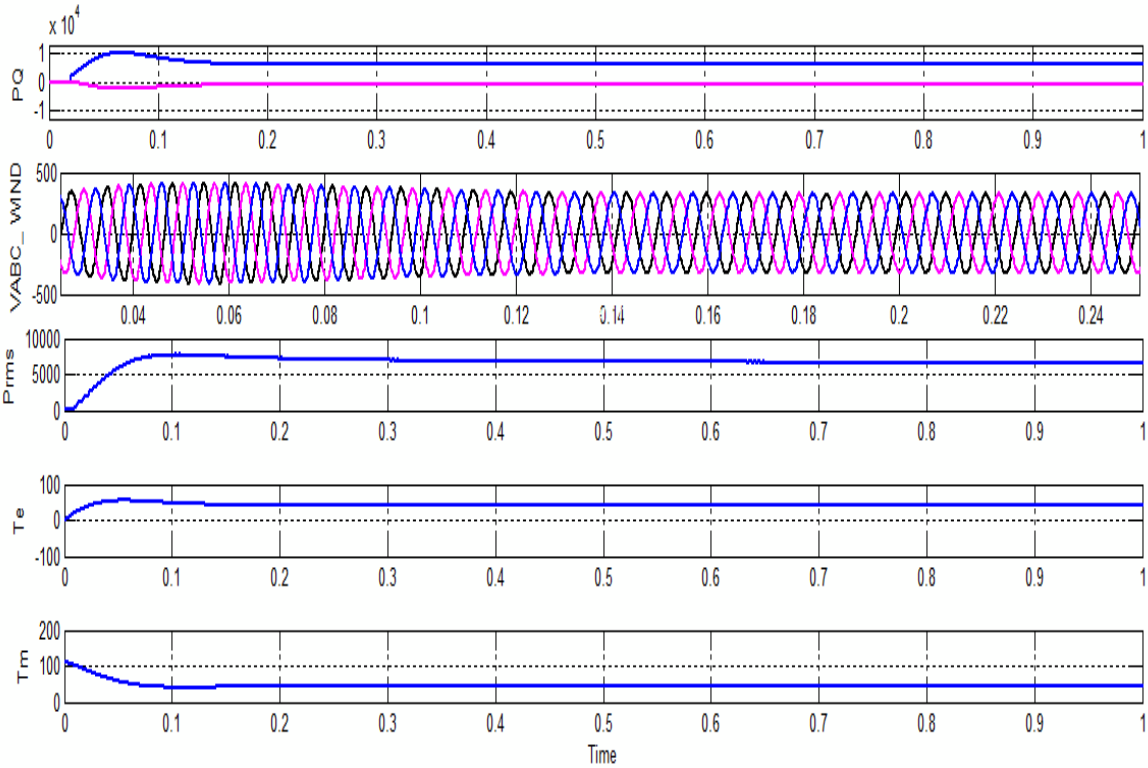

Fig.6 Output of the wind energy system (a) PQ (b) voltage (c) RMS power (d) electromagnetic torque (e) mechanical torque

Simulation Result of The Statcom

Fig.7 (a) shows output voltage wave forms without filter and Fig. (b) shows output voltage and current wave forms of the
STATCOM.STATCOM inject current at the PCC after the time 0.32 second

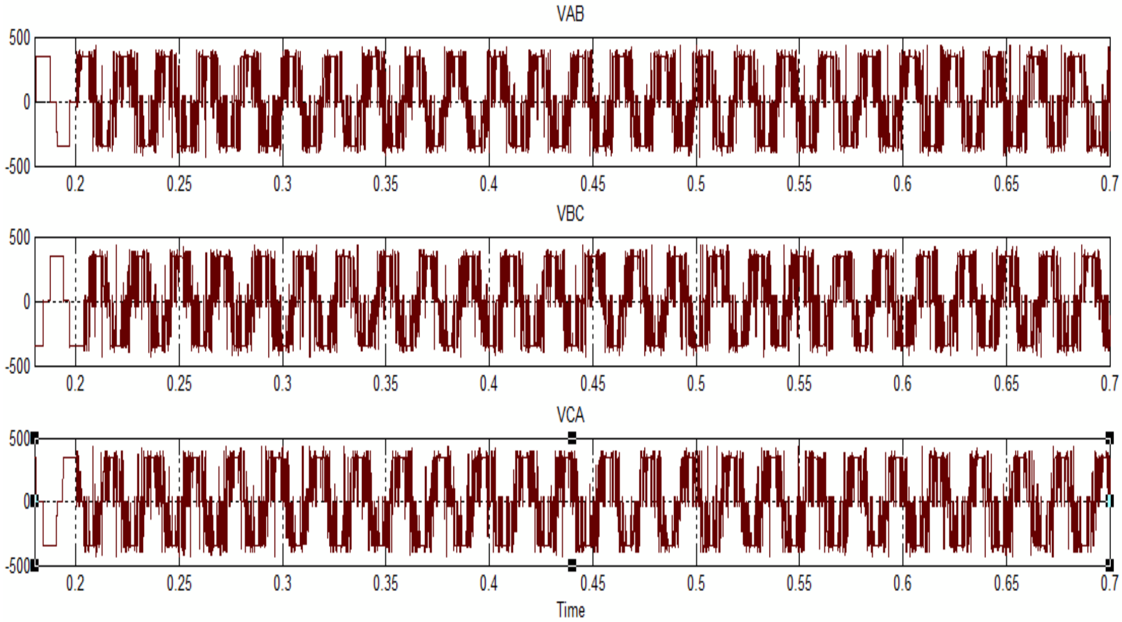

Fig.7(a) shows output voltage wave forms of the STATCOM without Filter

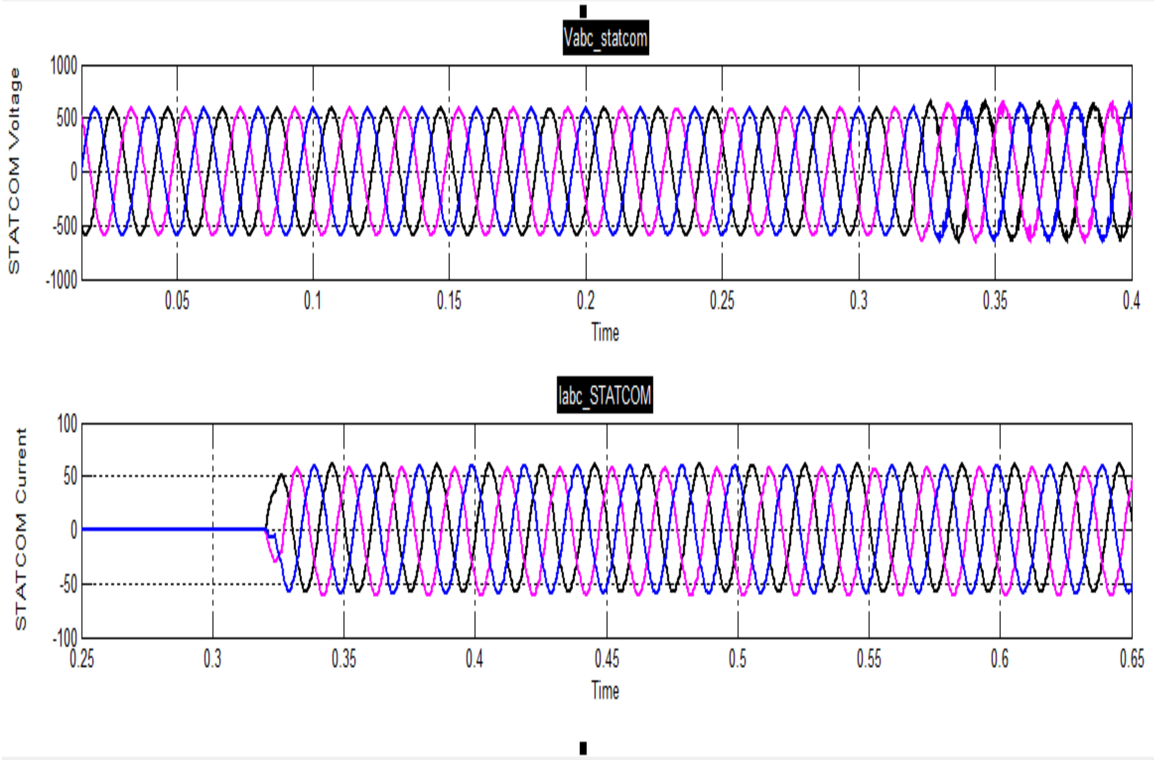

Fig.7(b) shows output voltage and current waveforms of the STATCOM with filter

III. Simulation Result At The PCC

The three phase injected current into the grid from the STATCOM will cancel out the distortion caused by the nonlinear load and wind generator Fig.8 shows the output voltage and current waveform at the PCC

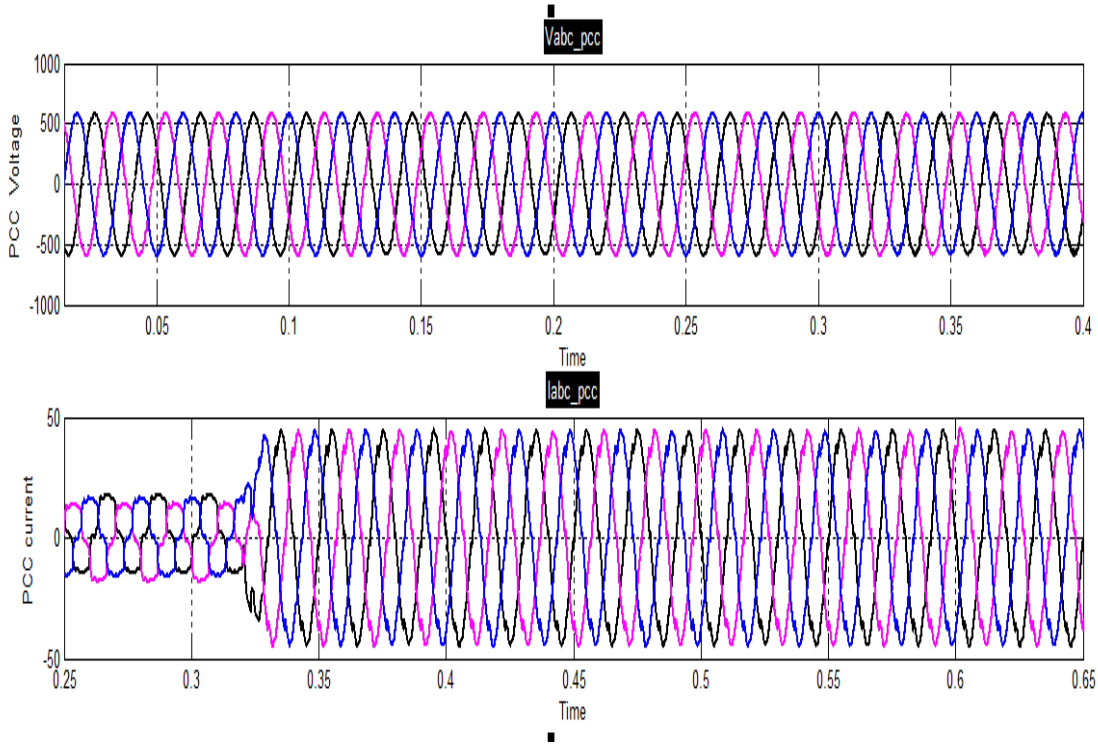

Fig.8 Output voltages and current waveform at the PCC

IV. Simulation Result At The Nonlinear Load

Fig.9 shows output voltage and current waveforms of nonlinear three phase RL load.

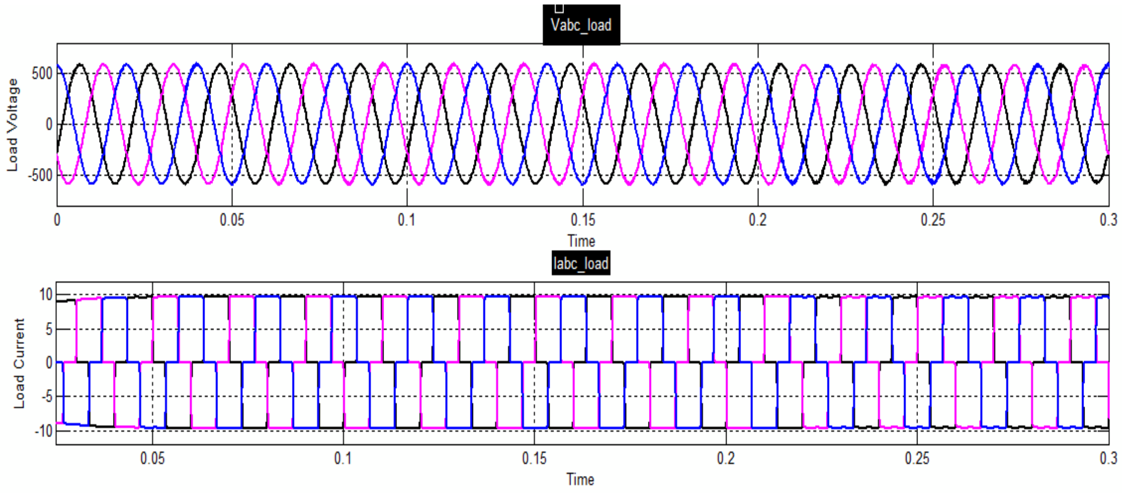

Fig.9 Output voltage and current waveform at the nonlinear load

V. FFT Analysis Of The Fifty Cycle Of The Current Wave Form At The PCC

FFT analysis shows that total harmonic distortion in the current waveform at the PCC without STATCOM is 20% more than as compare to with STATCOM

Fig.10 shows FFT analysis of the fifty cycles of current wave forms at the PCC with STATCOM and Fig.11 show FFT analysis of the fifty cycle of current waveform at the PCC without STATCOM

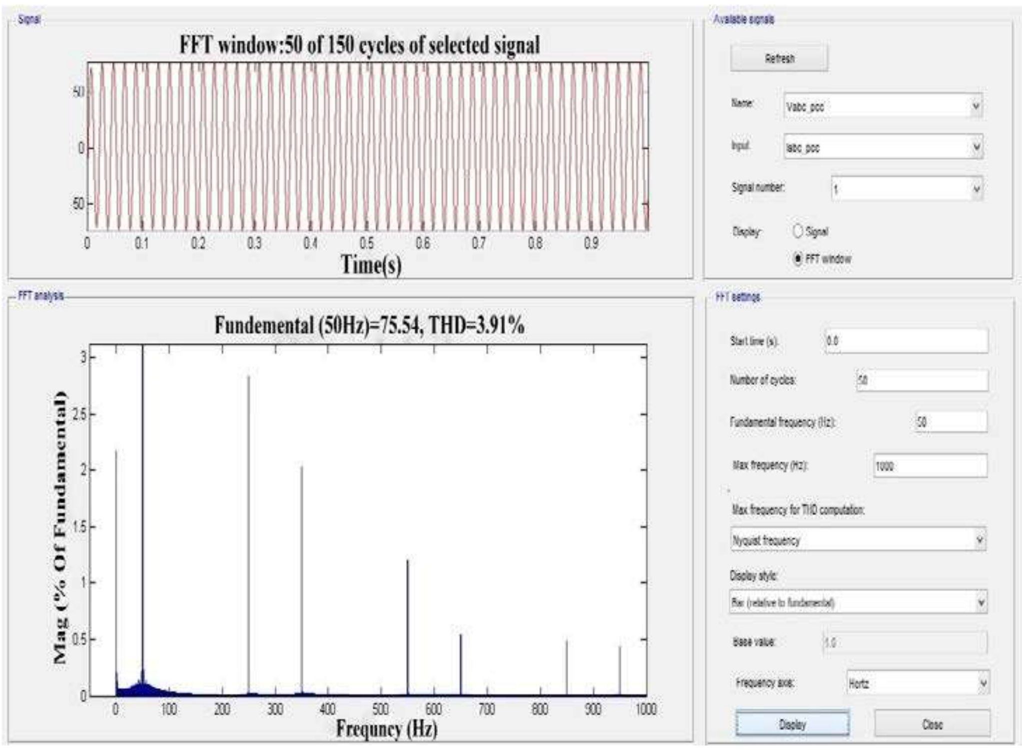

Fig.10 FFT analysis of the current wave form at the PCC with STATCOM

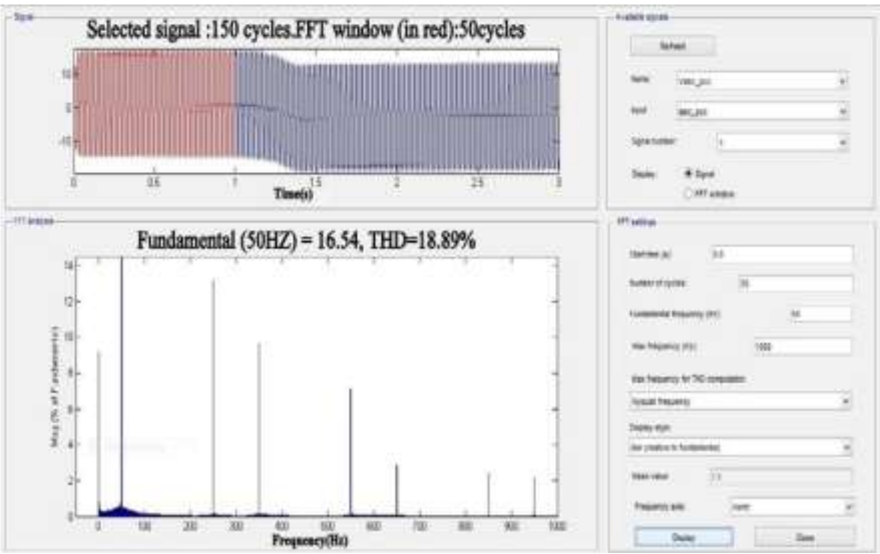

Fig.11 FFT analysis of the current wave form at the PCC without STATCOM

VI. Conclusions

Simulation results of the STATCOM system have been observed under grid connected wind energy system with nonlinear load. The STATCOM control algorithm has been found capable of improving power quality, voltage profile and harmonic elimination. It has been found that the STATCOM system reduces harmonics in the voltage at the PCC and supply current.

References

[1]. N.F. Jamaludin, 2A.F. Abidin "Phase-Locked Loop (PLL) Controller for Distribution Synchronous Static Compensator (D- STATCOM) to Mitigate Voltage Flicker"
[2]. C.N Bhende and G.K Singh "Modeling and performance of sinusoidal PWM based Dstatcom" NPSC volume-2 DEC27-30,2004 [3] Jovitha Jerome,And R.Subha "Power Quality Enhancement In Distribution System(DSTATCOM)" NPSC Volume 2 DEC 27-30
[3]. S.Meschi and E.Hashemzadeh, "MATLAB Simulation of a DSTATCOM using Hysteresis current control for electrical Arc furnace Filker Mitigation"2006
[4]. V.Suresh Kumar , Ahmed F.Zobaa , R.Dinesh Kannan , and K.Kalaiselvi "Power Quality and Stability Improvement in Wind Park System Using STATCOM
[5]. Vaisakh V, M.Tech (Power system), EEE, Sunilkumar A V, Assistant Professor, EEE, "Power-Quality Improvement Features In Grid Interconnection of
[6]. Wind Energy Source at the Distribution Level" International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 5 (June 2014)
[7]. Mukhtiar Singh "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 26, NO. 1, JANUARY 2011.
[8]. Jay Verma, Yogesh Tiwari, Anup Mishra, Nirbhay Singh "Performance, Analysis and Simulation of Wind Energy Conversion System Connected With Grid
[9]. M. M. Chowdhury "Enhanced Control of a Direct Drive Grid Connected Wind Energy System with STATCOM".
[10]. Neeraj Pareta , Naveen Sen "Modelling and Simulation of Permanent Magnet Synchronous Motoer Based Wind Energy Conversion System".
[11]. S.Venkateshwaran, G.Vijaya gowri "STATCOM with TBESS to improve the power quality in grid connected wind energy system" International Journal of Advanced Technology & Engineering Research (IJATER)

Biographies

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