POWER QUALITY IMPROVEMENT OF A GRID CONNECTED WIND ENERGY SYSTEM USING STATCOM-CONTROL

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ABSTRACT

When we inject wind power into an electric grid affects the power quality, The performance of the wind turbine and there by power quality. 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 with a battery energy storage system (BESS) to mitigate the power quality issues.

However, the generated power from renewable energies is always fluctuating due to environmental status. Energy storage system is indispensable to compensate these fluctuating components. Energy capacitor system (ECS) connected an electric double layer capacitor (EDLC) with power-electronics devices is useful for the compensation of fluctuating power since one is capable of controlling both active and reactive power simultaneously. The battery energy storage is integrated wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker and harmonics to sustain the real power source under fluctuating wind power.

The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator.

Keyword:- *Wind generating systems(WGS), Static compensator(STATCOM), Energy capacitor system(ECS), Battery energy storage system(BESS).*

I. INDRODUCTION

In recent years, an energy capacitor system (ECS) connected an electric double-layer capacitor (EDLC) with power electronics devices have been developed as energy storage system and applied in power system . An EDLC is safer and has a longer service life than the secondary battery, and requires virtually no maintenance, but having the following disadvantages: the dielectric voltage-withstand level of a EDLC-cell is 3 V or lower and high internal-resistive loss is directly proportional to squared current **T**O 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 In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plan.

There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity [3]. Today, more than 28 000 wind generating turbine are successfully operating all over the world. 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. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc.

The WECS model used in a particular assessment must be compatible with the system adequacy assessment technique in use and therefore potentially there could be a wide variety of models. The key requirement, however, in a WECS model is the ability to provide an accurate portrayal of the variability and intermittency of the WECS power output. Some models contain much more information than other models and therefore have the potential to provide more accurate adequacy assessments. The simplest WECS model is an annual multi-state capacity outage probability table (COPT) that can be utilized to create the system COPT used to calculate the conventional loss of load expectation (LOLE). Additional factors could include the recognition and incorporation of seasonal COPTS or modified COPTS to include wind farm maintenance scheduling. These factors and the resulting WECS models should be compatible with the procedures and protocols established for incorporating conventional generating units in the overall generating capacity adequacy assessment process.

A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. 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 proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives.

• Unity power factor at the source side.

• Reactive power support only from STATCOM to wind Generator and Load.

• Simple bang-bang controller for STATCOM to achieve fast dynamic response.

The paper is organized as fallows. The Section II introduces the power quality standards, issues and its consequences of wind turbine. The Section III introduces the grid coordination rule for grid quality limits. The Section IV describes the topology for power quality improvement. The Sections V, VI, VII describes the control scheme, system performance and conclusion respectively.

II. POWER QUALITY ISSUES AND ITS CONSEQUENCES

2.1. 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. Thus the power fluctuation from wind turbine occurs during continuous operation.

2.2. 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. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution.

2.3. 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.

2.4. Grid Frequency

The grid frequency in India is specified in the range of 47.5–51.5 Hz, for wind farm connection. The wind farm shall able to withstand change in frequency up to 0.5 Hz/s

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The STATCOM based current control voltage source inverter 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. 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. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC) is shown in figure 1.

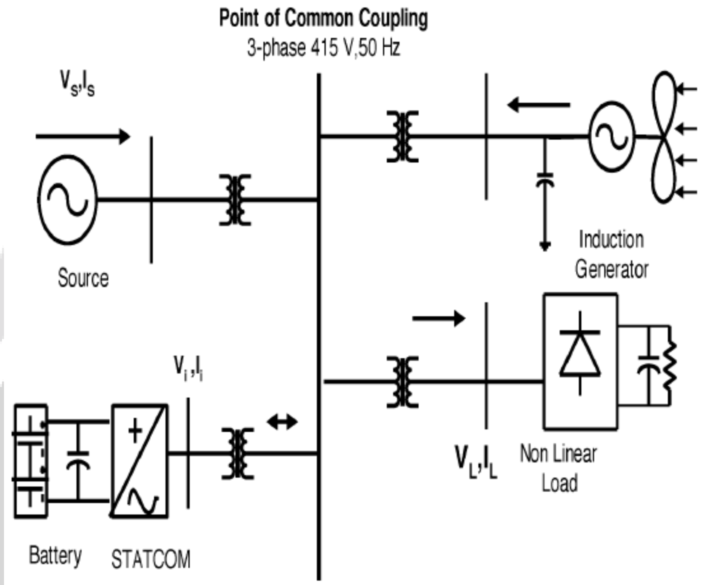

Fig:- 1. Grid connected system for power quality improvement.

3.1 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. The available power of wind energy system is presented as under in (1).

$$P_{\text{wind}} = \frac{1}{2}\rho A V_{\text{wind}}^3 \quad (1)$$

where (kg/m) is the air density and A (m) is the area swept out by turbine blade, is the wind speed in mtr/s. It is not possible to extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient *Cp* of the wind turbine, and is given in (2).

$$P_{\text{mech}} = C_p P_{\text{wind}} \quad (2)$$

where *Cp* is the power coefficient, depends on type and operating condition of wind turbine. This coefficient can be express as a function of tip speed ratio and pitch angle . The mechanical power produce by wind turbine is given in (3)

$$P_{\text{mech}} = \frac{1}{2}\rho \Pi R^2 V_{\text{wind}}^3 C_p \quad (3)$$

Where R is the radius of the blade (m).

3.2 BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also control the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the BESS can be used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM [10]–[14]. The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling.

3.3 System Operation

The shunt connected STATCOM with battery energy storage is connected with the interface of the induction generator and non-linear load at the PCC in the grid system. The STATCOM compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system. The current control strategy is included in the control scheme that defines the functional operation of the STATCOM compensator in the power 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 Figure. 2.

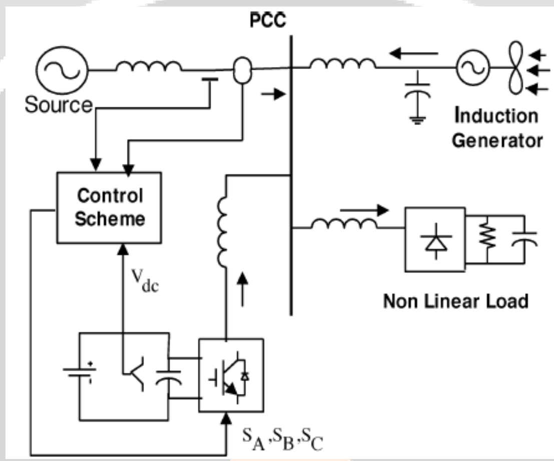

Fig:- 2 System operational scheme in grid system.

IV. CONTROL SCHEME

4.1 Grid Synchronization

In three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltage (*Vsa, Vsb, Vsc*) and is expressed, as sample template Vsm, sampled peak voltage, as in (4).

$$V_{\rm sm} = \left\{ \frac{2}{3} \left(V_{\rm sa}^2 + V_{\rm sb}^2 + V_{\rm sc}^2 \right) \right\}^{1/2} \tag{4}$$

The in-phase unit vectors are obtained from AC source—phase voltage and the RMS value of unit vector as shown in (5).

$$u_{\rm sa} = \frac{V_{\rm Sa}}{V_{\rm sm}}, \quad u_{\rm sb} = \frac{V_{\rm Sb}}{V_{\rm sm}}, \quad u_{\rm sc} = \frac{V_{\rm Sc}}{V_{\rm sm}} \tag{5}$$

The in-phase generated reference currents are derived using in-phase unit voltage template as, in (6)

$$i_{\rm Sa}^* = I.u_{\rm Sa}, \quad i_{\rm Sb}^* = I.u_{\rm Sb}, \quad i_{\rm Sc}^* = I.u_{\rm Sc} \tag{6}$$

Where *I* is proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal. The unit vectors implement the important function in the grid connection for the synchronization for STATCOM. This method is simple, robust and favorable as compared with other methods.

The control scheme approach is based on injecting the currents into the grid using “bang-bang controller.” The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation. The control system scheme for generating the switching signals to the STATCOM.

The control system scheme for generating the switching signals to the STATCOM is shown in Fig. 3. The control algorithm needs the measurements of several variables such as three-phase source current , DC voltage , inverter current with the help of sensor. The current control block, receives an input of reference current and actual current are subtracted so as to activate the operation of STATCOM in current control mode.

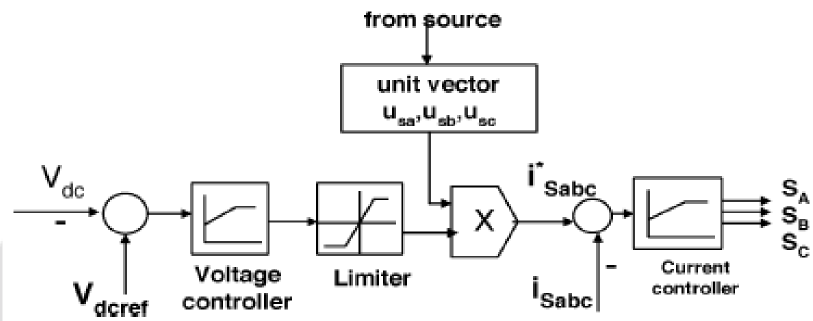

Fig:- 3. control system scheme

4.2 Bang-Bang Current Controller

Bang-Bang current controller is implemented in the current control scheme. The reference current is generated and actual current are detected by current sensors and are subtracted for obtaining a current error for a hysteresis based bang-bang controller. Thus the ON/OFF switching signals for IGBT of STATCOM are derived from hysteresis controlled.

4.3 STATCOM—Performance under Load Variations

The wind energy generating system is connected with grid having the nonlinear load. The performance of the system is measured by switching the STATCOM at time s in the system and how the STATCOM responds to the step change command for increase in additional load at 1.0 s is shown in the simulation. When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate for reactive demand as well as harmonic current. The dynamic performance is also carried out by step change in a load, when applied at 1.0 s. This additional demand is fulfill by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The result of source current, load current are shown in Fig. 6(a) and (b) respectively. While the results of injected current from STATCOM are shown in Fig. 6(c) and the generated current from wind generator at PCC are depicted in Fig.

V. SYSTEM PERFORMANCE

The proposed control scheme is simulated using SIMULINK in power system block set. The system parameter for given system is given Table I. The system performance of proposed system under dynamic condition is also presented.

TABLE I
SYSTEM PARAMETERS

S.N.	Parameters	Ratings
1	Grid Voltage	3-phase ,415V,50 Hz
2	Induction Motor/Generator	3.35 kVA,415V, 50 Hz, P = 4, Speed = 1440 rpm, Rs = 0.01Ω, Rr=0.015Ω,Ls =0.06H,Lr=0.06H
3	Line Series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage = 800V, DC link Capacitance = 100 μF. Switching frequency = 2 kHz,
5	IGBT Rating	Collector Voltage =1200V, Forward Current =50A,Gate voltage =20V, Power dissipation = 310W
6	Load Parameter	Non-linear Load 25kW.

5.1 Voltage Source Current Control—Inverter Operation

The three phase injected current into the grid from STATCOM will cancel out the distortion caused by the nonlinear load and wind generator. The IGBT based three-phase inverter is connected to grid through the transformer. The generation of switching signals from reference current is simulated within hysteresis band of 0.08. The choice of narrow hysteresis band switching in the system improves the current quality. The choice of the current band depends on the operating voltage and the interfacing transformer impedance. The compensated current for the nonlinear load and demanded reactive power is provided by the inverter. The real power transfer from the batteries is also supported by the controller of this inverter. The three phase inverter injected current are shown in Fig:- 4.

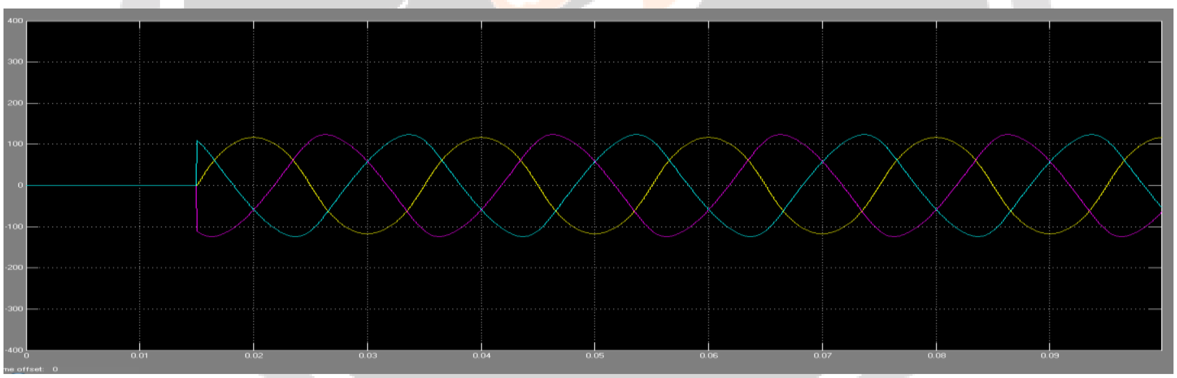

Fig:- 4.Three phase injected inverter current

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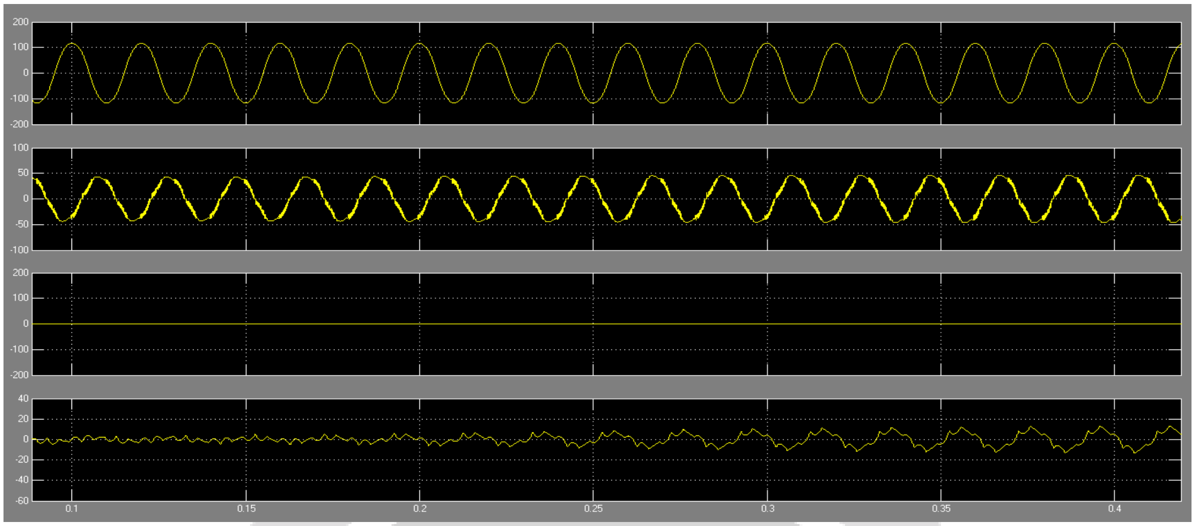

Fig:- 5.A)source current, B) load current, C) Inverter injected current, D)wind generator current.

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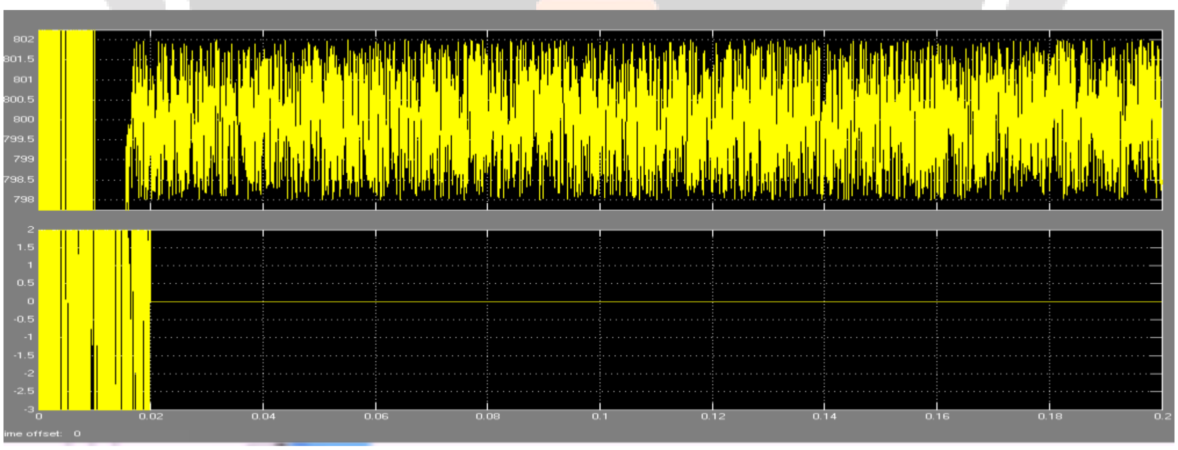

Fig:- 6.a) DC link b) Current through capacitor.

5.3 Power Quality Improvement

It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system. The inverter output voltage under STATCOM operation with load variation is shown in Fig. 7. The dynamic load does affect the inverter output voltage. The source current with and without STATCOM operation is shown in Fig. 8. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation. The current waveform before and after the STATCOM operation is analyzed. The power quality improvement is observed at point of common coupling, when the controller is in ON condition.

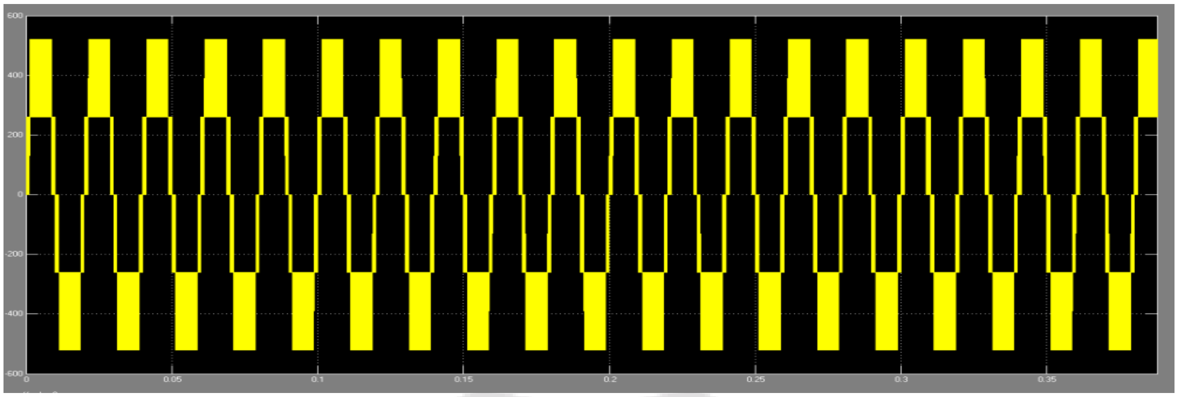

Fig:- 7.STATCOM Output voltage

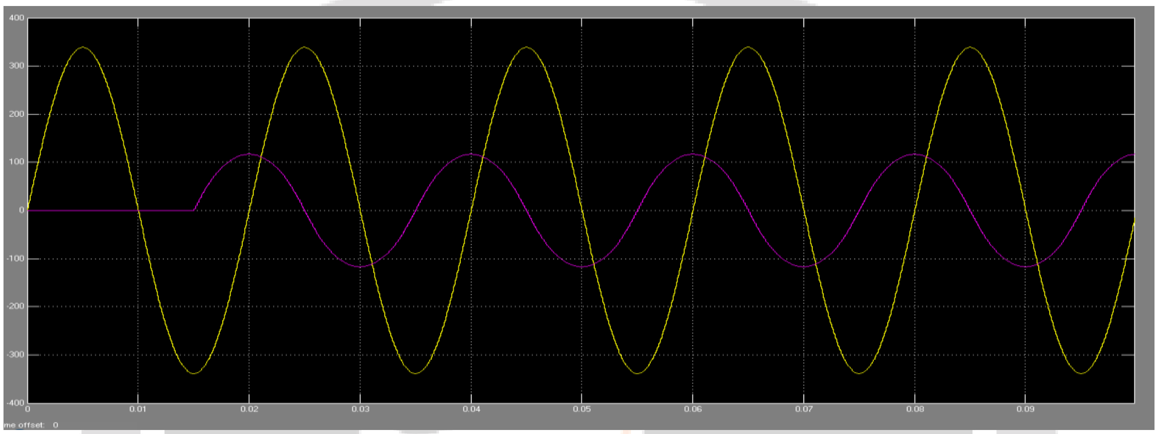

Fig:- 8.Supply Voltage and Current at PCC.

VI. CONCLUSION

The paper presents the STATCOM-based 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 power quality can be improved by connecting STATCOM system. The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and STATCOM with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

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