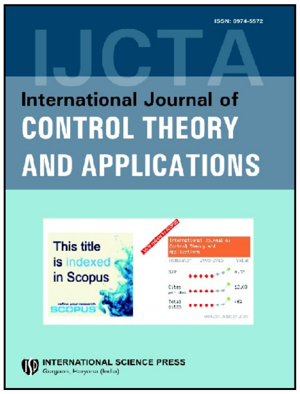

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Statcom Controlled Grid Connected Wind Generated System for Improvement in Power Quality

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Abstract: This paper presents the power quality issue with establishment of wind turbine to the grid. In this methodology a STATCOM is associated with BESS at PCC to attenuate power quality issues, by using MATLAB/SIMULINK software. The power quality improvement has been done with this compensator control method for grid associated wind generating system. In this paper a cascaded current –voltage control technique is used for inverters to enhance the power quality of inverter load voltage and the current exchanging with the networks. The results are empowering.

Key words: Power quality, voltage source inverter, point of common coupling (PCC), battery energy storage system (BESS).

1. INTRODUCTION

In present day scenario, nonconventional energy sources like hydro, wind, biomass etc., are the sources to meet the increased load. For economical strategy, the energy preservation and utilization nonconventional source are important and need to integrate the power system to the renewable energy system reduce atmospheric burden on standard plant. The process of integrating the wind energy system to the power system affects parameters like voltage regulation, strength, problems of power supply. Power quality is an important parameter to the customer affected by transmission and distribution network. Maintaining power quality is an important issue for wind turbine.

In recent years wind energy system is widely used to generate power. The units individually rated up to 2MW, connected nearly to the customer that is at the distribution side. At present period of time 28,000and above wind turbines are operating promisingly. For constant speed the changes in wind velocity are transferred as mechanical torque, electrical power on the grid so causes fluctuation in the voltage. Under the normal operation, it offers continuously changeable power output. This effects the turbulence, wind shear, tower-shadow in power system.

Hence, power system has to withstand such variations. Power quality issues can be represented as wind generation, transmission and distribution network like voltage sag, voltage swells, harmonic flickers etc. Wind generators creates disturbance in distribution system. One of the easy method to run a wind turbine is, by using an induction generator which is integrated to grid. The advantages of Induction generator are cost effective, robustness, but it requires reactive power magnetisation. The terminal voltage and absorbed reactive power of an induction generator are changed due to wind. So a proper control method is needed to control the active power production. For this grid disturbances BESS is involved to compensate variations generated by the wind turbine. For improving the power quality a new technique i.e. STATCOM based technology is proposed to manage the power level. The objective of this technology is

- Source side we can maintain unity power factor.
- To wind generator and load reactive power should be from STATCOM.
- Fast dynamic response for STATCOM achieve by Simple bang-bang controller.

2. MODELLING OF STATCOM

STATCOM is solid state power converted brand of SVC. The output currents of inductor or capacitor are managed separately from its alternating voltage. When operating as shunt connected SVC, STATCOM provides faster response for a sudden change in the system because of fast switching power converter. Also changes in system voltage STATCOM reacts effectively desired response as the capacitor will not allow sudden voltage changes.

2.1. Construction of STATCOM

Fundamentally, STATCOM involved three primary parts, a voltage source converter (VSC), a step up coupling transformer, and a controller.

The leakage inductance of step up transformer operates as coupling reactors in very high voltage system. The current harmonics are filter by coupling inverters, generated by the fluctuating voltage output of the power converter.

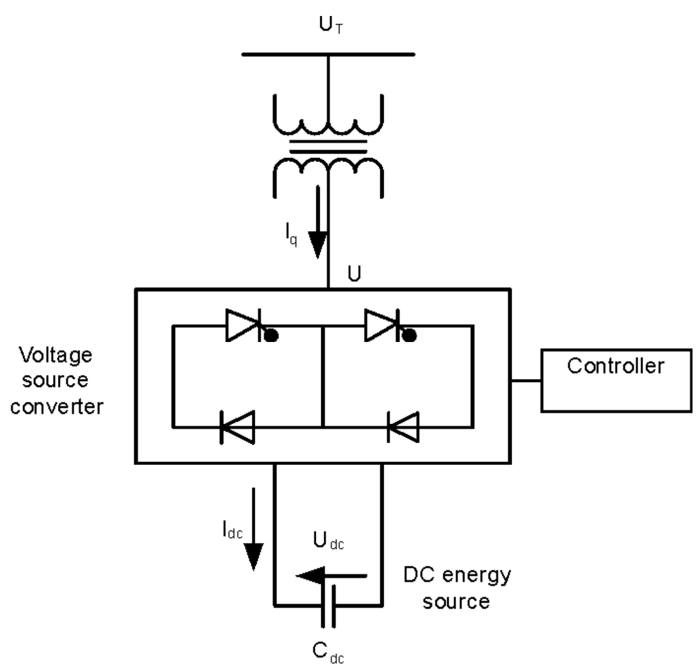

Figure 1: Generation of reactive power using STATCOM

2.2. Statcom Control

The converter voltage and line voltage phase angle is adjusted as well as synchronised to operate the converter by controller of a STATCOM which create or ingest desired VAR at point of common coupling. The Thevenin reactance, STATCOM and tie reactance connected with voltage source are shown in fig4.

2.3. Two Modes of Operations

STATCOM has two modes of operations Inductive mode and capacitive mode. When the transmission line voltage is lesser than the converter voltage capacitive reactance is used to connect compensator. Hence in system point of view STATCOM works in capacitive mode. If the converter voltage is beneath the system voltage if connected through inductive acts as inductive mode.

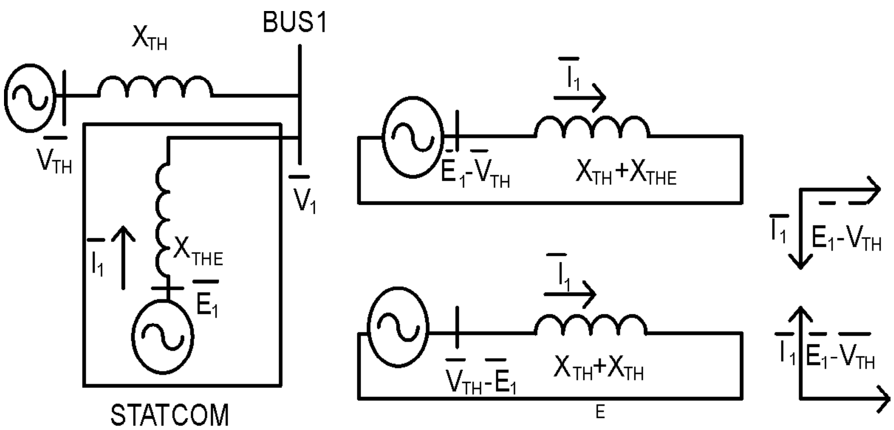

Figure 2: STATCOM operations

2.3.1. Current Control

The below figure demonstrates the block diagram of reactive current control of the STATCOM. The reference angle θ and phase of line voltage are calculated by using three phase set of instantaneous line voltages. The calculated three phase converter currents i_1 divided into two components, absolute component i_{1d} and quadrature component i_{1q} respectively. An immediate measured three-phase set converter currents, i1, is deteriorated into

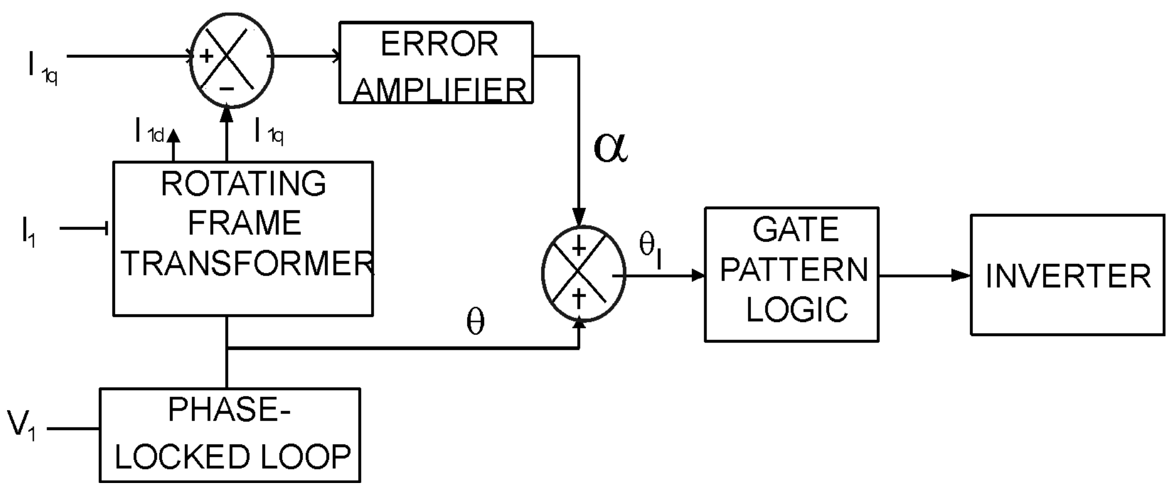

Figure 3: Current controlled block diagram of STATCOM

genuine component, I1d, and reactive segment, I1q, respectively. The required reference value I_{1q}* is compared by quadrature component I_{1q} the error which is generated by comparison is passed through an amplifier. The relative angle α for the converter voltage is determined with respect to voltage of the transmission line. The phase locked loop angle and relative angle are added to get phase angle$_1$. The reference quadratic component I_{1q} is positive when the capacitor evaluates inductive reactance. The reference quadrature component I_{1q} is negative when the compensator evaluates capacitive reactance. According to the converter voltage, V_{DC} is adjusted. Irrespective of line voltage the reactive current flow through the STATCOM is controlled by the inner control loop.

2.3.2. Voltage Control

Outer voltage loop regulates the line voltage. Inner current control loop for reference reactive current is determined outer voltage control loop which regulates the line voltage.

Voltage control of STATCOM is shown below. V1 at bus1 which is decomposed into genuine component V_{1d} and reactive componentV_{1q} are correlated for desired reference value which gives an error. The reference current for inner current control loop is by error amplifier when the error is passed through it. The allowable voltage error at the rated reactive current flow at the STATCOM, is known as $K_{droop.}$

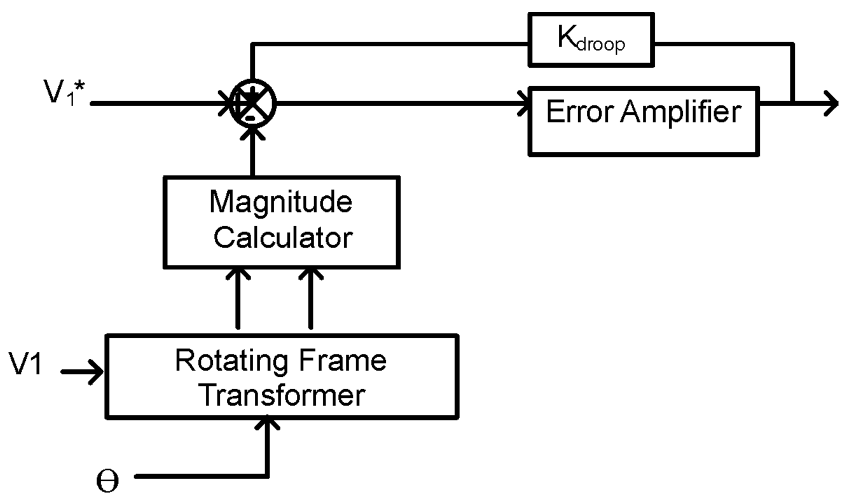

Figure 4: STATCOM Voltage controlled block diagram

The source currents are harmonic free when current control VSI injects current into grid. As a result it has a desired value with respect to source voltage.

Reactive component as well as harmonic component of load and induction generator current will compensate the injected current, along these lines it enhances the power quality. For the inverter, voltages of grid are detected and synchronized by creating current command. At PPC the improvement of power quality is implemented by grid connected system. The grid associated system comprises wind energy generation system and BESS with STATCOM.

3. WIND ENERGY ENGENDERING SYSTEM

In this structure, wind generating system has constant speed topologies with pitch control turbine. The main asset of the Induction generator is no need of field circuit but run for variable constant loads.This is the reason to adopt induction generator in this proposed scheme. And it has a natural protection against short circuit. The below equation describes the power of the system. $P_{wind} = 1/2 \rho A V^3_{wind}$

Where p (kilogram/meter) is density of air, A (meter 2) is area under turbine blade, V_{wind} is speed of turbine in metre/s. It unrealistic excerpt brisk energy, consequently separates small amount of wind.

$$P_{mech} = C_p P_{wind}$$

Where Cp is coefficient of power, relies upon working and type of wind turbine. It express as an element of pitch angle and edge speed proportion. The power deliver by wind turbine is given.

$$P_{mech} = 1/2\rho\pi R^2 V^3_{wind} C_p$$

R is the ambit of the blade (m)

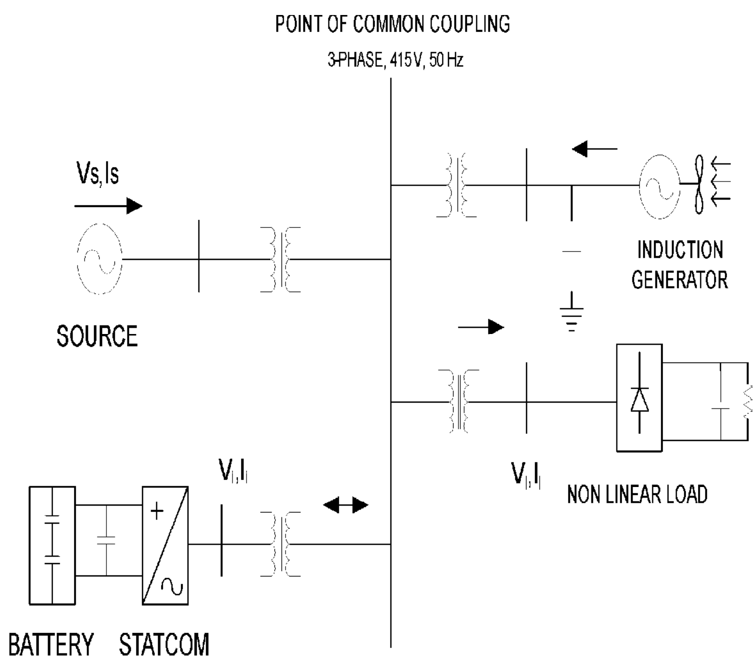

Figure 5: Improvement in power quality for grid connected system

4. BESS-STATCOM

To control the voltage there is a need of storage element so we use a Battery energy storage system. Normally it has a dc capacitor. It injects a constant voltage so it is well suited for STSTCOM it will easily introduce or take in reactive power into grid connected system. Battery energy storage system also has the capability to command the transmission and distribution system in a quick rate. The battery energy storage system has two operations that is charging and discharging operations by these operations by these operations the power fluctuations are compensated. DC capacitor of the STATCOM is connected in shunt with the battery. At PCC, STATCOM is connected which consist of three phase voltage source inverter having the capacitance at its DC link which injects the variable magnitude current and frequency component.

5. SYSTEM OPERATION

In grid at PCC STATCOM with BESS is associated with incorporate of nonlinear load and induction generator. To maintain power quality of grid network the output of STATCOM is differed by proposed control methodology. The current control procedure is incorporated into control scheme that characterizes the practical operation of compensator in the power system.

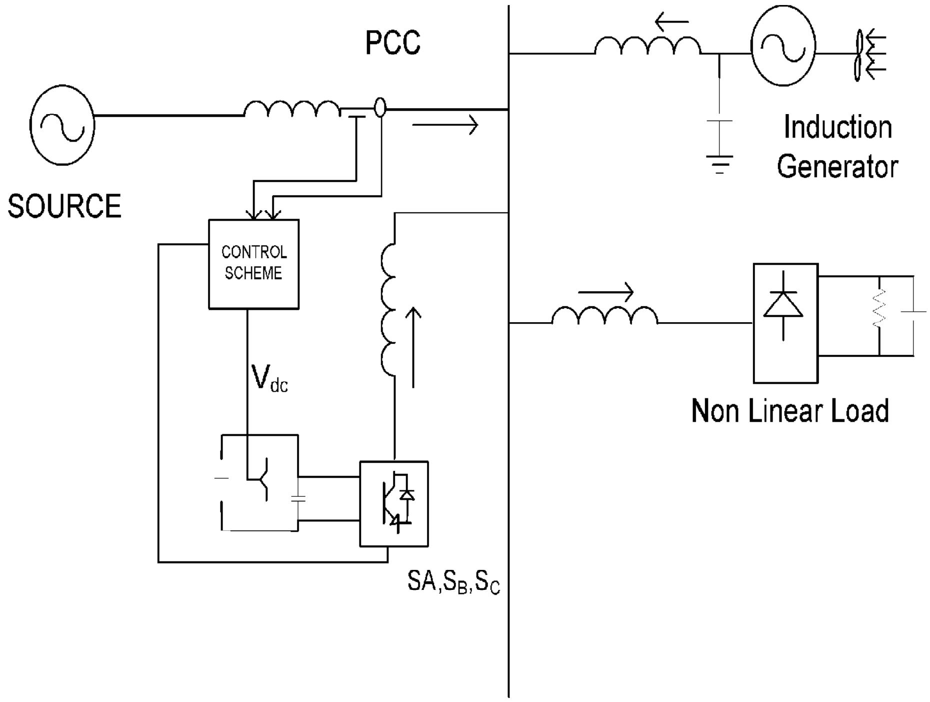

Figure 6: Operation scheme of grid system

In the network it is necessary to support the reactive power for that purpose. A STATCOM utilizing insulated gate bipolar transistor has placed. The above figure represents the main block diagram.

5.1. Control Scheme

Hysteresis current control technique is used by Bang-Bang controller. In order to infuse the currents into the grid in control scheme approach this technique helps in varying the control system between hysteresis area boundaries and giving switching signals correctly for operation of compensator.

The below figure shows the control scheme of generating the switching signals to the STATCOM.

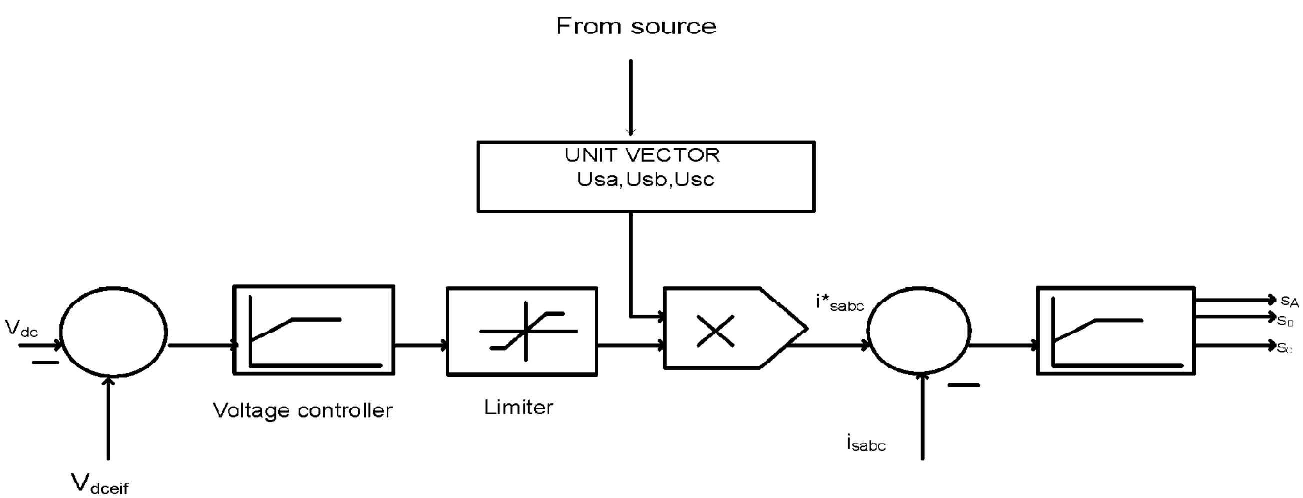

Figure 7: Control scheme strategy

The command algorithm require the estimations of a few factors, three-stage source current isabc, DC voltage Vdc, inverter current isabc with aid of sensor. To active current control mode controller subtracts the real current from reference current which is input of controller.

5.2. Grid Synchronization

At sampling frequency voltage source amplitude is calculated from source voltage is expressed as Vfa, Vfb, Vfc.

$$V_{sf} = \{2/3(V_{fa}^{2} + V_{fb}^{2} + V_{fc}^{2})\}^{½} \quad 6.1$$

The RMS value of unit vector from source voltage are obtained from in phase unit vector as

$$U_{a}= V_{fa}/V_{sf}, U_{b} =V_{fb}/V_{sf}, U_{c}= V_{fc}/V_{sf} \quad 6.2$$

By using in-phase unit voltage template, generated reference currents are derived as shown below equation

$$i^*_{a}= I.U_{a}, i^*_{b}= I.U_{b}, i^*_{c} = I.U_{c} \quad 6.3$$

Where I is proportional to significance of source voltage at particular phases this confirm the source current is regulated to be sinusoidal. Important function in grid connection for synchronization is incremented by unit vector for compensator. When compared with other methods this is great, straightforward and powerful.

5.3. Bang-Bang Current Controller

It is actualized in current control scheme. The source current is created as 6.2. For a bang -bang controller real current is recognized by current sensors and subtracted from current error.In this manner the changing signals for IGBT of STATCOM are gotten from hysteresis controller.

The function of switching Sa for phase 'a' is expressed as

$$I_{sa}< (i_{sa}^* - HB) \rightarrow SA = 0 \quad 6.4$$

$$I_{sa}> (i_{sa}^* - HB) \rightarrow SA = 1 \quad 6.5$$

Thefunction of switching can be derived from phases "c" and "b" where HB is a hysteresis current-band.

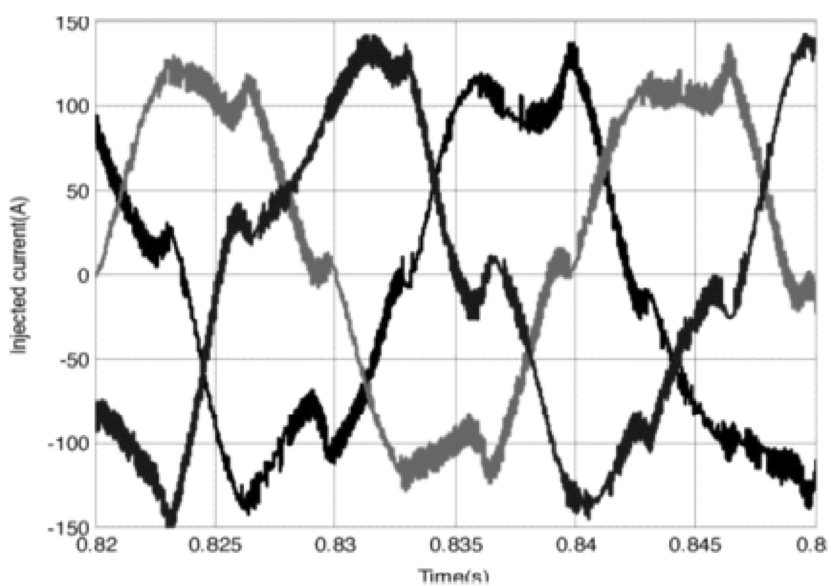

Figure 8: Inverter current for three phase

5.4. Load Variations and Statcom Performances

The generating system of wind energy is associated with network having non direct load. Switching time t=0.7s is obtained from performance of the system and how compensator reacts to convert command for increment in extra load at 1.0 s is appeared in the simulation. When compensator is ON, without changes at different +load condition parameters, it begins to moderate for harmonic current as well as reactive demand. This performance is additionally carried by change in load, when connected at 1.0 s. The available real power is controlled by the compensator. The result are shown below.

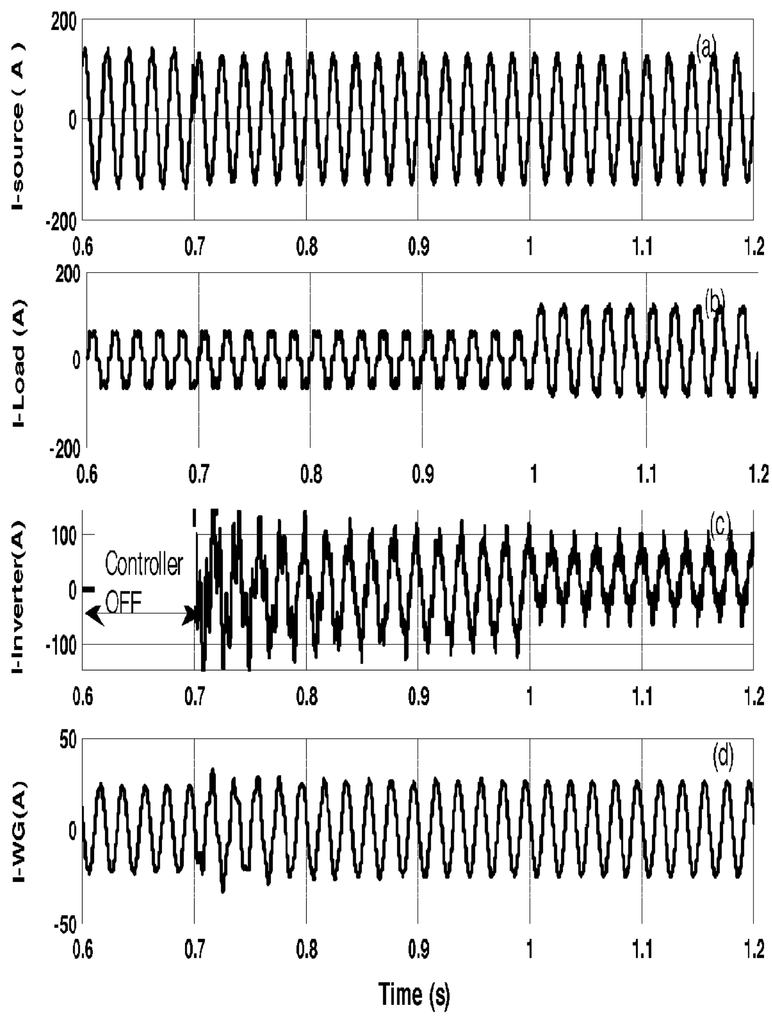

Figure 9: (a) Supply Current.(b) Load Current.(c) Inverter Injected Current. (d)Wind generator (Induction generator) Current

The DC link voltage across the capacitor is constant as(a).The charging and discharging operation of the dc link capacitor through the currents as shown in below figure.

5.5. Improvement of Power Quality

The nonlinear load change the purity of waveform on both sides of network. With variations of load the output voltage of inverter under operation of compensator is shown in figure 11. The output voltage of inverter is caused by dynamic load. The STATCOM operation with and without supply current is shown in Fig.12.

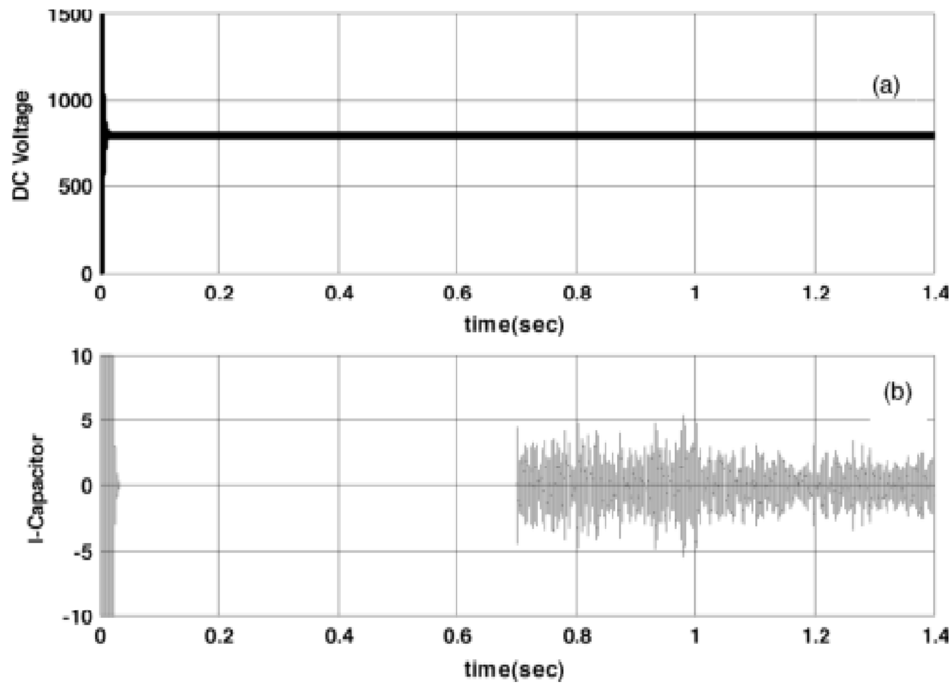

Figure 10: (a) DC channel voltage. (b) Capacitor current

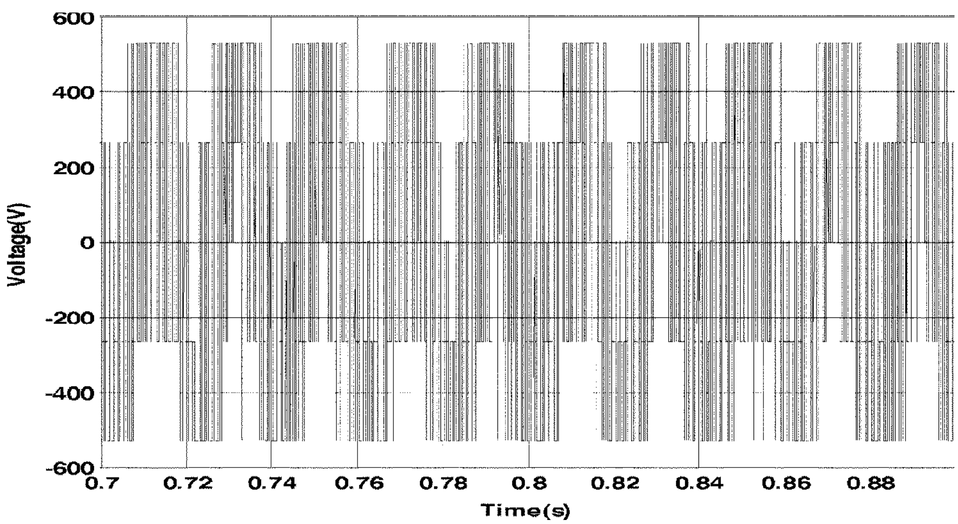

Figure 11: Output voltage of STATCOM

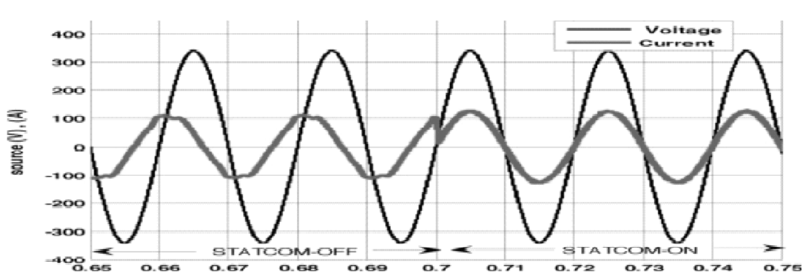

Figure 12: Current PCC and supply voltage

When the STATCOM is in operation the unity power factor component is maintained from supply power. Without STATCOM the THD of supply current is 4.71% at PCC appeared below.

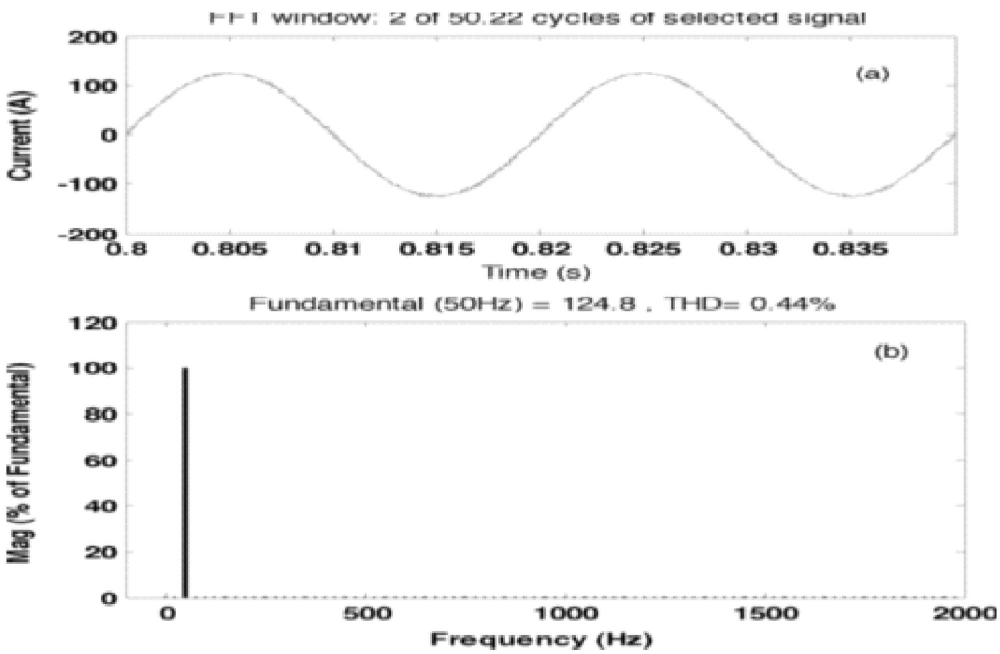

Figure 13: (a) Supply Current. (b)Source current of FFT

When the controller is in ON condition, power quality change is seen at PCC. When the controller is set to operation at 0.7 s then the source current waveform is appeared as shown in above fig. with its FFT,THD.

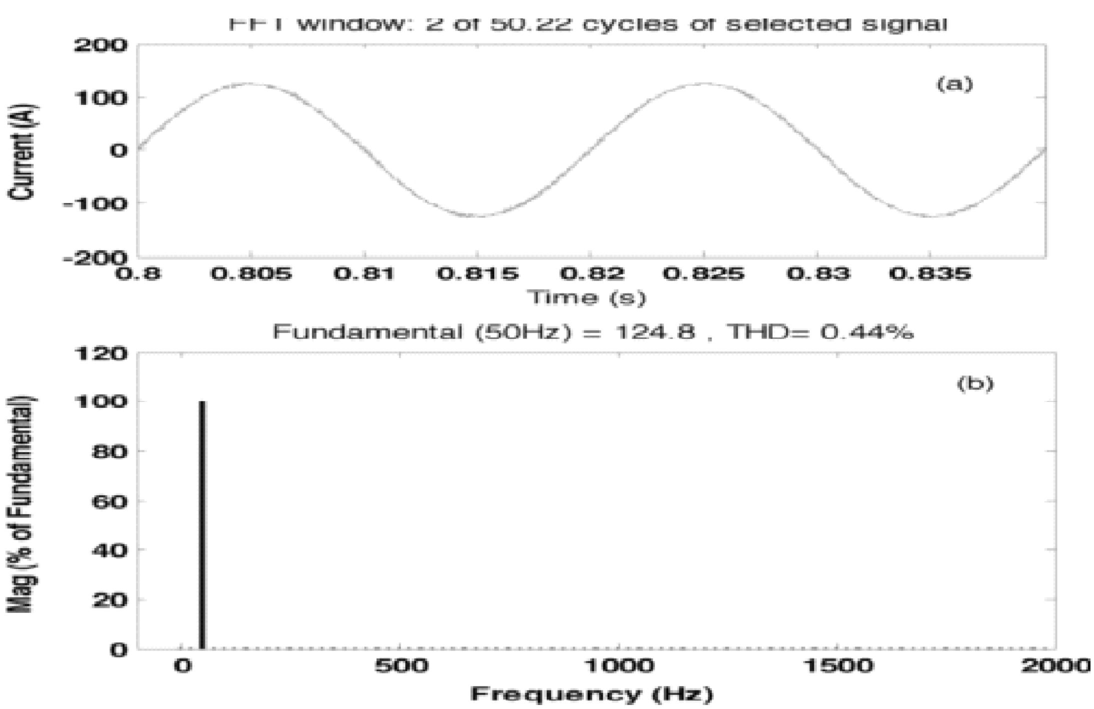

Figure 14: (a) Supply Current. (b)Supply current of FFT

The above test have sustain capability with energy storage through batteries to support the load along with the power quality improvement.

6. CONCLUSION

This paper presents a STATCOM based control strategy in grid connected wind generating system for improving power quality. Electrical utility and consequences of power quality issues are explained. STATCOM is capable of cancelling out the harmonic parts of load current. It not only supports reactive power demand for wind generator and the load at the PCC in grid system but also maintains source voltage and current in phase in order to improve the utilization of transmission line. Outstanding performance of integrated wind generation and STATCOM with BESS has been proved. This proposed method is analysed by using MATLAB/SIMULINK software.

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