Statcom Based Development Of Power Quality Of Grid Connected Wind Energy System

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Abstract - The renewable energy resources like wind, solar, hydro, biomass etc. are required for sustainable growth and social progress, it is essential to meet the energy need by utilizing the renewable energy resources. The necessity of integrated renewable energy like wind energy into the power system is to make it possible to minimize the environmental impacts. This project proposes the STATCOM control scheme for grid connected wind energy system for power quality enhancement. A bang-bang controller which is based on hysteresis current control scheme is developed for STATCOM. STATCOM is connected at a point of common coupling (PCC) to mitigate the power quality problems. The STATCOM control scheme applied for the grid connected wind energy generation system (WEGS) used for enhancement of power quality is simulated using MATLAB/SIMULINK in power system block set. This proposed scheme assures the enhancement of power quality in a generated output.

IndexTerms- FACTS devices, Power quality issues, STATCOM, Wind turbine, Point of Common Coupling.

I.   INTRODUCTION

To have supportable growth and social progress, it is necessary to fulfill the energy demand by using the renewable energy resources like solar, wind, biomass, hydro, co-generation, etc. in property energy system, energy preservation and therefore the use of renewable source are the important paradigm. The necessity to include the renewable energy like wind energy into power system is to create it potential to minimize the environmental impact on standard power plant [1]. Due to multiplied power demand and environmental concern, wind power generation is immediately growing and wind plants are being integrated to power networks worldwide in massive numbers. Injection of alternative energy into a utility grid results in violation of power quality because of the fluctuating nature of the wind. According to the IEC standard, determination of the power quality is from the performance of wind generators. During this work power quality problem such as voltage variations, flickers, harmonics are demonstrated because of installation of wind turbine with the grid. FACTS devices will be used to overcome these power quality issues. This project proposes the STATCOM control scheme for grid connected wind energy system for power quality improvement. The simulation has been done in MATLAB/Simulink block set. It's

Shown that STATCOM enhances the power quality of power grid consisting induction generator primarily based wind plant [2].
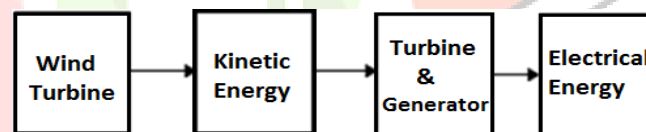

Fig.1.1 Basic Flow diagram of Wind Power Generation

Wind Energy

Wind power is the conversion of wind energy into a useful type of energy, such as using wind turbines to develop electrical power, windmills use for mechanical power, wind pumps use for water pumping or drainage, or sails to propel ships. A wind farm is a pair of wind turbines in the same location used for production of electricity. In a large wind farm have been contain several hundred individual wind turbines, and cover an enlarged area of hundreds of square miles, but the land between the turbines might be used for agricultural or other purposes. A wind farm is also be located offshore

Wind generating system

There are plenty of wind generating turbines are successfully operating all over the world. Into the operation of fixed-speed wind turbine, all fluctuations into the wind speed are transmitted as fluctuations into the mechanical torque, power on the grid side and accelerate large voltage fluctuations. The power quality problems can be observed with concern to the wind generation, transmission and distribution network, like voltage sag, swells, flickers, harmonics etc. but the wind generator introduces disturbances into the distribution network. One among the simple way of running a wind generating system is to use the induction generator (IG) connected directly to the grid system.

II. SIMULINK MODEL OF WIND TURBINE

The Simulink model of the turbine is shown below Fig .2.1. This model is derived from MATLAB/SIMULINLK software in which three inputs are (i) generator speed (ωr_pu) in pu of the nominal speed of this generator, (ii) is pitch angle is in degrees and (iii) is wind speed is in m/s. The tip speed ratio λ is in pu of λ_nom is obtained by the division of the rational speed in per unit of the base rotational speed and the wind speed in pu of the base wind speed. The output is the torque give to the generator shaft. The nominal power of the electrical generator pair with wind turbine in VA. These parameters are used to figure out the output torque in pu of the nominal torque of the generator. The wind speed base value is in m/s, it is used in the per unit system. Mean value of the expected the wind speed is called base wind speed. This base wind speed produces a mechanical power and its value typically lower than the turbine nominal power. Simulink model of Wind Turbine shown in Fig. 2.1
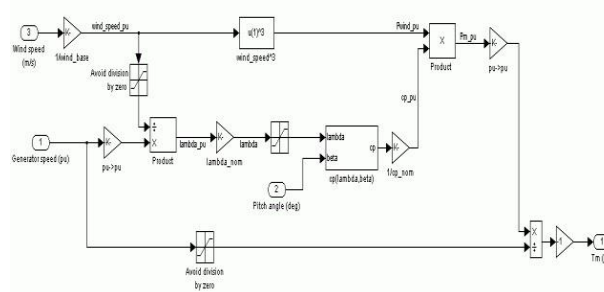

Fig.2.1 Simulink model of Wind Turbine

The model is based on the steady-state power characteristics of the turbine. The stiffness of the drive train is infinite and the friction factor and the inertia of turbine must be combined with those generator coupled to the turbine. The output power of the turbine is given by the following equation.

$$P_m = C_p(\lambda, \beta) \frac{\rho A}{2} v_{wind}^3 \qquad (1)$$

Where Pm is Mechanical o/p power of turbine (W), Cp is Performance coefficient of the turbine, P is Air density (kg/m^2) A is Turbine swept area (m^2), B is Blade pitch angle (deg) and A is Tip speed ratio of the rotor blade tip speed to wind speed.

III. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

International electro technical commission guidelines:

The guidelines area unit provided for measure of power quality of turbine. The International standards are developed by the unit of Technical Committee-88 of the International Electro-technical Commission (IEC), IEC standard 61400-21, describes the procedure for deciding the ability quality characteristics of the turbine [17].

The standard norms are specific.
1) IEC 61400-21: wind turbine generating system, part-21. Measurement and Assessment of power quality characteristic of the 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 limits for fluctuating load IEC 61400-12: wind turbine performance. The information sheet with electrical characteristic of wind turbine provides the base for the utility assessment regarding a grid association.

Voltage Variation

The voltage variation issue results from the wind rate and generator torque. The voltage variation is directly relating to real and reactive power variations. The voltage variation is usually classified as under:

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

The voltage flicker issue describes dynamic variations within the network caused by wind turbine or by variable loads. So the power fluctuation from wind turbine occurs throughout continuous operation. The amplitude of voltage fluctuation depends on grid strength, network resistance, and phase- angle and power issue of the wind turbines

Flicker

Electric power could be a necessary commodity for several industrial, industrial and domestic processes. As a product, electrical power ought to be of an acceptable quality, to confirm the correct behavior of the equipment connected to the power distribution system. The IEC 610002-1 standard classifies low frequency conducted disturbances in the subsequent 5 groups: harmonics and inter harmonics and short provide interruptions, voltage dips, power frequency variations and voltage fluctuations, voltage unbalance, flicker. Voltage fluctuations are outlined as cyclic variations in voltage with amplitude below 100% of the face value. Most of the connected

instrumentation is not tormented by voltage fluctuations, however these fluctuations may cause changes inside the illumination intensity of light sources, known as flicker.
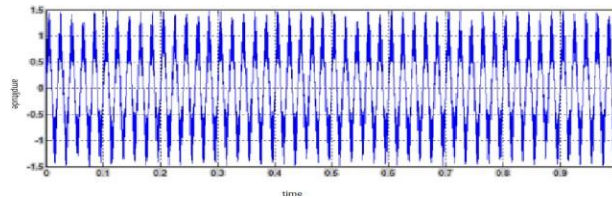

Fig.3.1 Voltage Flicker

IV. SYSTEM CONFIGURATION AND PRINCIPLE OF OPERATION

The Static Synchronous Compensator is principally based current control voltage source inverter (VSI) injects the current into the grid in such the simplest way that the supply current are harmonic free and their phase-angle with respect to supply voltage includes a desired value. The injected current from inverter can eliminate the reactive part and harmonic a part of the non-linear load and induction generator current, so it improves the power factor and therefore the power quality. To accomplish these goals, the grid voltages are perceived and are synchronized in generating the current command for the electrical converter. The projected grid connected system is implemented for power quality improvement at point of common coupling (PCC). The grid connected system shown in Fig.4.1.
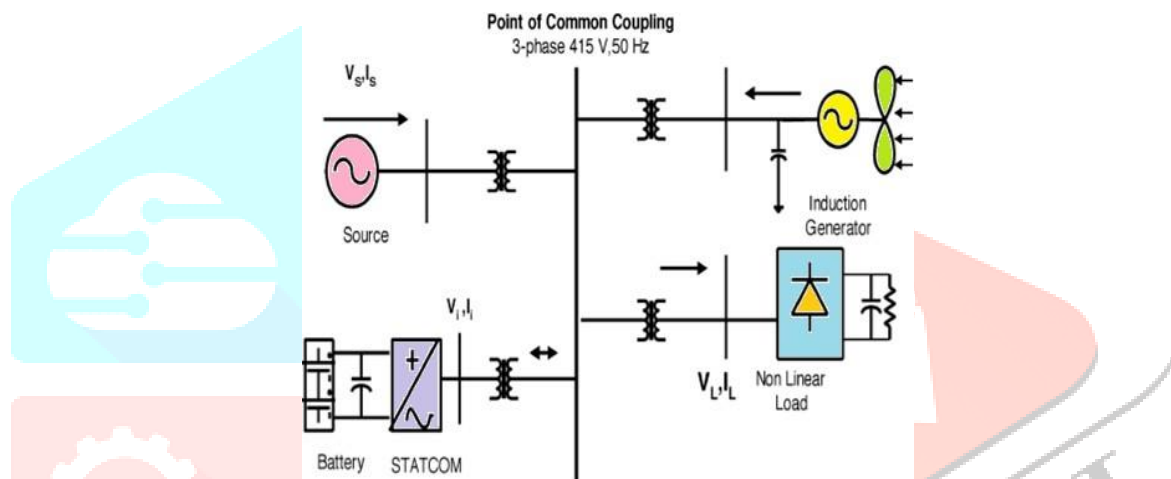

Fig.4.1 Grid Connected Wind Energy System

V. MATLAB/ SIMULINK MODEL OF BANG-BANG CURRENT CONTROLLER

Bang-Bang current controller is enhancement in the current control scheme. The reference current is generated and actual current are detected from the current sensors and are subtracted for obtaining a current error for a hysteresis based on bang-bang controller. Thus the ON/OFF switching signals for the IGBT of STATCOM are derived from the hysteresis controller. The switching function 'Sa' for phase 'a' is expressed as below, Where HB is a hysteresis current- band, similarly the switching function can be derived for phases "b" and "c". Simulink model shown in Fig. 5.1.
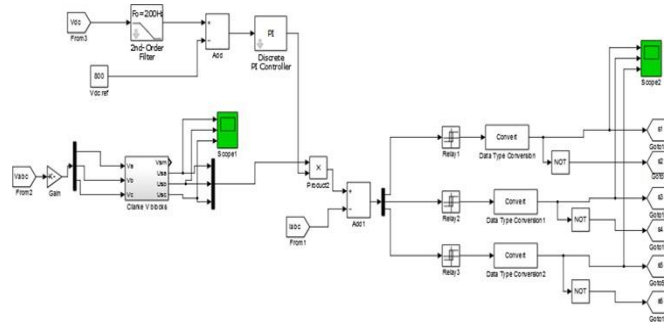
Fig 5.1 SIMULINK model of the proposed Bang-Bang Controller scheme.

VI. CONTROL SCHEME AND ITS RESULT

The STATCOM control scheme is based on injecting the currents into the grid using bang-bang controller. The controller uses a hysteresis current controlled technique. Using this method, the controller maintain the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation. Basically control system scheme for generating the switching signals to the STATCOM is shown in Fig. 6.1. This control algorithm needs to measurements of various variables such as 3 phase source current, DC voltage and the inverter current with the help of sensor. The current control block will receives an input of reference current and actual current are subtracted here for activate the operation of STATCOM in current control mode.
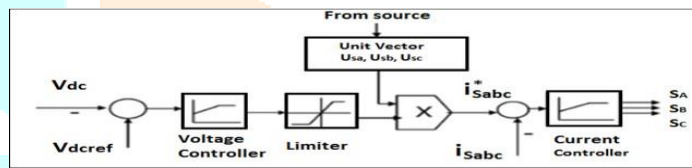

Fig 6.1 Control System Scheme

Grid Synchronization

In to the three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source side phase voltage (Vsabc) and is expressed, as sample template Vsm, sampled peak voltage.

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

In phase unit vectors are access from AC source phase voltage and the RMS value of unit vector as shown below,

$$=u_{sa}\frac{V_{sa}}{V_{sm}}, \qquad =u_{sb}\frac{V_{sb}}{V_{sm}}, \qquad =u_{sc}\frac{V_{sc}}{V_{sm}} \qquad (3)$$

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

$$=i_{sa}^* \quad ,u_{sa}=I.i_{sb}^* \quad ,u_{sb}=I.i_{sc}^* \quad u_{sc} \qquad (4)$$

Here I is proportional to magnitude of filtered source voltage for respective phases. This makes secure that the source current is controlled to be sinusoidal. The unit vectors implement the important function into the grid connection for the synchronization for STATCOM.

The reference current is generated as in equation above and actual current are detected from the current sensors and are subtracted for obtaining a current error for a hysteresis based current controller. Thus the ON/OFF switching signals generated for IGBT of STATCOM are derived from hysteresis controller. The switching function SA for phase "a" is expressed below

When ia< (i*a - HB), SA = 0 When ia> (i*b - HB), SA = 1
Here HB is a hysteresis current band, as well as the switching function SB, SC can be derived for phase b & c.

Principle of STATCOM

The Static Synchronous Compensator (STATCOM) could be a shunt device of the flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids. The STATCOM is regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. Once system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). Once system voltage is high, it absorbs reactive power (STATCOM inductive). In synchronization with the demand to stabilize the voltage of the facility network.

Usually a STATCOM is installed to support electrical networks that have a poor power issue and sometimes poor voltage regulation. The most common use of this device is for voltage stability. Essentially it is a voltage source converter (VSC) based device, with the voltage source behind a reactor. The voltage source is formed from a DC capacitor and therefore the device has little active power capability. However, its active power capability may be increased if a suitable energy storage device is connected across the DC capacitor.
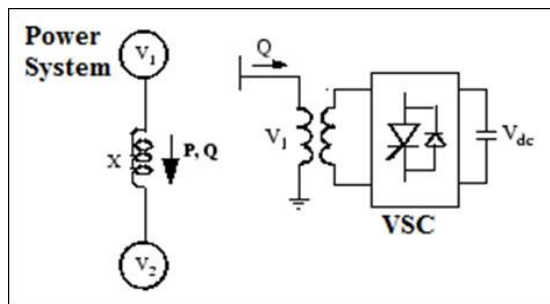
Fig. 6.2 Single line diagram of the STATCOM

VII. SIMULATIONS AND RESULTS

The proposed operational and control scheme simulated using SIMULINK in to power system block set is shown in Fig. 7.1
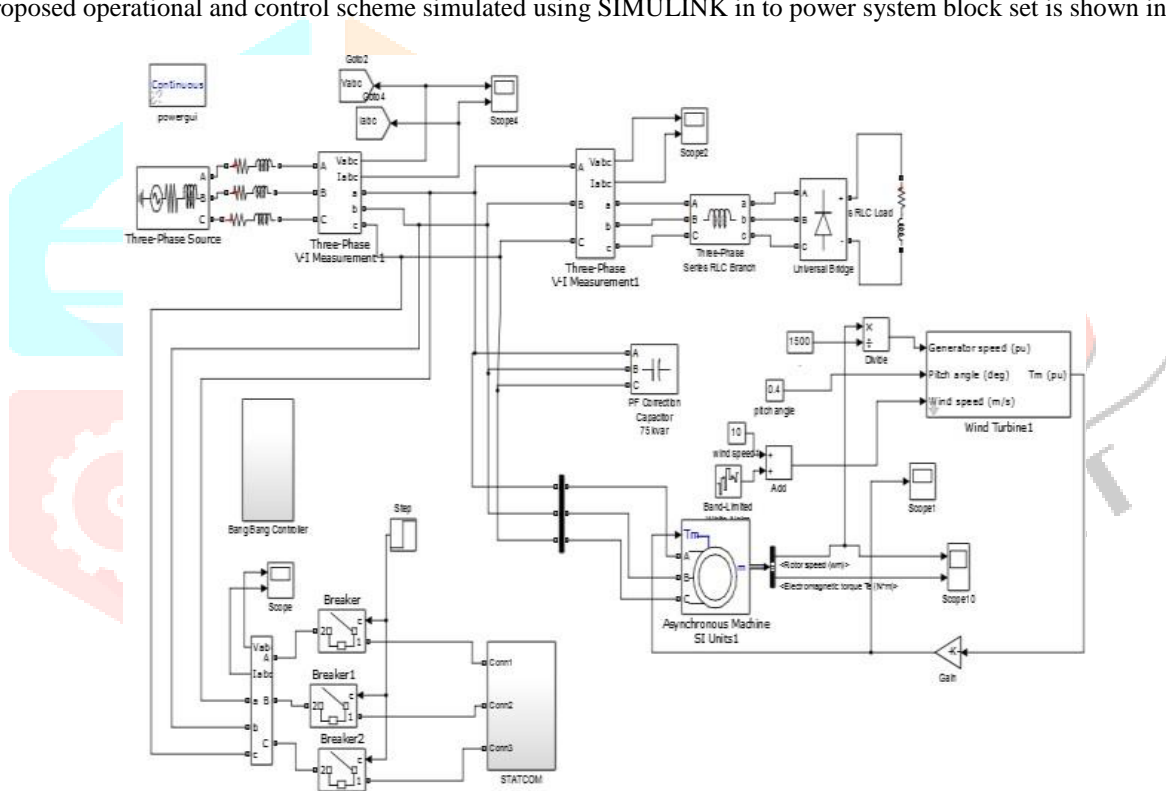

Fig.7.1 SIMULINK model of the proposed operational scheme.
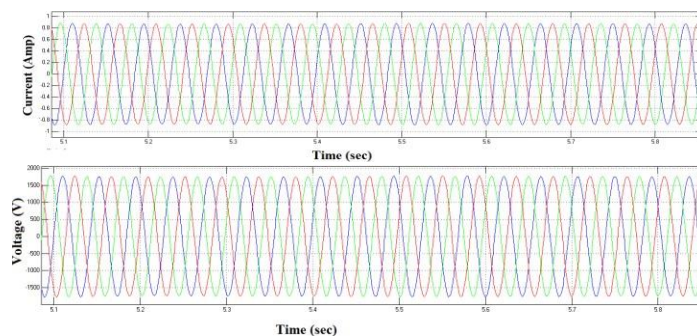
Output waveform with Linear Load and Nonlinear Load
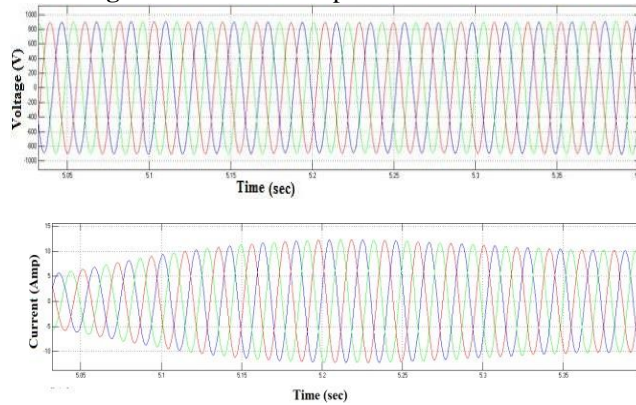
Fig. 7.2 linear load Output Wave form

Fig. 7.3 nonlinear load Output Wave form

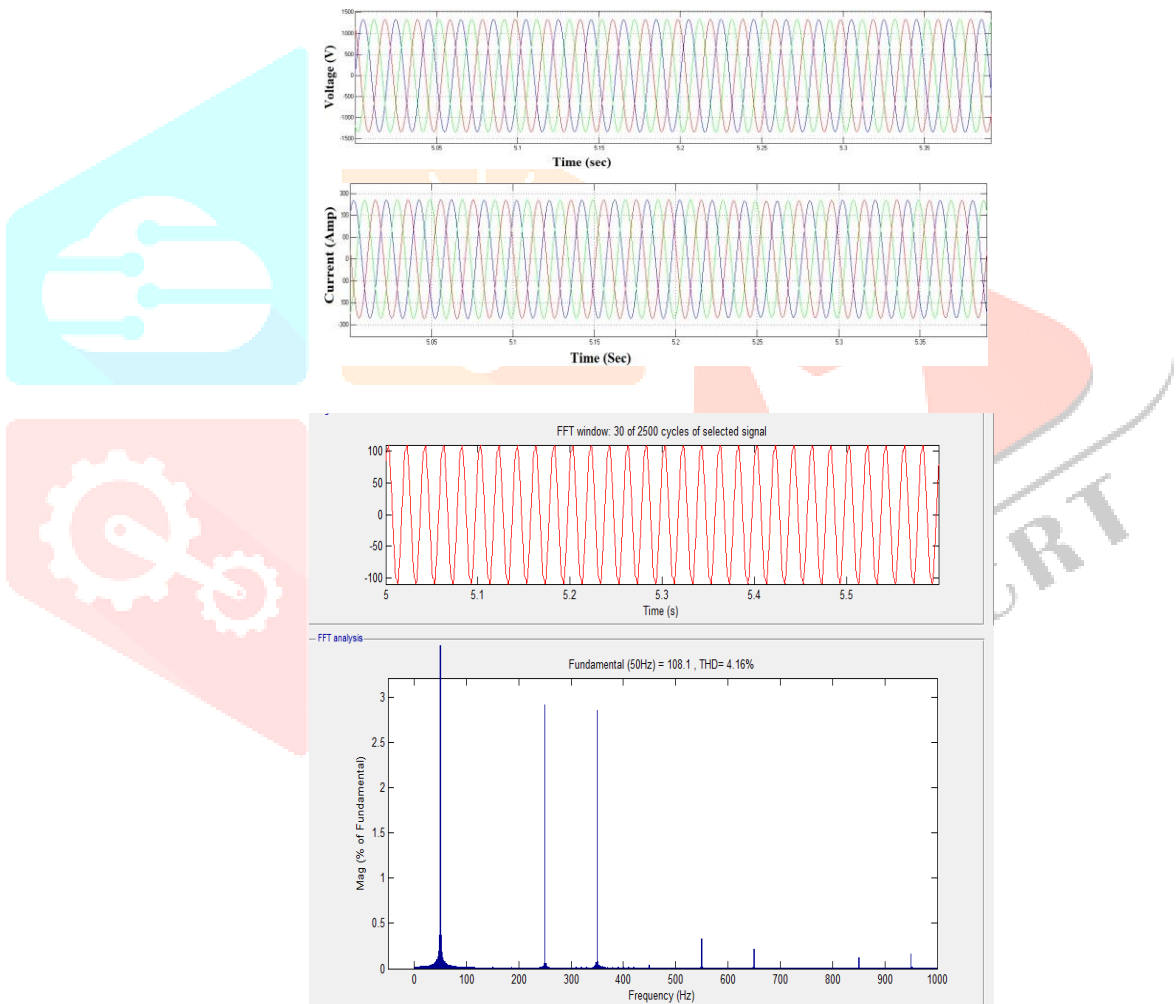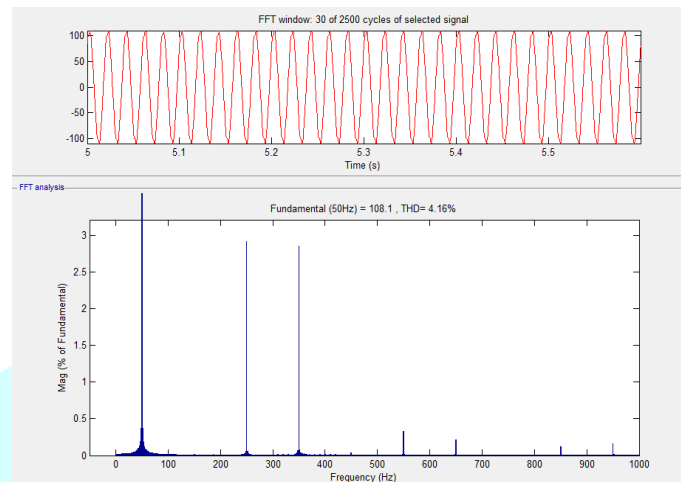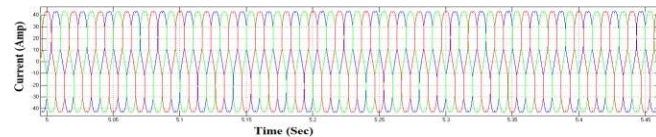## Source and Load side output with STATCOM and its FFT analysis

Fig.7.4 Source side Voltage and current output with STATCOM and its FFT analysis

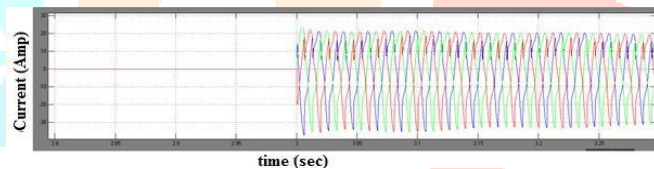**7.5** Load side Voltage and current output with STATCOM and its FFT analysis

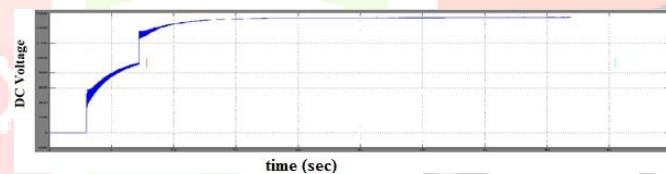
Fig. 7.6 Inverter Injected Current.

Fig. 9.7 DC link voltage

7. CONCLUSIONS

In this paper work the implementation of STATCOM-based control scheme for power quality development in to the grid connected wind generating system with nonlinear load is done. Power quality issues and its consequences on the consumer and electric utility are filtered. The operation of the control system developed for the STATCOM based control scheme as a controller we used Bang-Bang Controller in MATLAB/SIMULINK for maintain the power quality is simulated. It has a capability to cancel out the flicker 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 Point of Common Coupling (PCC) in the grid system, therefore it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and STATCOM with Bang-Bang controller results in mitigation of flicker from generated output.

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