Development of A Novel Control Scheme for Grid Integrated Wind Energy System using FACTS Controller

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Abstract: The need to integrate the renewable energy like wind energy into power system is to minimize the environmental impact on conventional plant. The proposed work demonstrates the power quality problems due to installation of wind turbine with the grid. The Injection of the wind power into an electric grid affects the power quality The performance of the wind turbine and there by power quality are determined on the basis of measurements and the norms followed. The influence of the wind turbine in the grid system concerning the power quality are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behaviour of switching operation etc. In this proposed scheme STATCOM is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated 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.

Keywords: Wind energy, power quality, Facts controller, Grid interconnected system, Hormonics.

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 in sustainable energy system, energy conservation and the use of renewable source are the key paradigm [1]. The integration of wind energy in to existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. 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 [3]. However the wind generator introduces disturbances in to the distribution network. 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 [2]. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has objectives of unity power factor at the source side, reactive power support only from STATCOM to wind generator and load, and simple bang-bang controller for STATCOM to achieve fast dynamic response [4].

II. Power Quality Issues

The quality of power has often been characterized as "clean" or "dirty." Clean power refers to power that has sinusoidal voltage and current without any distortion and operates at the designed magnitude and frequency. Dirty power describes power that has a distorted sinusoidal voltage and current or operates outside the design limits of voltage, current, and/or frequency. Natural and man-made events in the power system provide sources or initiating events that cause clean power to become dirty. Categories of dirty power quality sources include power system events, nonlinear loads, and poor wiring and grounding. In solving power quality problems, the power quality engineer uses classical problem-solving techniques [6].

The power quality characteristics of the disturbance identify the type of power quality problem. The nature of the variation in the basic components of the sine wave, i.e., voltage, current, and frequency, identifies the type of power quality problem [5]. Voltage sags are the most common type of power quality problem. The voltage variation issues results from the wind velocity and generator torque. The voltage variation is directly related to real and reactive power variations. The voltage flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads [11]. Voltage fluctuation, or variation in the voltage at the electrical outlet, can be caused by events at many different points in the power distribution system [7]. Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment has caused harmonics to become more common. Harmonics are integral multiples of the fundamental frequency of the sine wave. Voltage fluctuation, or variation in the voltage at the electrical outlet, can be caused by events at many different points in the power distribution system 9]. Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment has caused harmonics to become more common. Harmonics are integral multiples of the fundamental frequency of the sine wave. Nonlinear loads cause harmonic currents to change from a sinusoidal current to a non-sinusoidal current by drawing short bursts of current each cycle or interrupting the current during a cycle [8]. This causes the sinusoidal current waveform to become distorted. The total distorted wave shape is cumulative. Harmonic currents and voltages have a detrimental effect on utility and end-user equipment. They cause overheating of transformers, power cables, and motors; inadvertent tripping of relays; and incorrect measurement of voltage and current by meters.

III. The Proposed System

The STATCOM is a static compensator used to regulate voltage and to improve dynamic stability. There are some variations of the STATCOM, but the composition of it is basically the same. It is composed of inverters with a capacitor in its dc side, coupling transformers, and a control system. The inverters are in conventional STATCOM, switched with a single pulse per period and the transformers are connected in order to provide harmonic minimization. The studies have shown that the STATCOM has a good performance under balanced conditions but using the conventional control methods it is subjected to oscillations when negative sequence components are present in the AC system. The use of PWM technique brings better “average” voltage, current and power behavior results.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. 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 proposed grid connected system is implemented for power quality improvement at point of common coupling is shown in Fig:1. The grid connected system consists of wind energy generation system and battery energy storage system with STATCOM. 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.

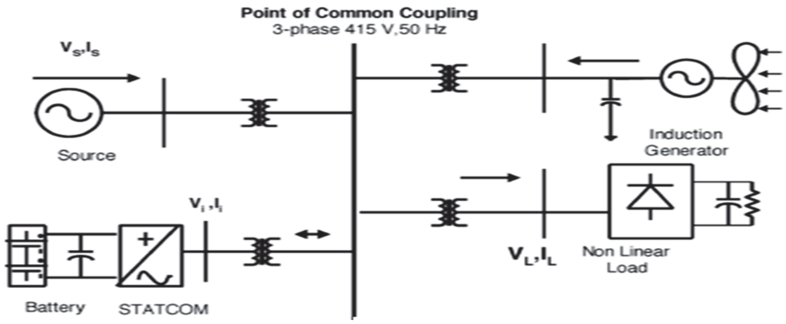

Fig: 1. Grid connected system for power quality improvement.

The shunt connected STATCOM with battery energy storage is connected with the interface of the induction generator and non-linear load at the point of common coupling (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 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.

V. Results and Discussions

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 mat lab simulated main block diagram of the system operational scheme is shown in Fig 2.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 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 simulated three phase inverter injected current are shown in Fig. 3

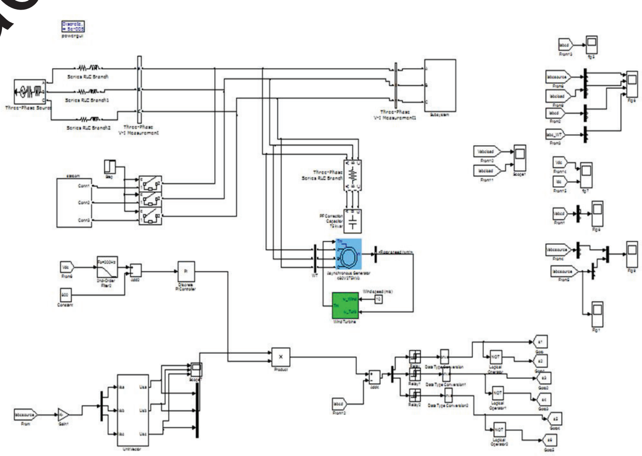

Fig: 2. system operational scheme

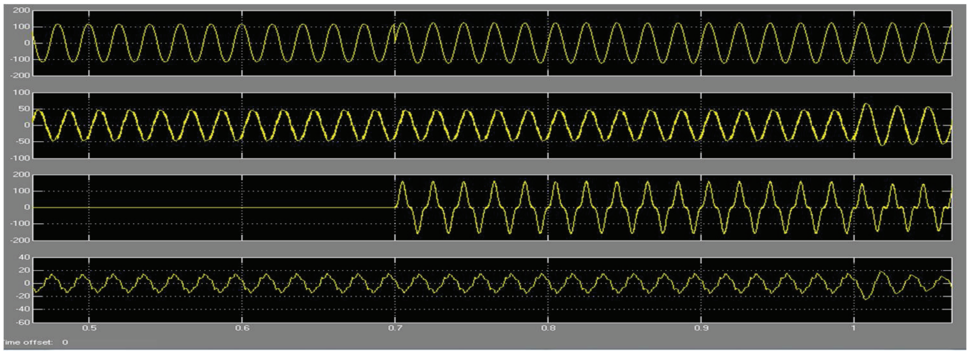

Fig.3 (a) Source Current. (b) Load Current. (c) Inverter Injected Current. (d) Induction generator current.

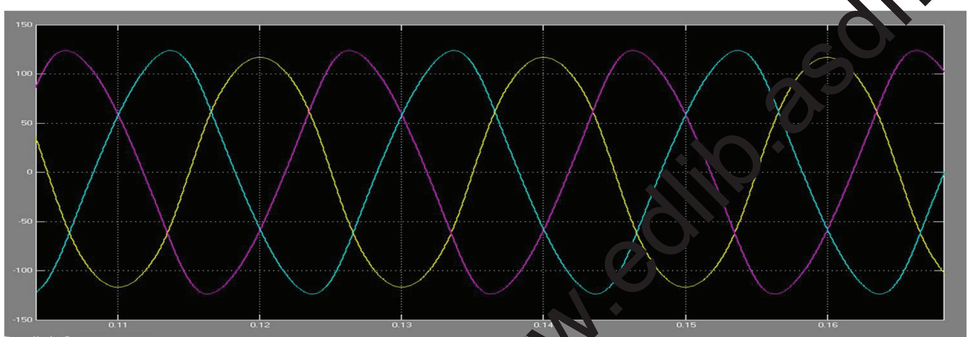

Fig 4. Three phase Source Current

The performance of the system is measured by switching the STATCOM at times in the system and how the STATCOM responds to the step change command for increase in additional load at1.0 s is shown in the simulation.

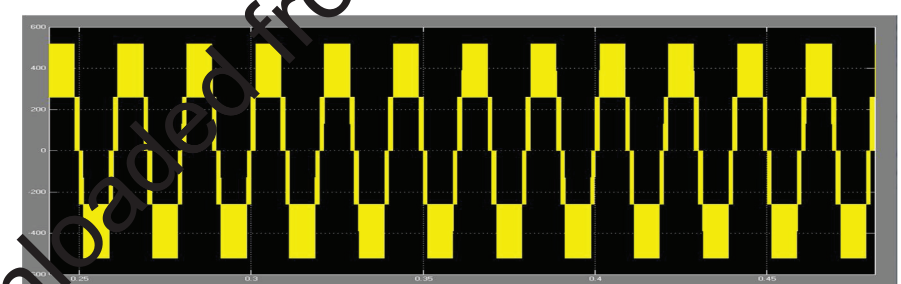

Fig: 5. STATCOM output voltage

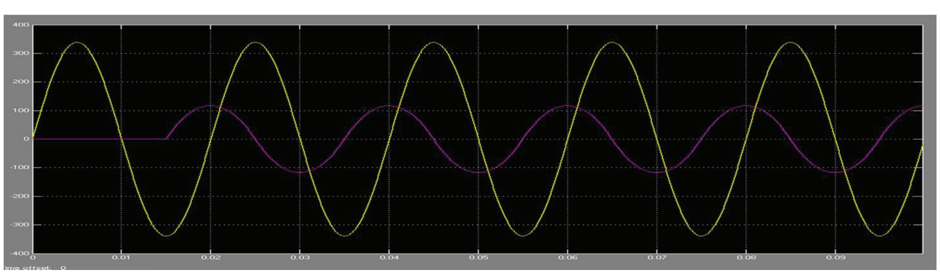

Fig.6. Supply Voltage and Current at PCC.

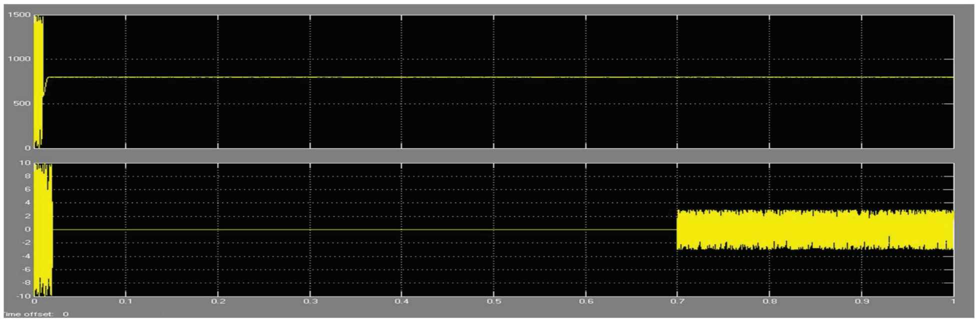

Fig.7. (a) DC link voltage. (b) Current through Capacitor

VI. Conclusion

This 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 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.

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