`POWER QUALITY IMPROVEMENT FOR GRID CONNECTED WIND ENERGY SYSTEM USING STATCOM - CONTROL SCHEME

CH.SHARATH CHANDRA[1]
EMAIL:ch.sharath99@gmail.com

G.SRINIVASA RAO[2]
EMAIL:gundala_247@yahoo.com

Abstract: The renewable energy sources such as wind and solar are considered as promising alternative energy sources. The power from wind varies due to the different environmental conditions. The generated power from renewable energy sources is always fluctuating due to environmental conditions. The power arising out of wind turbine connected to grid system concerning the power quality measurements such as active power, reactive power, voltage sag, voltage swell, harmonics and electrical behavior of switching operations. The power quality problems when wind turbine installed to grid side is demonstrated here. A static Compensator (STATCOM) is connected at the point of common coupling with battery energy storage system (BESS) to rectify the power quality problems. The battery energy storage system is used to maintain constant real power from varying wind power. The generated wind power can be stored in batteries when power demand is low. The Combination of battery storage with wind energy generation system will synthesize the output waveform by absorbing or injecting reactive power and enable the real power flow required by the load. The amount of energy consumed or given to the grid can be view through an online smart meter connected in the circuit. The energy consumption of each system can be viewed using online smart meter.

Keywords: Battery energy storage system (BESS), Power quality, Smart energy meter, Wind energy generating system (WEGS), Static compensator (STATCOM).

I. INTRODUCTION

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impacts. Wind energy conversion systems are the fastest growing renewable source of electrical energy having tremendous environmental, social, and economic benefits [1]. Power Quality is defined as power that enables the equipment to work properly. A power quality problem can be defined as any deviation of magnitude, frequency, or purity from the ideal sinusoidal voltage waveform. Good power quality [2] is benefit to the operation of electrical equipment, but poor power quality will produce great harm to the power system. However, the generated power from wind energy conversion system is always fluctuating due to the fluctuation nature of the wind. Therefore injection of the wind power into an electric grid affects the power quality.

The important factors to be considered in power quality measurement are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The power quality problem is of great importance to the wind turbine. There has been an extensive growth and quick development in the exploitation of wind energy now days. Each unit has high capacity up to 2 MW, fed into distribution network, which is very near to the customers [3].

In this proposed scheme Static Synchronous Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. Therefore STATCOM [4] provides Reactive Power support to wind generator and load. 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 in power system block set. In this paper there will be the analysis of factors which are responsible for the power quality problems in the wind energy conversion system and implementation of proper control scheme for power quality improvement in the wind energy conversion system connected to the grid. In normal operating system we need a control circuit for the active power production. For reducing the disturbance we use a battery storage system.

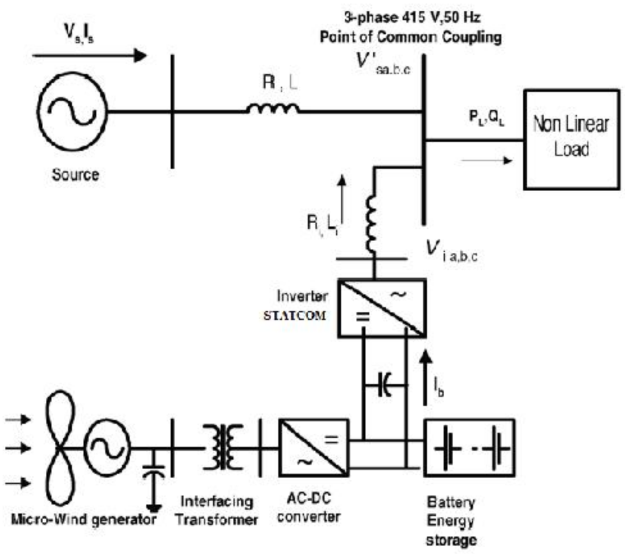


Figure1. Scheme of wind generator with battery storage

This compensates the disturbance generated by wind turbine. The wind energy system is used to charge the battery as and when the wind power is available. The voltage source inverter is controlled by using the current control mode. The utility companies can view the current, voltage and power of each system simultaneously by using the online smart metes. The utility can measure power generation of each system.

II. POWER QUALITY ISSUES AND ITS CONSEQUENCES

Perfect power quality means that the voltage is continuous and sinusoidal having constant figures of amplitude and frequency. Power quality can be expressed in terms of physical characteristics and properties of electricity. It is most often described in terms of voltage, frequency and interruptions [3]. Some of the power quality issues are

1) Voltage Variations: 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. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines.

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. The rapid switching gives large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

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.

4. Absorption of Reactive power: Induction generators require reactive power for magnetization. Induction generators, however, do not contribute to regulation of grid voltage, and they are substantial absorbers of reactive power when the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be affected.

b) Consequences of the Issues: The voltage variation, flicker, harmonics causes the malfunction of equipment‘s namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipment‘s like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipment‘s. Thus it degrades the power quality in the grid.

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The proposed wind energy extraction from wind generator and battery energy storage with distributed network is configured on its operating principle and is based on the control strategy for the switching the inverter [9].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), as shown in Fig. 1.It consists of wind energy generation system and battery energy storage system with STATCOM.

A. WIND ENERGY GENERATING SYSTEM:

The wind generating system (WEGS) consists of turbine, induction generator, interfacing transformer, and rectifier to get dc bus voltage. For constant dc bus voltage, the power flow is represented with constant dc bus current. 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

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3$$

Where ρ (kg/m) is the air density and A (m) is the area swept out by turbine blade, V wind 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

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

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

$$P_{mech} = C_p \frac{1}{2} \rho A V_{wind}^3$$

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

B. DC LINK FOR BATTERY STORAGE AND WIND ENERGY GENERATOR:

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The battery storage and µ WEGS are connected across the dc link as shown in Fig. 2. The dc link consists of capacitor which decouples the µwind generating system and ac source (Grid) system. The battery storage will get charged with the help of µwind generator. The use of capacitor in dc link is more efficient, less expensive and is modeled as follows.

$$C\frac{d}{dt}V_{dc} = I_{dc(rect)} - I_{dc(inv)} - I_b$$

Where C is dc link capacitance, Vdc is rectifier voltage, Idc (rect) is rectified dc-side current, Idc (inv) is inverter dc-side current, and Ib is the battery current. The battery storage is connected to dc link and is represented by a voltage source Eb connected in series with an internal resistance Rb. The internal voltage varies with the charged status of the battery. The terminal voltage Vdc is given in

$$V_{dc} = E_b - I_b * R_b$$

Where Ib represents the battery current

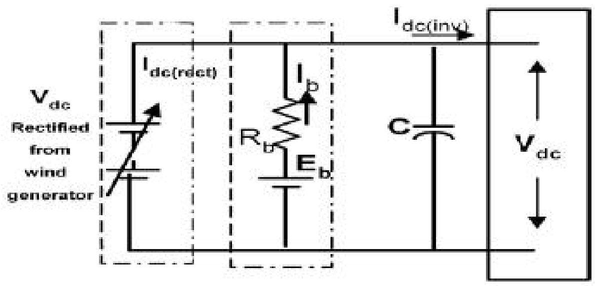


Figure 2. Dc link battery storage and wind generator

C. STATCOM-CURRENT CONTROLLED DEVICE:

The STATCOM is also a three-phase voltage source inverter having the capacitor on its DC link and connected at the point of common coupling (PCC) [10]. The STATCOM injects the compensating controlled current of variable magnitude and the frequency component at the bus of common coupling. The shunt connected STATCOM with battery energy storage is connected as the interface of the induction generator and non-linear load at the PCC in the grid system.

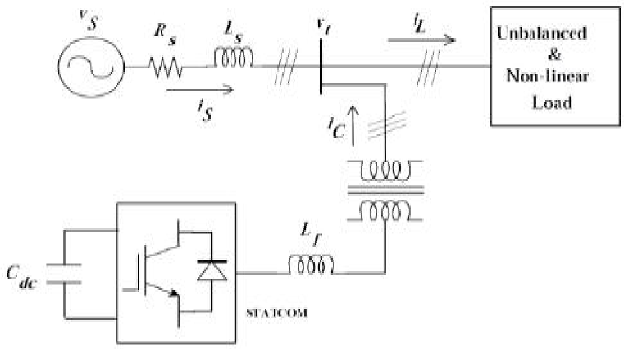


Figure 3: Shunt connected static compensator in grid

According to the controlled strategy the STATCOM compensator output is varied so as to maintain the power quality standards in the grid system [4]. Current control strategy is included in the control scheme so that it defines the functional operation of the STATCOM compensator in the power system. STATCOM using insulated gate bipolar transistor is proposed to provide reactive power support, to the nonlinear load and to the induction generator in the grid system [5]. The operational diagram of the shunt connected static compensator in grid in figure 3.

IV CONTROL SCHEME OF SYSTEM

The control scheme approach is based on injecting the currents into the grid using —PID controller. 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 is shown in Fig. 4.

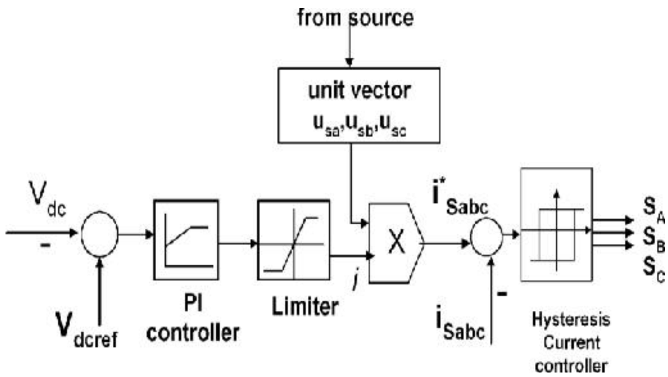


Figure 4. Control circuit for switching inverter circuit

The control scheme with battery storage and micro- wind generating system utilizes the dc link to extract the energy from the wind. The Wind generator is connected through a step up interfacing transformer and to the rectifier bridge so as to obtain the dc voltage. Also a lead acid cell battery is used for maintaining the dc bus voltage constant. Thus the inverter is implemented successfully in the distributed system. The control scheme approach is based on injecting the current into the grid using hysteresis band current controller [9]. Using such techniques controller keeps the control system variables between the boundaries of hysteresis area and thus gives correct switching signals for the inverter operation [4]. Fig.

4shows the control scheme for generating the switching signals to the inverter

The control algorithm needs the measurement of several variables such as three-phase source current iSabc for each phases, dc bus voltage Vdc, and inverter current iiabc with the help of measurement sensors. The current control unit receives an input of reference current i* Sabc and actual current iSabc is measured from each phases respectively, which are subtracted so as to activate the operation of the inverter in current control mode [3].

B. HYSTERESIS BASED CURRENT CONTROLLER:

Current control based hysteresis controller is used in this particular scheme. The reference current is generated as in and the actual current is detected by current sensors that are subtracted for obtaining current errors for a hysteresis based controller [9]. ON/OFF pulse signals for IGBT switches of inverter are derived from hysteresis current controller. When the measured current is higher than the generated reference current, it is necessary to get negative inverter output voltage so that corresponding switches are commutated [9]. Thus output voltages are decreased so that the output current reaches the reference current [4]. Also, if the measured current is less than the reference current, positive inverter output voltage are obtained by commutating particular switch Thus output current increases to the reference current. Hence, the output current will be within a band around the reference one. The switching function SA for phase ‘a’ is expressed as follows. Where HB is a hysteresis current-band, similarly the switching function SB, SC can be derived for phases ‘‘b’’ and ‘‘c,’’respectively [9]. The current control mode of inverter injects the current into the grid in such a way that the source currents are harmonic free and their phase-angles are inphase with respect to source voltage. The reactive and harmonic part of load side is cancel out by the injected current at shunt part. Thus, overall it reduces harmonic content and improves the source current quality at the PCC [9].

V. SIMULATION AND RESULTS

Simulation was done on MATLAB R2013a, the results was shown that the features of input videos are trained and tested perfectly for obtaining face detection and eye recognition.

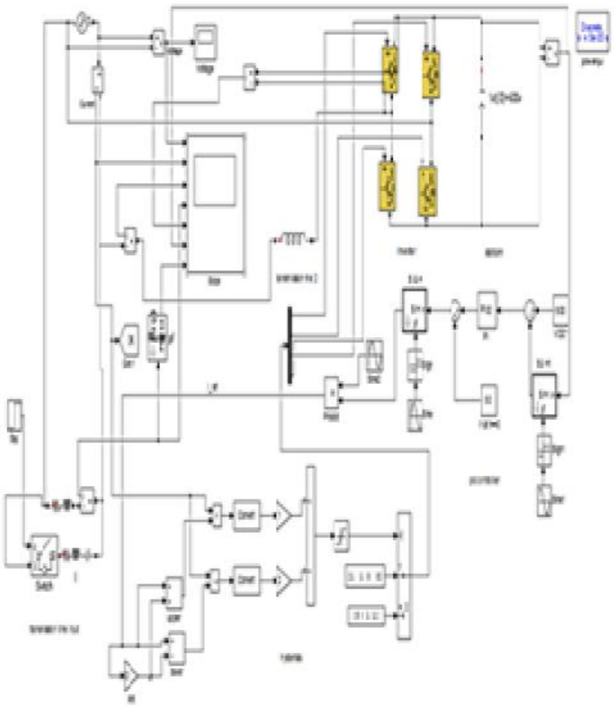


Figure 5: Matlab/Simulink diagram of proposed system

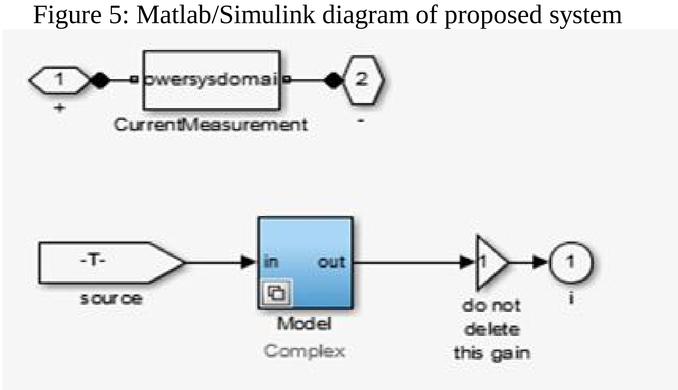
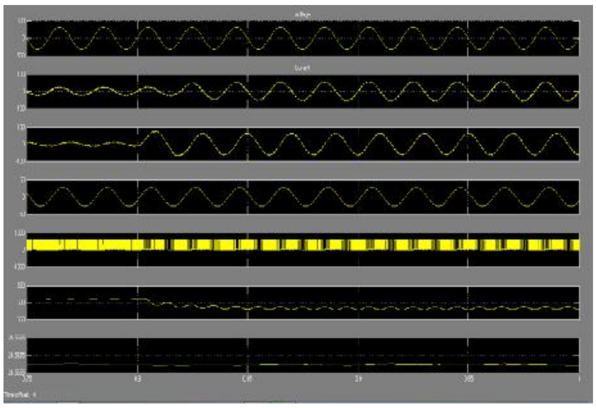
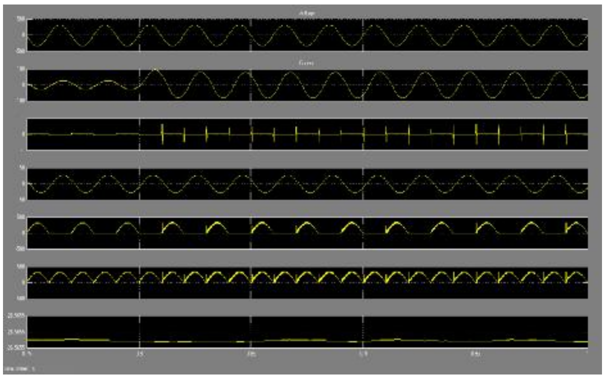


Figure 6: current measurement



(a)



(b)

Figure 7: Statcom outputs

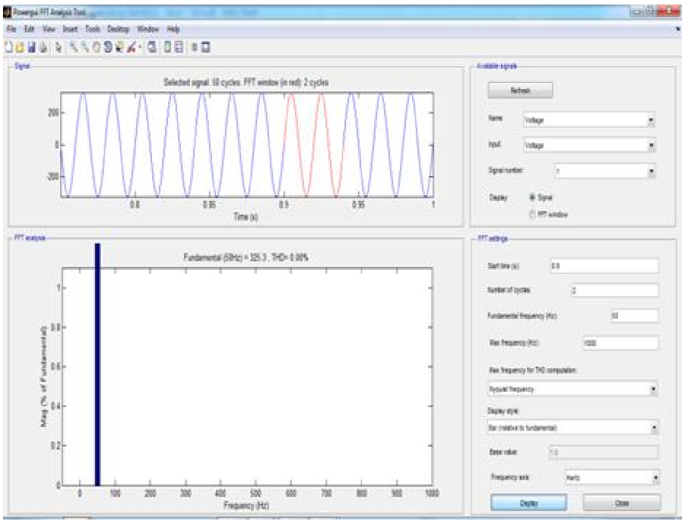


Figure 7: Total Harmonic Distortion Analysis

VI. CONCLUSION

Proposed study on wind energy conversion scheme using battery energy storage for nonlinear load includes interface of inverter incurrent controlled mode for exchange of real and reactive power. The hysteresis current controller is used to generate the switching signal for inverter in such a way that it will cancel the harmonic current in the system. This scheme improves power factor and also make harmonic free source current in the distributed network at the point of common connection. The wind power exchange is regulated across the dc bus having energy storage and is made available under the steady state condition. This also makes real power flow at instantaneous demand of the load. Rapid injection or absorption of reactive/real power flow in the power system can be made possible through battery energy storage and static compensator. Battery energy storage provides rapid response and enhances the performance under the fluctuation of wind turbine output and improves the voltage stability of the system. The utility can view each power plant simultaneously and accurately by using online smart meter. This scheme thus provides the system to operate both in power quality mode as well as in stand-alone**.**

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AUTHORS:

Mr. Ch. Sharath Chandra has completed his B.Tech in EEE Department from Sri Venkateswara engineering college, JNTU Hyderabad. Presently he is pursuing his Masters in Power Electronics in Sri Venkateswara Engineering College, suryapet, Nalgonda (district), Telangana, India.

Mr. Gundala Srinivasa Rao is currently pursuing Ph.D. at KL University.He has obtained his M.Tech in Power Electronics from Jawaharlal Nehru Technological University, Hyderabad in 2012 and B.Tech degree from SVEC, Suryapet in 2010.He has 5 years of teaching experience and presently working as Assistant Professor in EEE Dept. at Sri Venkateswara engineering college, Suryapet, Nalgonda district, Telangana state, India