Power Quality Improvement Of Grid Connected Wind Power System Using STATCOM

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ABSTRACT- ***The injection of the wind power into an electric grid affects the power quality. The influence of the wind turbine in the grid system concerning the power quality measurements and the norms followed according to the guidelines specified in the International Electrotechnical Commission standard, IEC61400 are the active and reactive power variations, variation of voltages,flicker,harmonics and electrical behavior of switching operations. The paper study demonstrates has overall good functional characteristics, better performance and faster response than existing systems. The proposed system of having STATCOM is smaller in size and less costly when compared to the existing system. In this proposed system static compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to reduce the power quality issues. The effectiveness of the proposed scheme gives the reactive power demand of load and the induction generator.Simulation is done by using MATLAB/SIMULINK-Sim power system software.***

Keywords: ***International electro-technical commission(IEC),power quality,wind generating system(WGS),STATCOM,BESS.***

1. INTRODUCTION

Nonrenewable energy sources are exhausted in the near future. So for the sustainable growth and social progress of an country, it is necessary that energy demand is meet by utility of renewable energy sources like wind, biomass, sun etc. the renewable sources are inexhaustible and therefore we can readily access to have the supply of energy from the renewable sources. The various advantages of renewable energy sources are as follows:

*The sun, wind, geothermal, ocean energy are available in the abundant quantity and free to use

*The non-renewable sources of energy that we are using are limited and are bound to expire one day.

The voltage of wind power generating station generally fluctuates due to nature of wind. When wind power generating station is integrated to the power grid power quality issues arises like injection of harmonics, poor power factor and distortion from pure sine wave of fundamental frequency. 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 plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability,power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operationof a distribution and transmission network. The issue of power quality is of great importance to the wind turbine.

In this proposed scheme, to minimize the power quality problems at the common coupling point of the power grid, STATCOM with battery energy system storage is connected. The STATCOM relieves the load and the main supply source of the reactive power demand. The proposed scheme is simulated in MATLAB/SIMULINK power lib. The proposed scheme has not only the effectiveness of relieving reactive power demand but also maintains unity power factor at the source side and has faster response of STATCOM by bang - bang controller as well as harmonics distortion reduction.

2. POWER QUALITY STANDARDS,ISSUES AND ITS CONSEQUENCES

A.Voltage variation

The quality of power transfer on a network may also be poor if the voltage varies erratically.

The most common problems are:

*Flicker- Larger loads connected to the network that vary or switch regularly can cause small voltage variation on the surrounding network. These cause brightness of incandescent lights to change which is irritating to users

*Dips- Starting a large motor on a weak motor usually in the distribution network can cause a large dip lasting up to 10 seconds. A dip in voltage can cause other loads connected nearby to switch off, In severe causes, damage may be caused.

*Harmonics- The connection of large variable speed drives to a network introduces power noise onto the surrounding network. This is called ‘harmonics’. The current flow caused by harmonics can cause other electrical devices to overheat & malfunction. The prolonged presence of harmonics on a system will shorten the life of sensitive equipment

*Unbalance- Voltage unbalance will cause heating of three phase machines & in reduction in motor output torque which leads to increased machine loses and reduced efficiency.

C. *Harmonics*

The current flowing through a given circuit in the network should not exceed the rating of connected equipment. Currents above the rated current can cause equipment to suffer excessive mechanical stress and overheat. This may result in permanent damage to equipment. A fault at some point along a circuit can cause large currents to flow in the network to the fault point. The equipment surrounding the fault needs to be capable of handling large currents without overheating until protection can isolate the supply of power to the fault.

D. Consequences of the issues

The voltage variation, flicker, harmonics causes the malfunction of equipments 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 equipments like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipments. Thus it degrade the power quality in the grid.

3. 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), as shown in Figure The grid connected system in Figure. 1consists of wind energy generation system and battery energy storage system with STATCOM.

A. 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)

$$Pwind = \frac{1}{2}\rho A V_{\mathrm{WIND}}{}^{3} \quad \text{-----} (1)$$

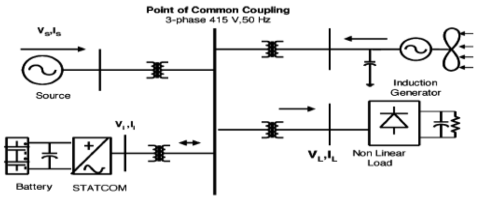


Figure.1 Grid connected system for power quality improvement

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(2)

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

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 λ and pitch angle θ.The mechanical power produce by wind turbine is given in (3)

$$P_{mech=}1/2\ \rho\ \pi\ R^2 V_{wind}{}^{3} C_p \text{------}(3)$$

Where R is the radius of the blade (m)

B. BESS-STATCOM:

The applications of the BESS-STATCOM are as following,

- Power quality improvement
- Load shifting
- Peak power shaving
- Uninterrupted power supply
- Intermittency mitigation
- Frequencregulation

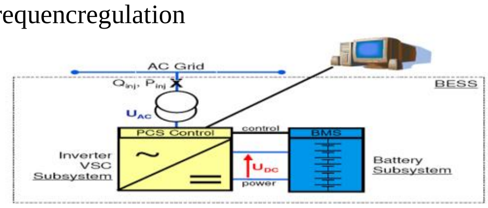


Figure.2. Battery Energy Storage System

C. System Operation:

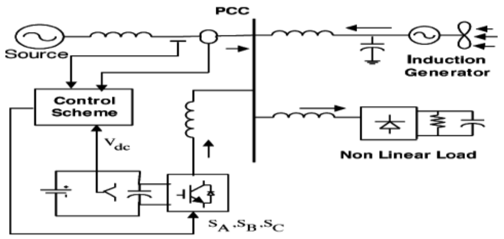


Figure.3 System Operation

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.4

4. CONTROL SCHEME

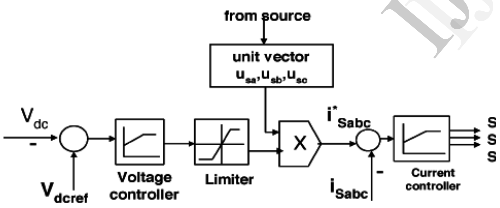


Figure.4 Control System Scheme

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 is shown in Figure.5 . 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.

A. Grid Synchronization:

In three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltage (V_{sa}, V_{sb}, V_{sc}) and is expressed, as sample template *Vsm*, sampled peak voltage, as in (4)

$$V_{sm}=\{2/3[V_{sa}^{2}+V_{sb}^{2}+V_{sc}^{2}]\}^{1/2} \quad \text{--------(4)}$$

The in-phase unit vectors are obtained from AC source—phase voltage and the RMS value of unit vector u_{sa}, u_{sb}, u_{sc} as shown in (5)

$$u_{sa}= V_{sa}/ V_{sm}$$
$$u_{sb}= V_{sb}/ V_{sm}$$
$$u_{sc}= V_{sc}/ V_{sm}$$

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

$$u_{sa}^{*}=I.\, u_{sa}$$
$$u_{sb}^{*}=I.\, u_{sb}$$
$$u_{sc}^{*}=I.\, u_{sc}$$

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.

B. Bang-Bang Current Controller

In control theory, a **bang–bang controller** (**on–off controller**), also known as a **hysteresis controller**, is a feedback controller that switches abruptly between two states. These controllers may be realized in terms of any element that provides hysteresis. They are often used to control a plant that accepts a binary input, for example a furnace that is either completely on or completely off. Most common residential thermostats are bang–bang controllers. The Heaviside step function in its discrete form is an example of a bang–bang control signal. Due to the discontinuous control signal, systems that include bang–bang controllers are variable structure systems, and bang–bang controllers are thus variable structure controllers.

Thus the ON/OFF switching signals for IGBT of STATCOM are derived from hysteresis controller .The switching function for phase 'a' is expressed as

$$i_{sa} < (i_{sa}^{*}-HB) \quad S_{A=0}$$

$$i_{sb} < (i_{sb}^{*}-HB) \quad S_{A}=1$$

here HB is a hysteresis current-band, similarly the switching function can be derived for phases "b" and "c".

5. 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.

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.

The system performance of proposed system under dynamic condition is also presented.

i) 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 control signal of switching frequency within its operating band, as shown in Figure.6

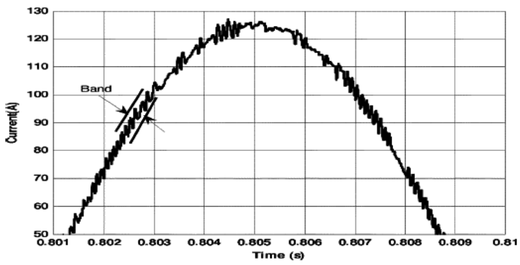


Figure.5 Switching Signal Within a Control Hysteresis Band

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 Figure.6

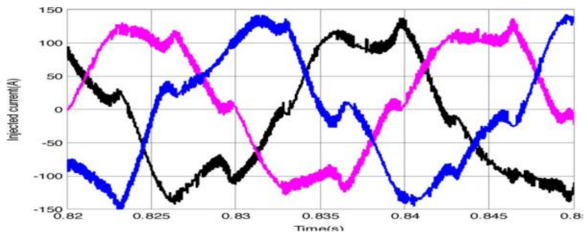


Figure.6 Three Phase Injected Inverter Current

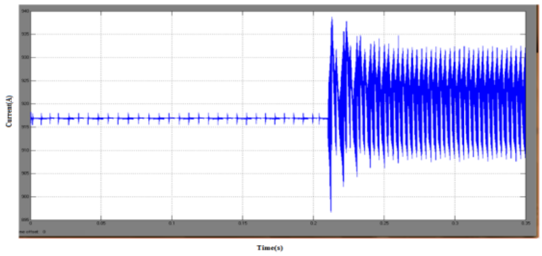


Figure.7 The Current through the capacitor

The current through the capacitor is shown in the above figure.7

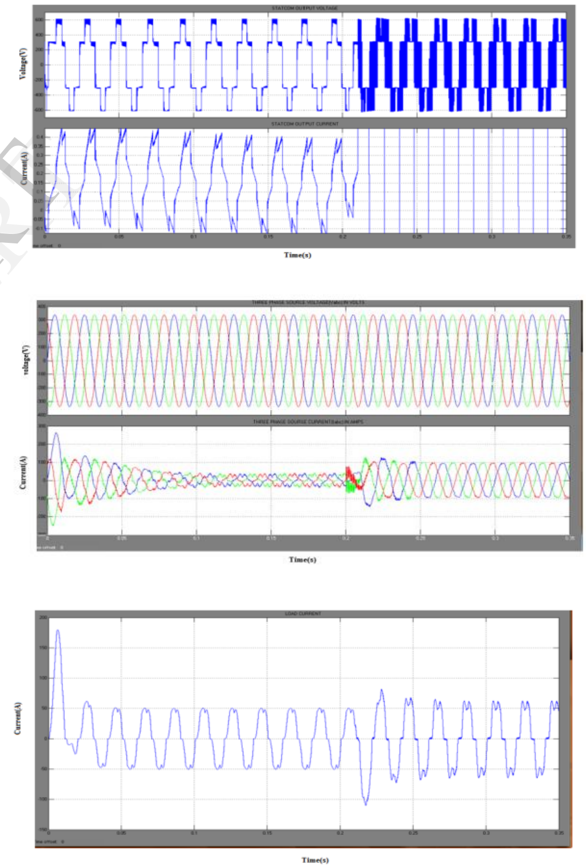


Figure.8 (a)STATCOM Injected Current
(b) Generated Current from Wind
(c) Load Current
Generator

STATCOM can regulate the available real power from source. The result of load current are shown in Figure (b) respectively. While the result of injected current from STATCOM are shown in

Figure (c) and the generated current from wind generator at PCC are depicted in Figure (d).

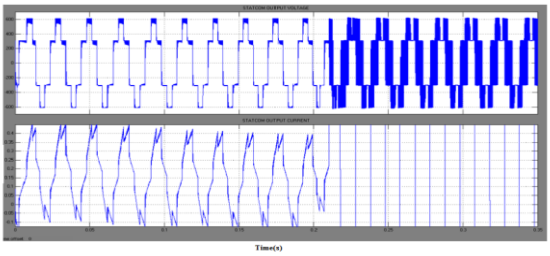


Figure.9 STATCOM Output Voltage

ii) 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 the 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 Figure.10

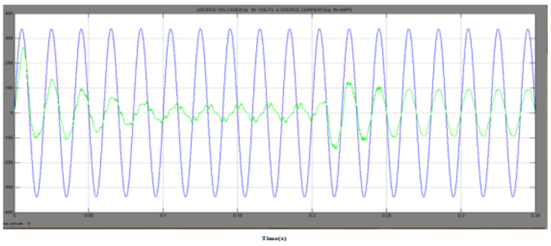
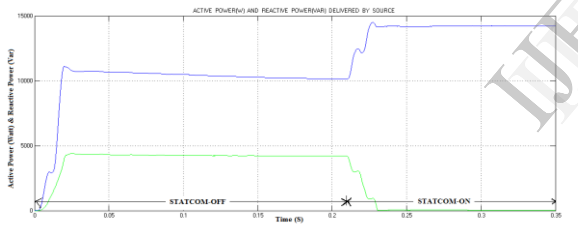
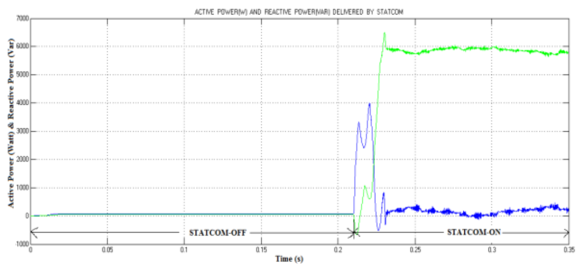


Figure.10 Supply voltage and current at PCC





The dynamic load does affect the inverter output voltage. The source current with and without STATCOM operation is shown in Figure.10 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.

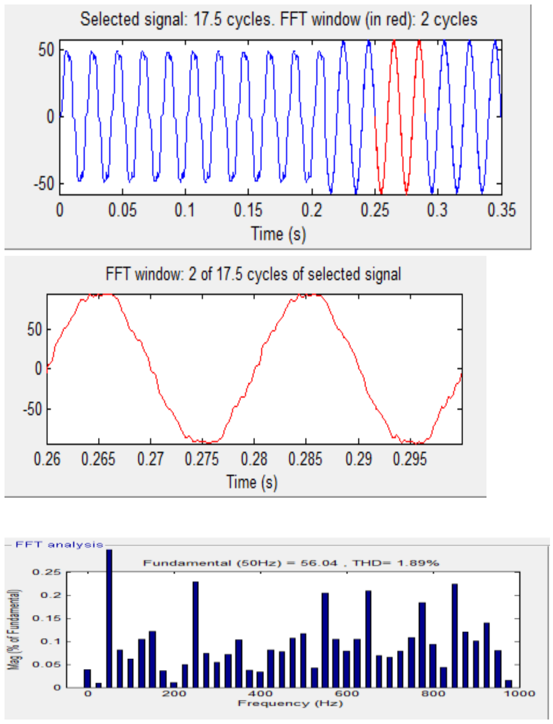


Figure.11 (a) Source current (b) FFT of source current

The Fourier analysis of this waveform is expressed and the THD of this source current at PCC without STATCOM is 1.89%, as shown in Figure.11 The power quality improvement is observed at point of common coupling, when the controller is in ON condition. The above tests with proposed scheme has not only power quality improvement feature but it also has sustain capability to support the load with the energy storage through the batteries.

6. 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 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 a 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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