International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-3637-3640 ISSN: 2249-6645

Power Quality Improvement in Wind Energy system by using STATCOM on Integration to the Grid

V. Amarnath Reddy[1], P. Harshavardhan Reddy[2], M. Sudheer babu[3]
[1, 3] M. Tech Studet, Department of EEE, [2]Assistant Professor, Department of EEE
A.I.T.S Engineering College, Rajempeta,India.

Abstract: *Renewable energy sources are alternative energy source, can bring new challenges when it is connected to the power grid. Generated power from wind energy system is always fluctuating due to the fluctuations in the wind. According to the guidelines specified in IEC-61400 standard (International Electro-technical Commission) provides some norms and measurements. The performance of the wind turbine, power quality is determined. The power quality measurements are-the active power, reactive power, voltage sag, voltage swell, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national/international guidelines. The paper clearly shows the existence of power quality problem due to installation of wind turbine with the grid. In this STATCOM is used with energy storage system (BESS) to reduce the power quality problems. The STATCOM control scheme for the grid connected wind energy generation system to improve the power quality is simulated using MATLAB/SIMULINK in power system block set.*

Keywords: *Power Quality, Wind Generating System (WGS), STATCOM, BESS, IEC standard.*

I. INTRODUCTION

The need to integrate the renewable energy like wind energy into power system is to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents requires the consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network.

The individual units can be of large capacity up to 2 MW wind turbine, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28 000 wind generating turbines are successfully operating all over the world. Fluctuations in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. Fluctuations in network, such as voltage sag, swells, flickers, harmonics etc. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Maintains Unity power factor at source side.
- Supports Reactive power only from STATCOM to wind Generator and Load.
- Simple PI controller for STATCOM to achieve fast dynamic response.

The paper is organized as follows. The Section II introduces the power quality standards, issues and its consequences of wind turbine and the grid coordination rule for grid quality limits. The Section III describes the topology for power quality improvement. The Sections IV, V, VI describes the control scheme, system performance and conclusion respectively.

II. POWER QUALITY IMPROVEMENT

A. Power quality standards, issues and its consequences

1) *International electro technical commission guidelines:* Some guidelines of measurements and norms are specified under IEC 61400 standard which determines the power quality of wind turbines.

The standard norms are specified.
1) IEC 61400-21: Measuring the power quality characteristic of grid connected wind turbine.
2) IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.
3) IEC 61400-3-7: Measures the emission limits for fluctuating load and IEC 61400-12: Wind Turbine performance.

2) *Harmonics:* It is due to the operation of power electronic converters. Harmonic voltage and current should be in limited as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current and higher order harmonics are filtered out by using filters.

3) *VOLTAGE VARIATION:* This is due to the fluctuations in the wind turbine due to wind. 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. Amplitude of voltage fluctuations depends on grid strength, network impedance, phase angle and power factor of wind turbine.

During voltage variations frequency is in the range 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly.

4) WIND TURBINE LOCATION IN POWER SYSTEM: It is located where the power quality is highly influenced.

Its operation and its influence on the power system depend on the structure of the network.

5) *SELF EXCITATION OF WIND TURBINE GENERATING SYSTEM:* The self-excitation of wind turbine generating system (WTGS arises a risk equipped with commutating capacitor. It provides the reactive power compensation to the induction generator.

The disadvantages of self-excitation are the safety aspect and balance between real and reactive power.

6) *CONSEQUENCES OF THE ISSUES:* Voltage variations, voltage flicker, harmonics causes the malfunctions of equipments. It leads to tripping of protection devices, damaging the sensitive equipments. Overall it degrades the power quality in the grid.

B. GRID COORDINATION RULE

American Wind Energy Association (AWEA) led the effort to develop its own grid code for stable operation as per IEC-61400-21 for the interconnection of wind plants to the utility systems, after the blockout in United State in August 2003.

According to these, operator of transmission grid is responsible for the organization and operation of interconnected system.

1) Voltage rise (u)

The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power Smax of the turbine, the grid impedances R and X at the point of common coupling and the phase angle , given in Eq. 1.

$$\Delta u = \frac{s_{max}(R\cos\Phi - X\sin\Phi)}{u^2} \qquad (1)$$

Where Δu —voltage rise,
smax —max. apparent power,
Φ—phase difference,
U—nominal voltage of grid.

The Limiting voltage rise value is <2 %

2) Voltage dips (d)

The voltage dips is due to startup of wind turbine and it causes a sudden reduction of voltage. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

$$D = K_u\, s_n/s_k \qquad (2)$$

Where d is relative voltage change,
sn is rated apparent power,
sk is short circuit apparent power, and
Ku is sudden voltage reduction factor.
The acceptable voltage dips limiting value is <3%.

3) Flicker

The measurements are made for maximum number of specified switching operation of wind turbine with 10-min period and 2-h period are specified, as given in Eq. 3.

$$P_u = c(\psi_k)\; s_n/s_k \qquad (3)$$

Where P_u —Long term flicker.
c (ψk) —Flicker coefficient

The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 h.

4) Harmonics

The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point of common connection. The total harmonic voltage distortion of voltage is given as in Eq. 4.

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1}}\,100 \qquad (4)$$

Where Vn is the nth harmonic voltage and V1 is the fundamental frequency (50) Hz.

The THD limit for 132 KV is < 3%.

THD of current ITHD is given as in Eq. 5

$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_n}{I_1}}\,100 \qquad (5)$$

where *I*n is the nth harmonic current and *I*1is the fundamental frequency (50) Hz.
The THD of current and limit for 132 KV is <2.5%.

5) *GRID FREQUENCY*

The grid frequency in India is specified in the range of 47.5–51.5 Hz, for wind farm connection.

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The STATCOM based current control voltage source inverter injects the current into the grid 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.

The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), for grid connected system in Fig. 1

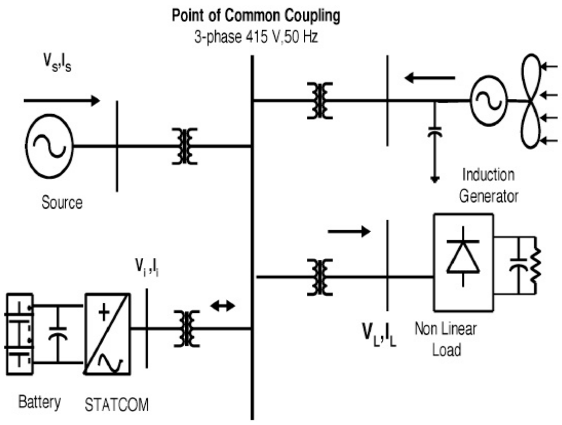

Fig.1. Grid connected system for power quality improvement.

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 Eq.6.

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3 \qquad (6)$$

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 Eq.7

$$P_{mech} = C_p P_{wind} \qquad (7)$$

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 γ and θ pitch angle. The mechanical power produce by wind turbine is given in Eq. 8.

$$P_{mech} = \frac{1}{2}\rho \Pi \mathrm{R}^2 \mathrm{V}_{\mathrm{wind}}^3 C_p \qquad (8)$$

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

B. STATCOM – STATIC SYNCHRONOUS COMPENSATOR

The STATCOM (or SSC) is a shunt-connected reactive-power compensation device that is capable of generating and/ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system.

In general it is solid state switching converter which is capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source at its input terminals.

Specifically, the STATCOM considered in this is a voltage-source converter from a given input of dc voltage produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through leakage reactance.

The dc voltage is provided by an energy-storage capacitor.

A STATCOM can improve power-system performance in such areas as the following:

1. The dynamic voltage control in Transmission and distribution systems;
2. The power-oscillation damping in power transmission systems;
3. The transient stability;
4. The voltage flicker control; and
5. It also controls real power in line when it is needed.

Advantages
1) It occupies small areas.
2) It replaces the large passive banks and circuit elements by compact converters.
3) Reduces site work and time.
4) Its reponse is very fast.

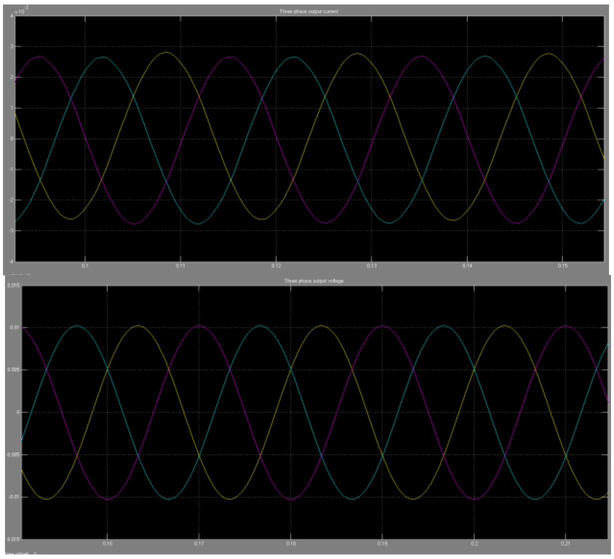

Fig.3. 3phase output current and voltage of grid

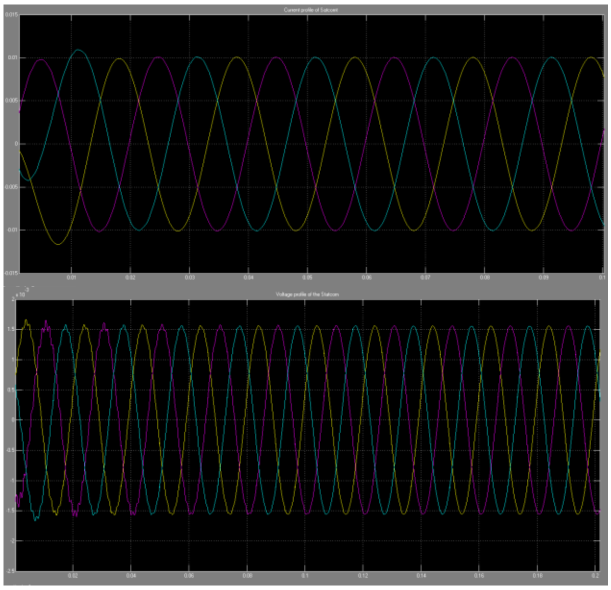

Fig.4. 6-pulse statcom ouput current and voltage

IV. CONTROLLER DESIGN OF PI, PD AND PID

It is possible to improve the STATCOM response by employing the PID control method by choosing kp, kI and kD. It is a time consuming process but response speed, settling time and proper overshoot rate all guarantees the system stability.

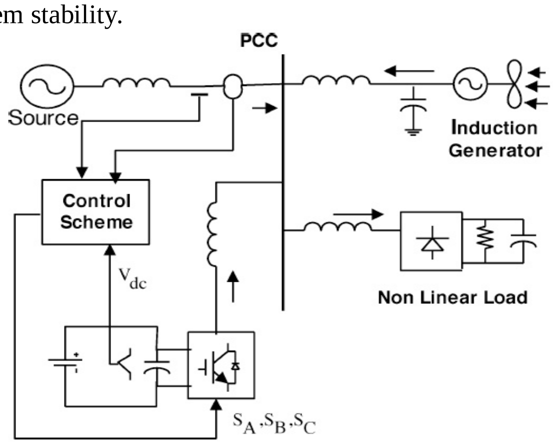

Fig. 2. System operational scheme in grid system.

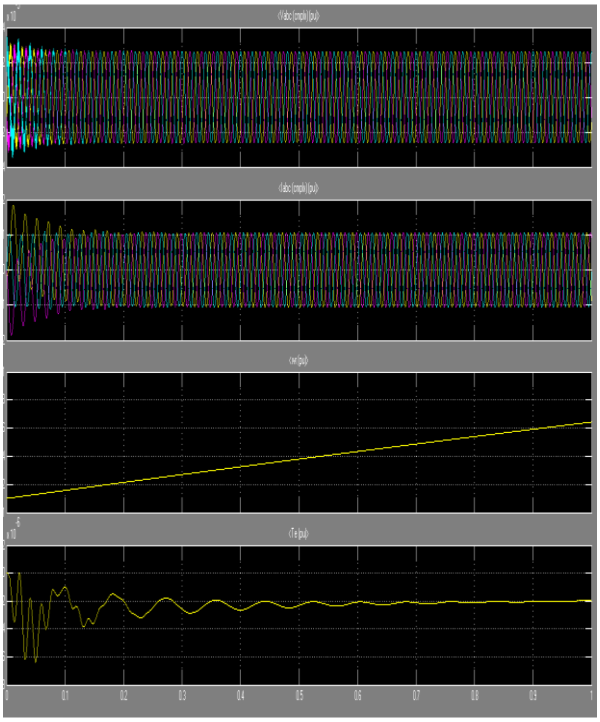

Fig 5. Voltage and current profile of wind generator

V. 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.

	Parameters	Ratings
1	Grid Voltage	3-Phase, 415V,50Hz
2	Induction motor/generator	3.35KVA, 415V,Hz,P=4, Speed=1440rpm,Rr=0.01Ω, Rs=0.015Ω,Ls=Lr=0.06H
3	Line series inductance	0.05mH
4	Inverter Parameters	DC Link Voltage=800V, DC Link capacitance=100µF, Switching Frequency=2kHz
5	IGBT rating	Collector Voltage=1200V, Forward Current=50A,Gate Voltage=20V,Power Dissipation=310w
6	Load Parameter	Non-Linear Load=25kw

VI. CONCLUSION

In this paper we present the FACTS device (STATCOM) -based control scheme for power quality improvement in wind generating system on integration to the grid and with nonlinear 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 in MATLAB/SIMULINK for maintaining the power quality is to be 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 enhance the utilization factor of transmission line. The integrated wind generation and FACTS device 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.

ACKNOWLEDGMENT

The authors wish to acknowledge the support provided by Annamacharya institute of Technology and Sciences, Rajempet to complete the work successfully.

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