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Power Quality Improvement of grid connected wind energy system using static compensator

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Abstract— Renewable energy sources which are promising alternative energy source, can bring new challenges when it is connected to the power grid. The performance of the wind turbine and power quality is determined accounting to the guidelines given in IEC-61400 (International Electro-technical Commission).When we inject wind power into grid it affects power quality. There are many power quality issues when wind energy is connected to grid, and we have to mitigate these issues by using different system such as STATCOM (static compensator).These issues are voltage sag, voltage swell, flicker, harmonics, etc. which are measured according to national/international guidelines. This problems are exists due to installation of wind turbine with the grid. This paper shows the existence of power quality problem which are due to installation of wind turbines with the grid. In this proposed scheme for mitigating power quality issues Static Compensator (STATCOM) is connected with the battery energy storage system (BESS) at a point of common coupling. This grid connected wind energy system with STATCOM control scheme is simulated using MATLAB/SIMULINK in power system block set.

Index Terms—*International electro-technical commission (IEC),power quality, wind generating system (WGS),STATCOM(Static Compensator), BESS(Battery energy storage system)*

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I. Introduction

For having sustainable growth and social progress it is necessary to meet the energy need by utilizing the renewable energy resources like wind, hydro,biomass, co-generation, etc. Wind power production is fastest type of renewable energy. Wind energy is integrated into existing power system for minimizing the environmental impact on conventional plant[1] There are some technical challenges when we are integrating wind energy into existing power system and that requires consideration of voltage regulation, stability, power quality problems etc. The power quality is greatly affected by the operation of a distribution and transmission network. For wind turbine the issue of power quality is of great importance. The individual units of wind generating system which are feeding into the distribution network can be of large capacity up to 2 MW, particularly with customers connected in close proximity [3].Under the normal operation; wind turbine produces a continuous variable output power and these variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system.The network needs to manage for such fluctuations. The power quality issues such as voltage sag/voltage dips, swells, flickers, harmonics etc. can be viewed with respect to the wind generation, transmission and distribution network, Due to wind generator it introduces disturbances into the distribution network. Induction generator can be use for running grid connected wind generating system and this system is cost effective and robust and it requires reactive power for magnetization and that reactive power absorbed by Induction generator when the generated active power by it is varied due to wind and terminal voltage of an induction generator can be significantly affected. Battery energy storage system is required for compensating the fluctuation generated by wind turbine.

A STATCOM controlled technology which is implemented at the point of common coupling is used for power quality improvement which manages the power level associates with the commercial wind turbines. The main objectives of STATCOM control scheme for grid connected wind energy generation has following objectives for power quality improvement.

- Source side must have unity power factor.
- Reactive power support only from STATCOM to wind Generator and Load.
- For achieving fast dynamic response simple bang-bang controller for STATCOM.

In this paper the Section II introduces the power quality issues, standards, and its consequences of wind turbine. The Section III introduces the grid coordination rule for grid quality limits. In Section IV the topology for power quality improvement is given. System performance, control scheme and conclusion is given in the Sections V, VI, VII.

II. Power Quality Standards, Issues and It's Consequences

A. International Electro Technical Commission Guidelines

For measurement of wind turbine power quality IEC guidelines are provided. The International standards are developed by the working group of Technical Committee-88 of the International Electro-technical Commission (IEC), IEC standard 61400-21.This commission describes the procedure for determining the power quality characteristics of the wind turbine [4]. The standard norms are specified.

1) IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.

2) IEC 61400-21: Wind turbine generating system, part-21. Measurement and Assessment of power quality characteristic of grid connected wind turbine

3) IEC 61400-3-7: Assessment of emission limits for fluctuating load IEC 61400-12: Wind Turbine performance. The data sheet with electrical characteristic of wind turbine gives the base for the utility assessment regarding a grid connection.

B. Voltage Variation

Voltage variation are occurs due to wind velocity and generator torque, which is depend on real and reactive power variations. The voltage variation is classified as under:

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

The voltage flicker defines dynamic variations in the network which is caused by varying loads or by wind turbine. The power fluctuation occurs from the wind turbine during continuous operation. The amplitude of voltage fluctuation depends on, network impedance, grid strength and phase angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter which can be used to measure flicker directly.

C. Harmonics

At the point of wind turbine connection to the network the harmonic current and voltage should be limited to the satisfactory level. This harmonic is occurs due to the operation of power electronic converters. As per the IEC-61400-36 guideline each source of harmonic current can allow only a limited contribution for having the harmonic voltage within limit. There is a large reduction in lower order harmonic current compared to the line commutated converter due to rapid switching, but the output current can be filter out easily and have high frequency current.

D. Wind Turbine Location in Power System

Power quality is affected by wind turbine location in power system. Thus the power network is joined by considering operation and its effects on power system.

E. Self-Excitation of Wind Turbine Generating System

When wind turbine generation system is equipped with compensating capacitor there is self excitation. And also when there is disconnection of wind turbine generating system with local load, the self-excitation of wind turbine generating system with an asynchronous generator takes place. The capacitor provides reactive power compensation which is connected to the induction generator and by balancing the system the voltage and frequency are determined. The drawbacks of self-excitation are the balance between real and reactive power and safety aspect [5]

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F. Consequences of the Issues

There is malfunction of some equipments such as microprocessor based control system, programmable logic controller, flickering of light and screen, adjustable speed drives. It also causes stoppage of sensitive equipment's such as personal computer, programmable logic control system, it may stop the process and also can damage a sensitive equipment's which degrades the power quality in the grid.

III. GRID COORDINATION RULE

For stable grid operation the United State wind energy industry took a stand in developing its own grid code and the rules are defined as per IEC-61400-21. The grid quality characteristics and restrictions are given for references that the customer and the utility grid may expect. The operator of transmission grid is responsible for the organization and operation of interconnected system [6].

1) VOLTAGE RISE (u)

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

$$u = \frac{S_{\max}(RCOS\phi - XSIN\phi)}{U^2} \tag{1}$$

The Limiting voltage rise value is ±2 %

2) VOLTAGE DIPS (d)

Due to voltage dips there is sudden reduction of voltage and these voltage dips are due to startup of wind turbine. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

$$d = K_u \frac{S_n}{S_K} \tag{2}$$

The acceptable voltage dips limiting value is ± 3%.

3) FLICKER

The measurements are made for maximum number of specified switching operation of wind turbine as given in Eq. 3.

$$P_{lt} = C(\psi_K)\frac{S_n}{S_k} \tag{3}$$

Where P_{lt} Long term flicker. $C(\psi_k)$ Flicker coefficient which is calculated from Rayleigh distribution of the wind

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speed. The Limiting Value for flicker coefficient is ≤ 0.4, for average time of 2 h. [8]

4) HARMONICS

For variable speed turbine with a electronic power converter harmonic distortion is measured at the point of common connection [9]. The total harmonic voltage distortion of voltage is as given in (4)

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

Where V_n is the nth harmonic voltage and V_1 is the fundamental frequency which is 50 Hz. The THD limit for 132 KV is < 3%

THD of current I_{THD} is given as in (5)

$$I_{THD} = \sqrt{\sum \frac{I_n}{I_1}} 100 \quad (5)$$

Where I_n is the nth harmonic current and I_1 is the fundamental Frequency which is 50 Hz. The THD of current and limit for 132 KV is < 2.5%.

5) GRID FREQUENCY

In India the grid frequency is specified in the range of 47.5–51.5 Hz, for wind farm connection and the wind farm shall able to withstand change in frequency up to 0.5 Hz/s [9].

IV. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The source current are harmonic free and their phase-angle with respect to source voltage has a desired value when the STATCOM based current control voltage source inverter injects the current into the grid .This injected current will cancel out the harmonic part, reactive part of the load and induction generator current, due to which it improves the power factor and the power quality. For getting this the grid voltages are sensed and are synchronized in generating the current command for the inverter. Figure. 1. Shows the proposed grid connected system for power quality improvement at point of common coupling (PCC)and it consists ofs consists of wind energy generation system and battery energy storage system with STATCOM.

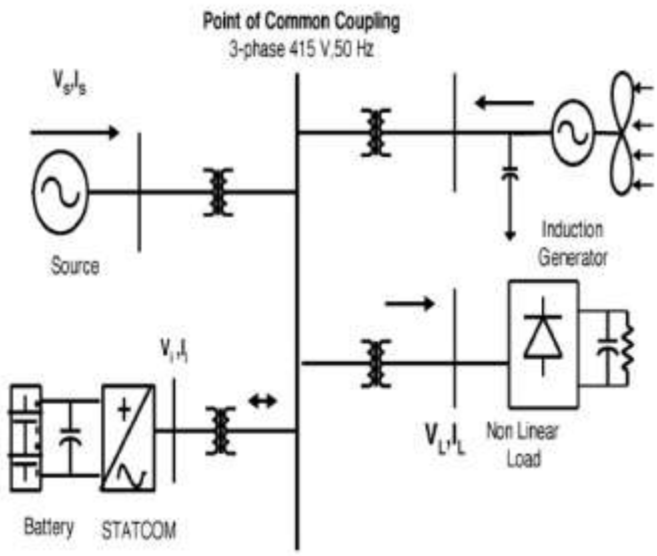

Figure.1 Grid connected system for power quality improvement

A. Wind Energy Generating System

Induction generator is used here due to its simplicity ,it can accept constant and variable loads and has natural protection against short circuits. Wind generations are based on constant speed topologies with pitch control turbine. The available power of wind energy system is presented as under in Eq.6.

$$P_{WIND} = \frac{1}{2} \rho A V^3 \quad (6)$$

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 C_p of the wind turbine, and is given in Eq.7.

$$p_{mech} = C_P P_{wind} \quad (7)$$

Where C_p 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 sangle θ .

The mechanical power produce by wind turbine is given in Eq.8.

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

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

B. BESS-STATCOM

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For voltage regulation the battery energy storage system (BESS) is used as an energy storage element. It will maintain dc capacitor voltage constant and is best suited in STATCOM as it rapidly injects or absorbed reactive power to stabilize the grid system. It also controls the distribution and transmission system in a very fast rate. This BESS use charging and discharging operation when power fluctuation occurs in the system, to level the power fluctuation. The battery is connected in parallel to the dc capacitor of STATCOM. The STATCOM injects a compensating current which is of variable magnitude and frequency component at the bus of common coupling. The Static compensator (STATCOM) is a three-phase voltage source inverter which have the capacitance on its DC link and connected at the point of common coupling.

C. System Operation

The STATCOM with battery energy storage system is connected with the interface of the induction generator and non-linear load at the Point of common coupling in the grid system. According to the controlled strategy the STATCOM compensator output is varied, for maintaining the power quality norms in the grid system. This strategy is included in the control scheme that defines the functional operation of the STATCOM compensator. A single STATCOM using insulated gate bipolar transistor is planned 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.2.

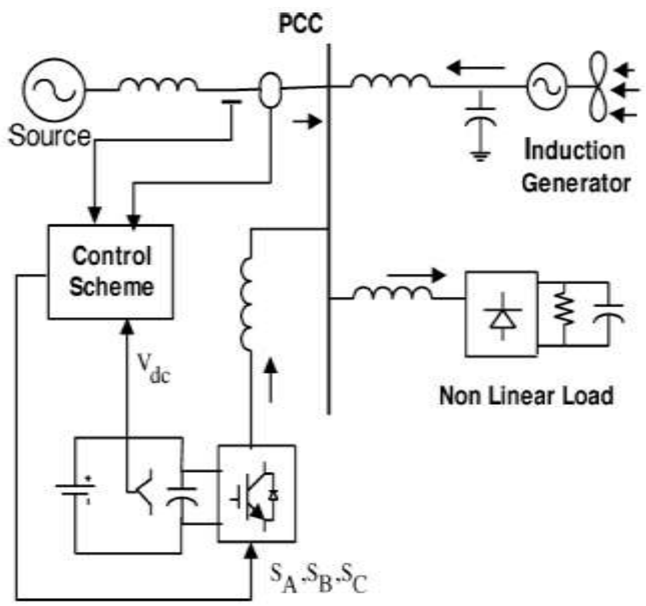

Figure 2. System operational scheme in grid system.

V. SYSTEM PERFORMANCE

The control scheme is simulated using MATLAB/ SIMULINK in power system block set. Table 1. shows the system parameter for given system. The system performance of proposed system under dynamic condition is also presented.

TABLE 1 SYSTEM PARAMETERS

S.N	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

A. Voltage Source Current Control—Inverter Operation

The distortion caused by the nonlinear load and wind generator will cancel by the three phase injected current into the grid from STATCOM. The three-phase inverter is connected to grid through the transformer. The switching signals generation from reference current is simulated within hysteresis band of 0.08. The current quality is enhanced by the choice of narrow hysteresis band switching in the system. The inverter provides the compensated current for the nonlinear load and demanded reactive power.

SIMULATION RESULT

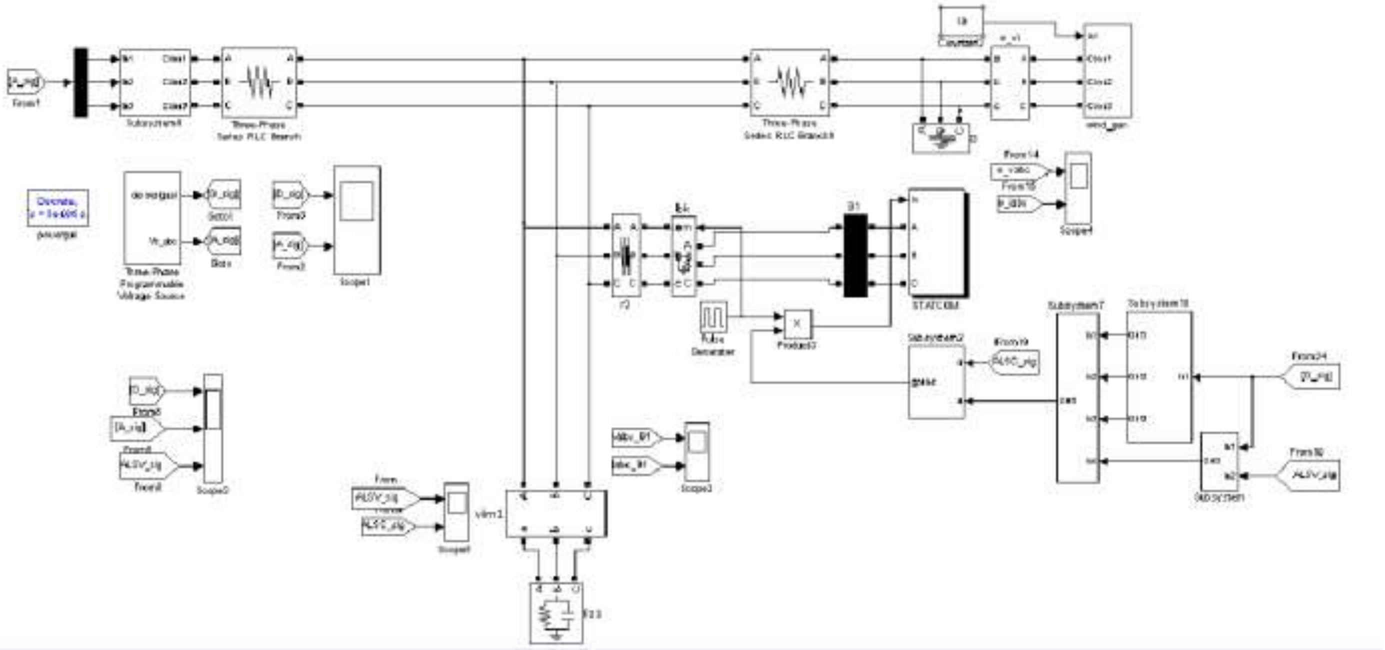

Figure. 3 Simulation Result

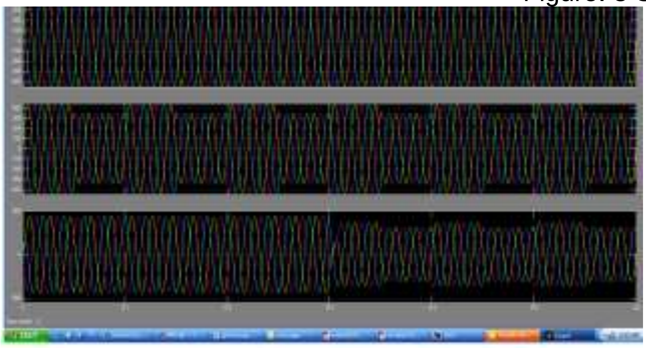

Figure. 4 a) Source voltage b)load voltage c)Inverter Injected current

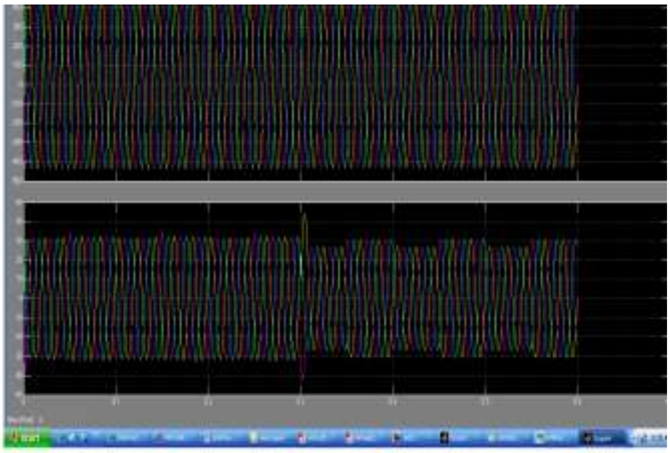

Figure 5 a) Wind generator Voltage b) Wind generator Current

VI. CONCLUSION

In this paper we are using STATCOM control scheme with battery energy storage system for power quality improvement with nonlinear load. We presented different power quality issues and its consequences on the customer and also on electric utility. By using this system the harmonic parts of the load current can be cancel out. It support the reactive power demand for wind generator and load at point of common coupling in grid system and also maintain the source voltage and current in phase, thus it gives a chance to enhance the utilization factor of transmission line. The combination of wind generation and FACTS device STATCOM with battery energy storage system has 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.

REFERENCES

[1] A. Sannino, "Global power systems for sustainable development," in IEEE General Meeting, Denver, CO, Jun. 2004.

[2] K. S. Hook, Y. Liu, and S. Atcitty, "Mitigation of the wind generation integration related power quality

[3] issues by energy storage," EPQU J., vol. XII, no. 2, 2006.

[4] R. Billinton and Y. Gao, "Energy conversion system models for adequacy assessment of generating systems incorporating wind energy," IEEE Trans. on E. Conv., vol. 23, no. 1, pp. 163–169, 2008, Multistate.

[5] Wind Turbine Generating System—Part 21, International standard-IEC 61400-21, 2001.

[6] J. Manel, "Power electronic system for grid integration of renewable energy source: A survey,"

IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1014, 2006, Carrasco.

[7] M. Tsili and S. Papathanassiou, “A review of grid code technology requirements for wind turbine,” Proc. IET Renew.power gen., vol. 3, pp. 308–332, 2009.

[8] S. Heier, Grid Integration of Wind Energy Conversions. Hoboken, NJ: Wiley, 2007, pp. 256–259.

[9] J. J. Gutierrez, J. Ruiz, L. Leturiondo, and A. Lazkano, “Flicker measurement system for wind turbine certification,” IEEE Trans. Instrum. Meas., vol. 58, no. 2, pp. 375–382, Feb. 2009.

[10] Sharad W.Mohod, Member IEEE and Mohan V.Aware (2010) “A STATCOM Control Scheme for Grid connected Wind Energy System for Power Quality improvement” IEEE SYSTEMS JOURNAL, Vol .4,No.3, pp:576-583