ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

The STATCOM-Based Control Scheme for Power Quality Improvement in Grid Connected Wind Generating System

Masulu Goutham , B. Subba Reddy

M.Tech. Department of EEE, SVEC, Tirupathi, India

Assistant Professor, Department of EEE, SVEC, Tirupathi, India

ABSTRACT: When the wind power is connected to an electric grid affects the power quality. The influence of wind turbine in the grid system of the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operations. The installation of wind turbine with the grid causes power quality problems are determined by studying this paper. To mitigate the power Quality Issues by using Statcom in Grid Connected Wind Generating System. The grid connected wind energy generation system for power quality improvement by using STATCOM-control scheme is simulated using SIMULINK in power system block set. This relives the main supply source from the reactive power demand of the load and the induction generator in this proposed scheme. The improvement in power quality on the grid has been presented here according to the guidelines specified in IEC-61400 standard (International Electro-technical Commission) provides some norms and measurements.

KEYWORDS: International electro technical commission (IEC), power quality, wind generating system(WGS).

I. INTRODUCTION

To have continuous growth and social progress, it is nec- essary to meet the energy need by utilizing the renewable energy resources like wind, biomass, co-generation, etc. In continuous energy system, energy conservation and the use of renewable source are the key criterion. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental brunt on ordinary plant [1]. 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 centralizes measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine [2].

There has been an wide ranging growth and quick development in the using of wind energy in recent years. The personalised units can be of large capacity up to 2 MW, encourage into distri- bution network, particularly with customers connected in close proximity [3]. Today, more than 28 000 wind generating turbine are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as variations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a endless variable output power. These power variations are mainly caused by the effect of disturbance, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. 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. However the wind generator introduces distur- bances into the distribution network. One of the simple methods of running a wind generating system is to use the induction gen- erator connected directly to the grid system. The induction gen- erator has built in advantages of cost capability and strength. However, induction generators require reactive power for magnetization. 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 significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compen- sate the variation generated by wind turbine. 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. The proposed STATCOM control scheme for grid connected wind energy gen- eration for power quality improvement has following objectives.

• Unity power factor at the source side.

• Reactive power support only from STATCOM to wind Generator and Load.

The paper is organized as fallows. The Section II introduces

the power quality standards, issues and its consequences of wind turbine. The Section III introduces the grid coordination rule for grid quality limits. The Section IV describes the topology for power quality improvement. The Sections V, VI, VII de- scribes the control scheme, system performance and conclusion respectively.

II. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. International Electro Technical Commission Guidelines

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

The standard norms are specified.

1) IEC 61400-21: Wind turbine generating system, part-21.

Measurement and Determination of power quality characteristic of grid connected wind turbine

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

3) IEC 61400-3-7: Assessment of emission limit for fluctu-
ating load IEC 61400-12: Wind Turbine performance.

The data sheet with electrical characteristic of wind turbine provides the base for the utility assessment regarding a grid connection.

B. Voltage Variation

E. Self Excitation of Wind Turbine Generating System

The self excitation of wind turbine generating system (WTGS) with an asynchronous generator takes place after disconnection of wind turbine generating system (WTGS) with local load. The risk of self excitation arises especially when WTGS is equipped with compensating capacitor. The capacitor connected to induction generator provides reactive power compensation. However the voltage and frequency are determined by the balancing of the system. The disadvantages of self excitation are the safety aspect and balance between real and reactive power [5].

F. Consequences of the Issues

The voltage variation, flicker, harmonics causes the mal- function of equipments namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of con- tractors, 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 detiorate the power quality in the grid.

III. GRID COORDINATION RULE

The American Wind Energy Association (AWEA) led the effort in the united state for acceptance of the grid code for the interconnection of the wind plants to the utility system. The first grid code was focused on the distribution level, after the blackout in the United State in August 2003. The United State wind energy industry took a stand in developing its own grid code for contributing to a stable grid operation. The rules for realization of grid operation of wind generating system at the distribution net- work are defined as-per IEC-61400-21. The grid quality characteristics and limits are given for references that the customer and the utility grid may expect. According to Energy-Economic Law, the operator of transmission grid is responsible for the organization and operation of interconnected system [6].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

1) *Voltage Rise (u):* The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power of the turbine, the grid impedances R and X at the point of common coupling and the phase angle [7], given in (1)

$$\Delta u = S_{\max}(R\cos\phi - X\sin\phi)/U^2 \qquad (1)$$

where u voltage rise, Smax. Apparent power, phase difference, is the nominal voltage of grid. The Limiting voltage rise value is %

2) *Voltage Dips (d):* The voltage dips is due to start up 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 (2).

$$d = K_u \frac{S_n}{S_K} \qquad (2)$$

where is relative voltage change, rated apparent power, short circuit apparent power, and sudden voltage reduction factor. The acceptable voltage dips limiting value is %.

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 (3)

$$P_{\mathrm{lt}} = C(\Psi_K)\frac{S_n}{S_K} \qquad (3)$$

Where —Long term flicker. —Flicker coefficient calculated from Rayleigh distribution of the wind speed. The Limiting Value for flicker coefficient is about , for average time of 2 h [8].

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

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

where is the nth harmonic voltage and is the fundamental frequency (50) Hz. The THD limit for 132 KV is %. THD of current is given as in (5)

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

where is the nth harmonic current and is the fundamental frequency (50) Hz. The THD of current and limit for 132 KV is
%.

5) *Grid Frequency:* The grid frequency in India is stated in the range of 47.5–51.5 Hz, for wind farm nature. The wind farm shall able to withstand development in frequency up to 0.5 Hz/s [9].

IV. TOPOLOGYFOR POWER QUALITY IMPROVEMENT

The STATCOM established current control voltage source inverter insert 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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it better 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 complete for power quality improvement at point of common coupling (PCC), as shown in Fig. 1.
The grid connected system in Fig. 1, consists of wind en- ergy generation system and battery energy storage system with STATCOM.

A. Wind Energy Generating System

In this structure, wind generations are based on constant speed earth science with pitch control turbine. The induction generator is used in the proposed scheme because of its integrity, 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 (6).

$$P_{\text{wind}} = \frac{1}{2}\rho A V_{\text{wind}}^3 \tag{6}$$

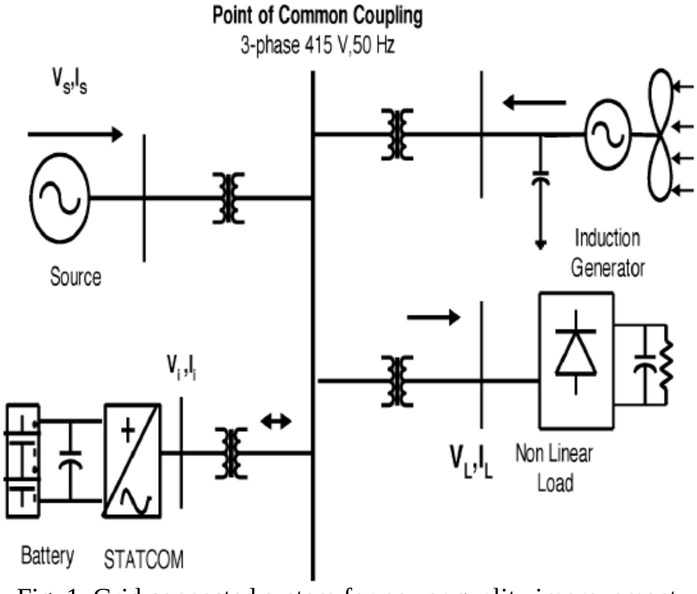


Fig. 1. Grid connected system for power quality improvement.

where (kg/m) is the air density and A (m) is the area swept out by turbine blade, 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 (7).

$$P_{\text{mech}} = C_p P_{\text{wind}} \tag{7}$$

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 and pitch angle. The mechanical power produce by wind turbine is given in (8)

$$P_{\text{mech}} = \frac{1}{2}\rho \Pi R^2 V_{\text{wind}}^3 C_p \tag{8}$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

Where is the radius of the blade (m).

B. BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also control the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the BESS can be used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM [10]–[14].

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling.

C. 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

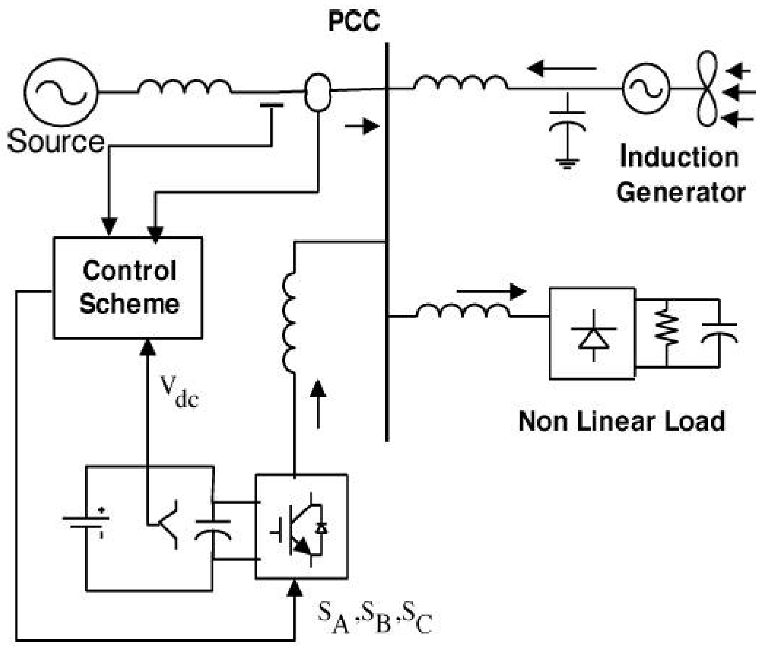


Fig. 2. System operational scheme in grid system.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

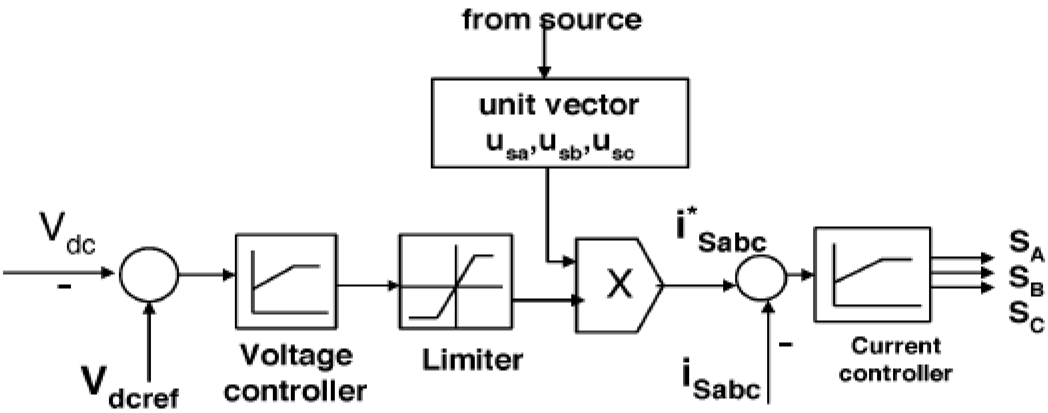


Fig. 3. Control system scheme.

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 Fig. 2.

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

A. 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 Fig. 4.

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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

TABLEI :SYSTEMPARAMETERS

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.

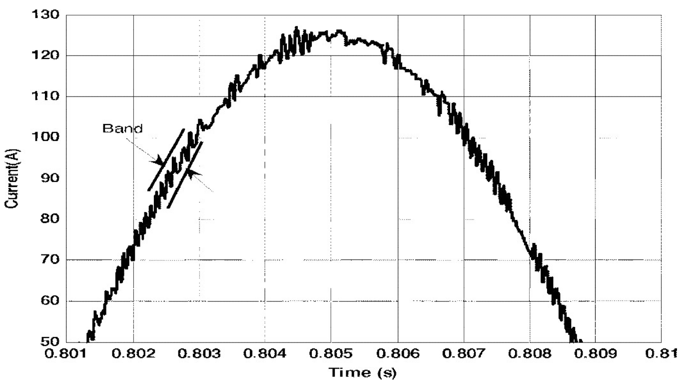


Fig. 4. Switching signal with in a control hysteresis band.

the batteries is also supported by the controller of this inverter. The three phase inverter injected current are shown in Fig. 5.

B. STATCOM—Performance Under Load Variations

The wind energy generating system is connected with grid having the nonlinear load. The performance of the system is measured by switching the STATCOM at time s in the system and how the STATCOM responds to the step change command for increase in additional load at 1.0 s is shown in the simulation. When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate for reactive demand as well as harmonic current.

The dynamic performance is also carried out by step change in a load, when applied at 1.0 s. This additional demand is fulfill by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The result of source current, load current are shown in Fig. 6(a) and (b) respectively. While the result of injected current from STATCOM are shown in Fig. 6(c) and the generated current from wind generator at PCC are depicted in Fig. 6(d).

The DC link voltage regulates the source current in the grid system, so the DC link voltage is maintained constant across the capacitor as shown in Fig. 7(a). The current through the dc link capacitor indicating the charging and discharging operation as shown in Fig. 7(b)

IJAREEIE

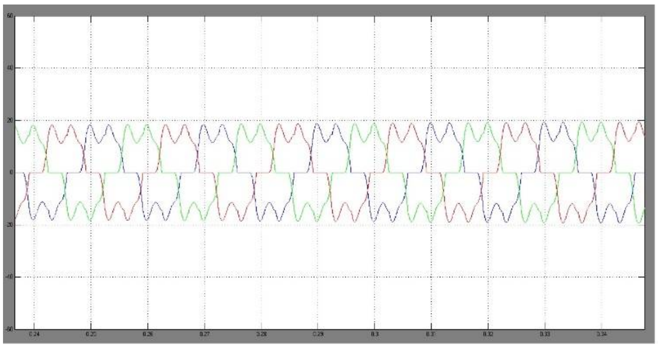
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017



Time(S)

Fig.5. Three phase injected inverter Current.

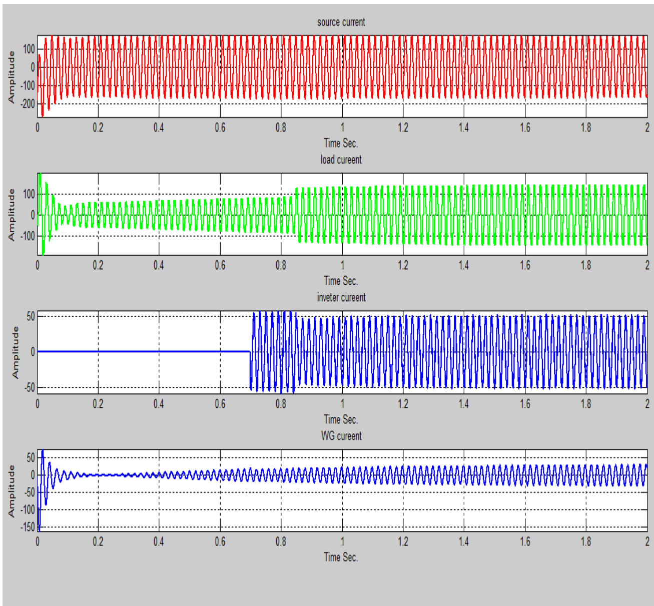


Fig.6. (a)SourceCurrent.(b)LoadCurrent.(c)InverterInjectedCurrent. (d)Windgenerator(Inductiongenerator)current.

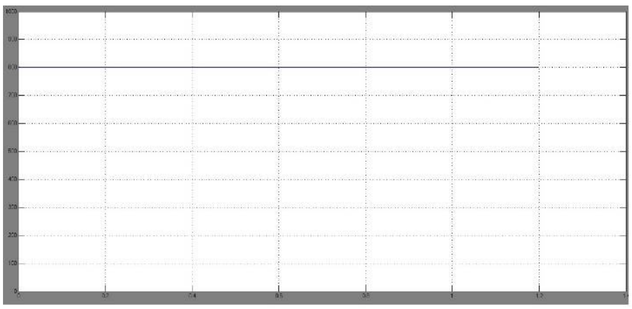


Fig.7. (a)DC link voltage.

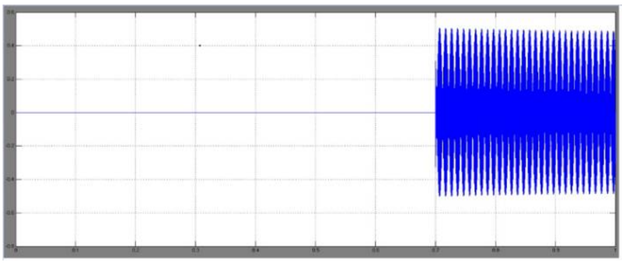
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017



(b) Current through Capacitor

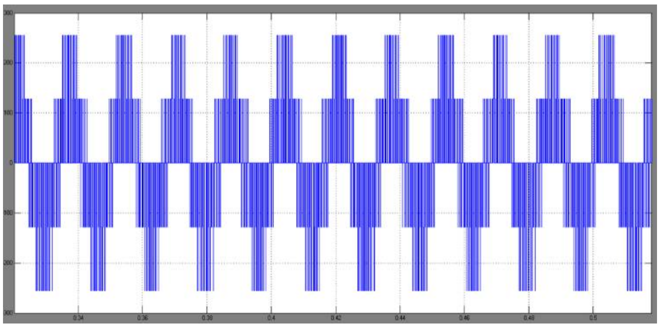


Fig.8. STATCOM output voltage.

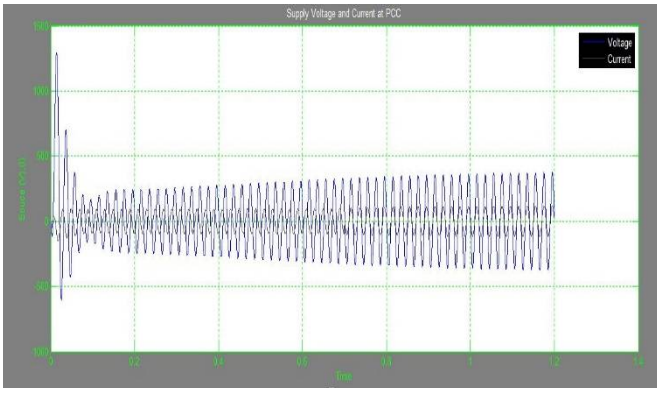


Fig.9. Supply Voltage and Current at PCC.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

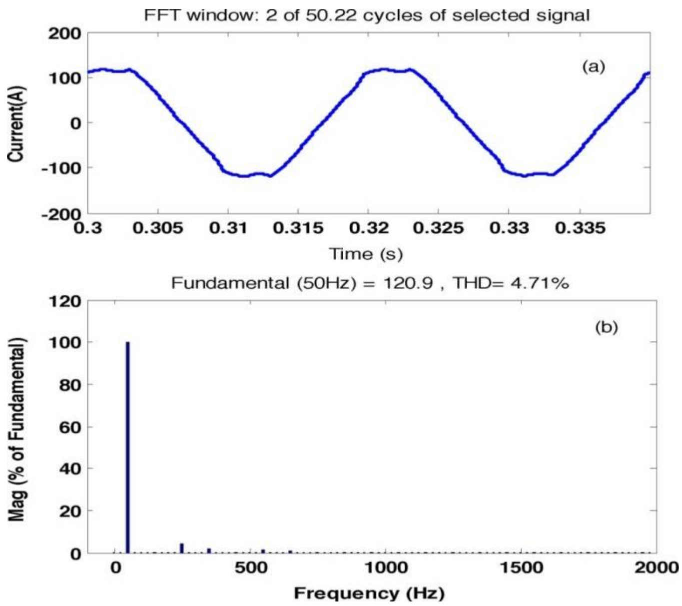


Fig. 10. (a)Source Current.(b) FFT of source current.

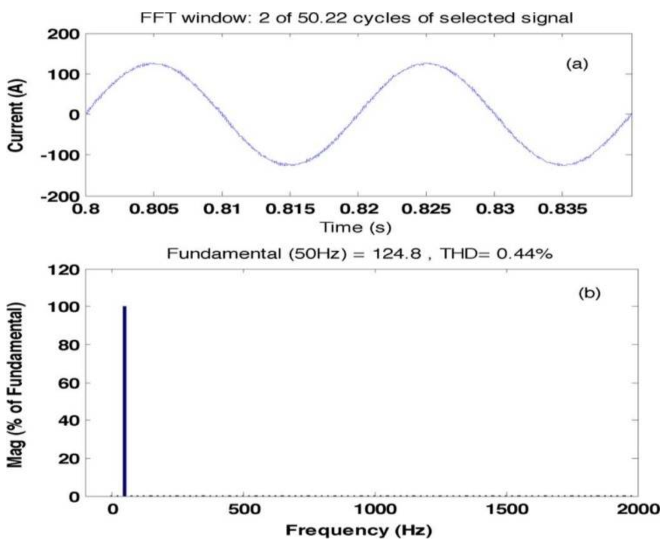


Fig. 11. (a)Source Current.(b) FFT of source current.

C. 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 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 Fig. 8. The dynamic load does affect the inverter output voltage. The source current with and without STATCOM operation is shown in Fig. 9. 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. The Fourier analysis of this waveform is expressed and the THD of this source current at PCC without STATCOM is 4.71%, as shown in Fig. 10. The power quality improvement is observed at point

of common coupling, when the controller is in ON condition. The STATCOM is placed in the operation at 0.7 s and source current waveform is shown in Fig. 11 with its FFT. It is shown that the THD has been improved considerably and within the norms of the standard.
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.

VI. 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 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.

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 issues by energy storage," *EPQU J.*, vol. XII, no. 2, 2006.
[3] 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.
[4] *Wind Turbine Generating System—Part 21*, International standard-IEC 61400-21, 2001.
[5] J. Manel, "Power electronic system for grid integration of renewabl energy source: A survey," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1014, 2006, Carrasco.
[6] 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.
[7] S. Heier, *Grid Integration of Wind Energy Conversions*. Hoboken, NJ: Wiley, 2007, pp. 256–259.
[8] 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.
[9] Indian Wind Grid Code Draft report on, Jul. 2009, pp. 15–18, C-NET.
[10] C. Han, A. Q. Huang, M. Baran, S. Bhattacharya, and W. Litzenberger, "STATCOM impact study on the integration of a large wind farm into a weak loop power system," *IEEE Trans. Energy Conv.*, vol. 23, no. 1, pp. 226–232, Mar. 2008.
[11] D. L. Yao, S. S. Choi, K. J. Tseng, and T. T. Lie, "A statistical approach to the design of a dispatchable wind power—Battery energy storage system," *IEEE Trans. Energy Conv.*, vol. 24, no. 4, Dec. 2009.
[12] F. Zhou, G. Joos, and C. Abhey, "Voltage stability in weak connection wind farm," in *IEEE PES Gen. Meeting*, 2005, vol. 2, pp. 1483–1488.
[13] T. Kinjo and T. Senjyu, "Output leveling of renewable energy by electric double layer capacitor applied for energy storage system," *IEEE Trans. Energy Conv.*, vol. 21, no. 1, Mar. 2006.
[14] R. S. Bhatia, S. P. Jain, D. K. Jain, and B. Singh, "Battery energy storage system for power conditioning of renewable energy sources," in *Proc. Int. Conf. Power Electron Drives System*, Jan. 2006, vol. 1, pp. 501–506.
[15] S. W. Mohod and M. V. Aware, "Grid power quality with variable speed wind energy conversion," in *Proc. IEEE Int. Conf. Power Electronic Drives and Energy System (PEDES)*, Delhi, Dec. 2006.
[16] Fu. S. Pai and S.-I. Hung, "Design and operation of power converter for microturbine powered distributed generator with capacity expansion capability," *IEEE Trans. Energy Conv.*, vol. 3, no. 1, pp. 110–116, Mar. 2008.
[17] J. Zeng, C. Yu, Q. Qi, and Z. Yan, "A novel hysteresis current control for active power filter with constant frequency," *Elect. Power Syst. Res.*, vol. 68, pp. 75–82, 2004.
[18] M. I. Milands, E. R. Cadavai, and F. B. Gonzalez, "Comparison ofcontrol strategies for shunt active power filters in three phase four wire system," *IEEE Trans. Power Electron.*, vol. 22, no. 1, pp. 229–236, Jan. 2007.
[19] S. W. Mohod and M. V. Aware, "Power quality issues & it's mitigation technique in wind energy conversion," in *Proc. of IEEE Int. Conf. Quality Power & Harmonic*, Wollongong, Australia, 2008.

BIOGRAPHY

Masulu GouthamM.Tech degree in the stream of Electrical Power Systems from SreeVidyanikethan Engineering College (Autonomous), Tiurpati, India. He was completed his B.Tech from Sri Satyanarayana Engineering College, Ongole (2011-15) in the stream of Electrical and Electronics Engineering.