© 2016 IJSRSET | Volume 2 | Issue 3 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Power Quality Improvement of Electric Grid Connected Wind–Solar Hybrid Energy System using STATCOM

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ABSTRACT

Voltage, current, time or frequency is the nonstandard occurrence due to a power quality problem that manifested in a failure or uncontrollable or bug locked end user equipment's. The service interruptions developed by such the nonstandard occurrences may affect the utility distribution networks, critical commercial operations and the industrial sensitive loads, which can lead to the cost significant financial losses. In this paper, the issue of this power quality has taken on new dimensions to achieve the distributed and dispersed generation by restructuring the power systems with a modified shifting trend. Usually in the distribution center, the electric grids affect the power quality when the wind power is injected on it. International Electro-technical Commission standard, IEC-61400 provides the guidelines to measure the power quality through the performance of wind turbine. Active power, reactive power, harmonics, electrical switching behaviour, variation of voltage, and flicker are the power quality measurements and are obtained from the grid systems of wind turbine based on national and international guidelines. This paper proposes a new procedure to install the wind turbine with the electric grid. The static synchronous compensator is connected in a common coupling point to migrate the power quality issue of a conventional technique. The proposed wind energy generation system is simulated in MATLAB-Simulink with both linear and nonlinear loads to observe the power quality improvement.

Keywords: Wind energy, Solar Energy, STATCOM, Electric grid, IGBT, PWM.

I. INTRODUCTION

In day to day observation it is evident that the voltage dip is the major factor that causes disturbance in obtaining a quality power. A voltage dip is a short time (10 ms to 1 minute) event that occurs whenever there is reduction in the magnitude of the r.m.s voltage. It is viewed with two parameters, depth/magnitude and duration. The magnitude of the voltage dip range between 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration of half a cycle to 1 min. The voltage dip in a three phase system affects both the phase-to-ground and phase-to-phase voltages. A large increase of the load current, like starting a motor or energizing a transformer cause a fault in the utility system which results in a voltage drop over the network impedance. The voltage drops close to zero of the faulted phases at the fault location. The voltage in the non-faulted phases is more or less unchanged. The voltage dips occur more often and cause severe problems and economical losses, due to the disturbances, flicker, harmonics etc., from end-user equipment as the main power quality problems. One of the most common causes to voltage dips on overhead lines is Faults due to lightning. If the losses due to voltage dips are at considerable limit, mitigation actions can be suggested which is profitable for the customer and even in different cases of utility. Each mitigation action must be carefully planned and evaluated because there is no any standard solution which would work for every site.

In transmission and distribution systems there are different ways to mitigate voltage dips, swell and interruptions. At present, a wide range of latest technology, very flexible controllers are incorporated on newly available power electronics components are available for custom power applications. The most effective devices that use VSC principle are the distribution static compensator and the dynamic voltage restorer. The power quality issues are associated with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. Although it causes disturbances into the distribution network, it has excellent advantages of cost effectiveness, robustness and requires reactive power for magnetization. The change of wind causes the variation in active power and will affect the absorbed reactive power and terminal voltage of an induction generator. In wind energy generation system under normal operating condition a trusted control scheme is required to ensure the proper control over the active power production. A battery energy storage system is required to compensate the fluctuation generated by wind turbine.

In this paper a STATCOM based control technology has been proposed for commercial wind turbines for improving the power quality which can technically manage the power level associated with it. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives. Unity power factor at the source side, Reactive power support only from STATCOM to wind Generator & Load and Simple bang-bang controller for STATCOM to achieve fast dynamic response. The latest wind turbine generating systems are installed with pulse controlled inverters. Due to the improvement in switching techniques, the voltage and current at the point of common connection can be made in sinusoidal form and at unity power factor to improve the power quality at PCC.

II. METHODS AND MATERIAL

1. Proposed Statcom System

Proposed STATCOM

The block diagram of STATCOM shown in Fig. 1 has been used as a VSC (Voltage source converter) which is connected to the grid with an inductance. The inductance can be replaced with a reactor or a transformer. The working of a statcom is understood by the phasor diagram as shown in Fig. 4. In this system to maintain the grid voltage vector UGrid at a constant value, a constant grid voltage with a transformer turns ration of 1:1 is considered.

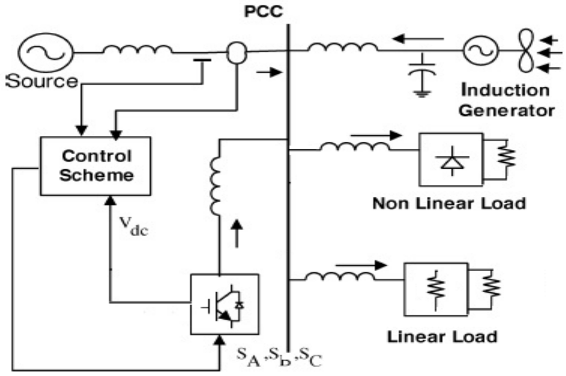

Figure 1. Block Diagram

The compensator current IGrid flows in positive direction. If the value of the compensator voltage vector UComp is higher than the grid voltage vector, then it is found that the vector of the voltage drop across the inductance XT is in the same direction as that of the compensator voltage vector. In order to operate the STATCOM as an inductor, the compensator current IGrid should flows in positive direction. This is achieved only if the value of the compensator voltage vector UComp is lower than the grid voltage vector. Under this condition it is found that the vector of the voltage drop across the inductance XT is in the opposite direction as that of the compensator voltage vector.

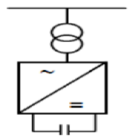

Figure 2. Grid Connection

In three-phase balance system, the RMS value of the voltage source is calculated at the sampling frequency from the source phase voltage (Vsa, Vsb, Vsc) and is expressed in equation (1) with the reference of sampled peak voltage.

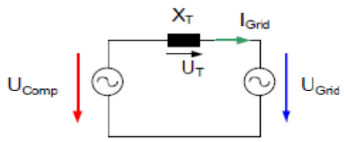

Figure 3. Single Line Grid Connection

$$V_{sm} = \{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)\}^{1/2} \qquad (1)$$

The in-phase unit vectors are obtained from AC sourcephase voltage and the RMS value of unit vector (Usa, Usb, Usc) as shown in equation (2).

$$U_{sa} = \frac{V_{sa}}{V_{sm}}, U_{sb} = \frac{V_{sb}}{V_{sm}}, U_{sc} = \frac{V_{sc}}{V_{sm}} \qquad (2)$$

The in-phase generated reference currents are derived using in-phase unit voltage template as in equation (3).

$$i_{sa} = I.U_{sa}, i_{sb} = I.U_{sb}, i_{sc} = I.U_{sc} \qquad (3)$$

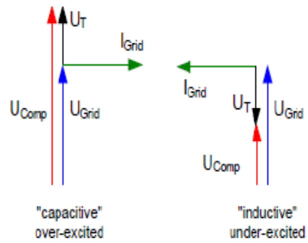

Figure 4. Phasor Diagram

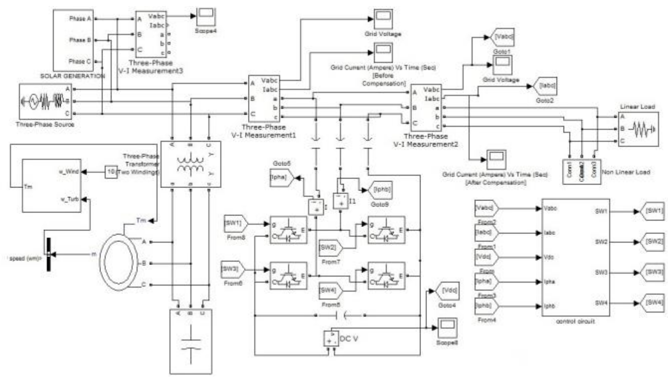

Figure 5. Circuit Diagram

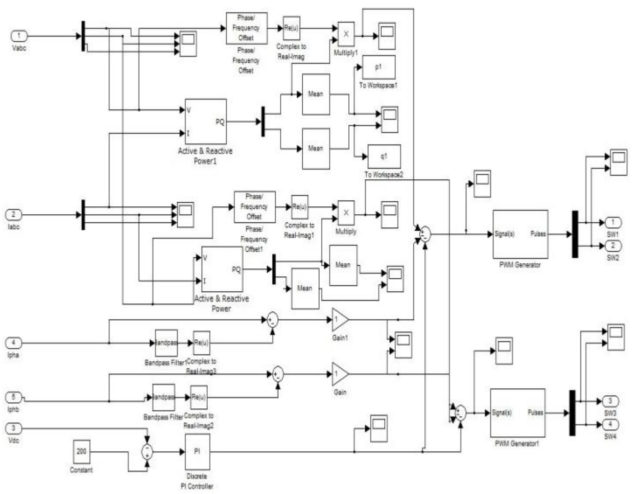

Figure 6. Control Unit

Where, I is proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal. Bang-bang controller with a current controlled technique is a proposed control scheme for the STATCOM to inject/absorb the currents into/from the grid. The control scheme needs the measurement of various control system variables such as three-phase source current, DC voltage, inverter current which is measured with the help of sensor and is used to maintain them between boundaries values. This control scheme also provides correct switching signals for STATCOM. The STATCOM operates in the current control mode only when it receives a current which is the difference between the reference current and the actual current. The supply currents and instantaneous reference currents are sensed using a carrier less hysteresis PWM controller which generates gating pulses for the six IGBTs of the VSI working as STATCOM

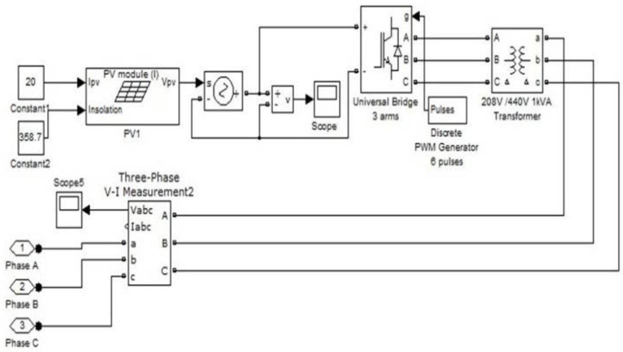

Figure 7. Circuit Diagram of proposed STATCOM

III. RESULTS AND DISCUSSION

The STATCOM control scheme for the grid connected wind – solar Hybrid energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. Bang-Bang Current Controller for the grid connected system is implemented in the current control scheme. Here the actual current is detected by current sensors and are subtracted from the reference current which is generated as in (10) for obtaining a current error for a hysteresis based bang-bang controller. The switching signals are generated from the reference current and are simulated within hysteresis band of 0.08. The compensated current for the nonlinear load and demanded reactive power is provided by the inverter. The system parameter for given system is given in Table I.

Table I. System Parameters

Sl.No	Parameters	Rating
1	Grid voltage	415 V
2	Operating frequency	50 HZ
3	Induction generator	200KVA, 415V, 60 Hz, Speed 1500rpm.
4	Inverter	DC Link Voltage 800V, DC Link Capacitance 100µF
5	Switching Frequency	2 kHz.
6	Linear Load	15Kw
7	Nonlinear load	25 KW
8	Solar PV parameters	212.2kV, Short circuit current = 5A,Temperature coefficient = 35^0 C, Solar irradiation (Sx)=165W/M^2

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 0.22 s. This additional demand is fulfilled by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The simulation results are shown in the figures below

Simulated Results of a proposed STATCOM

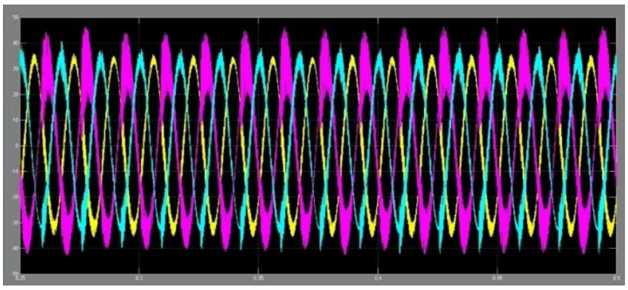

Figure 8. Without Compensation

Simulation results are presented to demonstrate the impact of integration of wind generating system with the grid and the effectiveness of the STATCOM control scheme in minimizing the impact.FFT analysis carried out for the source current shows that the THD is considerably reduced and is clearly within limits imposed by standards with STATCOM connected at point of common coupling (PCC).

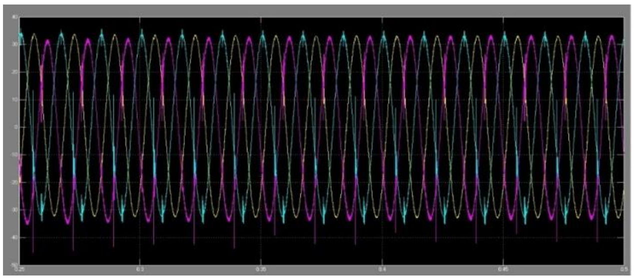

Figure 9. With Compensation

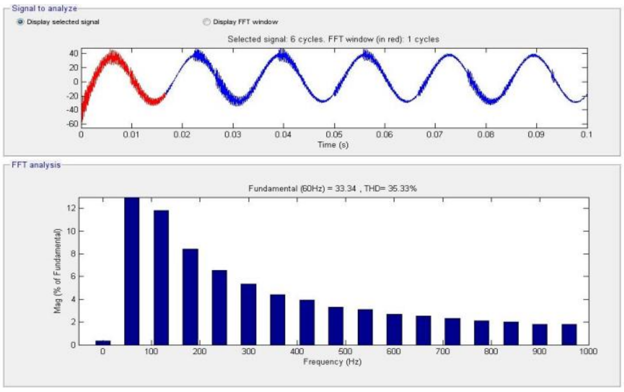

Figure 10. THD without Compensation

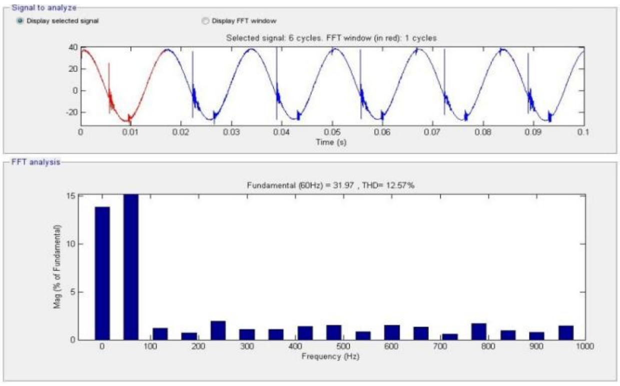

Figure 11. THD with Compensation

IV. CONCLUSION

STATCOM system is one of the effective equipment for controlling the mitigation of PQ disturbances that are caused in the grid connected system. The STATCOM compensator is an excellent device which can operate in current control and voltage control mode for compensating voltage variation, unbalance and reactive power respectively. The simulation results show that the performance of STATCOM system is found to be satisfactory in compensating the dip from the power supply system and to improve the power quality at the consumer premises. STATCOM control algorithm is simple and able to correcting the power factor close to unity, eliminate harmonics in supply currents, provide load balancing and regulate voltage at PCC. Due to the unique property of providing a self-supporting DC bus to the STATCOM, it reduces the THD in the supply currents for nonlinear loads and eliminates the generated harmonics for rectifier based non liner loads. The unbalanced load current caused in the single phase system is also balanced using the STATCOM current.

V. REFERENCES

[1] Abrantes A. (2012). Overview of power quality aspects in wind generation “North American Power Symposium (NAPS)”, Champaign, IL, 1 – 6.

[2] Wenxia Pan, Wenzhong GMuljadiE. (2009). The dynamic performance and effect of hybrid renewable power system with diesel/wind/PV/battery “proc. Of IEEE-International Conference on Sustainable Power Generation and Supply, 2009. SUPERGEN '09”Nanjing,1 – 5.

[3] Muthusamy, M.; Kumar, C.S. (2014). New STATCOM control scheme for power quality improvement in wind farm “proc. Of IEEE-International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE)”Coimbatore,1 – 5.

[4] Mohod, S.W, Aware M.V. (2010). A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement “IEEE journal of systems” 346 - 352.

[5] Nirmala, N, Kumar, V.S. (2013). A STATCOM-control scheme for wind energy system to improve power quality “proc. Of IEEE-International Conference on Information Communication and Embedded Systems (ICICES)” Chennai,1108 - 1113.

[6] Arezki, S. Boudour, M.(2014). Improvement of power quality of wind-FC energy power hybrid system connected to network “proc. Of IEEE-International Symposium on Environmental Friendly Energies and Applications (EFEA)”St. Ouen,1 –7.

[7] Rahmani S. Hamadi A. Al-Haddad K. Kanaan H.Y. (2012). A multifunctional power flow controller for photovoltaic generation systems with compliance to power quality standards “proc. Of International Conference on IEEE Industrial Electronics Society”Montreal,894 - 903.

[8] Sunil T.P. Loganathan N. (2012). Power quality improvement of a grid-connected wind energy conversion system with harmonics reduction using FACTS device “proc. Of IEEE-International Conference on Advances in Engineering, Science and Management (ICAESM)”Nagapattinam, Tamil Nadu,415 - 420.

[9] Aboul-Seoud T,Sharaf A.M. (2010). Utilization of the Modulated Power Filter Compensator scheme for a grid connected rural hybrid wind/tidal energy conversion scheme “proc. Of IEEE-International Conference on Electric Power and Energy Conference (EPEC)”Halifax, NS,1 –6.

[10] GhorbanianM.J. Goodarzvand F. Poudaryaei A. Mahadi W.N.L. (2014). Power quality improvement of grid connected doubly fed induction generator using STATCOM and BESS “proc. Of IEEE-International Conference on Engineering Technology and Technopreneuship (ICE2T)”Kuala Lumpur, Malaysia,110 - 115.

[11] George S.K. Chacko F.M. (2013). Comparison of different control strategies of STATCOM for power quality improvement of grid connected wind energy system “proc. Of IEEE-International Conference Automation, Computing, Communication, Control and Compressed Sensing (iMac4s)”Kottayam,650 – 655