

GRID CONNECTED WIND ENERGY SYSTEM BASED ON A STATCOM CONTROL SCHEME FOR POWER QUALITY IMPROVEMENT

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Abstract

Injecting of the wind power into electric grid affects the power quality. The performance of the wind turbine and thereby power quality are determined on the basis of measurements and the norms followed according to the guideline specified in International Electro-technical Commission standard, IEC-61400. The influence of the wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national/international guidelines. The project study demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATic COMpensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relieves the main supply source from the reactive power demand of the load and the induction generator. 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 and Load, Simple bang-bang controller for STATCOM to achieve fast dynamic response. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented.

Keywords—International electro-technical commission (IEC), power quality, wind generating system (WGS).

1. Introduction

To have growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to reduce 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 operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine.

There has been an extensive growth and quick improvement in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28000 wind generating turbines are successfully

operating all over the world. In the fixed speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, 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 disturbances into the distribution network. One of the easiest methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent merits of cost effectiveness and robustness. However; the 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 power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation 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 generation 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.
- Simple bang-bang controller for STATCOM to achieve fast dynamic response.

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 developed 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.

The standard norms are specified.

- IEC 61400-21: Wind turbine generating system, Part-21 Measurement and Assessment of power quality characteristic of grid connected wind turbine
- IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.
- 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 provides the base for the utility assessment regarding a grid connection.

B. Voltage Variation

The voltage variation issue results from the wind velocity and generator torque. 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. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, 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 that can be used to measure flicker directly.

C. Harmonics

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

D. Wind Turbine Location in Power System

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

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 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 degrades the power quality in the grid.

III. Proposed System of Statcom

A static synchronous compensator (STATCOM), also known as a static synchronous condenser (STATCON) is a regulating device used on AC electricity transmission networks. It is based on a power electronics voltage source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices.

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 Fig. 1.

The grid connected system in Fig. 1, consists 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 (6).

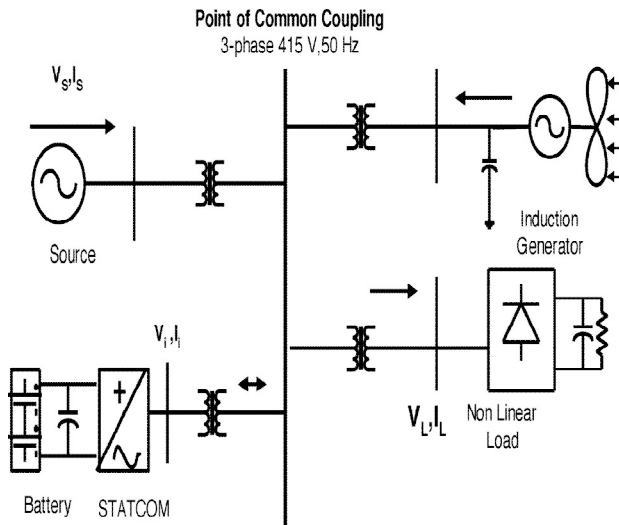


Fig. 1. Grid connected system for power quality improvement.

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 (7).

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. When the data file (winddata.dat) is clicked, the wind data gets into the workspace. Now the model file is run for a specified time say 0.2. Now the Wind turbine modeled for 1800 rpm will produce a Torque T_m .

This torque is the input for all the three asynchronous generators. Here we consider three setup of wind turbine and three asynchronous generators just for the sake of more power. Immediately after the output of the generators, a capacitor filter bank is employed in order to maintain the power factor nearly to one. Because any less power factor will lead to the loss of power in the form of reactive power.

Apart from this generator, another form of generator is also connected to the grid. So all the power generated by various means are commonly connected to the grid.

Now the statcom function is to maintain the stability in the output voltage. So the basic principle is to convert the DC power obtained in battery into ac power, and that has to be injected into the distribution line, by means of some switching techniques. Here we use IGBT, to perform this operation. Initially, the wind power obtained itself is utilized as a DC source, after rectifying the generated supply using three arm rectifier, we get that DC. Now this DC is inverted using 3 arm, IGBT based inverter.. The PWM pulses are given at a frequency of 20KHZ. After this is inverted, an LC filter is connected in series in order to allow only 50H components into the grid. The various waveforms are observed in oscilloscopes through a corresponding measurement block. The THD obtained is less than 0.01% without any hysteresis.

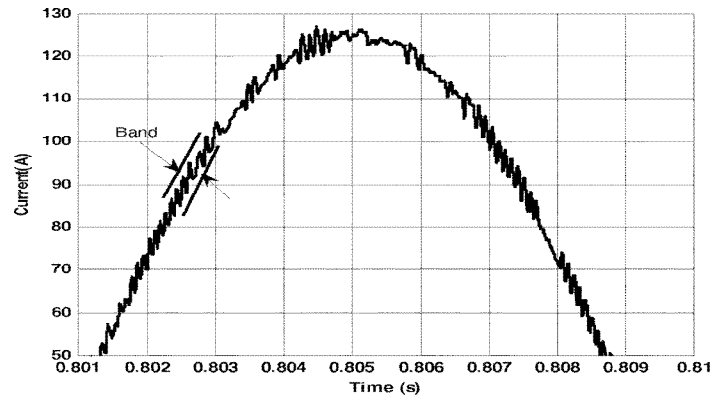
A. Voltage Source Current Control—Inverter Operation

The three phase injected current into the grid from STATCOM will cancel out the distortion caused by the non- linear 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.

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, $R_s = 0.01\Omega$, $R_r = 0.015\Omega$, $L_s = 0.06H$, $L_r = 0.06H$
3	Line Series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage = 800V, DC link Capacitance = 100 μ F, 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 within a control hysteresis band.**

The real power transfer from the batteries is also supported by the controller of this inverter.

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 $t = 1.0$ 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 fulfilled by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The result of source current, load current are shown in Fig. 5(a) and (b) respectively. While the results of injected current from STATCOM are shown in Fig. 5(c) and the generated output voltage from wind generator are depicted in Fig. 5(d).

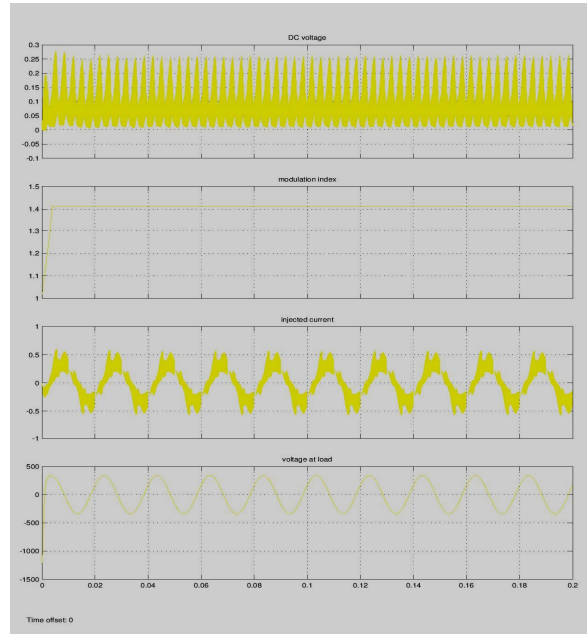


Fig. 5. (a) DC Voltage. (b) Modulation index. (c) Inverter Injected Current. (d) Voltage at Load.

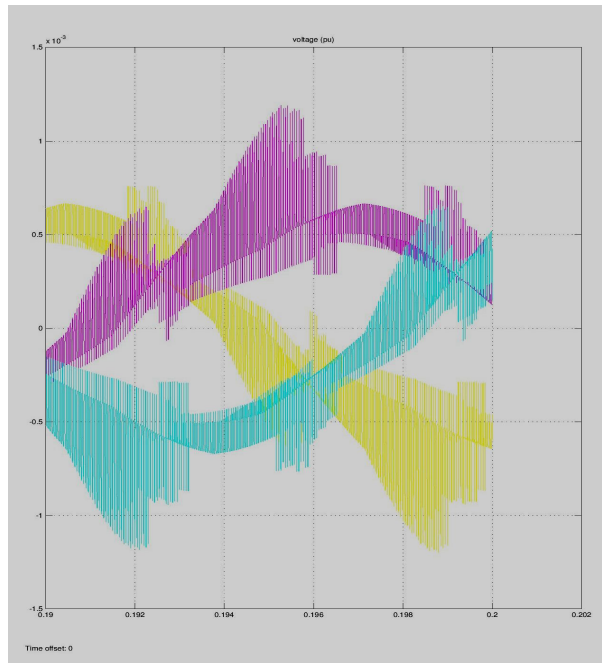


Fig. 6. STATCOM output voltage.

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. 5. The dynamic load does affect the inverter output voltage. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation.

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. 6 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.

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.

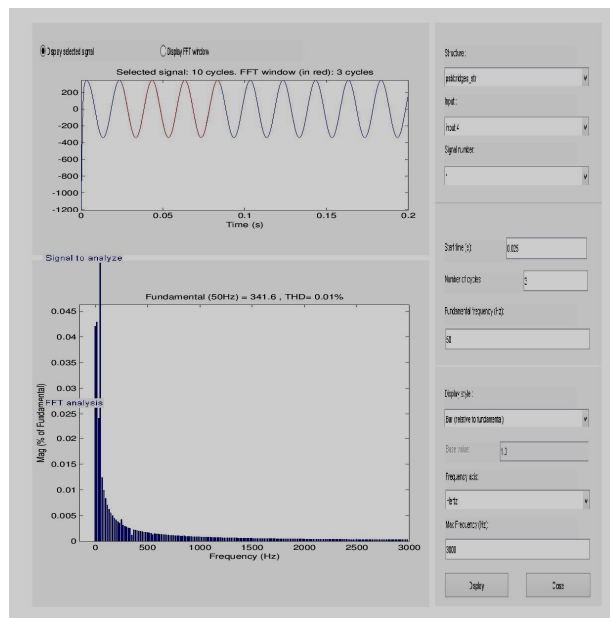


Fig. 7. (a) Source Current. (b) FFT of source current.

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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