Power Quality Improvement By Using Statcom To Grid Connected Wind Energy System

Brijesh Kumar Dohare¹, Raghvendra Pratap Singh²
¹ (electrical engineering / maharishi university of information technology, India)  
² (electrical engineering / maharishi university of information technology, India)

Abstract: Now a days the electrical energy is basic necessary of all over world. Due to generation, transmission and utilization of wind energy system is affected the voltage variation, flicker, harmonics, and electrical behavior of switching operations. The voltage varying, voltage stability will be loss and power factor is lagging to connect the load. In this paper we studying use of static compensator (STATCOM) with battery energy stored system (BESS) at point common coupling to minimize the power quality matter. The wind energy system is connected to grid connected power quality improvement by using of STATCOM scheme of simulated of matlab/simulink in power system of block set. The desired power system maintain voltage stability and phase difference is zero, minimize distortion, harmonics of power system according to guidelines specified in IEC-61400 standard (International Electro-technical Commission) provides some norms and measurements parameter.

Keywords: BESS, STATCOM, FACT, GTO, PWM, THD

I. Introduction

When the power supply is transmitted through transmission line, It has two disadvantages one is power quality and another is reliability. First part has distortion harmonics, swell etc. and another part has voltage sags and outage. Voltage sags is much serious problem and more danger of transmission line. When the distortion, harmonics generated all equipment’s are unstable condition. Due to harmonics, distortion line has transmitted power loss, power substantial fraction of the problems of power distribution system. if the harmonics insert some cycles it cannot maintain control of process. Due to sag and distortion, unwanted electrical wave form the supply is interrupted. My main purpose to maintained power quality to supply. The active power of wind energy system is proper control at normal condition. On happening of increasing grid disturbance of the energy storage battery system of wind energy generating station is compensate the voltage variation by wind turbine. The uses of STATCOM CONTROL scheme to grid connected wind energy generation for power factor and power quality improvement has following objectives.

- The power factor is unity on source side.
- STATCOM is support only Reactive power to wind Generator and Load.

Simple impact controller for STATCOM to achieve brisk component response

II. STATCOM

A STATCOM is a voltage-source converter which converts dc power into ac power of variable amplitude and phase angle. It is Flexible Alternating Current Transmission Systems (FACTS) devices, namely Static Synchronous Compensator (STATCOM) are used to control the power flow through an electrical transmission line connecting various generators and loads at its sending and receiving ends. FACTS devices consist of a solid-state voltage source inverter with several Gate Turn Off (GTO) thyristor switch-based valves and a DC link capacitor, a magnetic circuit, and a controller. Static synchronous compensators (STATCOMs), consist primarily of a three-phase PWM rectifier/inverter that can be shunt-connected to any system in order to dynamically compensate the reactive power requirement of the system, through its ac side so that active power is returned to the ac power system, thereby discharging the capacitor.

Pulse-Width-Modulated

Pulse-width modulation (PWM) provides a way to decrease the total harmonic distortion of load current. A PWM inverter output, with some filtering, can generally meet THD requirements more easily than the square wave switching scheme. The unfiltered PWM output will have a relatively high THD, but the harmonics will be at much higher frequencies than for a square wave, making filtering easier. Control of the switches for sinusoidal PWM output requires a reference signal, sometimes called a modulating or control signal, which is a sinusoid in this case and a carrier signal, which is a triangular wave that controls the switching frequency.

(a) Sinusoidal reference and triangular carrier
(b) Output is +Vdc when Vsine>Vtri and is -Vdc when Vsine<Vtri

DOI: 10.9790/1676-1203030108
**Grid Connected System Configuration**

The STATCOM is injects the current from the grid in such a way free from the harmonics and their phase angle is needed to desired value. This inject current is cancel out reactive part and 3\textsuperscript{rd} and 5\textsuperscript{th} harmonics of the load and current of induction generator, improve power factor and power quality. The improvement power quality of grid connected system is implemented at point of common coupling (PCC), as shown in Fig. 1.

The available power of wind energy system is presented as under in (4.6).

\[
P_{\text{wind}} = \frac{1}{2} \rho A V_{\text{wind}}^3
\]  

(4.6)

Where \(\rho\) (kg/m\(^3\)) is the air density and \(A\) (m\(^2\)) is the area swept out by turbine blade, \(V_{\text{wind}}\) is the wind speed in m/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 (4.7)

\[
P_{\text{mech}} = C_p P_{\text{wind}}
\]  

(4.7)

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

\[
P_{\text{mech}} = \frac{1}{2} \rho \Pi A V_{\text{wind}}^3 C_p
\]  

(4.8)

where \(R\) is the radius of the blade (m)

**BESS-STATCOM**

The voltage regulation is depend upon energy storage element like (BESS) the battery energy storage system. They will normally keep up dc capacitor voltage steady and is most appropriate in STATCOM since it quickly infuses or ingested responsive energy to balance out the matrix framework. The distribution and transmission system control rate is very fast. The BESS can be used in charging and discharging operation due to power fluctuation. The battery is connected in parallel to the dc capacitor of STATCOM.

**System Operation**

The induction generator is connected to STATCOM in shunt with interface with battery energy storage and nonlinear load at the PCC in the gridsystem. The strategy of output STATCOM compensator is varied according controller and maintains the power quality to 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.
The reactive power support STATCOM using IGBT. The main block diagram of the system operational scheme is shown in Fig. 6.10

Reactive Power
In the wind generator withdraw three phase current from the grid system fed to statom will cancel out the distortion to nonlinear load in the grid connected through the transformer to fed three phase inverter. The IGBT based three phase inverter is connected to grid through the transformer. The era of changing signs from reference current is recreated inside controller. The compensated current for the nonlinear load and demanded reactive power is provided by the inverter. The real power transfer from the batteries is also supported by the controller of this inverter.

Non-Linear Load
The non-linear load is considered for diode front-end rectifiers, which are widely used in power converters and ac machine drives with a dc-link capacitor. A non-linear load causes a distorted voltage wave from \( V_p \) at the point of common coupling due to current \( (in) \). The voltage include odd harmonics with order \( 6n\pm1(n = 1,2,\ldots) \) multiples of synchronous frequency \( \omega_s) \).

\[
V_P = V_S - V_{NS} = V_S - R_S i_S - L_S \ldots \ldots ..(4.9)
\]

where \( R_S \) stator resistance, \( V_P \) stator output voltage at the point of common coupling, \( V_{NS} \) non-linear voltage, \( V_S \) induced stator voltage, \( i_S \) stator current.

Voltage Regulator
The effectiveness of the STATCOM is providing continuous voltage regulation for distribution system. The STATCOM current of phase A lags behind the load voltage by 90° which illustrate the operation of the system as an inductive compensator. The dc voltage and reactive power response are measured with STATCOM connected and switched at \( t = 2.1ms \), it can be seen that the dc power is reduced and the reactive power of the inductive load is absorbed by the STATCOM.

Statcom Current Control:
Control Strategy
The control scheme approach is based on injecting the currents into the grid using “Direct Control. Direct current control uses track PWM technology on current instantaneous value to feedback control. Basically indirect current is respectively simple, the quality is not high slow speed, the current control way is fast and quality is high, it can get control method respectively simple.

\[ \text{figure 5.2 Instantaneous reactive and harmonic current detection} \]
Power Quality Improvement By Using Statcom To Grid Connected Wind Energy System

Figure 5.2 in the detection method load current Ia, Ib, Ic of three phase instantaneous rective and harmonic current detection method, in which Ia, Ib, Ic is a three-phase load currents, Udcref is DC side voltage reference value, Udc is the detected DC side voltage. Firstly, transform Ia, Ib, Ic into α-β phase coordinates through abc three-phase coordinate, so get ip and iq. The process compose of a phase voltage Ua and through the lock link PLL acquisition to get the sine and cosine signals which has the same phase voltage as a phase. In order to obtain the harmonic current and reactive power signal, disconnect. The calculate the fundamental active current signal, we will compare to the \( p+iq=s \) equations so iq reactive channel iq filtered signal as compared with active current channel imperative channel iq( and iq=0 ), and the DC control signal and the filtered signal are compared with active ip. The control system scheme for generating the switching signal to the STATCOM is shown in Fig. 5.3.

![Figure 5.3 dq Current Control Based on PI control](image)

In the link of modulation, switch frequency varies with the compensation current in the modulation, which causes the great pulsating current and switching noise, while using the triangle wave modulation method, switching frequency is equal to the triangular carrier frequency, pulse current is small, and the output voltage of less harmonic content. the pulse as the inverter switching device to control signal, resulting in the inverter output to obtain the desired current waveform, the control process is shown in figure 5.3.

![Figure 5.4 Triangle wave comparison](image)

Figure 5.3 shows that control mode is different to the use of other triangular wave as carrier wave of PWM control.

MATLAB Simulation

The Simulink model library includes the model of Conventional Source, Asynchronous Generator, STATCOM, Non-Linear Load, Inverter, Grid Voltage, Battery, Line Series Inductance and others that has been constructed for simulation. The simulation parameter values for the given system are given in Table 5.1

<table>
<thead>
<tr>
<th>System Parameters</th>
<th>3-Phase, 415, 50 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grid Voltage</td>
</tr>
<tr>
<td>2</td>
<td>Induction Motor</td>
</tr>
<tr>
<td>3</td>
<td>Inverter parameters</td>
</tr>
<tr>
<td>4</td>
<td>IGBT Rating</td>
</tr>
<tr>
<td>5</td>
<td>Load Parameter</td>
</tr>
</tbody>
</table>
5.4.1 MATLAB Simulation Grid Connected Wind Energy System using STATCOM

MATLAB Simulation of Current Controller

A) Control Block for STATCOM

B) ST PWM control Block

Figure 5.8 Simulation Model of Control System

Figure 5.9 Simulation Model of STATCOM Control System (Detailed)

Figure 5.10 Simulation Model of PWM
III. Results And Discussion

Simulation of wind energy system connected to the grid is carried out in MATLAB/Simulink environment. Following two cases are analyzed as follows:

Wind connected to grid without STATCOM

In this case, simulation of defined system is carried out without using STATCOM and waveforms are analyzed. The current and voltage waveform shown in the graph fig. 6.1 in this graph wind power generation station is connected to grid , we can observed discontinuous waveform due to integration of voltage and current are not in same phase, it is seen that the total harmonics distortion (THD) without use of STATCOM with FET analysis for grid connected system wind energy system of current is found to be 10.30%.

Wind connected to grid with STATCOM

In this case, simulation is carried out using STATCOM control to analyze effect of this on system. The current and voltage waveform of phase shown in the figure 6.3 it is observed that the source current waveform are in phase with source voltage after connection of STATCOM. Fig 6.4 in the presents the wind energy system is

FIGURE 5.11 SIMULATION MODEL OF WIND ENERGY SYSTEM

FIGURES AND TABLES

Figure 6.1 Source Voltage and Current of Phase A (without STATCOM)

Figure 6.2 FFT analysis of source current

DOI: 10.9790/1676-1203030108 www.iosrjournals.org 6 | Page
connected to grid with STATCOM fed from FET analysis for the source current waveform with STATCOM is 1.17%.

**Figure 6.3** Source voltage and current with STATCOM

**Figure 6.4** FFT analysis of source current with STATCOM

In the DC link voltage regulates the source current in the grid system, so the DC link voltage is maintained constant across the capacitor as show in figure 6.5. The current through dc link capacitor indicating the charging and discharging operation

**Figure 6.5** DC link Voltage

**IV. Conclusion**

**Conclusion:**
The control of VSI based Direct Current controls carried out using MATLAB/Simulink. Results depicts THD, active and reactive power of grid connected wind energy system dynamic performance.

**Conclusions**
1- The DC current control scheme for power quality improvement to grid connected wind energy system with linear or nonlinear load.
2- thus the waveform of voltage and current are distorted on both sides in wind energy system in source current on the grid is affected due to the effects of nonlinear load and windgenerator,
3- STATCOM-BESS based SIMULINK MODEL for grid connected wind energy system is proposed. The harmonic part of load current is cancel out.
4-It maintains the source voltage and current in phase and supports the reactive power demand for the wind generator and load at PCC in the grid system.
5- It is demonstrated that the THD after using STATCOM has been improved considerably and is within the norms of the IEC standards.
6-The 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.

Acknowledgements

Suggestions for future work

STATCOM-BESS based control has capability of improving power quality as demonstrated already. However, work can be done to make switching period of STATCOM faster and reliable. Also, improving quality of battery is one of the major areas which can further improve performance of proposed controller.

References

[18] Polly Thomas - Received B-Tech in Electrical & Electronics from St. Joseph”s College of Engineering and Technology , Palai Kerala under the Mahatma Gandhi University in 2010