Simulation Of Power Quality Enhancement On Grid Integrated Wind Energy System Using Solar Powered STATCOM

R. Janakiraman
Research Scholar,
JNT University, Hyderabad, India,

S. Paramasivam
[2] R&D Head,
ESAB Group,
Chennai, India

Abstract

In this paper, the Simulation of Power Quality Enhancement on Grid Integrated Wind Energy System (PQEGWES) using Solar Powered STATCOM is to be presented. This scheme has to be improving the power quality of the grid integrated wind energy system using solar power, is used to be charging the capacitor in STATCOM. The injection of the wind power into the grid is affects the power quality of the system. Some of the power quality issues like voltage sag and harmonics. In this proposed system, simulation model of 3-phase system without compensation and with compensation are modelled and simulated. In this system a solar powered STATCOM is used and it is capable to improve the grid voltage and to reduce the harmonic components. The complete system is to be modelled and simulated in the MATLAB/ SIMULINK environment. The results of this sustainable and renewable model and design are to be promoting green energy systems to meet the power demand.

Keywords

Power quality, STATCOM, wind turbine (WT), wind generator (WG), solar power

1. Introduction

In the increasing rate of depletion of conventional energy sources (like fossil fuels) have given rise to increase and emphasis on renewable energy sources such as wind, solar, micro-hydro, biogas, etc. Particularly, wind power generation is popular for the grid integrated system, as well as the electricity supply in isolated areas. Apart from the utilization of wind power, the power quality is essential factor for the power system. Both of the electric utilities and end users of electric power are increasingly concerned about the quality of power. The manifests of the power quality are voltage, current and frequency that, results in failure or mal-operation of the customer equipments.

An integration of the wind power into an electric grid affects the power quality. The group of devices used for mitigation of power quality problems is known by the name of Customer Power Devices (CPDs). The family of compensating devices are mainly: Static Synchronous Compensator (STATCOM), Dynamic Voltage Restorer (DVR) and Unified Power quality Conditioner (UPQC). The performance analyses of STATCOM with a battery energy storage system (BESS), which is connected at the point of common coupling of wind power generating system, and the existing power systems to mitigate the power quality issues.

During the normal operation, wind turbine produces a continuous variable output power, and these power variations are mainly caused by the effect of turbulence, wind shear and tower-shadow and of control system in the power system have been presented [1], [2]. The coordinated voltage control scheme of SEIG based Wind Park is to be improving the network voltage profile and for minimizing the steady-state loading of the STSTCOM is effectively support the system during the contingencies have been discussed [3]. The permanent magnet stator-less contra-rotating wind power generation (PMSLCRWPG) is designed and tested for various wind speeds. The experimental output results of single unit of PMSLCRWPG will be equivalent to the output power produced by the two single-rotor generator has been given [4]. Variation of the mutual inductance of stator and rotor windings of SEIG is taking care of the wind speed variations, and to maintain the output voltage at its rated value which has been presented [5]. The performance of Field Oriented Control (FOC) and Direct Torque Control (DTC) schemes is evaluated in terms of torque and flux ripples, and their transient response to step variations of the torque command. Both of the schemes were compared and the FOC alone shows the high flux and torque ripples have been given [6]. A network needs to manage the fluctuations, due to the load variations, erratic operations etc. The main power quality issues are voltage sag, swell, flickers, harmonics etc., are to be compensated. Also, a wind generating system is directly coupled to the induction generator and, grid integrated system has been discussed [7].

A STATCOM based control technology has been proposed for mitigating the power quality issues from the integration of the wind farms to the grid system. In the event of increasing grid disturbance, a battery energy storage system for the wind energy generating system (BESS) is generally required to compensate the fluctuation generated by wind turbine has been presented [8], [9]. The battery energy storage system (BESS) is connected in parallel to the dc capacitor of STATCOM, and it is naturally maintain the dc capacitor voltage constant. This mechanism is best suited for the STATCOM; since it is rapidly injects or absorbs reactive power to stabilize the grid system has been discussed [10]. In a DFIG based wind energy system, the effects of several parameters are (drive-train inertias, stiffness, generator mutual inductance, and stator resistance), operating points (rotor speed, reactive power loading, and terminal voltage level), and grid strength (external line reactance value) on the system are modelled and discussed [11]. A complete analysis of a wind turbine (WT) driven self- excited induction generator (SEIG) is modelled and it is to supply the isolated load and tTo achieve this, a new simplified model first been derived for a WT driven SEIG system [12].

The steady state performance of the SEIG with different optimization technique is available and the effects of various system parameters have been presented in [13]. A series-parallel compensation system tracks the maximum power curve of the wind turbine and this system can be scaled up to a higher voltage and higher power to process very high power in SEIG based wind power generation which has been studied [14]. A number of approximations and simplifications had to be made to describe the fault behaviour and to determine the equations for the short circuit current analysis of DFIG has been studied [15]. The new control strategies to tackle problems such as vibration and ride through and the mechanical phenomena of DFIG based wind turbine have been presented in [16].

In [17], the d-q modelling for the three phase self-excited induction generator (SEIG) with squirrel cage rotor and its operating performance have been evaluated. In [18], a new hybrid high voltage direct current (HVDC) connection for large wind farms with DFIGs system model which has also been described and derived. A real-time model of a DFIG-based grid-connected WTGS model has been developed with accurate and efficient manner through the real-time simulator [19]. The development is based on applying a mixture of linear and nonlinear control design techniques on three time scales, including feedback linearization, pole placement, and gradient-based minimization of potential function which has been studied [20].

2. Topology for Power Quality Improvement

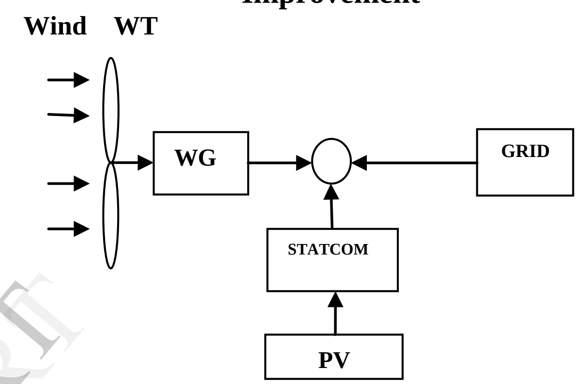

Fig.1.1 Block diagram of system operational scheme in grid system

Figure1.1. shows the block diagram of system operational scheme in grid system. The blocks are wind turbine (WT), wind generator (WG), static synchronous compensator (STATCOM), photo voltaic panel (PV panel) power, grid system (GRID) and transmission lines. The wind turbine-generator module generates power at low voltage with grid frequency and integrated with the grid supply. The STATCOM provides compensation from the solar (PV) powered, capacitor charging mechanism. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling. Here the utility source, wind energy system and STATCOM with The battery energy storage system (BESS) are integrated to the grid system. The STATCOM based current controlled voltage source inverter injects the current into the grid in such a way that, the source current are harmonic free and they are in phased with the source voltage. The injected current will nullify the reactive part and harmonic part of the load and the induction generator current. Thus, it improves the power quality of the wind power integrated grid system. This injected current generation is by the

proper operation (closing and opening) of the switches of voltage source inverter of the STATCOM.

2.1 Wind Energy Conversion System

In this configuration, wind generation system is modelled, based on constant speed topology, with pitch control of the turbine. In this system induction generator is used for the power generation, because of its simplicity, robustness, low cost, low maintenance and it does not require a separate field excitation circuit. Also it can be supported the constant and variable loads, and has natural protection against short circuit faults. The generated power of wind energy system is presented as:

$$P_w = \frac{1}{2} \rho \text{ A } v_w \qquad (1)$$

Where ρ = air density (kg/m^3), A = Swept area of the turbine blade (m^2), v_w = wind speed (m/s).

The wind energy system is not possible to extract all the kinetic energy of wind source. Thus, it extracts a fractional constant of power, is called power coefficient C_p of the wind turbine, and it is given by:

$$P_m = C_p \, P_w \qquad (2)$$

The mechanical power produced by the wind turbine is given by:

$$P_m = \frac{1}{2} \rho \, R^2 \, v_w{}^3 \, C_p v_w \qquad (3)$$

Where, R = Radius of the wind turbine blades in m.

3. BESS-STATCOM

The battery energy storage system (BESS) is charged by the solar power from the PV panel. The tracking control of PV panel is provided for the continuous and sustainable charging the BESS to supply the dc voltage is maintained constant for the capacitor of the STATCOM unit, and the BESS used for the purpose of voltage regulation. Since, the BESS is rapidly injects or absorbs the reactive power to stabilize the grid system. It also been controls the distribution and transmission system in a very fast rates.

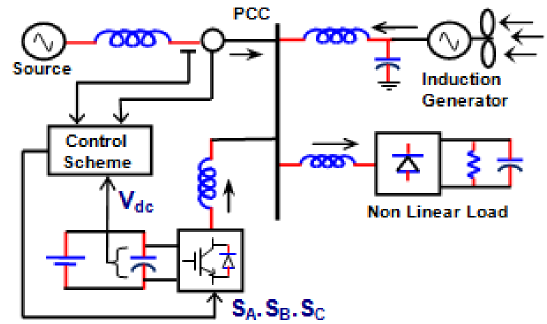

Fig. 2.1 Schematic model of system operational scheme in grid system

The battery system is connected in parallel to the dc capacitor of STATCOM. When the power fluctuation occurs in the grid system, the BESS can be utilized to compensate the power fluctuation by charging and discharging operations.

3.1 System Operation

The shunt connected STATCOM with battery energy storage system (BESS) is interfaced with the induction generator and non-linear load at the PCC in the grid system. The Fig.2 represents the schematic model of system operational scheme in grid system. The static synchronous compensator (STATCOM) output is varied, according to the control strategy, and to maintain the power quality of the grid system. The current control strategy for STATCOM is the Bang-Bang control scheme that defines the functional operation of the static synchronous compensator (STATCOM) in the grid power system. A single STATCOM using insulated gate bipolar transistor (IGBT) is proposed to have a reactive power support, to the induction generator and to support the nonlinear load in the grid system.

3.2 Grid Synchronization

In three-phase balanced system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltages V_{sa}, V_{sb} and V_{sc} and expressed as sample template (sampled peak voltage), Vsm:

$$V_{sm} = \left[{}^2/_3 \left(V_{sa}{}^2 + V_{sb}{}^2 + V_{sc}{}^2 \right) \right] \qquad (4)$$

The in-phase unit vectors are obtained from AC source phase voltage and the RMS value of unit vector as shown below:

$$U_{sa} = V_{sa} / V_{sm} \qquad (5)$$
$$U_{sb} = V_{sb} / V_{sm} \qquad (6)$$
$$U_{sc} = V_{sc} / V_{sm} \qquad (7)$$

The in-phase generated reference currents are derived using in-phase unit voltage template.

4. MAT LAB/ SIMULINK Model of MSGCWES

The MAT LAB/SIMULINK is a powerful software tool, in which it is implemented in this system for the simulation.

4.1 Mat Lab Simulink model without using the STATCOM

Fig. 4.1(a) shows that, Mat Lab Simulink model for the wind energy system is integrated with 3-Phase grid system, without using the STATCOM compensation. There are two loads at the receiving end, at t=0.3sec. The voltage decreases due to the connection of the second load as shown in fig 4.1(b) and rms voltage wave form is shown in Fig.4.1(c). The rms current wave form is shown in Fig. 4.1(d). The real power wave form is shown in Fig. 4.1(e) and reactive power wave form is shown in Fig. 4.1(f).

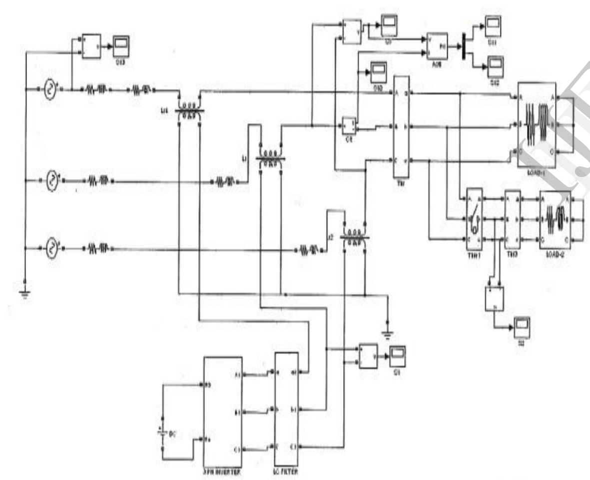

Fig 4.1(a) Simulink model of 3 phase, 2 bus, grid system without STATCOM

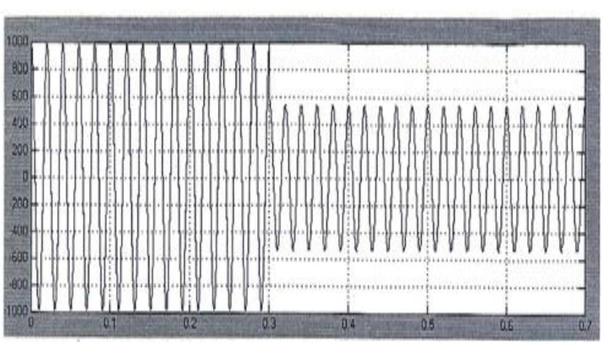

Fig. 4.1(b) Load Voltage waveform

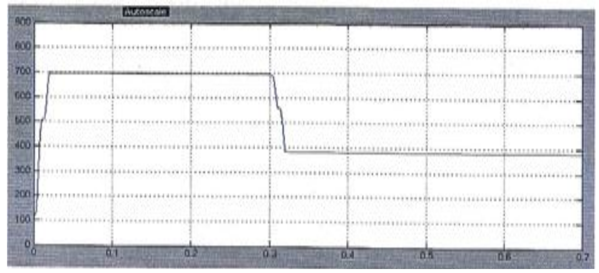

Fig.4.1(c) RMS Voltage waveform

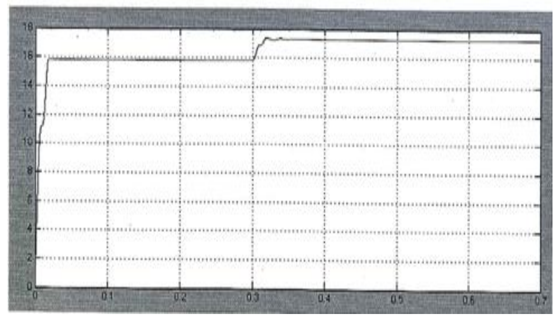

Fig.4.1 (d) RMS Load Current waveform

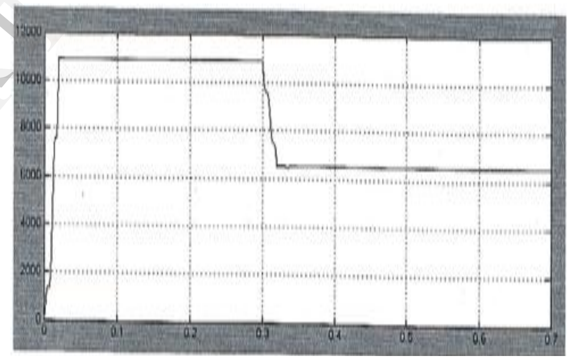

Fig.4.1 (e) Real Power waveform

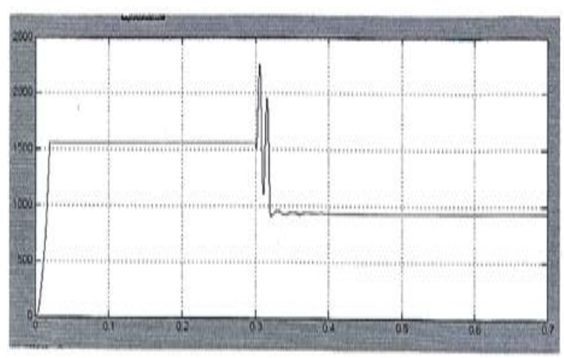

Fig.4.1 (f) Reactive Power waveform

From Fig. 4(b) and 4(c), the load voltage and rms voltage are reduces, after connecting the load to wind energy system integrated grid system, respectively. Fig(d), shows the load current of the system, Fig. 4(e) and 4(f), are the real power and reactive power also reduces, respectively.

4.2 Mat Lab Simulink model with using the STATCOM

Fig. 4.2(a) shows, the Mat Lab Simulink model, for the 3-phase, 2 bus system with STATCOM. The STATCOM injects the reactive power through a transformer to compensate the voltage drop in the line. The load voltage wave form is shown Fig. 4.2(b), rms value of load voltage wave form and load current wave form are shown in Fig. 4.2(c) and 4.2(d) respectively. The real and reactive power wave forms are shown in Fig. 4.2(e) & 4.2(f) respectively. The load voltage reaches the normal value due to the injection from the STATCOM.

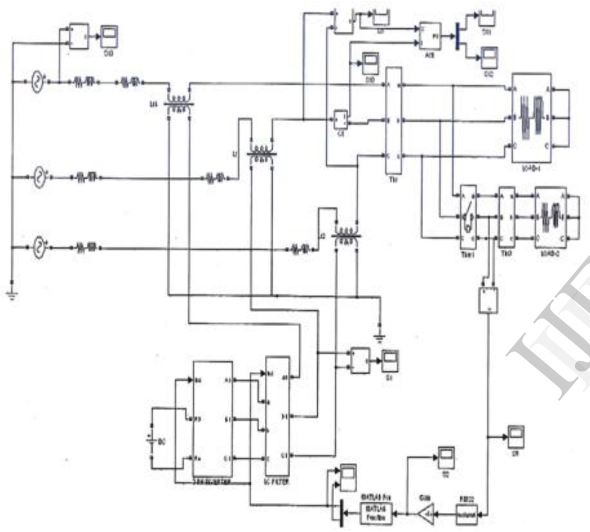

Fig.4.2 (a) 3-phase, 2-bus System with STATCOM

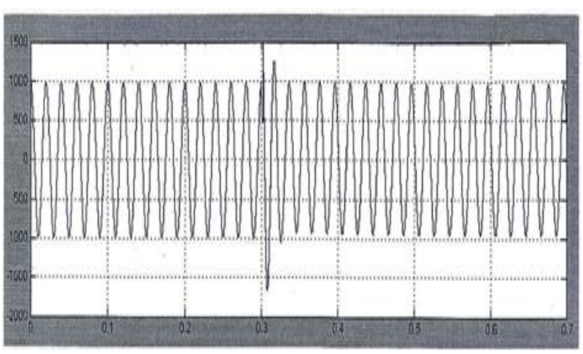

Fig. 4.2(b) Load Voltage waveform

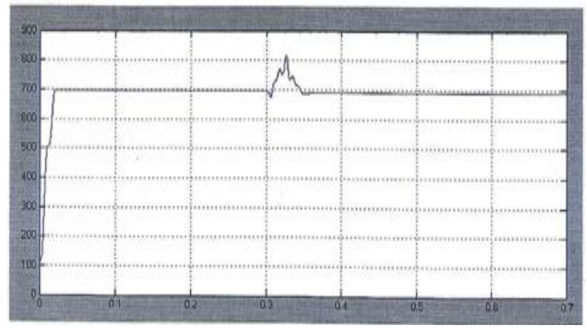

Fig.4.2(c) RMS Voltage waveform

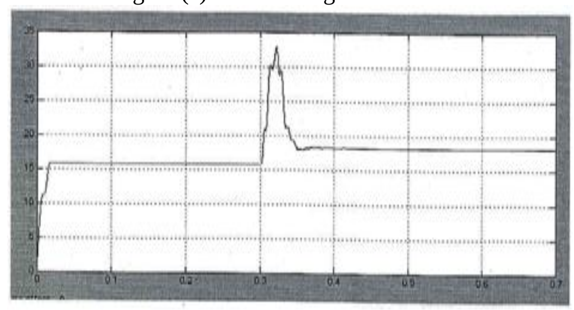

Fig.4.2 (d) RMS Load Current waveform

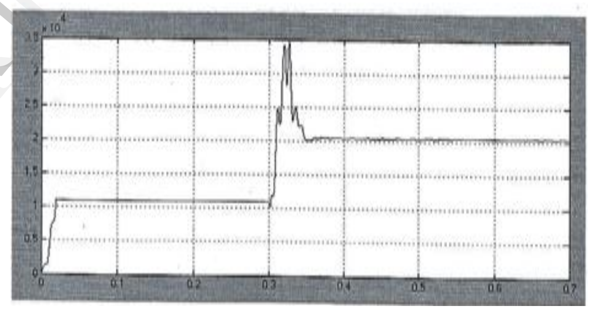

Fig.4.2 (e) Real Power waveform

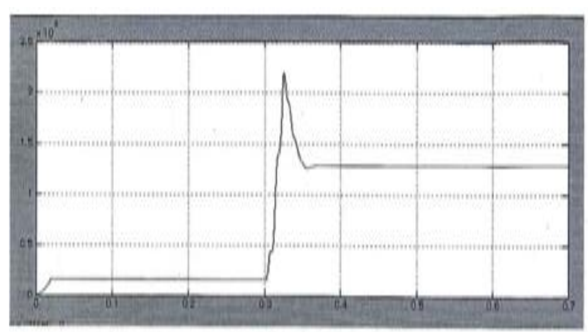

Fig.4.2 (f) Reactive Power waveform

From Fig. 4.2(b) and 4.2(c), the load voltage and rms voltage are improved, after connecting the STATCOM compensation, with the wind energy system integrated grid system, respectively. Fig4.2(d), shows the load current is stabilised after the compensation of STATCOM. Fig.4.2(e) and

4.2(f), are the real power and reactive power are also improved, due to the STATCOM compensation respectively. Table1 Shows the comparison of wind energy system integrated grid system without STATCOM and with compensation system of various results. The various results are rms voltages, rms currents, real power outputs, reactive power outputs and power factor are tabulated for the without compensating system and with compensating system respectively. All the results of compensated system is improved than the without compensated system.

Table 1
Comparison of Results

PARAMETER	WITHOUT COMPENSATION	WITH COMPENSATION
Voltage (RMS) (V)	2184	2495
Current (RMS)(A)	11.93	10.68
Real Power (MW)	0.0158	0.0189
Reactive Power (MVAR)	0.0201	0.0242
Power Factor	0.76	0.81

5. Conclusion

This paper presented, the wind energy system integrated grid system using the STSTCOM based compensation scheme, for the power quality improvements for the non-linear loads. The operation of this STATCOM control scheme is developed with MATLAB SIMULINK environment (version MATLAB 7.9). The load voltage is successfully compensated, using solar powered STATCOM. The control is easy, maintain the V_d and V_q are in static manner. The simulation results of uncompensated and compensated outputs are compared, and it shows that, the compensated system is improved than the uncompensated system. It is suggested that this scheme is more suitable for in practice and to meet the future power demand.

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