STATCOM BASED MITIGATING POWER QUALITY ISSUES IN GRID CONNECTED WIND ENERGY SYSTEM USING LABVIEW

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Abstract— **The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. In a grid connected wind power generation system, there are some power quality issues. During the normal operation, a wind turbine produces continuous variable voltage fluctuations, flicker, harmonics and electrical behaviour of switching operation. This paper demonstrates the power quality problems due to installation of wind turbine with the grid. In this proposed method STATic COMpensator is connected at a point of common coupling with a battery energy storage system to mitigating power quality issues. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is carried out Labview.**

Keywords— **Labview, Wind power, STATCOM, Grid, Power quality.**

I. INTRODUCTION

The value of wind power can be extensively increased if it is capable of contributing to the grid support. The wind energy is experiencing extraordinary growth. The worldwide capacity reached 159,213 MW out of which 38,312 MW was added. This environmentally friendly power source will be significantly improved for its long term goal. The increasing number of renewable energy sources and distributed generator requires a new strategy for operation and management of electric grid system. Today, wind energy generating system is connected into the power system to meet the consumers demand and to support the grid. The wind power generation has become a very attractive utilization of renewable energy becomes it is now possible to improve the capability of capturing wind energy. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems [1]. The battery energy storage system is integrated to sustain the real power source under fluctuating wind power [2]. In wind power system is well established technologies for renewable energy sources. Each technology has its own individual instrumentation requirements to measure and control system variables. Laboratory Virtual Instrument Engineering Workbench (LabView) is a powerful and flexible instrumentation and analysis software application tool which was developed in 1986 by the National Instruments. National Instrument's LabView data acquisition software module has become one of the most widely used tools to capture view, process controls and instrumentation in power system.

This paper describes to improve power quality at LabView based data acquisition and instrumentation up to 275 kW wind energy generating system. The addition of the new LabView system provides a control and simulation module. It's to design such as wind speed, wind direction, wind turbine, drive train model and wound rotor AC induction machines.

In a grid connected wind power system can operates in parallel operation of multisim modelling, particularly in that multisim modelling a conventional plant, 800Ah battery bank which includes STATCOM and non-linear load. The STATCOM control scheme for the grid connected wind energy generation system is to mitigating power quality issues is simulated using LABVIEW and MULTISIM in power system block set. The proposed STATCOM control system for grid connected wind energy generation with battery storage has the following objectives,

- Mitigating power quality issues in grid and improve power factor.

II WIND GENERATION

The modelling of wind turbine generator is very difficult to know all parameters, because the wind turbine generator is very complex system [3]. The input is real time wind speed and the output being the power output resulting in the performance of power curve. The wind output power is

$$P_w = \frac{1}{2}\rho\pi R^2 V_{wind}^3 C_p(\lambda, \beta) \quad (1)$$

where ρ air density, R radius of rotor blade, V velocity of wind speed, C_p Co-efficient of power, λ tip speed ratio, β blade pitch angle.

$$C_p = \frac{1}{2}(\lambda - 0.022\,\beta^2 - 5.6)\, e^{-0.17\lambda} \quad (2)$$

$$\lambda = \frac{v_w}{\omega_B} \quad (3)$$

where ω_B rotational speed of turbine. The Torque

$$T = \frac{1}{2}\rho\left(\frac{C_p}{\lambda}\right) V_{wind}^3\, \pi R^2 \quad (4)$$

A single line diagram of grid connected conventional source, wind model, non-linear load and STATCOM with BESS is shown in Fig. 1.

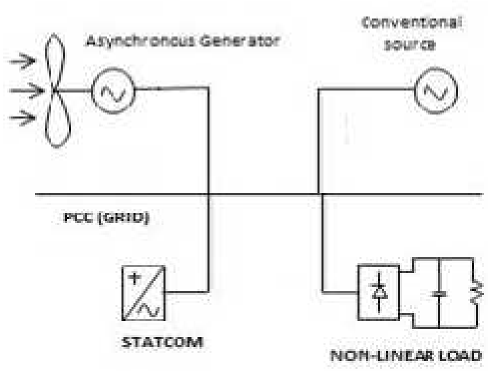

Fig. 1 Grid Connecting System for STATCOM

A. Conventional Source:

The three phase source at specified base voltage. These parameters are available only specific impedance using short circuits level is selected [4]. The internal L in H is computed from the inductive three phase short circuit power P_{sc} in VA, base voltage V_{base} in V_{rms} phase-to-phase and source, f in Hz.

$$L = \frac{(V_{base})^2}{P_{sc}} \frac{1}{2\pi f} \quad (5)$$

The phase angle of the internal voltage generated by phase A, in degrees. The three voltages are generated in positive sequence. Thus phase B and phase C internal voltages are lagging phase A respectively by 120̊ and 240̊.

B. STATCOM

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at a point of common coupling. The capacitor is used as the intermediate element of STATCOM which couples the wind generating system and battery storage as

$$C\frac{d}{dt}V_{dc} = I_{dc(rect)} - I_{dc(inv)} \quad (6)$$

where C is circuit capacitance V_{dc} is rectifier voltage $I_{dc(rect)}$ is rectified dc-side current, $I_{dc(inv)}$ is inverter dc-side current.

$$V_{dc} = \frac{2\sqrt{2}}{M_a} V_{inv} \quad (7)$$

where V_{inv} is line to neutral rms voltage of inverter , switching frequency 2kHz, inverter output frequency 50Hz and M_a is modulation index. The dc battery is designed for 800Ah.

C. Non-Linear Load

The non-linear load is considered for diode front-end rectifiers, which are widely used in power converters and ac machine drivers with a dc-link capacitor [5]. A non-linear load causes a distorted voltage wave from (V_p) at the point of common coupling due to current (i_n). The voltage include odd harmonics with order 6n±(n = 1,2…) multiples of synchronous frequency(ωs).

$$V_P = V_S - V_{NS} = V_S - R_S i_S - L_S\frac{di_S}{dt} \quad (10)$$

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.

III Statcom Control Scheme

A. Control System

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 current control scheme is included in the control system that defines the functional operation of the STATCOM compensator in the power system [6]. The STATCOM diagram is shown in fig. 2.

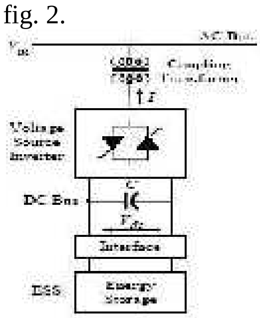

Fig. 2 Statcom

A single STATCOM using insulated gate bipolar transistor is proposed to have a reactive power support to the asynchronous generator and non-linear load. The STATCOM control system circuit diagram is shown Fig. 3.

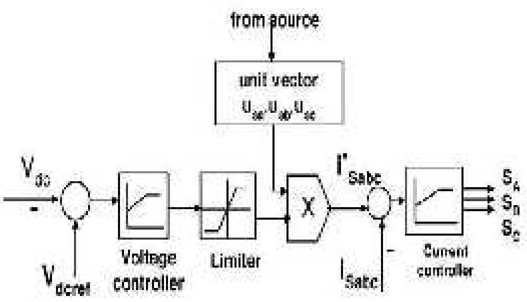

Fig. 3 STATCOM Control System

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. The STATCOM responds to the step change command for increase in additional load. When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate reactive demand as well as harmonic current. The dynamic performance is also carried out by step change in a load. This additional demand is fulfilled by STATCOM compensator. Thus, STATCOM can regulate the available real power from source.

C. 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 90̊ which illustrate the operation of the system as an inductive compensator, the dc [8] 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.

D. Sag Compensation

The source bus voltage drops from 1pu to 0.9pu it represent heavy load or fault conditions in the grid. The STATCOM response to the voltage sag quickly and the PCC bus voltage restores. The recovery speed is actually limited by the ramp of Q reference inside the control to avoid current distortion at the transient [7]. When the STATCOM reactive power and current magnitude increases, the system capacitor voltage ripple increases. The capacitor voltages are well regulated and balanced throughout the voltage sag transient.

E. Power Factor

The power factor of an ac electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit and is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a nonlinear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

F. Modeling of Grid

Considering the grid connected voltage source connected as ideal voltage sources [9], the relationship between the voltage and line current can be expressed in the αβ reference frame as

$$U_{g\alpha\beta} = V_{g\alpha\beta} + L_g \frac{dI_{g\alpha\beta}}{dt} + R_g I_{g\alpha\beta} \quad (11)$$

where U_g, V_g are grid and converter voltage vectors, I_g- converter ac current vector, L_g, R_g are line inductance and resistance, α,β are stationary axis, g-grid connected voltage source converter. The grid connected intermittent wind energy characteristics of these resources largely affect the quality of power supply [10]. The estimated grid voltage V^e_{gd}, V^e_{gq} is given by expression

$$\begin{bmatrix} V^e_{gd} \\ V^e_{gq} \end{bmatrix} = \begin{bmatrix} V_d \\ V_q \end{bmatrix} - \begin{bmatrix} R & 0 \\ 0 & R \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix} - \begin{bmatrix} 0 & -\omega L \\ \omega L & 0 \end{bmatrix} \begin{bmatrix} I_d \\ I_q \end{bmatrix} \quad (12)$$

where V_d, V_q are applied voltage by the inverter in the IGBT control cycle, I_d, I_q are the inverter current transfer from STATCOM reference frame, V_d, V_q inverter output voltage.

IV. Simulation and Results

A. System Performance:

The Simulink model library includes the model of conventional source, STATCOM, non-linear load, and others that has been constructed simulation are shown in table 1.

Table 1 System Parameters

S.No.	PARAMETERS	RATINGS
1.	Conventional Source	3-phase, 415V, 50Hz
2.	Load Resistance	50 ohm
3.	Load Capacitance	5 µF
4.	Wind generation	275 kW
5.	IGBT Rating	Collector Voltage=100V, Forward Current=76A, Gate Voltage= 1V
6.	PWM Sinusoidal 3-Phase	Reference Frequency = 5kHz Modulation Frequency = 50Hz Amplitude Modulation Ratio = 0.8

B. Simulation Diagram

The overall simulation diagram of the proposed grid connected MULTISIM based conventional source, STATCOM, non-linear load is shown in fig.4 In this system

IGBT based converter and voltage controlled voltage source operates based on PWM signals.

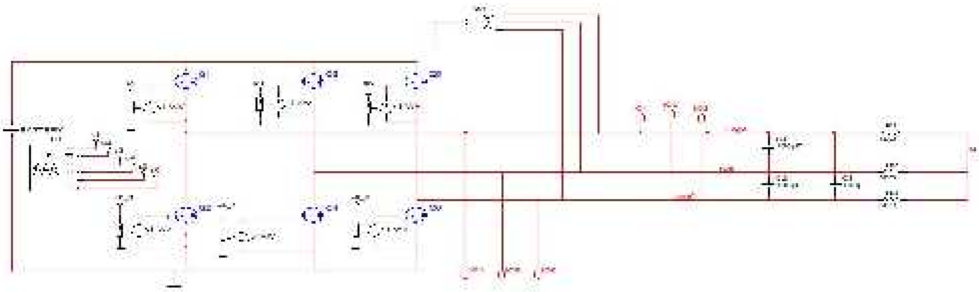

Fig. 4 NI Multisim Conventional Source, STATCOM, Non-linear Load

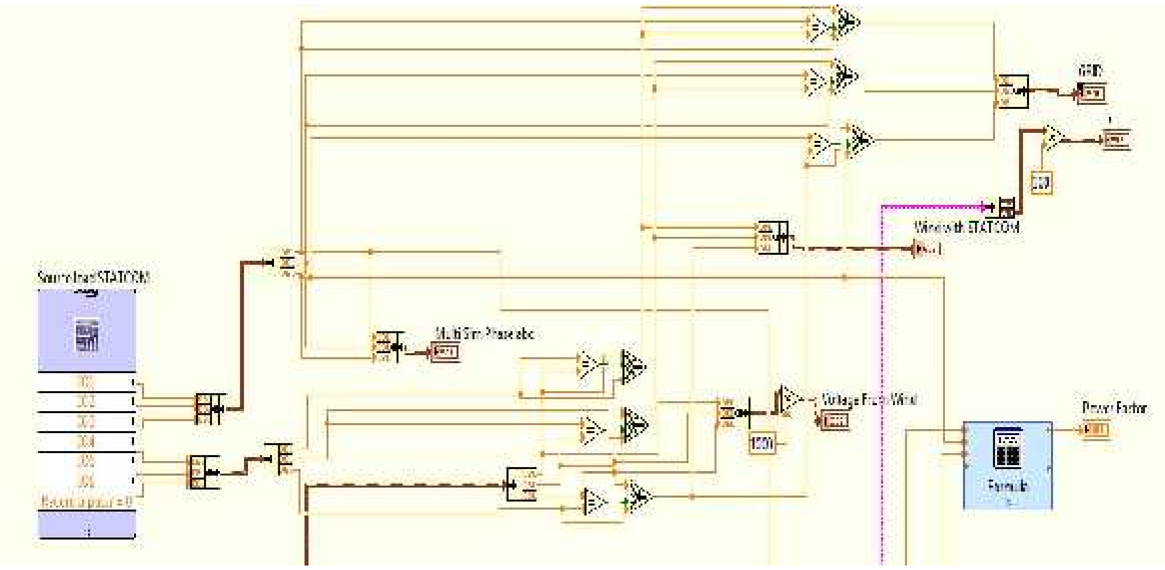

Fig. 5 NI LabVIEW Grid Controller

The complete MULTISIM model of STATCOM is along with control circuit. The power circuit as well as control system are modeled using power system block set and Simulink. The grid source is represented by three-phase AC source. Three-phase AC loads are connected at the load end. STATCOM is connected in shunt and it consists of PWM voltage source inverter circuit with Battery bank. An IGBT-based PWM inverter is implemented using universal bridge block from power electronics subset of PSB. Snubber circuits are connected in parallel with each IGBT for protection. Simulation of STATCOM system is carried out for linear and nonlinear loads.

D. **Grid Controller with Multisim Output**

The control scheme approach is based on injecting the voltage into the grid using STATCOM controller. The controller uses a comparison controlled technique. Using such technique, the controller keeps the control system variable between wind output and multisim output for GRID operation. The control system scheme for generating the switching signals to the STATCOM. The voltage control block, receives an input of reference voltage and wind voltage are compared so as to activate the operation of true or false control mode. The wind turbine control circuit is shown in fig.5.

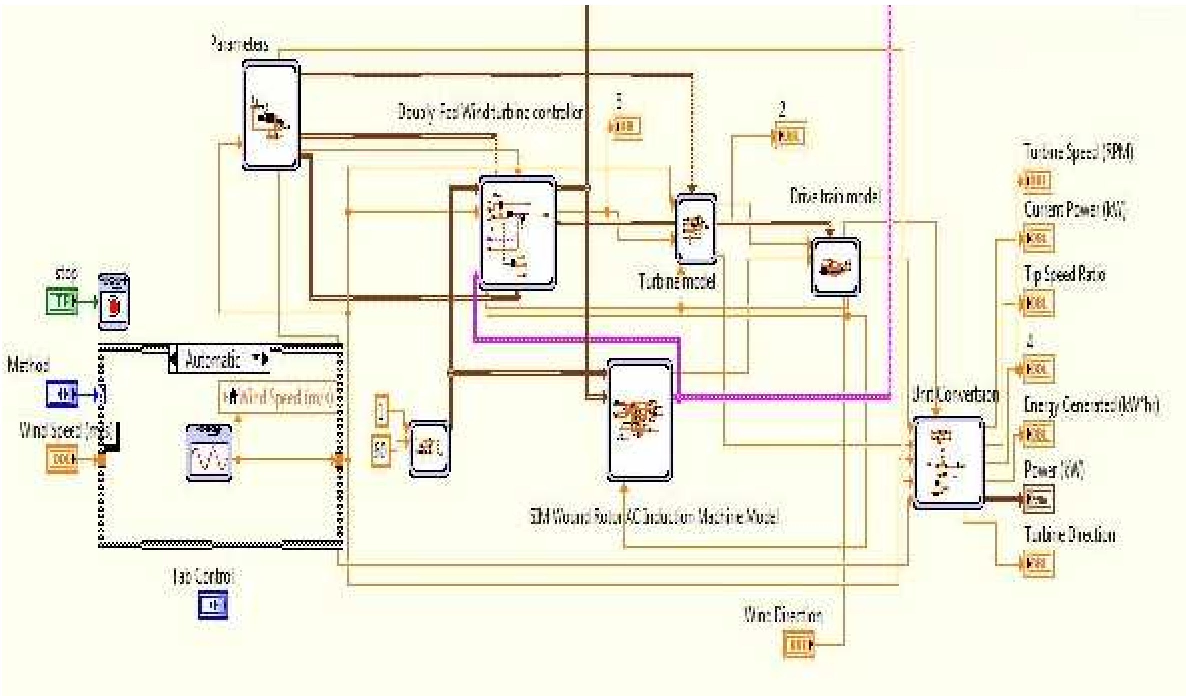

Fig. 6 NI LabVIEW Wind Turbine Module

E. **Wind Turbine Module**

The wind turbine module is based on work parameter settings, wind speed and method. Method are two types; first one being manual in which method turbine works as motor and second one is automatic in which method turbine works as high speed rotating system so is generator type. Wind turbine model have various sub system block sets parameter settings, doubly fed wind turbine controller, Wound rotor AC induction machine model, turbine model, Drive train model and unit conversion block is shown in fig.6.

F. **Results**

The effectiveness of the proposed method is demonstrated through simulation result of three phase source voltage of 415V from Multisim modelling which is shown in fig. 7.

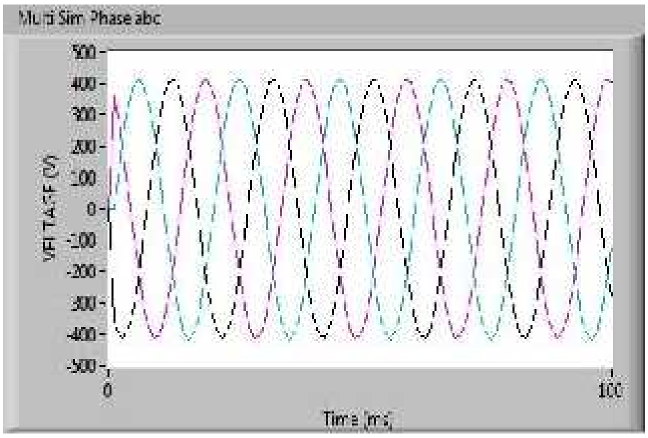

Fig. 7 Multisim Three Phase Output Voltage

The wind energy generating source voltage has large voltage fluctuation from LabVIEW based wind power design system. The source voltage without STATCOM operation is shown fig. 8.

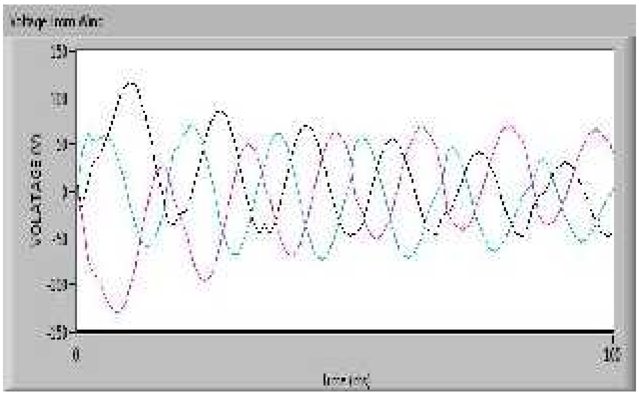

Fig. 8 Wind Output Voltage

When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate voltage fluctuations. The dynamic performance is also carried out by step change in a load. This additional demand is fulfiled by STATCOM compensator. Thus, STATCOM can compensate the required reactive power from battery source is shown in fig. 9.

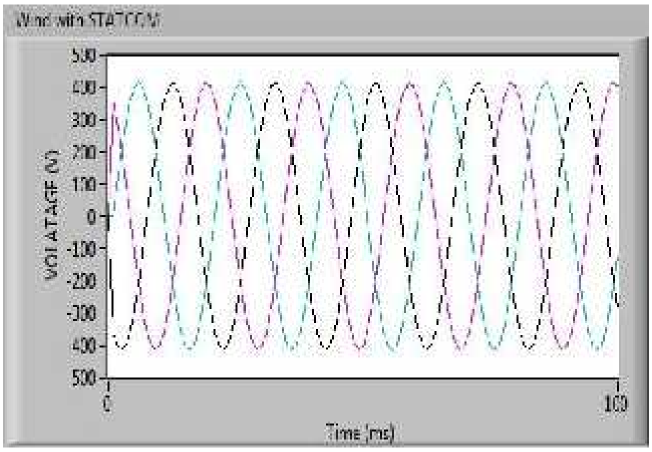

Fig. 9 Wind Output Voltage with STATCOM

The grid system voltage is maintained constant at 415V. The source voltage indicating the power factor 0.91 at point of common coupling satisfying power quality norm is due to the reference derived from the grid voltage which is shown in fig 10.

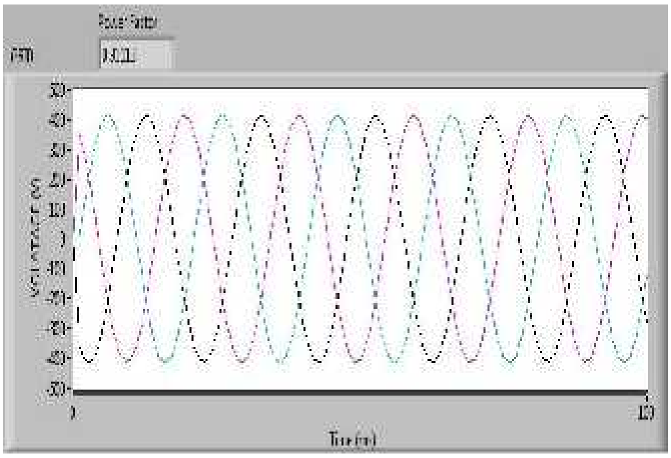

Fig. 10 GRID Voltage and Power Factor

V. CONCLUSION

In this work, to improve the power quality in grid connected wind generating system STATCOM based control scheme is proposed. The operation of the control system in MULTISIM and wind turbine design is using LabVIEW. The power quality is simulated for 275kW capacity of wind turbine system. It has a capability to cancel out the sag and swell of load voltage. It maintains the source voltage in-phase for the wind generation and STATCOM with battery energy storage system have shown the outstanding performance and also it improves the power factor to 0.91. In future work, the LABVIEW will be used to develop the wind turbine capacity up to 5MW using STATCOM battery energy storage system to improve the quality of power.

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