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POWER QUALITY IMPROVEMENT OF GRID CONNECTED WIND ENERGY SYSTEM BY USING STATCOM

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ABSTRACT

The wind generated power always vary irregularly due to its time varying nature and causing stability problems. This weak interconnection of wind generating source to the electrical grid affects the power quality and reliability. Here we have designed static compensator (STATCOM) using Voltage Source Inverter to reduce voltage sags, swells, transients, harmonics hence enhance power quality of the system. We have used Pulse Width modulation technique to control voltage source converter. The STATCOM is modeled and its performance is simulated and load, source voltages and currents waveforms are taken and Total Harmonic Distortion (THD) is calculated by using MATLAB simulation. 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: Wind energy, STATCOM, VSC, PWM, THD.

INTRODUCTION

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impacts. Wind energy conversion systems are the fastest growing renewable source of electrical energy having tremendous environmental, social, and economic benefits.

Power Quality is defined as power that enables the equipment to work properly. A power quality problem can be defined as any deviation of magnitude, frequency, or purity from the ideal sinusoidal voltage waveform. Good power quality is benefit to the operation of electrical equipment, but poor power quality will produce great harm to the power system. However, the generated power from wind energy conversion system is always fluctuating due to the fluctuation nature of the wind. Therefore injection of the wind power into an electric grid affects the power quality. The important factors to be considered in power quality measurement are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation.

In this proposed scheme Static Synchronous Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. Therefore STATCOM provides Reactive Power support to wind generator and load. 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.

Power Quality (PQ) related issues are of most concern nowadays. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Due to their non-linearity, all these loads cause disturbances in the voltage waveform.

In this seminar topic there will be the analysis of factors which are responsible for the power quality problems in the wind energy conversion system and implementation of proper control scheme for power quality improvement in the wind energy conversion system connected to the grid. The paper is organized as follows. The chapter 2 introduces the power quality standards, issues and its consequences of wind turbine. The chapter 5 introduces the grid coordination rule for grid quality limits. The chapter 6 describes the topology for power quality improvement.

TOPOLOGY FOR PQ IMPROVEMENT

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 as shown in Fig. 1. The grid connected system in Fig. 1, consists of wind energy generation system and STATCOM with VSC

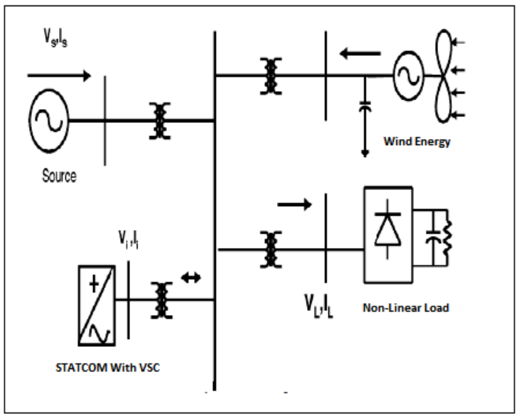

Fig. 1

STATCOM OPERATION

The STATCOM (or SSC) is a shunt-connected reactive power compensation device that is capable of generating and/ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals. Specifically, the STATCOM considered in this chapter is a voltage-source converter that, from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor. A STATCOM can improve power-system performance in such areas as the following:

a. The power-oscillation damping in power transmission systems.
b. The dynamic voltage control in transmission and distribution systems.
c. The transient stability.
d. The voltage flicker control.

GRID CO-ORDINATION RULE

The rules for realization of grid operation of wind generating system at the distribution network are defined as-per IEC-61400-21.

Voltage Rise (Δv):

The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power Smax of the turbine, the grid impedances R and X at the point of common coupling and the phase angle β given in Eq.1

$\Delta v = Smax (R\cos\beta - X\sin\beta)/V$ (1)

Where, Δv — voltage rise
Smax — maximum apparent power
β — phase difference.
V — nominal voltage of grid
The limiting voltage rise value is < 2%.

Voltage Dips (d):

The voltage dips is due to startup of wind turbine and it causes a sudden reduction of voltage. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

$d=K_u S_n/S_k$ (2)

Where, d is relative voltage change, S_n is rated apparent power. S_k is short circuit apparent power. K_u is sudden voltage reduction factor. The acceptance voltage dips limiting value is ≤ 3%.

C. Harmonics :

The harmonic distortion is assessed for variable speed turbine with an electronic power converter at the point of common connection. The total harmonic voltage distortion of voltage is given as in Eq.

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1}} 100 \qquad (4)$$

Where, V_n is the nth harmonic voltage. V_1 is the fundamental frequency(50) Hz. The THD limit for 132 KV is 3%. THD of current I_{THD} is given as in Eq. 5

$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_n}{I_1}} 100 \qquad (5)$$

Where, I_n is the nth harmonic current. I_1 is the fundamental frequency (50) Hz. The THD of current and limit for 132 KV is <2.5%.

CONTROL TECHNIQUE

The aim of the control scheme is to maintain constant voltage magnitude at the point of common coupling(PCC), under system disturbances. The control system only measures the rms voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. In fig .2 shows that the controller input is an error signal obtained from the reference voltage and the value rms of the terminal voltage measured. Such error is processed by a PI controller and the output is the angle d, which is provided to the PWM signal generator. An error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller process the error signal and generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

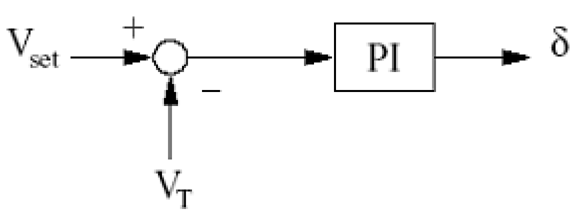

Fig. 2

The sinusoidal signal VCONTROL is phase-modulated by means of the angle δ. The modulated signal VCONTROL is compared against a triangular signal (carrier) in order to generate the switching signals for the VSC valves. The main parameters of the sinusoidal PWM scheme are the amplitude modulation index of signal, and the frequency modulation index of the triangular signal. The amplitude index is kept fixed at 1 p.u, in order to obtain the highest fundamental voltage component at the controller output.

The modulating angle is applied to the PWM generators in phase A. The angles for phases B and C are shifted by 240° and 120° respectively. It can be seen in that the control implementation is kept very simple by using only voltage measurements as the feedback variable in the control scheme. The speed of response and robustness of the control scheme are clearly shown in the simulation results. The Simulink block diagram of SPWM generator is as shown in fig.3

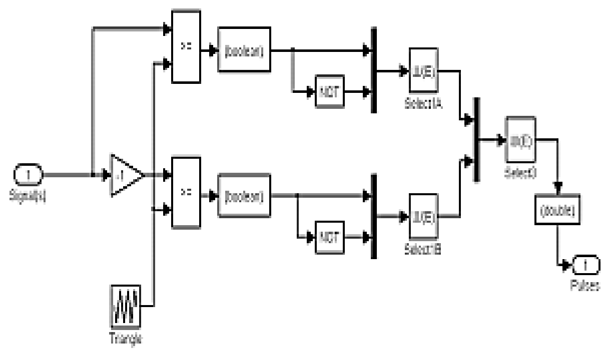

Fig.3 Simulink block diagram of SWPM generator

SYSTEM MODELING

MATLAB Simulink diagram:

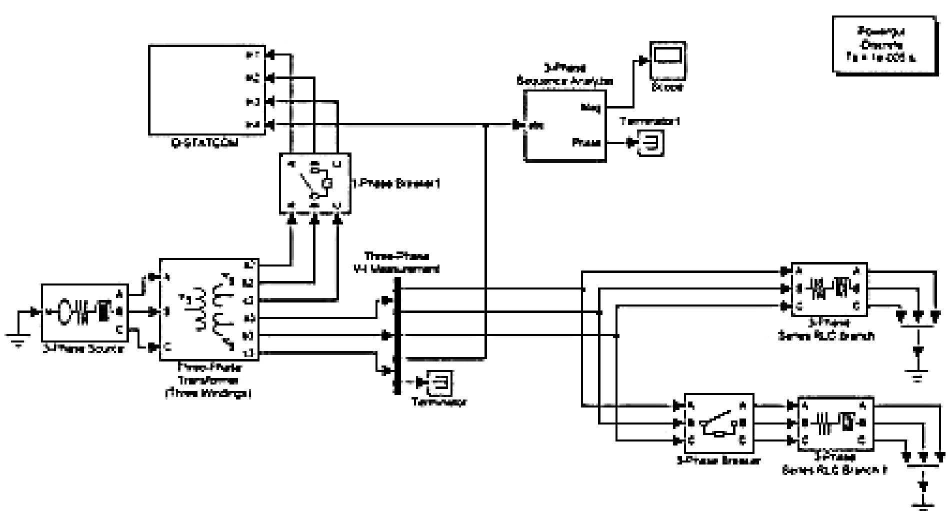

Fig.4 Simulink model

System Parameters:

Source voltage	11 KV
DC bus capacitance	15.5 mF
Inverter series inductance	10 mH
Source resistance	0.1 Ohm
Source inductance	0.9 mH

RESULTS

This paper shows the simulation results without STATCOM and with STATCOM. First the model is run without connecting STATCOM and source voltage and load current is checked. Then after connecting STATCOM same waveforms are observed. Source voltage and current waveforms without STATCOM are shown fig.5 and fig.6 while Fig.7 and fig.8 shows load voltage and load current. Then after connecting STATCOM all the above observed parameters are shown in fig.9,10,11,12 respectively. THD in source voltage and current, load voltage and current is shown by FFT analysis done in MATLAB.

Without STATCOM:

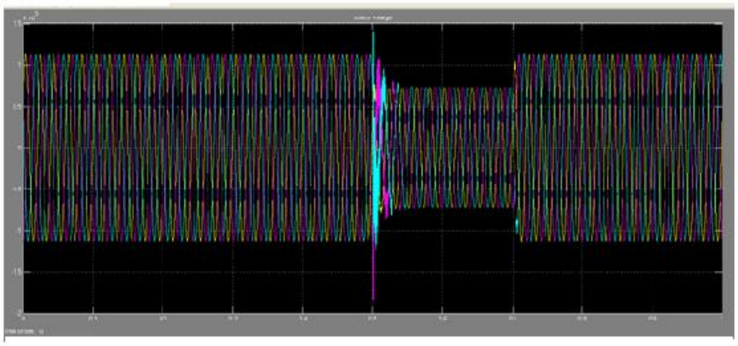

Fig.5 Source Voltage

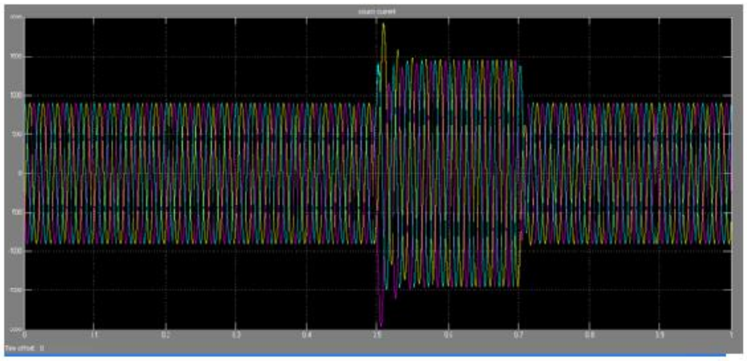

Fig.6 Source Current

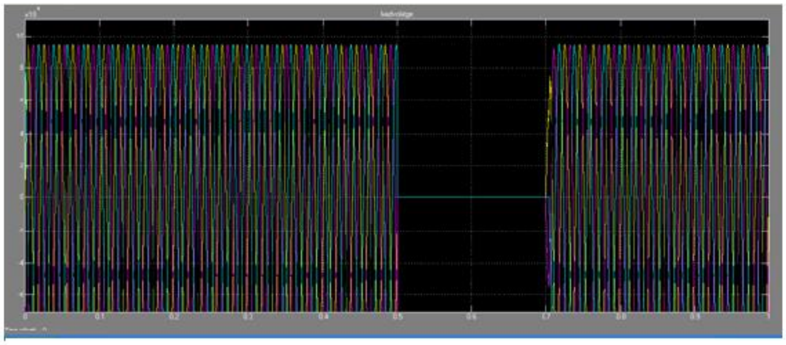

Fig.7 Load Voltage

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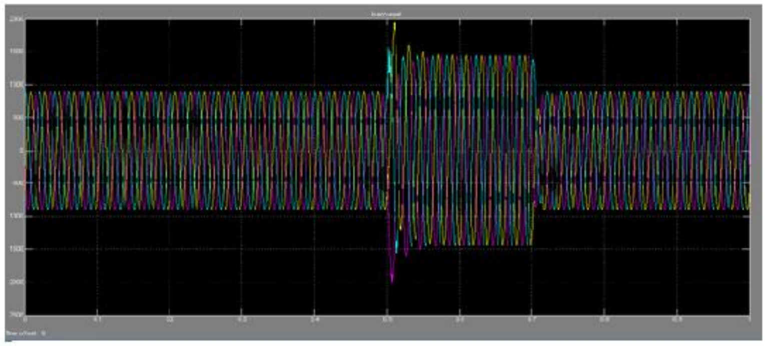

Fig.8 Load Current

With STATCOM:

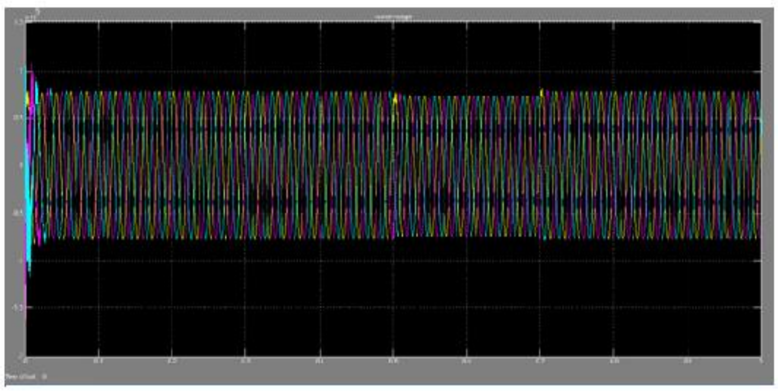

Fig.9 Source Voltage

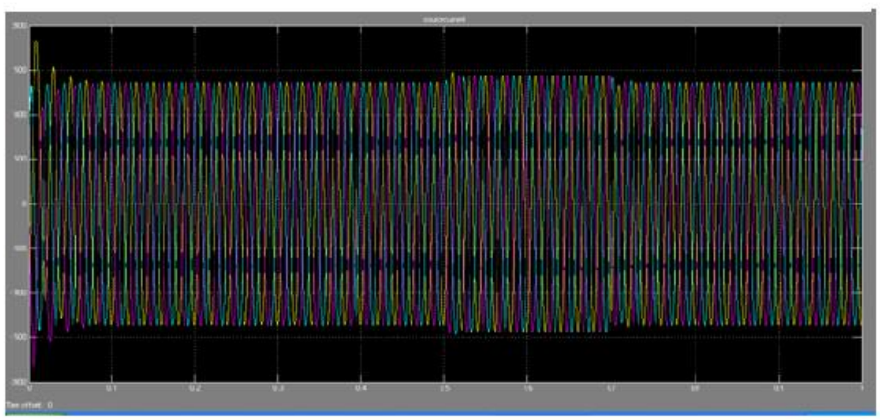

Fig.10 Load Voltage

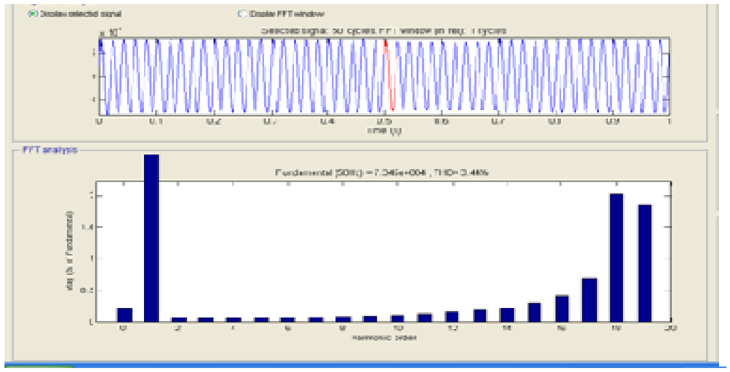

Fig.11 THD without STATCOM

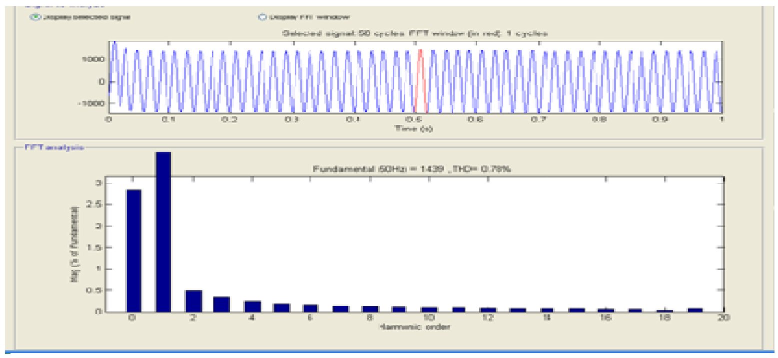

Fig.12 THD with STATCOM

CONCLUSION

In this paper we present static shunt compensator (STATCOM) connected in parallel to PCC between wind energy system and electrical grid. The control technique used is PWM to control voltage source inverter. The STATCOM is used to reduce power quality problems like voltage sags, swells, harmonics etc. The circuit is modeled in MATLAB-Simulink and results are taken. The results shows that voltage sag, swell is reduced in source and load voltage waveforms (Fig 9 and 10). From fig 11 and 12 it is observed that Total Harmonic Distortion (THD) is reduced from 3.5 % to almost 0.7 % and hence power quality is improved.

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