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Mitigation of Power Quality Issue of Wind Energy System Connected To Electricity Grid by Using STATCOM

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ABSTRACT:Wind energy has become the centre of attention for every country in order to reduce environmental impact of conventional power plants like diesel and thermal. In spite of being bio-friendly, the continuous fluctuation in the renewable sources and new types of induction generators as load in the electricity grid, it results in various types power quality issues. This paper deals with various power quality problems associated with the grid when connected to wind power plant and focus on static synchronous compensator (STATCOM) to be connected at the point of common coupling in order to overcome such problems. The model containing electricity grid, wind turbine and interfaced STATCOM is designed and simulated using Mat lab/Simulink's software. The result thus obtained helps to analyse and observe that the reactive power demand on the load is easily provided by STATCOM whenever fault occurred in the system and helps in the stability of the power system.

KEYWORDS: Electricity Grid, Wind Power Plant, STATCOM

I.INTRODUCTION

Electricity demand is increasing every year in India due to rapid growing rate of economy and population. In order to have sustainable growth and social progress, the utilization of renewable sources (RES) like wind, biomass, hydro, solar, etc. [4]. is necessary. According to Indian Energy Statics 2013, wind energy is leading and fastest growing RES among other. Out of total installed generation capacity of renewable power as on March 2012 wind power accounted for about 65.65% which is then followed by small hydro power (13.63%) And biomass power (12.58%).Tamil Nadu had the highest installed capacity of grid connected renewable power (76604.03MW) followed by Maharashtra (3644.05MW) and Gujarat (3,607.27MW). This capacity will be increasing every year in every states of India in order to meet the increasing demand of load .It has become important requirement to address all the problems associated with maintaining a stable power system. Here the concept the electricity grid emerges which is an interconnected network for delivering electric from suppliers to consumers. The grid comprises of generating stations, high voltage transmission lines and distribution lines. The electrical power is produced at generation plants which is carried to the demand centres through high voltage transmission lines and thus to the costumers via distribution lines. The stability of the power supply is the primary concern when the wind generation system is attached to the grid.

The wind generation system consists of wind turbine which gives the fluctuating output under normal operation due to variation in the wind. The induction generators that produce electricity on getting the mechanical input from the wind turbine absorbs reactive power. The deficiency of the reactive power significantly affects the terminal voltage of the plant. The power quality issues like voltage sag, swell, flickers etc. occurs when wind plant is directly connected to the electricity grid [6]. Here in this paper the static synchronous compensator (STATCOM) is interfaced between wind generating plant and electricity grid in order to overcome the power quality issues. With the help of MATLAB/SIMULINK software the system consisting of Electricity grid, Induction type wind turbine model and STATCOM is designed and the result is observed and analysed.

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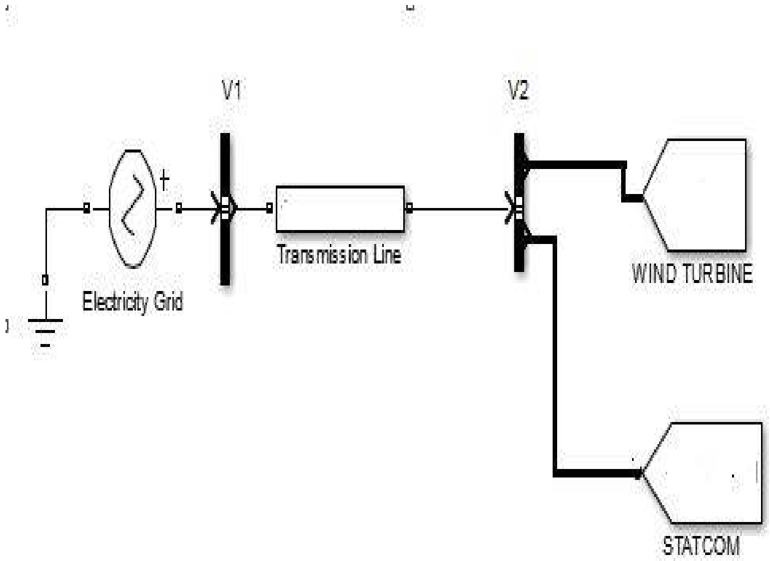

Fig.1 Grid connected wind generator interface to power system

The above figure 1 shows that grid consists of voltage source with voltage V_1 at bus bar near to it, while the bus bar connecting wind power and load is denoted by voltage V_2.This connect with the grid and is known as point of common coupling (PCC). Z represents the impedance of the transmission line and voltage drop at this point is given by

V_1-V_2=$\sqrt{3}$*IZ

Where I is the current in the line.

Short circuit power S_k at PCC is given by,

$S_{k\,=}\,V_1^2/Z$

Due to unsteady power production from wind plant voltage V_2 keeps on fluctuating. If short circuit power ratio is less than 2.5 then such system is termed as weak grid.

$P + jQ$ represents combined wind power and load, where P and Q are active and reactive power simultaneously. The expression for reactive power is given by:

$Q = P \; x \; Tan\Phi$

Where Φ is the phase angle between voltage and current

Voltage V_2 changes with the variation of reactive power that depends on load connected in the grid and wind power generating machine.

II. Wind Power Quality Causes and Consequences

Conversion of mechanical energy to electric energy from the wind is quite hectic job. When the speed of the wind varies, the torque applied to the motor of wind turbine also vary.

1. Power coefficient:

$$C_p = P_{mean}/P_{wind},$$
$$P_{wind} = 0.5\rho A V^3{}_{wind}$$

The power coefficient C_p depends on the wind speed. The variation of wind power changes the active power coefficient.Thus the power coefficient must be high in order to get real power.

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2. Induction Generator:

It is used in wind plants are of low cost, low requirement for maintenance, reduced in physical size, increased in robustness, increased electromechanical damping and can be synchronized directly to the grid. It requires reactive power from the grid based on the production of active power so, it is necessary to provide the variable VAR from the externally (i.e. via STATCOM) in order to maintain stability in the electric grid. The amount of reactive power withdrawn depends on the conduction of the fault occurs in the grid. Whenever the fault is sever in the grid, it is better to disconnect wind turbine and reconnected during the normal condition. This is only possible whenever the power fed to grid by the wind generation system is low.

3. Voltage Variation:

Voltage variation affects both real and reactive power. Smaller the voltage more will be current (ohm's low), this results in increasing the losses in the grid and equipment's connected to it. The power factor is significantly affected by low voltage and capacitive VAR also decreases. Similarly, if the voltage is increased more than required, then magnetizing VAR requirement increases that leads to the flow of negative sequence current in the induction machines so the variation must not be allowed in power system.

A. Voltage Sag:

Voltage sag is defined by reduction of nominal voltage level between 10% to 90% of nominal RMS voltage during decrease of power frequency from half cycle to 1 minute.

Causes:

a. Starting of wind turbine
b. Fault on transmission lines of the grid
c. Fault in the installation of costumer's electrical equipment's.
d. Sudden starting of large motor in heavy loads

Consequences:

1. Equipment's like microprocessor based control system may get damaged.
2. Frequent tripping of contractor relays may cause damage of connected equipment's.
3. Efficiency of electric machine get reduced.

The voltage sag variation of ±3%.

B. Voltage Swell:

IEEE 1159 states that the increase in the RMS voltage level of 110% to 180% of nominal voltage during power frequency of half cycle to 1 minute is to be voltage swell.

Cause:

a. Sudden start /stop of large and heavy loads
b. Occurrence of fault in the system.
c. Poor transformer regulation during off peak hour

Consequences:

a. Malfunctioning of components subjected to power supply.
b. Problems in controlling and failure of hardware of equipment's.
c. Damaging of electronics equipment's.

The voltage sag of value ±3% is acceptable.

4. Harmonic Distortion:

During motoring or soft starting the harmonic current is drawn by the induction generator of wind. These harmonic current appears as voltage harmonic on the output terminal during faulty condition. The availability of nonlinear loads in any place in the grid give to the harmonics.

Consequences:

a. Generators and transformers overheating.
b. Failure of connected capacitor due to increase in current.
c. Losses increases in transmission/ distribution lines, bus bars, isolators, relays, fuses.

5. Fluctuating Power Injection:

The nature of wind is given by annual, monthly, daily and hourly variation which shows character. When the wind generation plant is directly connected to the electricity grid, then the fluctuating power is being injected to the grid which brings the operational problem when more than 25% portion of such sources are available. Thus making the grid weak.

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6. Flickers:

For wind power system flickers is defined as the dynamics variation in network voltage caused by wind turbines. Long term flicker P_{it} is given by:

$P_{it} = C(\Psi_k)\, Sn/S_k$

$C(\Psi_k)$ =flicker coefficient of wind speed which is ≤ 0.4

In India grid frequency is specified as 47.5 to 51.5 Hz for wind farm interfaced with electricity grid. For wind from +0.5 to -0.5Hz/s frequency change is only acceptable.

III. STATCOM

STATCOM commonly known as Static Synchronous Compensator is a shunt connected reactive power consumption device that absorbs or generates reactive power. This is a solid-state switching converter acts to controlled reactive power source [1], which generates or absorbs controllable real and reactive power at its output terminal independently when it is fed from energy source or energy storage device.

In this paper, it is connected the point of common coupling (PCC) between electricity grid and wind energy system. It provide voltage source at PCC by absorbing or generating required reactive power. Thus the need of large external reactor or capacitor bank is eliminated. The areas of power system performance that can be improved by STATCOM are given below

1) The voltage variation in electricity grid and wind energy generation.
2) Voltage flicker reduction.
3) Transient stability.
4) The dynamic control of voltage in transmission and distribution system.
5) Power oscillation damping in grid.
6) Control of real and reactive power as needed.

It generates three sinusoidal voltage at fundamental frequency with the controllable amplitude and phase angle. As it is static device, it doesn't alter system impedance and internally generate reactive power for both capacitance and inductance.

IV. SIMULATION AND RESULTS

The above Fig. 2 is designed with the help of MATLAB/SIMULINK software. The electricity part consists of 120 KV 3 phase programmable source .The electric power is step down to 25 KV and transformed to 80 km of transmission lines through 47 MVA Two Windings Three Phase Transformers. Electrical power generated form wind turbine generator is step down to 25 KV. STATCOM is at the 25 KV bus bar which is the common point of coupling between electricity grid and wind generation system.

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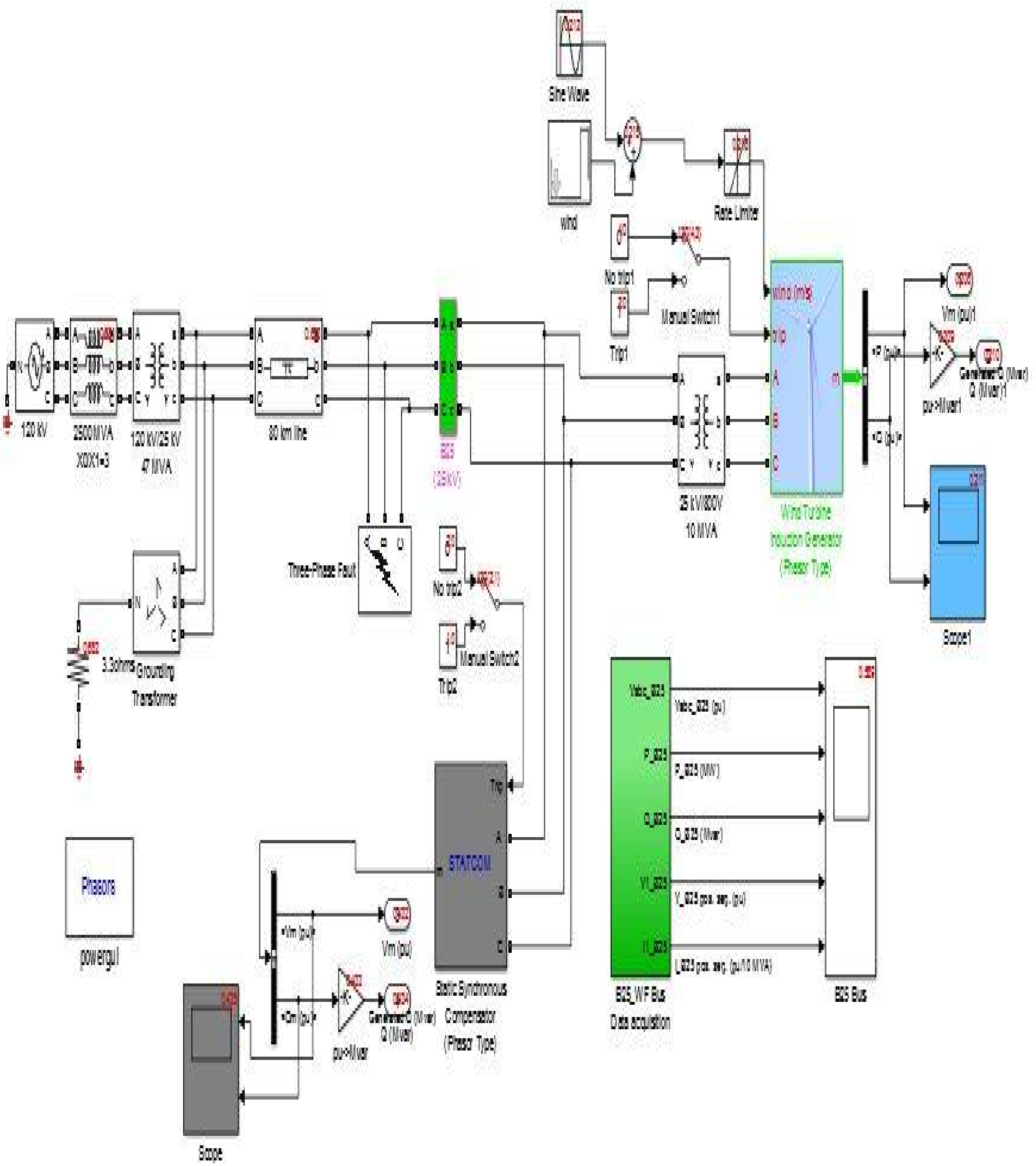

Fig. 2: Model of Electricity Grid and Wind turbine integrated with STATCOM

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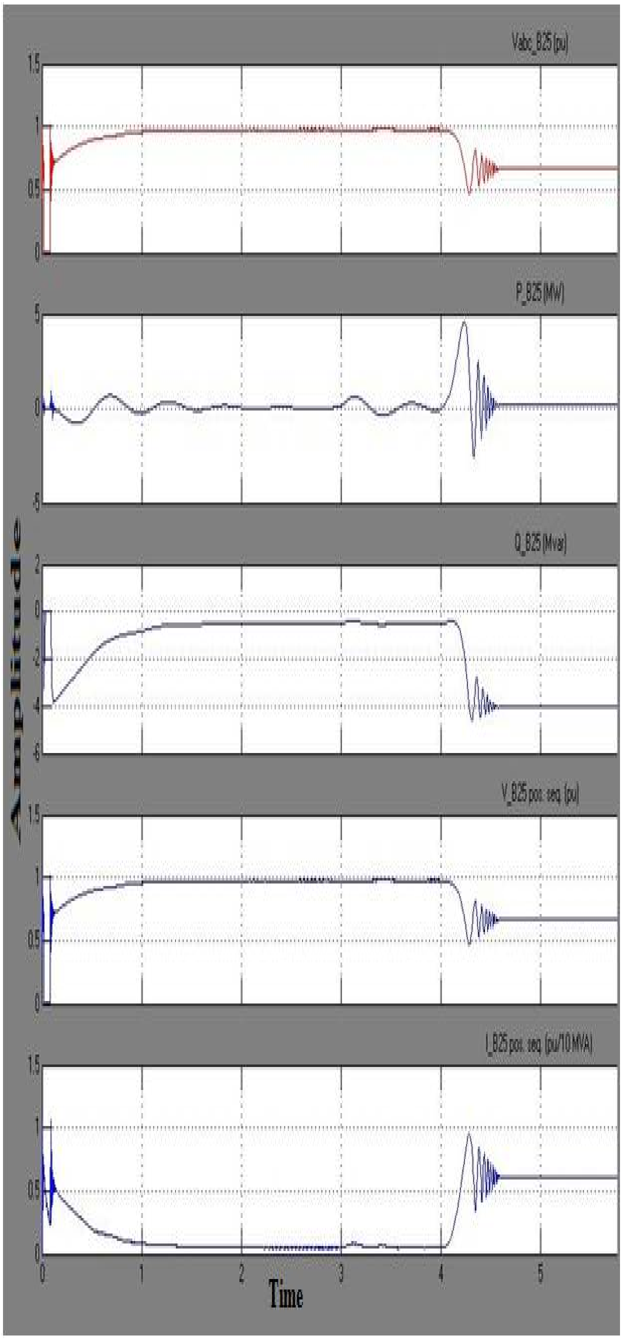
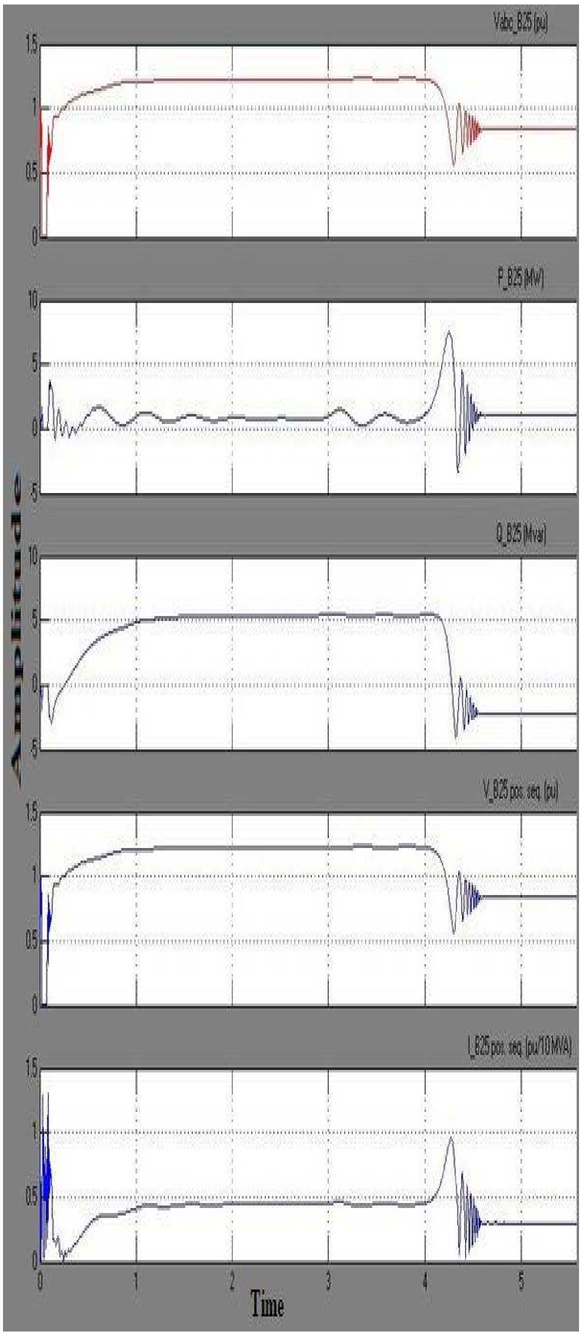
Output without STATCOM:



Output with STATCOM:



P_B25-Active Power at the Integrated Bus Bar
Q_B25-Reactive Power at the Integrated Bus Bar

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The result obtained shows that without STATCOM, after the occurrence of the fault at 4.3 sec, reactive power magnitude decreases to amplitude of -4 at the common point of coupling i.e.25 KV bus bar but when the STATCOM is interfaced decrease of reactive power is obtained by +2 of its original value.

V. CONCLUSION

STATCOM plays important role to improve overall performances of power system. The voltage distortion is seen when the three phase fault is applied to the electricity grid and fluctuating power is injected into the grid. The use of STATCOM clearly shows that voltage unbalance is overcome by providing reactive power, at the Point of Common Coupling (PCC). This made clear that voltage stability can be achieved and applied on the real system.

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