ENERGY STORAGE AND FACT BASED VOLTAGE CONTROL OF WIND ENERGY SYSTEM

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ABSTRACT

Greening the energy sector aims at a renewable and property energy system. This method involves enhancements in energy potency, a far bigger offer of energy from renewable sources and rising power quality of generated energy from those sources. The alternative energy that has been expected to be a promising energy supply will bring new challenges once it's connected to the facility grid because of the fluctuation nature of the wind and therefore the relatively new forms of its generators. This unsteady power offer affects the most installation.
When the alternative energy is connected to an electrical grid affects the facility quality because of the non-linear nature of wind energy. The installation of turbine with the grid causes power quality issues are determined by analyzing this paper methodology.
In this paper STATCOM is connected with grid at which wind turbine is connected. STATCOM is improving the power quality of the system by supplying reactive power or absorbing the reactive power during nonlinear nature of load and nonlinear nature of wind turbine. Excessive MATLAB simulation result shows the performance of the applied methodology.

Keyword: - *Wind energy, power quality improvement.*

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1. INTRODUCTION

Greening the energy sector aims at a renewable and property energy system. This method involves enhancements in energy potency, a far bigger offer of energy from renewable sources and rising power quality of generated energy from those sources.

India has nice potential to accelerate the employment of its invested renewable resources to power its growing economy with a secure and cheap energy offer. the govt. of Asian nation acknowledges that development of native, renewable resources is crucial to make sure that it's able to meet each its economic and environmental objectives, and it's promoted this development through policy action.

The quality of this electricity offer is obstructive India’s economic process. problems like voltage fluctuation, frequency variation, spikes, black-outs, brown-outs, and different disruptions impact industrial, commercial, and residential customers. The addition of gridtied renewable power will facilitate address these problems. The gap between the demand of shoppers connected to the grid and also the offered electricity provide according by the Central Electricity Authority for 2009–2010 was virtually eighty four TWh, that is 100 percent of the entire demand. the height demand deficit was quite fifteen GW, equivalent to a shortage of twelve.7%. Closing this gap are essential for Asian nation to realize its growth targets, and renewable energy has the potential to enhance energy security and scale back dependence on foreign fuels and electricity whereas nisus to satisfy those goals.

As the wind generation is mechanical energy supply for space fulfill with appropriate wind speed additionally as reduction of carbonic acid gas emission, its penetration level in installation is extended to considerably employed in future [1]. The put in rated capability of wind generation reached upto 46,000 MW worldwide throughout 2004, and it expected to succeed in 2,00,000 MW by 2016.

India has been a pioneer within the business use of wind energy in Asia since the Nineteen Nineties. In 2009, Asian nation had the fifth largest put in wind capability globally, solely behind the US, China, Germany, and Spain. throughout that year, Asian nation further one,338 MW, 97 of wind capability for a complete put in capability of ten,925 MW. This described a 14 July annual rate and contributed three.5% to the worldwide wind market.98 the foremost recent information offered at the time of this writing show that India's wind capability destroyed 12,009 MW at the top of Gregorian calendar month 2010, that described seventieth of India's total renewable energy capability.99 India's sturdy domestic market has reworked the Indian wind business into a big international player. The success of the Indian wind market may be attributed to the standard of the wind resource and to government incentives that became offered early because the international wind business began to grow. Indian company Suzlon is that the market-leader in wind generation in Asia and also the third largest manufacturer of wind turbines within the world. Together with its German subsidiary RE power, Suzlon includes a world market share of twelve.3% in put in new capability.

2. IMPROVING GRID POWER QUALITY ON INTEGRATION OF WIND ENERGY SYSTEM

This [1] system illustrates a possible solution to mitigate these integration issues of the wind power by application of the energy storage to the wind farm in power systems focusing on its short-duration perspective. The simulation model for the Energy Storage System (ESS) connected to the wind farm is implemented using the Power System Simulator for Engineering(PSS/E) which is one of the most widely used program for the power system analysis in US. Employing a sample power system, the control effect of the ESS for mitigating the wind generation related power quality issues by suppressing the power flow fluctuation of the wind farm, and improving power system stability is validated.

The system [2] clearly shows the existence of power quality problem due to installation of wind turbines with the grid. In this proposed scheme a FACTS device {STATIC COMPENSATOR (STATCOM)} is connected at a point of common coupling with a battery energy storage system (BESS) to reduce the power quality problems. The battery energy storage system is integrated to support the real power source under fluctuating wind power.

This system present the FACTS device (STATCOM) -based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The power quality issues and its consequences on the consumer and electric utility are presented. The integrated wind generation and FACTS device with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

The system [3] proposes a scheme based on FACTS device called SVC light which is connected at a Point of Common Coupling. Performance of the system with BESS under load variations and Fault ride through capability of the svc light is also analysed. This control scheme for the grid connected wind energy generation system is to improve the power quality.

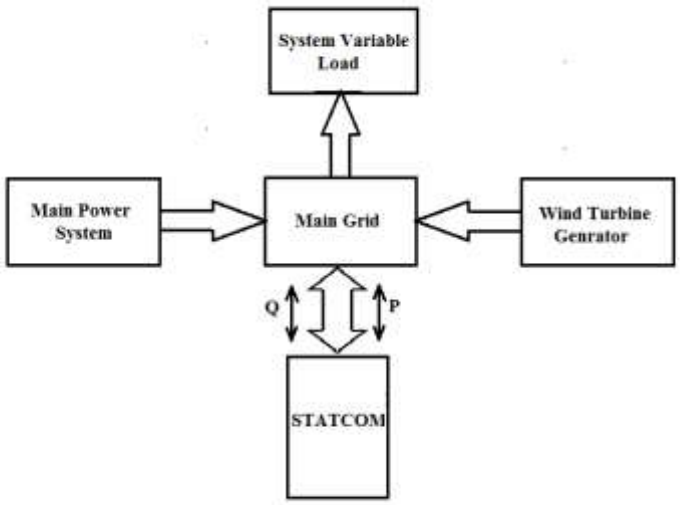
SVC Lightts is a STATCOM type of device, based on VSC (Voltage Source Converter) technology and equipped with IGBTs (Insulated Gate Bipolar Transistor) as semiconductors.

Power quality issues [5] are harmonics, voltage sag, voltage swell, voltage fluctuation and waveform distortion. To overcome power quality issue STATCOM based voltage source inverter is used to reduce harmonics content of the load current at the point of common coupling. By injecting the current into grid can achive pure sinusoidal waveform with the fundamental frequency of 50 Hz. Therefore system life time has been increased and these system is implementd in hardware.

STATCOM is connected at the point of common coupling to reduce the power qulity issues. it has capability to cancel out the harmonics part of the load current. It maintain the source voltage and current in phase and support the reactive power demand for the load at PCC in the grid system and enhance the utilization factor of transmission line.

The control scheme [6] approach is based on injecting the currents into the grid using “bang-bang controller.” The controller uses a hysteresis current controlled technique. Using such technique, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation. The control algorithm needs the measurements of several variables such as three-phase source current isabc, DC voltage Vdc, inverter current isabc with the help of sensor. The current control block, receives an input of reference current isabc* and actual current isabc are subtracted so as to activate the operation of STATCOM in current control mode.

3. PROPOSED METHODOLOGY



3.1 STATCOM

A [7] STATCOM could be a controlled reactive-power supply. Itprovides the specified reactive-power generation and absorption entirely by means that of electronic process of the voltage and current waveforms in a VSC. A STATCOM principle diagram is shown in Figure 2.

The VSC is connected to a utility bus through shunt electrical device. vacation is that the bus voltage. Iac is STATCOM injected current. Vout is that the VSC output voltage. Vdc and Idc square measure the DC electrical device aspect voltage and current. AN IGBT with back to back diode denotes the three arm IGBT Bridge.

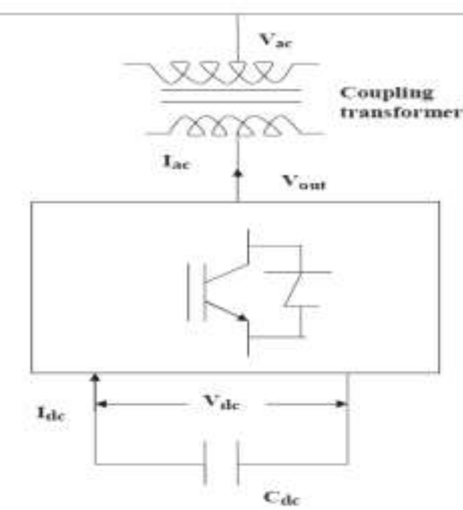


Fig 2:- A functional model of STATCOM

Top three IGBTs area unit referred to as as positive cluster and bottom three IGBTs area unit referred to as as negative cluster IGBTs. The electrical converter operation takes place, once IGBTs conduct and convertor operation takes place, once diodes conduct. Figure three shows the conception of STATCOM power exchange.

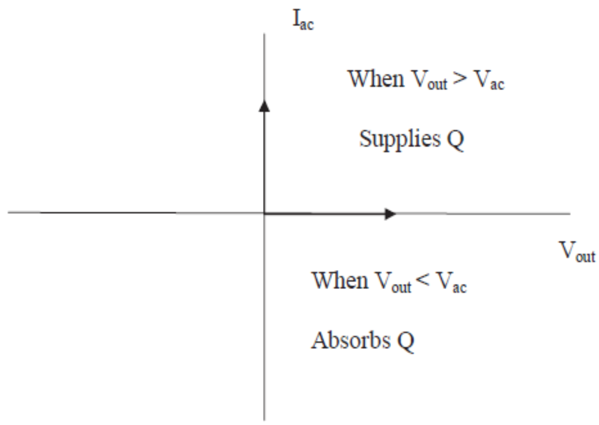


Fig 3:- STATCOM power exchange

STATCOM is seen as an adjustable voltage source behind a reactance. It means that the capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby it gives the STATCOM, a compact design. The equivalent circuit of the block diagram of VSC based STATCOM is shown in Figure 4.

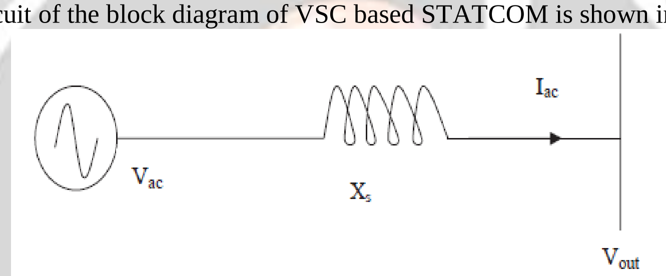


Fig 4:- Equivalent circuit of the STATCOM

3.2 Wind Turbine

Wind turbine components 1-Foundation, 2-Connection to the electric grid, 3-Tower, 4-Access ladder, 5-Wind orientation control (Yaw control), 6-Nacelle, 7-Generator, 8-Anemometer, 9-Electric or Mechanical Brake, 10-Gearbox, 11-Rotor blade, 12-Blade pitch control, 13-Rotor hub.

Wind turbine [4] design is the process of defining the form and specifications of a wind turbine to extract energy from the wind. A wind turbine installation consists of the necessary systems needed to capture the wind's energy, point the turbine into the wind, convert mechanical rotation into electrical power, and other systems to start, stop, and control the turbine.

In 1919 the physicist Albert Betz showed that for a hypothetical ideal wind-energy extraction machine, the fundamental laws of conservation of mass and energy allowed no more than 16/27 (59.3%) of the kinetic energy of the wind to be captured. This Betz' law limit can be approached by modern turbine designs which may reach 70 to 80% of this theoretical limit.

In addition to aerodynamic design of the blades, design of a complete wind power system must also address design of the hub, controls, generator, supporting structure and foundation. Further design questions arise when integrating wind turbines into electrical power grids.

4. SIMULATION MODEL

A wind park consisting of 2 one.5-MW wind turbines is connected to a 25-kV distribution system exports power to a 120-kV grid through a 25-km 25-kV feeder. The 9-MW wind park is simulated by 3 pairs of one.5 MW wind-turbines. Wind turbines use squirrel-cage induction generators (IG). The stator coil winding is connected on to the sixty Hertz grid and also the rotor is driven by a variable-pitch turbine. The pitch angle is controlled so as to limit the generator output power at its value for winds exceptional the nominal speed (9 m/s). so as to come up with power the immunoglobulin speed should be slightly on top of the synchronous speed. Speed varies more or less between one atomic number 94 at no load and one.005 atomic number 94 at full load.

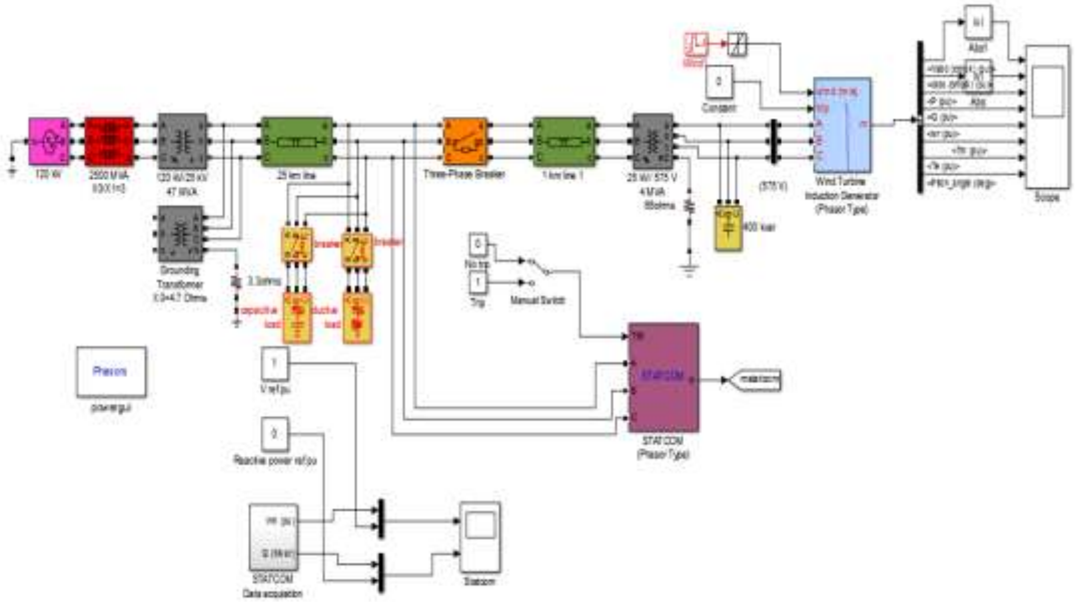


Fig 5:- Matlab simulation model for STATCOM based improving grid power quality on integration of wind energy system

Reactive power absorbed by the IGs is part paid by capacitance banks connected at every turbine low voltage bus (400 kvar for every combine of one.5 MW turbine). the remainder of reactive power needed to take care of the 25-kV voltage at bus B25 near one atomic number 94 is provided by a 3-Mvar STATCOM with a third droop setting.
Variable load area unit connected with main grid through 3 section breaker within which inductive load of 3000Mvar connected with system between four to five second of total simulation time whereas electrical phenomenon load of 3000Mvar connected in system between half dozen to seven second of total simulation time of model. This behavior of load act as non linear or variable load of system. Total simulation time is ten second.
The wind speed applied to rotary engine is controlled by the "Wind 1" block. Initially, wind speed is ready at eleven m/s, then beginning at t=2s for "Wind rotary engine ", wind speed is rammed to five m/s in four seconds. once more wind speed is 6m/s at five seconds so finally wind speed amendment to nine m/s at 8second and continue up to total simulation time. This shows the nonlinear behavior of alternative energy in turbine system.
In that simulation model turbine generator connected to grid at two second time with the assistance of 3 section breaker.

Table 1:- MATLAB simulation model block parameter specifications.

Sr. No.	Name of simulation block	Parameter specification
1.	Three phase programmable voltage source	Positive sequence Amplitude (Vrms ph-ph) = 120 KV; Frequency = 60Hz; Phase difference = 0 Degree; Generator type = Swing
2.	Three phase mutual inductance ($Z_0 - Z_1$)	R_1= 0.1 Ohm; L_1= 1.0H; R_0 = 0.3; L_0 = 3.0H
3.	47 MVA Three phase transformer	Nominal power = 47 MVA; Frequency=60Hz; Winding 1 (primery) =120KV; R_1= 0.08pu, L_1=0.08pu; Winding 2(Secondery) = 25KV; R_1= 0.08pu, L_1=0.08pu; Magnetizing resistance R_m=500 pu; Magnetizing inductance =5000 pu.
4.	Grounding transformer	Nominal power = 100 MW; Frequency=60Hz; Winding 1 (primery) =25KV; R_1= 0.08pu, L_1=0.08pu; Winding 2(Secondery) = 25KV; R_1= 0.08pu, L_1=0.08pu; Magnetizing resistance R_m=500 pu; Magnetizing inductance =5000 pu
5.	Transmission line 25Km	Frequency for RLC specification = 60Hz; Positive sequence resistance r1= 0.1153 Ohm/Km; Zero sequence resistance r0 = 0.413 Ohm/Km ;Positive

		sequence inductance L1= 1.05mH/Km; Zero sequence inductance L0= 3.32 mH/Km ; Positive sequence capacitor C1= 11.33Nf/Km; Zero sequence capacitor C0= 5.01nF/Km; Line length = 25Km.
6.	Capacitive load breaker	Initial status of breaker = open; Transition time = 6sec to 7+10/60sec; Breaker resistance Ron = 0.001Ohm; Snubber resistance Rp =1MOhm.
7.	Capacitive load	Nominal phase to phase voltage (Vn) = 500KV; Nominal frequency fn=60Hz; Active power=300MW; Inductive reactive power QL=0KVAR; capacitive reactive power QC=3000MVAR.
8.	Inductive load breaker	Initial status of breaker = open; Transition time = 4sec to 5+10/60sec; Breaker resistance Ron = 0.001Ohm; Snubber resistance Rp =1MOhm.
9.	Inductive load	Nominal phase to phase voltage (Vn) = 500KV; Nominal frequency fn=60Hz; Active power=300MW; Inductive reactive power QL=3000MVAR; capacitive reactive power QC= 0VAR.
10.	Wind energy system breaker	Initial status of breaker = open; Transition time =2sec ; Breaker resistance Ron = 0.001Ohm; Snubber resistance Rp =1MOhm.
11.	Transmission line 1Km	Frequency for RLC specification = 60Hz; Positive sequence resistance r1= 0.1153 Ohm/Km; Zero sequence resistance r0 = 0.413 Ohm/Km ;Positive sequence inductance L1= 1.05mH/Km; Zero sequence inductance L0= 3.32 mH/Km ; Positive sequence capacitor C1= 11.33Nf/Km; Zero sequence capacitor C0= 5.01nF/Km; Line length = 1Km.
12.	Wind turbine coupled transformer (4MVA)	Nominal power = 4 MVA; Frequency=60Hz; Winding 1 (secondery) =25KV; R_1= 0.25pu, L_1=0.25pu;Winding 2(primary) = 575V; R_1= 0.25pu, L_1=0.25pu; Magnetizing resistance R_m=500 pu; Magnetizing inductance =5000 pu.
13.	Shunt capacitor bank (400KVAR)	Nominal phase to phase voltage (Vn) = 575 V; Nominal frequency fn=60Hz; Active power=0MW; Inductive reactive power QL=0KVAR; capacitive reactive power QC=400 KVAR.
14.	Wind turbine (Phasor type)	Generator data: Nominal power Pn=3MW; Line to line voltage=575 V; Frequency f=50Hz; Stator resistance Rs= 0.004843 pu; Stator inductance Ls= 0.1248 pu; Rotor resistance Rr'= 0.004377 pu; Rotor inductance Rl'=0.1791 pu; Magnetizing inductance Lm= 6.77 pu; Inertia constant H=5.04 s; Friction factor=0.01 pu; Pair of poles =3; Turbine data: Pitch angle (beta) = 0 Degree; Nominal wind turbine mechanical output = 3 MW; Base wind speed = 9 m/s; Maximum power at base wind speed = 1 pu; Base rotational speed = 1 pu; Pitch angle controller gain Kp =5; Ki=25; Maximum rate of change of pitch angle rate = 2 degree/sec.
15.	STATCOM (Phasor model)	Control parameters: Refrence voltage Vref = 1 pu; Mximum rate of change of reference voltage = 10 pu/sec; STATCOM droop = 0.03 pu; Vac regulator gains Kp= 10; Ki= 2000; Vdc regulator gains Kp=0.1 * 10^{-3}; Ki=20*10^{-3}; Current regulator gain Kp= 0.3; Ki= 10; Kf=0.22. Power data: System nominal voltage (L-L) =25KV; Frequency = 50Hz; Convertor rating = 3MVA; DC link nominal voltage = 4000V.

5. SIMULATION RESULT

5.1 STATCOM Results

Below figure 6 and 7 shows that, When the simulation model run, at 2 second time wind turbine connected with main grid through three phase breaker. The wind speed applied to turbine is controlled by the "Wind 1" block. Initially, wind speed is set at 11 m/s, then starting at t=2s for "Wind turbine ", wind speed is rammed to 5 m/s in 4 seconds. Again wind speed is 6m/s at 5 seconds and then finally wind speed change to 9 m/s at 8second and continue up to total simulation time. This shows the nonlinear behavior of wind generation in wind turbine system.
At 2 second when wind turbine connected with grid system voltage get reduced but at that time STATCOM generate 3 pu reactive power and supply reactive power to grid for voltage improvement upto reference voltage that is 1 pu.

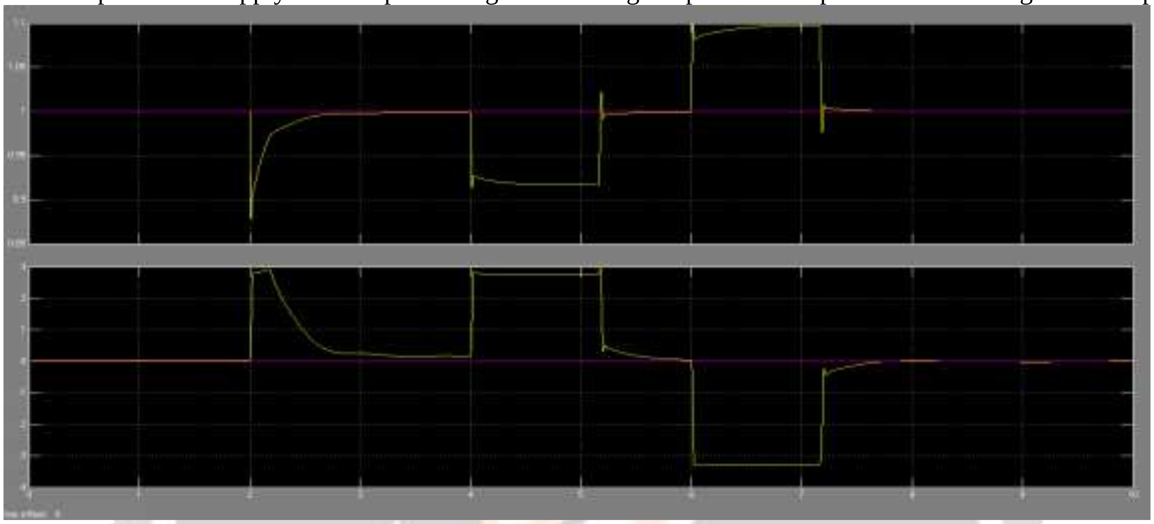


Fig 6:- STATCOM act as voltage regulator corrected grid voltage and generated and absorbing reactive power

At 4 second simulation time inductive load of 3000mVar connected in grid through breaker and closed at 5 second. During this period, due to inductive load grid voltage get drop upto -0.93 pu but STATCOM generate the +2.97 pu reactive power for improve the grid voltage of 1 pu.
At 6 second again capacitive load of 3000Mvar are connected with grid and disconnect at 7 second. During this period, due capacitive load grid voltage becomes rises upto +1.1 pu but STATCOM absorbing the reactive power of -3.2 pu for maintaining grid voltage as reference voltage that is 1 pu.

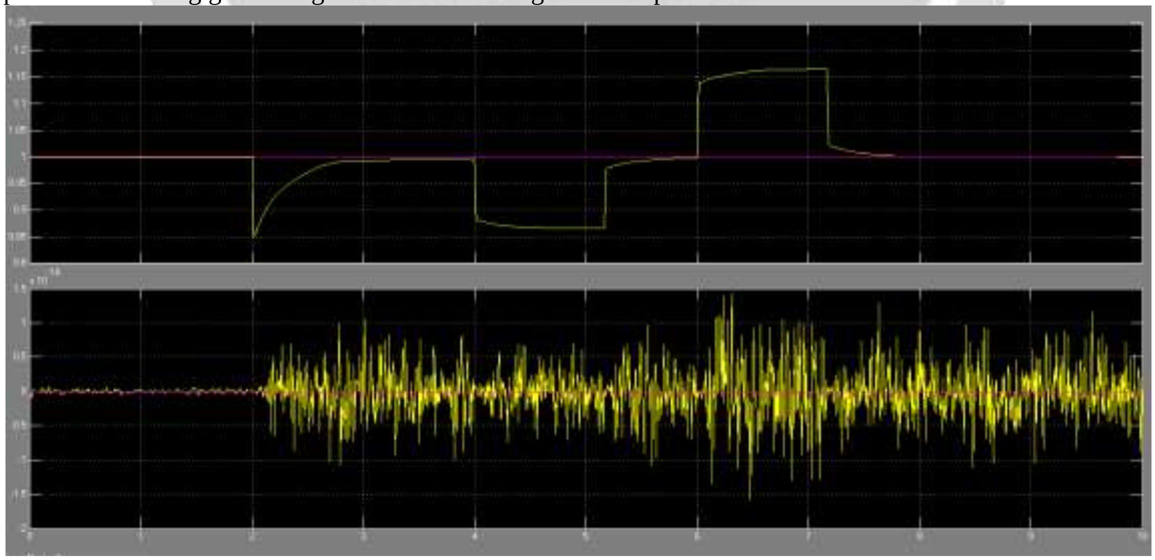


Fig 7:- STATCOM act as reactive power compensator for voltage profile improvement corrected grid voltage and generated and absorbing reactive power

5.2 Wind Turbine Results

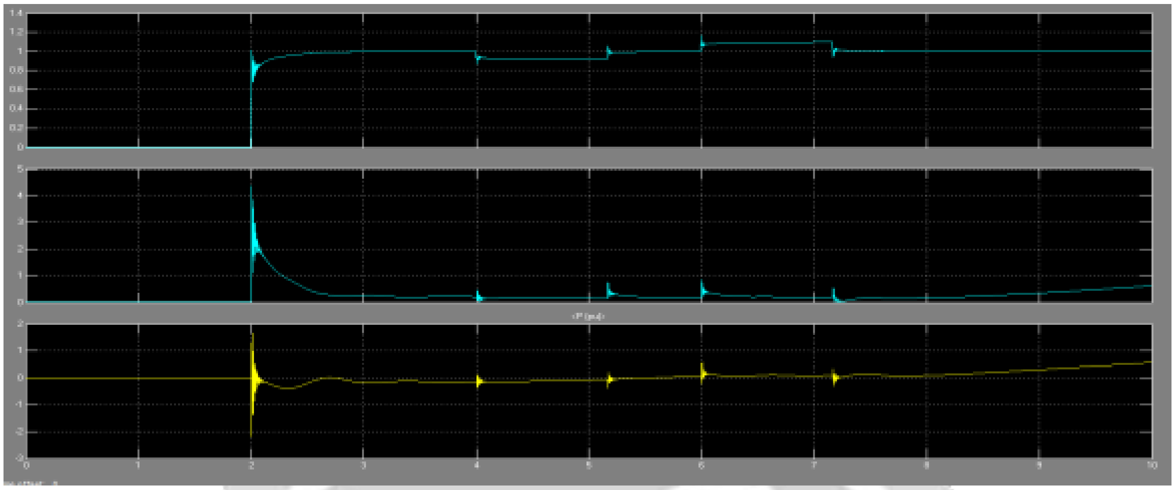


Fig 8:- Phasor voltages, Phasor currents Ia, Ib, Ic in pu and output power in pu respectively of wind turbine.

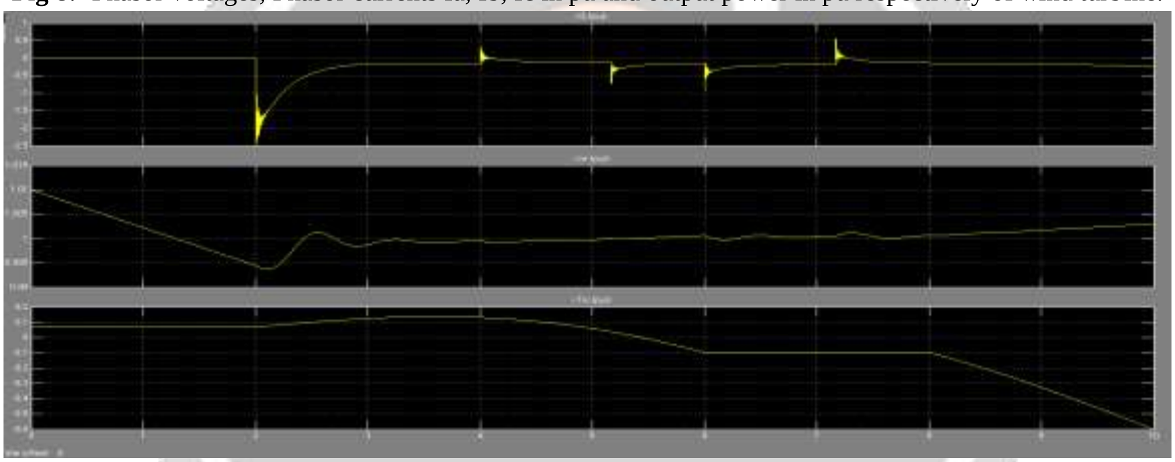


Fig 9:- output reactive power in pu, Generator rotor speed (pu) and Mechanical torque applied to the generator in pu respectively for wind turbine.

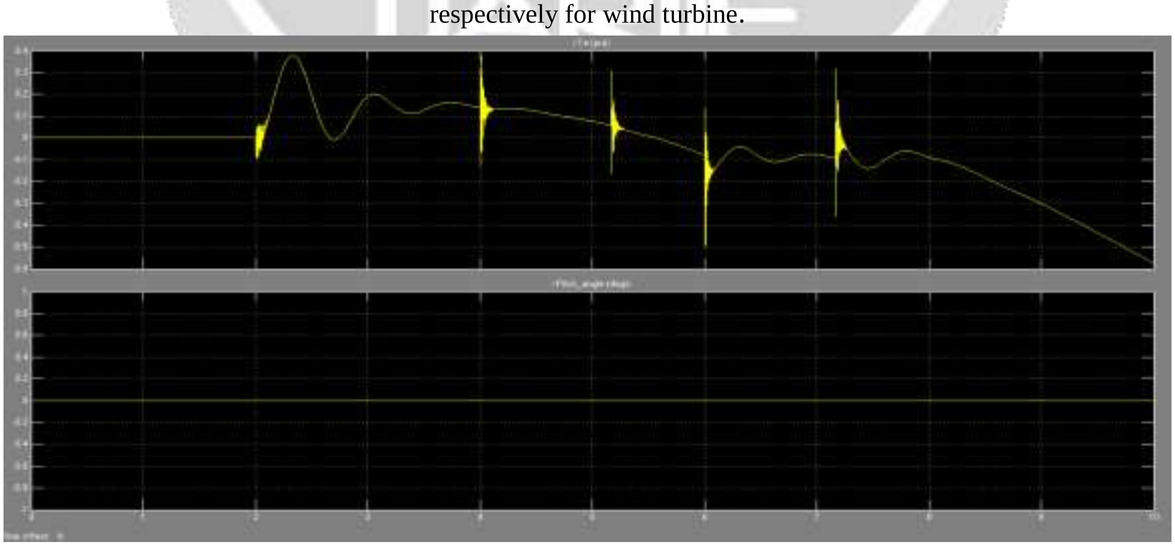


Fig 10:- Electromagnetic torque in pu and Blade pitch angle in degrees respectively for wind turbine.

6. CONCLUSION

This paper is an effort to present technique used for improve the power qulity of system when wind turbine connected with power system grid.The importance and technical significance of BESS with STATCOM is elaborated here. Advantages of using BESS in connection to STATCOM in the power system for minimizing the transient dynamics of the power system. It has been observed that the STATCOM-battery combination can be very effective in compensating generator rotor angle oscillations and thus well suited for improving transient stability and the dynamic behavior of the power system. STATCOM is suitable for improving the power quality of the grid when the wind turbine or wind farm connected with grid.
Also non-uniform nature of load disturb the quality of voltage at grid. This power quality also improve by STATCOM by absorbing and generating reactive power using Voltage Source Convertor using DC link that is battery system.

7. FUTURE SCOPE

This work extends for creating hybrid power system which consist of solar, wind and tidal energy resources. In that system STATCOM play important role for improving the power quality with renewable energy resources use.

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