# Enhancement Of Power Quality In A Wind Power Generating System integrated To Grid By using FACTS Controller STATCOM

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***Abstract—*** This paper study about power quality improvement of wind energy generating system concomitant to the grid. Connecting of wind power generating system into an grid affects the power quality. The operation of wind turbines has an impact on the power quality at the connected grid. Power quality problems such as voltage flicker and harmonic distortion along with reliability issues are some major concern and in this work the flicker & harmonics issues are considered. Wind turbine connected to an induction generator is modeled using MATLAB/SIMULINK to analyze power quality and reliability problems. STATCOM unit is developed to inject reactive power to mitigate power quality problems and to get stable grid operation. Due to continuously varying wind speed components, the active and reactive power along with terminal voltage fluctuates continuously. By connecting STATCOM into the grid, the active power, reactive power and voltage is maintained stable.

***Keywords-*** wind power generating system, STATCOM, Power quality improvement, Reliability, Reactive power, Active power, MATLAB/SIMULINK.

## I. INTRODUCTION

Now the situation of the world is like demand of electrical energy more compare with the generation. For development of any country socially and economically depends on electrical power generation. why because present day every equipment is operated or run by electrical energy only so that demand is increasing day by day very fast and also generating methods also increasing but not that much equal with load demand.

At present generation of electrical energy is by two source of energy

1. Conventional source of energy: - The resources which are finite and exhaustible.
   For example - Thermal energy and Hydro energy.
2. Nonconventional sources of energy: - These resources are being continuously produced in nature and these are inexhaustible. These are also called as renewable source of energy.
   For example- wind energy, solar power energy, tidal energy and biogas energy etc.

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 [1]. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer- focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine [2]. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 3MW, feeding into distribution network, particularly with customers connected in close proximity [3]. Today, more than 35000 wind generating turbines are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations[11]. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system[4]. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. A STATCOM based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives[12].

- Unity power factor at the source side.
- Reactive power support only from STATCOM to wind Generator and Load.
- Simple ON-OFF controller for STATCOM to achieve fast dynamic response.

By connecting the STATCOM electrical power flowing in the grid is increases and sable flow of power to load without any loss. So that reliability of the system also increases.

## II. POWER QUALITY PROBLEMS AND CONSEQUENCES

The major problem of decreasing in power quality is due to the large distance transmission when ever distance increases resistance and inductance of the line also increases and also when a distorting load is connected to the power system fundamental sinusoidal waveform of current flowing through system will vary. This will rise non-sinusoidal voltage drop across various network element connected to the system resulting in distorted waveform propagation throughout the system to buses remote from the original source.

### *Voltage variation*

The voltage variation problem results from the velocity of wind and generator torque[4]. The voltage difference is directly related to active and reactive power variations. The voltage changes is commonly classified as under:

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.
- Long duration voltage variation.

***Voltage flicker***

Voltage flicker describes dynamic variations in the network voltage. Traditionally it was of concern when the connection of large fluctuating loads (e.g. arc furnaces, rock crushing machinery sawmills, etc.) was under consideration. However, it is of considerable significance for wind farms, which: (i) often use relatively large individual items of plant compared to load equipment; (ii) may start and stop frequently; (iii) may be subject to continuous variations in input power. Flicker produced during continuous operation is caused by power fluctuations, which mainly emanate from variations in the wind speed, the tower shadow effect and mechanical properties of the wind turbine. Flicker due to switching operations arises from the start and shut down of the wind turbines[6][7].

***Harmonics and inter harmonics***

The emission of harmonic and inter harmonic currents from wind turbines with directly connected induction generators is expected to be negligible. But Wind turbines connected to the grid through power converters however emit harmonic and/or inter harmonic currents that contribute to the voltage distortion. Inverters based on new technologies have a limited emission of harmonics at lower frequencies compared to the converters used in the first generation of variable speed wind turbines. Instead they produce inter harmonics at higher frequencies[1][2][3]. Due to this harmonics the wind turbines generator affects

*High System Losses

* Generator Overheating

* Low Power Factor

* Electronic Protective Device Malfunction

* High Telephone Interference Factor

* Increased generator Vibration

### *Consequences of the Issues*

The voltage variation, flicker, harmonics causes the malfunction of equipments namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipments like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipments. Thus it degrade the power quality in the grid.

## III. POWER QUALITY IMPROVEMENT TECHNIQUE

The FACTS device are based on power electronic controllers that enhances the capacity of the transmission line .These controllers are fast and increases the stability operating limits of the transmission systems when their controllers are properly tuned[12]. FACTS devices are mostly used to regulate voltage and schedule power flow through some lines. FACTS device has the potential to operate the more flexible and economic way[6]. STATCOM is a voltage source inverter which means a DC capacitor voltage source regularly switched by gate turn off thyristor to generate alternating voltage and by surrounding the capacitor with four GTOs, each with a reverse diode, its voltage can be switched in the positive or negative direction[3][4]. STATCOM has potential to maintain its reactive current at low voltage since it has an essentially constant current characteristics while a thyristor SVC is constant impedance. Reduced land use to about 40% of a thyristor SVC requirement gives the potential for limited storage, if batteries replace capacitor Be applied as an active filter because each step can be switched in response to a harmonics.

A STATCOM can provide fast capacitive and inductive compensation and is able to control its output current independently of the AC system voltage. To mitigate power quality problems. The first approach is load conditioning, which ensures that equipment is made less sensitive to power disturbances, allowing the operation even under significant voltage distortion[2].

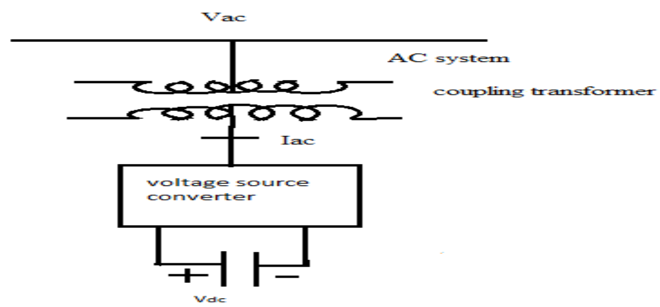


Fig 1 Basic STATCOM

The most basic configuration of the STATCOM consists of a two-level VSC with a DC energy storage device; a coupling transformer connected in shunt with the AC system, and associated control circuits. It is possible to change the reactive power flow on the connection line by using reactive shunt compensators, such as STATCOM, to mitigate the flicker level during continuous operation of grid connected wind turbines. The STATCOM consists of voltage source converter[5][6]. The voltage source converter is preferred to the current source converter because the devices are clamped against over-voltages by the voltage across the DC-link capacitor bank. The losses are lower and the devices do not have to able to withstand a large reverse voltage[3].

The power system performance can be improved by connecting STATCOM as desired below

1. The transient stability
2. The dynamic voltage regulation in transmission and distribution system
3. The power oscillation damping in grid
4. The regulation reactive power and also provide real power in line if needed.

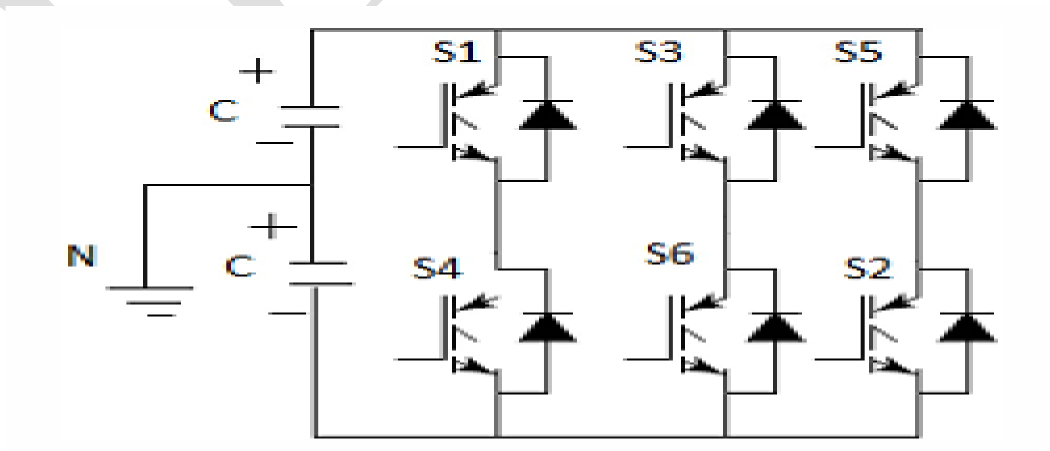


Fig 2 six pulse vsc STATCOM

The exchange of reactive power is done by regulating the output voltage of the inverter VSTATCOM , which is in phase with the mains voltage Vk. The operation can be described as follows.

If the voltage VSTATCOM is below Vk, the current through the inductor is phase shifted in relation to the voltage Vk which provides an Inductive current, then QS becomes positive and the STATCOM absorbs reactive power. If the voltage VSTATCOM exceeds Vk, the current through the inductor is phase shifted in relation to the voltage Vk which provides a capacitive current, then QS becomes negative and the STATCOM generates reactive power. If the voltage VSTATCOM is equal to Vk, the current through the inductor is zero and therefore there is no exchange of energy[4][5].

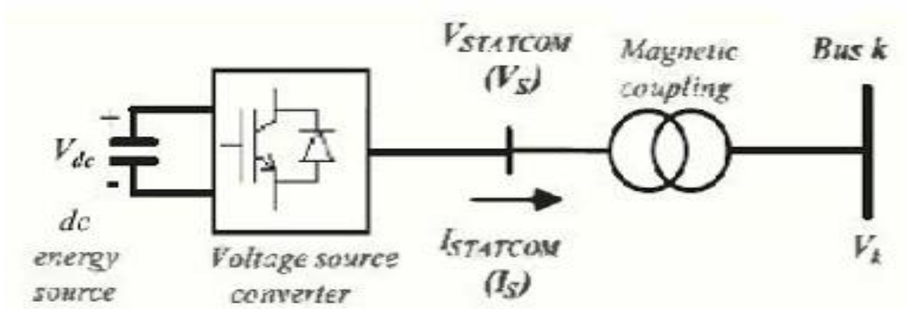


Fig 3 single line diagram

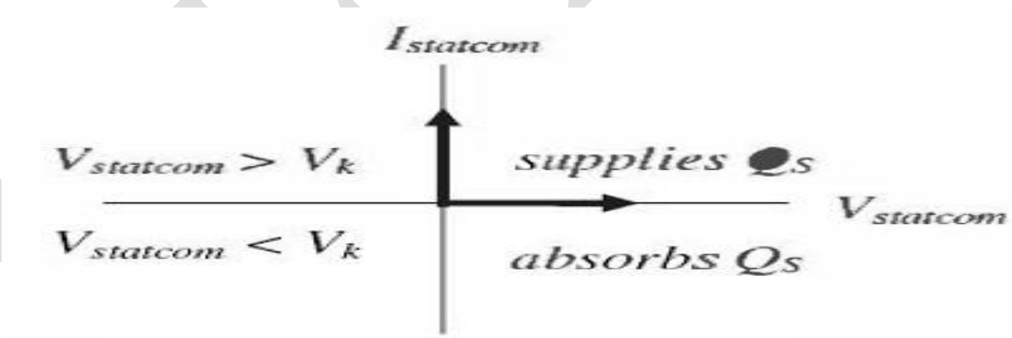


Fig 4 STATCOM operation

## Advantages of STATCOM

1.speed response

2. Requires less area as bulky passive components (such as reactors) are eliminated

3. Inherently modular and relocatable.

4. It can be interfaced with real power sources such as fuel cell, battery,or SMES (superconducting magnetic energy storage

5. A STATCOM has superior performance during low voltage condition.

## IV. SIMULATION AND OPERATION OF WIND POWER GENERATING SYSTEM

In this study wind power generator is modeled using MATLAB/SIMULINK . and studies are carried out in regarding to power quality and stability using STATCOM.

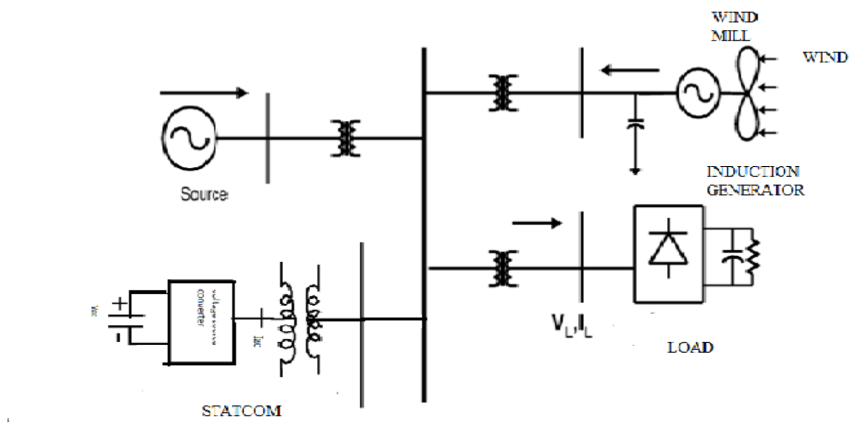


Fig 5 Wind power generating system connecting to the grid

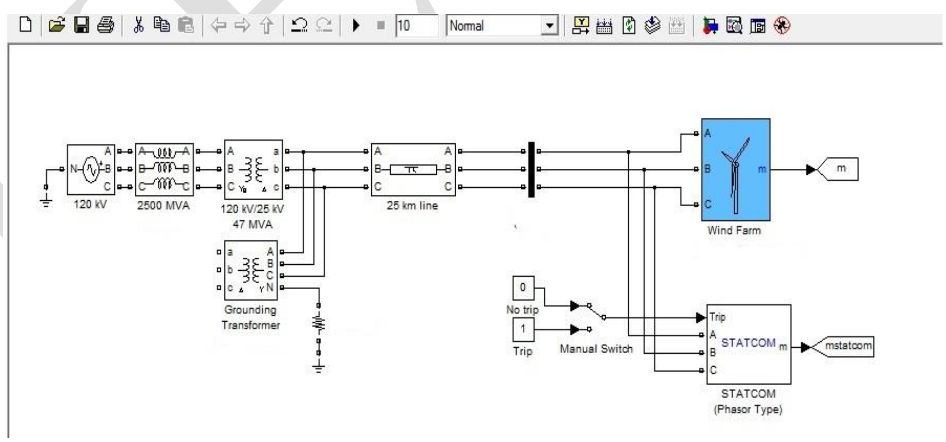


Fig 6 Simulation block diagram in MATLAB/SIMULINK

### *Wind energy generating system*

The wind power can be computed by using concept of kinetics. A wind mill works on the principle of changing kinetic energy of the wind to mechanical energy.

Let, Uw = Velocity of wind, km/h and

ϸ = Density of air (1.225 $kg/m^3$ at sea level);and

Air density is a function of altitude, temperature and barometric pressure

Air density A= area, through which tha air flows.

Then, the amount of air passing in the unit time(m) through area A, with velocity Uw is given by

Mass, m= ϸAUw

Therefore kinetic energy (K.E) = ½ $mUw^2$

=½× ϸAUw× $Uw^2$

=½ ϸA $Uw^3$ watts.

i.e. Total power ($P_{total}$) = ½ ϸA $Uw^3$

From above equation it is obvious that power output of a wind mill varies as cube of the wind velocity(i.e. power output α $Uw^3$).

$P_{total}$ = ½ ϸ×π/4 $D^2$×$Uw^3$

= $^1/_8$ ϸπ $D^2Uw^3$

D=diameter in horizontal axis aeroturbines (in meters).

Where,

All this power cannot be extracted because, for this wind velocity would have to be reduced to zero which means that the wind mill would accumulate static air around it which would prevent the wind mill operation.

### *STATCOM operation*

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling. STATCOM both inductive and capacitive regions of operations are possible.

The STATCOM will decrease the harmonics in the grid current by injecting superior reactive power in to the grid.

It can maintain a stable voltage even with a very weak AC system.

### *Control scheme*

The control method is injecting reactive power into the grid using ON and OFF control scheme.

The controller uses a current controlled method. Using such method, the controller keeps the control system variable between boundaries of hysteresis area and gives correct switching signals for STATCOM operation[4].

The control method requires the measurements of several values, such as three-phase source current $i_{sabc}$, , inverter current $i_{iabc}$ , DC voltage $V_{dc}$ with the help of sensor. The current control block, receives an input of reference current $i^*_{sabc}$, and actual current $i_{sabc}$, are subtracted so as to activate the operation of STATCOM in current control mode.

In three-phase system, the RMS voltage source is calculated at the sampling frequency from the source phase voltage ( $V_{sa}$,$V_{sb}$,$V_{sc}$ ) and is expressed[4][5], as sample *Vsm*, sampled peak voltage, as in

$$V_{sm}=\{{}^{2}/_{3}\,(V^2_{sa} + V^2_{sb}+ V^2_{sc})\}^{1/2}$$

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

$$Usa={}^{Vsa}/_{Vsm}\ ,\ Usb={}^{Vsb}/_{Vsm}\ ,\ Usc={}^{Vsc}/_{Vsm}$$

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

$$i^*_{sa} = I\,.U_{sa}$$

$$i^*_{sb} = I\,.U_{sb}$$

$$i^*_{sc} = I\,.U_{sc}$$

Whereis proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal. The unit vectors implement the important function in the grid connection for the synchronization for STATCOM. This method is simple, robust and favorable as compared with other methods .

## V. SYSTEM PERFORMANCE AND RESULTS AND RESULTS

The proposed control scheme is simulated using MATLAB/SIMULINK in power system block set.

### *Voltage source current control*

The current injected into the grid by the STATCOM will cancel out the distortion caused by the load and wind generator. The GTO based three-phase inverter is connected to grid through the transformer. The generation of switching signals from reference current is simulated within hysteresis band of 0.08[5]. The choice of narrow hysteresis band switching in the system improves the current quality. The control signal of switching frequency within its operating band.

fig 4 shows the response when there no connection of STATCOM to the grid.

*STATCOM performance*

The wind energy generating system is connected with grid having the load. When STATCOM controller is made on without change in load it start to decrease the reactive power demand, furcating voltage and also harmonics are eliminated.

**SYSTEM PARAMETERS**

| S.No. | Parameters | Ratings |
|---|---|---|
| 1 | Grid voltage | 3-phase, 575kV, 60Hz,<br>Length =25km |
| 2 | Induction generator | P=3MW, F=60,<br>Rs=0.0049Ω pu,<br>Ls=0.125H pu<br>Rr=0.0044Ω pu<br>Lr=0.18H pu |
| 3 | STATCOM parameters | Vrms=25kv,<br>DC link voltage= 4000V<br>DC link capacitance=375μF<br>Switching frequency=2KHZ |
| 4 | Load parameter | Inductive=400kw |

***System responces with and without statcom***

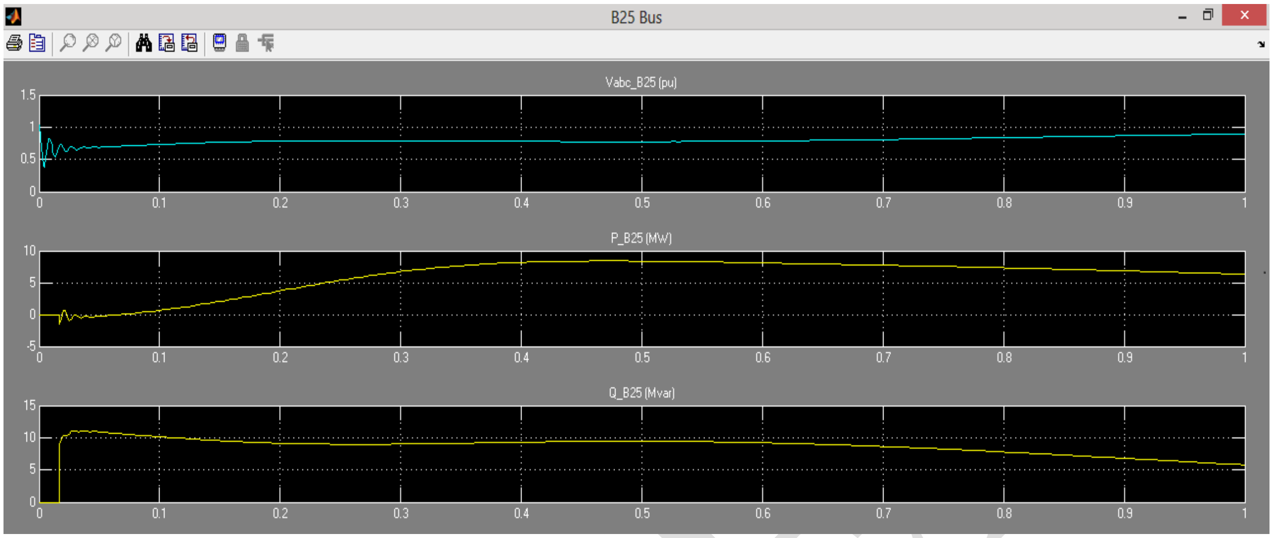


Fig 7 Response without STATCOM a) Voltage b) Active power c) Reactive power

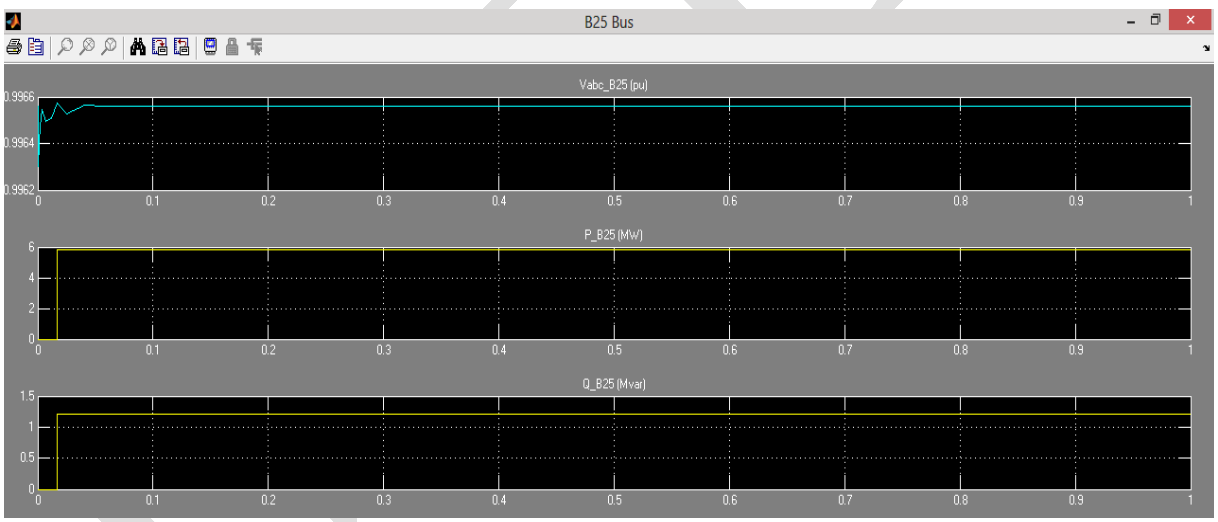


Fig 8 Response with STATCOM a) Voltage b) Active power c) reactive power

From the above fig 7 at time t= 0 to 0.1 we can observe that voltage, active power, reactive power is fluctuations are more and disturbances is high due to the unstable wind flow and load disturbances.

At t=0.1 to 1 we observe that fluctuation are decreased but there is little amount of fluctuation are present.

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From the fig 8 after connecting the STATCOM at time t=0 to 0.1 we can observe that voltage, active power, reactive power is fluctuations are less and disturbances is little low due to the three phase fault compared when STATCOM is not connected.

At t=0.1 to 1 we can observe that there is stable flow of voltage, active power and reactive power without any fluctuation power is also reduced. So it can be concluded that with the use of fuzzy logic controller the transient stability as well as steady state stabilities can be improved.

FFT analysis of the wind power generating system with and without STATCOM

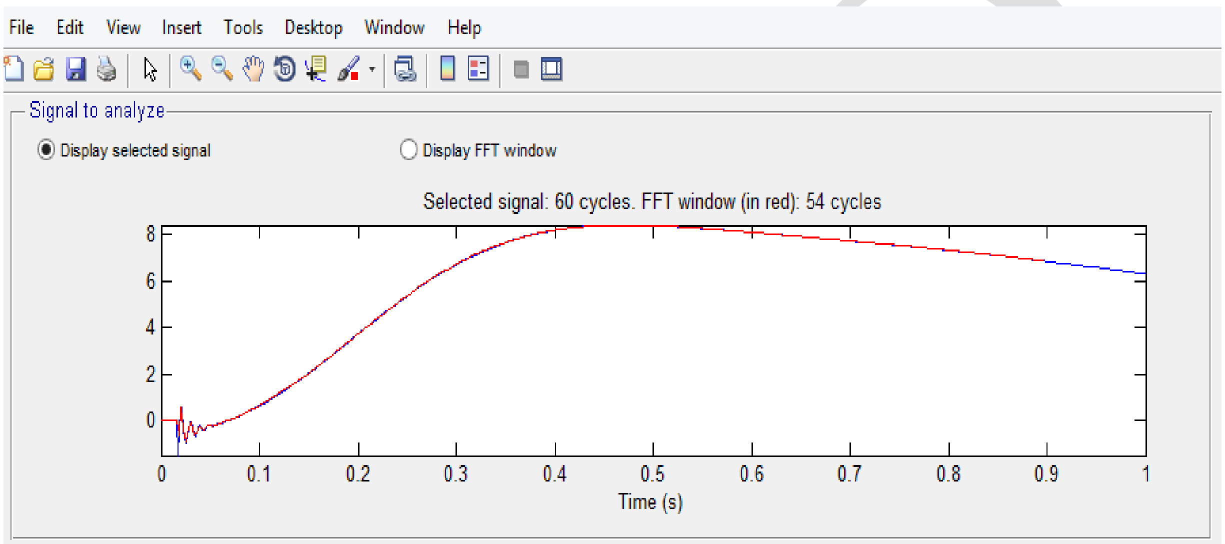


Fig 9 FFT waveform of power without STATCOM

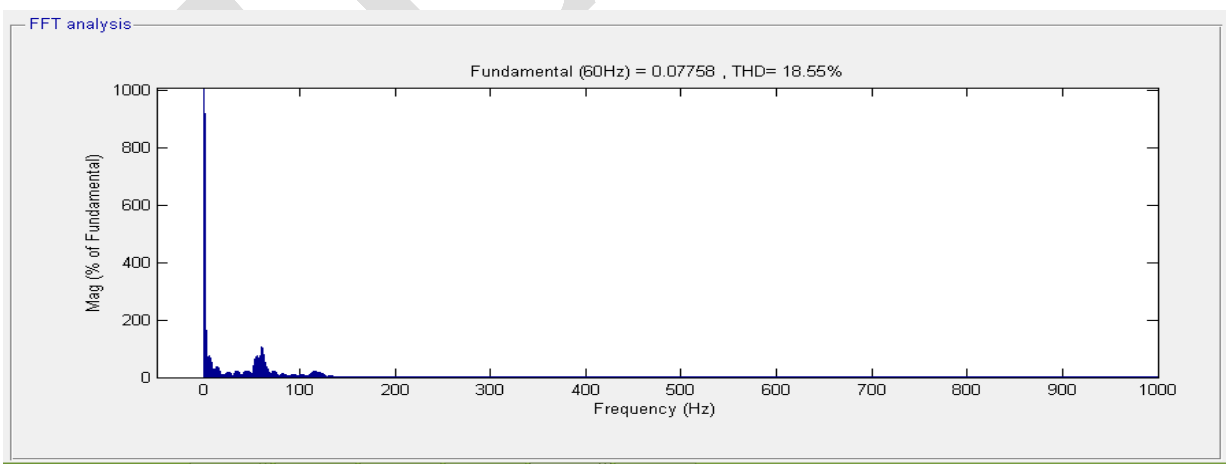


Fig 10 FFT analysis of power waveform without STATCOM THD=18.55%

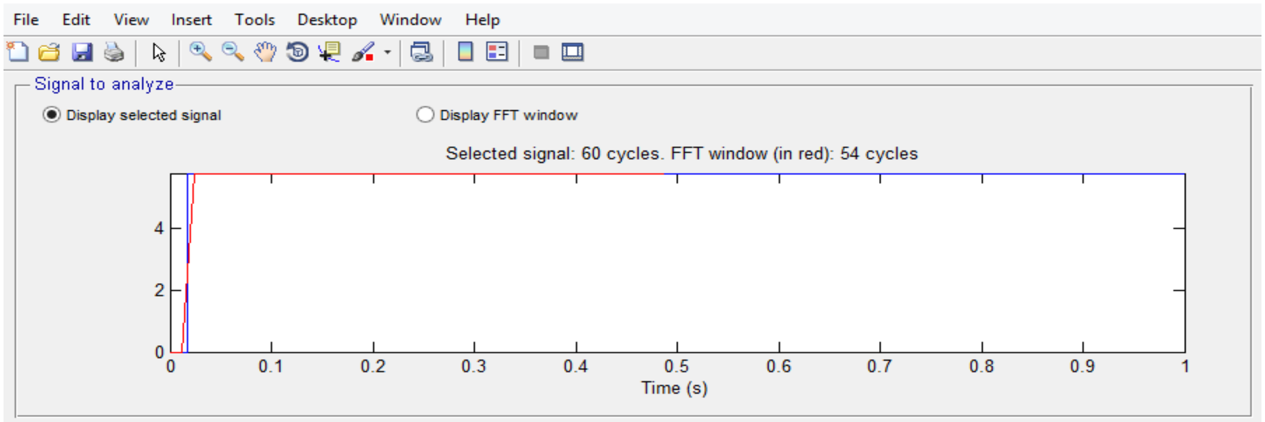


Fig 11 FFT waveform of power with STATCOM

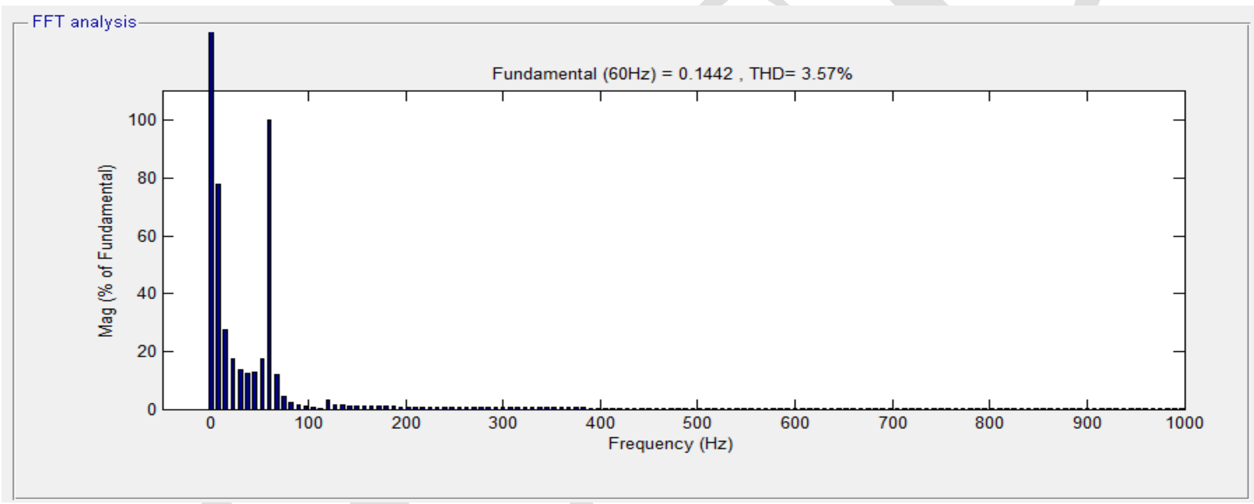


Fig 10 FFT analysis of power waveform without STATCOM THD=3.57%.

## VI. CONCLUSION

This paper presents the power quality improvement of wind power generating system connected to the grid with distorting load by using STATCOM. The power quality problems and its consequences on the consumer are explained. The operation of the control system developed for the STATCOM in MATLAB/SIMULINK for maintaining the power quality simulated. It has a capability to eliminate harmonic elements of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at grid system, it gives an chance to enhance the voltage stability, power quality and reliability of the system.

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