A Simulation of A STATCOM-Control For Grid Connected Wind Energy System For Improving Reliability of Power

Gourav Kumar[1], Dr. Mithilesh Singh[2], Gokul Dewangan[3]
[1]Dept of EE
[2]Associate Professor, Dept of EE
[3]Assistant Professor, Dept of EE
[1, 2, 3] SRU, RAIPUR, CG, INDIA

Abstract- *Injection of the wind power into an electric grid affects the strength exceptional. The overall performance of the wind turbine and thereby electricity nice are determined on the basis of measurements and the norms observed according to the rule specified in International Electro-technical Commission trendy, IEC-61400. The have an impact on of the wind turbine within the grid gadget concerning the electricity pleasant measurements are-the active strength, reactive power, variation of voltage, flicker, harmonics, and electrical conduct of switching operation and these are measured consistent with national/global suggestions. The electricity exceptional problem mainly due to set up of wind turbine with the grid. In this proposed scheme STATIC COMPENSATOR (STATCOM) is attached at a factor of common coupling with a battery electricity storage machine (BESS) to mitigate the energy first-class problems. The battery strength garage is included to sustain the actual strength source below fluctuating wind power. The STATCOM manipulate scheme for the grid linked wind electricity era machine for power excellent development is simulated the usage of MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the primary deliver source from the reactive power demand of the burden and the induction generator. The improvement of the grid co-ordination rule and the scheme for improvement in energy excellent norms as according to IEC-preferred at the grid has been supplied.*

Keywords- STATCOM, BESS, reactive power, IEC-61400, grid.

I. INTRODUCTION

Wind power is the conversion of wind energy into useful form, such as electricity, using wind turbines. Wind energy is directly used to crush grain or water pump .Wind energy is plentiful, renewable, widely distributed, cleans, and reduces greenhouse gas emissions when it displaces fossil-fuel-derived electricity. Today, modern energy industry faces a growing awareness regarding the impact of conventional power generation on the environment. Issues such as limited fossil fuel reserves, climate change due to $CO2$ emissions, bring to attention alternative technologies to generate electricity in a more sustainable manner. The intermittency of wind seldom creates insurmountable problems when using wind power to supply a low proportion of total demand, but it presents extra costs when wind is to be used for a large fraction of demand. The latest technological advancements in wind energy conversion and an increased support from governmental and private institutions have led to increased wind power generation in recent years. Wind power is the fastest growing renewable source of electrical energy [1].

The wind power has increased in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. The wind farm capacity is being continuously increased through the installation of more and larger wind turbines. Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes [1]. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies, but Nordic grid codes are becoming increasingly popular [2].

One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system [3]. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns.

Flexible AC Transmission Systems (FACTS) such as the Static Synchronous Compensator (STATCOM) are used in power systems because of their ability to provide flexible power flow control. The main aim for choosing STATCOM in wind farms is its ability to provide bus bar system voltage support either by supplying and/or absorbing reactive power into the system. The STATCOM in wind farms has been investigated and indicate that it is able to supply reactive power requirements of the wind farm under various operating conditions, thereby improving the steady-state stability limit of the network [4]. The methods used to develop an equivalence of a collector system in a large wind power plant are described in [5]. The requirements, assumptions and structure of an aggregate model of a wind park with constant speed turbine and variable speed turbines are discussed in [6].

OBJECTIVE OF THE PAPER

The causes of power quality problems are generally complex and difficult to detect when we integrate a wind turbine to the grid. The ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz). We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health. This project demonstrates that the power electronic based power conditioning using custom power devices like STATCOM can be effectively utilized to improve the quality of power supplied to the customers.

The aim of the project is to implement Wind turbine connected to a Grid consisting of Distribution generation and STATCOM with Back Up energy storage system (BESS) in the MATLAB, Simulink using Simpower systems tool box and to verify the results through various case studies applying Non-linear loads and study them in detail.

OVERVIEW OF THE PAPER

The Renewable energy sources, which have been expected to be a promising alternative energy source, can bring new challenges when it is connected to the power grid. However, the generated power from renewable energy source is always fluctuating due to environmental condition. In the same way Wind power injection into an electric grid affects the power quality due to the fluctuation nature of the wind and the comparatively new types of its generators. It is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, cogeneration, etc.

The need to integrate renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. The issue of power quality is of great importance to the wind turbine [7]. 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. 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.

Power quality and reliability cost the industry large amounts due to mainly sags and short-term interruptions. Distorted and unwanted voltage wave forms, too. And the main concern for the consumers of electricity was the reliability of supply. Here we define the reliability as the continuity of supply. The problem of distribution lines is divided into two major categories. First group is power quality, second is power reliability. First group consists of harmonic distortions, impulses and swells. Second group consists of voltage sags and outages. Voltage sags is much more serious and can cause a large amount of damage. If exceeds a few cycle, motors, robots, servo drives and machine tools cannot maintain control of process. Transmission lines are exposed to the forces of nature. Furthermore, each transmission line has its load ability limit that is often determined by either stability constraints or by thermal limits or by the dielectric limits. Even though the power quality problem is distribution side problem, transmission lines are often having an impact on the quality of the power supplied. It is however to be noted that while most problems associated with the transmission systems arise due to the forces of nature or due to the interconnection of power systems, individual customers are responsible for more substantial fraction of the problems of power distribution systems.

IMPACT OF WIND POWER ON SYSTEM SECURITY

The security of a power system is regarded as the ability of the system to withstand disturbances without causing a breakdown of the power system [8]. For wind power generators to contribute to the security of a power system, they must have the ability to contribute to both the voltage and frequency control in stabilizing the power system following a disturbance, they must be able to ramp up or down to avoid insecure power system operation, they must be able to ride through disturbances emanating from the power system, they must be able to avoid excess fault levels while still contributing to fault identification and clearance, and they should be able to operate in island mode when the supply from the grid is lost [9].

Wind power generation is often faced with difficulties with regards to reliability in terms of the generation, planning and scheduling of the supply of electricity [10]. There is always a lack of confidence by the utility operators in the system's capability to meet peak demands. Although, no electricity system is 100 percent reliable, intermittent generation will increase the level of uncertainty and therefore also the reserve capacity band of the power system which in turn increases the generation costs. The effect is minimal at low penetration levels, but could be challenging at high penetration levels [11, 12].Among these challenges are the effects on the power imbalance, reserve management, voltage control and system stability

II. METHODOLOGY

BASIC WIND GENERATION

Wind turbine utilizes the energy stored in air currents flowing close to earth's surface. The air currents create a torque on the rotor blades of the wind turbine and transfers wind's kinetic energy. The blades convert this energy into mechanical (rotational) form. A generator takes this mechanical energy as input and outputs electrical energy. Fig.2.1 shows an overview of the energy conversion process of a typical wind turbine. Each of these steps has its own efficiency factor. The efficiency of the overall process is the efficiency of the wind turbine.

Fig. 2.1 Energy Conversion Process of a Wind Turbine

ENERGY FROM WIND

The energy content of wind depends on its density, intercepting area and speed of impact on that area. For a wind turbine, the intercepting area is the area of the circle created by the rotation of the rotors. The following formula can be used to calculate the energy stored in wind.

$$P_{Wind} = \frac{1}{2}\rho A V^{3}_{Wind}$$

Where,
P=wind power stored in wind [W]
ρ =air density [kg/m^3]
A= intercepting area (area of the wind rotor) [m^2]
V=wind speed [m/s]

A wind turbine cannot extract all the power stored in the wind. If all the kinetic energy were transferred to the rotor blades, the air mass would stop completely near the wind turbine and any future energy conversion would be impossible. According to Betz' theorem, the theoretical maximum for energy conversion using wind turbines is limited to 59% of energy stored in the wind flowing through the turbine.

Wind is a continuously varying source of energy and so is the active power generated by the wind turbine. If a WT is connected to a weak grid (which has low short circuit power), the terminal voltage also fluctuates, producing flicker, harmonics and inter harmonics due to the presence of power electronics. For a set of connected wind turbines forming a wind farm, there exist certain grid codes or specific requirements with which each wind turbine must conform with in order to be allowed to be connected to the grid [14]. Most wind power systems are based in remote rural locations and are therefore prone to voltage sags, faults, and unbalances. These unbalanced grid voltages can cause many problems such as torque pulsations, unbalanced currents and reactive power pulsations.

When wind farms are connected to a strong grid, that is closer to a stiff source, voltage and frequency can be quickly re-established after a disturbance with the support of the power grid itself. To wait for the voltage to re-establish after the fault has been cleared in the case of a weak grid interconnection is not reliable because there is always a risk of voltage instability initiated by the disturbance. Hence, reactive power and voltage support that can be provided by mechanically switched capacitors, SVC or STATCOM is needed to help improve the short term voltage stability and reinforce the power network. This is also true for wind farms with all fixed speed wind turbines with no dynamic control or reactive power compensation. There are many wind turbine manufacturers who produce different wind turbine technologies.

WIND TURBINE SYSTEM

Wind turbines can operate with either fixed speed (actually within a speed range about 1 %) or variable speed. For fixed-speed wind turbines, the generator (induction generator) is directly connected to the grid. Since the speed is almost fixed to the grid frequency, and most certainly not controllable, it is not possible to store the turbulence of the wind in form of rotational energy. Therefore, for a fixed-speed system the turbulence of the wind will result in power variations, and thus affect the power quality of the grid. For a variable-speed wind turbine the generator is controlled by power electronic equipment, which makes it possible to control the rotor speed. In this way the power fluctuations caused by wind variations can be more or less absorbed by changing the rotor speed and thus power variations originating from the wind conversion and the drive train can be reduced. Hence, the power quality impact caused by the wind turbine can be improved compared to a fixed-speed turbine. The rotational speed of a wind turbine is fairly low and must therefore be adjusted to the electrical frequency. This can be done in two ways: with a gearbox or with the number of pole pairs of the generator. The number of pole pairs sets the mechanical speed of the generator with respect to the electrical frequency and the gearbox adjusts the rotor speed of the turbine to the mechanical speed of the generator.

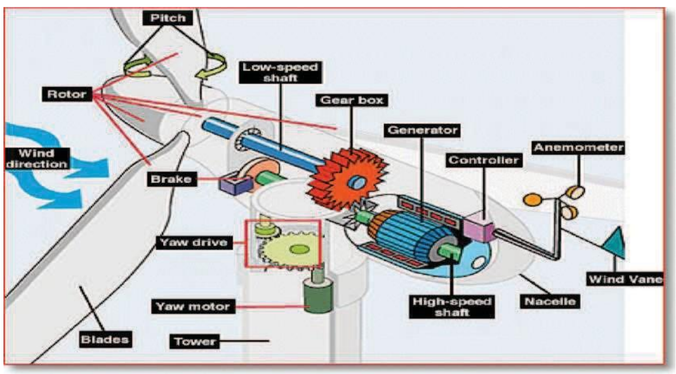
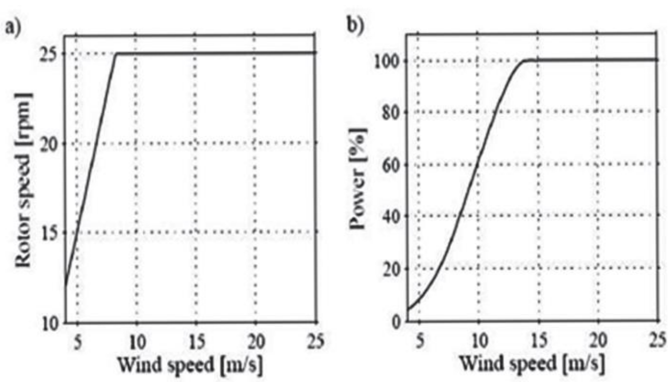


Fig. 2.1 Wind Turbine



(a) Rotor speed as a function wind speed (b) Mechanical power as a function of wind speed

Fig 2.2 characteristics for a variable –speed wind turbine

WIND TURBINE COMPONENTS

Horizontal turbine components include:

- A tower that supports the rotor and drive train;
- A drive train, usually including a gearbox and a generator;
- Blade or rotor, which converts the energy in the wind to rotational shaft energy;
- And other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.
- Wind turbines are often grouped together into a single wind power plant, also known as a wind farm, and generate bulk electrical power. Electricity from these turbines is fed into a utility grid and distributed to customers, just as with conventional power plants.

TYPES OF WIND TURBINE

There are two types of wind turbine:

1. Fixed speed generator.
2. Variable speed generators.

Fixed and Variable Speed- Fixed speed generators are induction generators with capacitor bank for self-excitation or two-pole pairs or those which use rotor resistance control. Fixed Speed Wind Turbine is a concept that uses a Squirrel Cage Induction Generator (SCIG) directly connected to grid. Therefore the speed of this WT is fixed by the grid frequency. Due to this fixed speed, the wind fluctuations are converted in power fluctuations which will cause voltage variations in weaker grids. Having large numbers of FSWT in a wind farm connected to grid, the reactive power consumption will be large. This reactive power can be compensated by adding capacitor banks to each individual WT, for achieving a PCC power factor close to unity. This type of WT lacks power electronic interfaces; therefore reactive power control is not possible. The tracking of optimum active power and assuring power quality cannot be fulfilled. In case of a grid fault there is a large amount of fault current contribution, thus the turbines need to rely on protection devices (over current, over- and under voltage, over and under frequencies). As a result FSWTs cannot meet grid code demands without any form of external support such as FACTS devices.

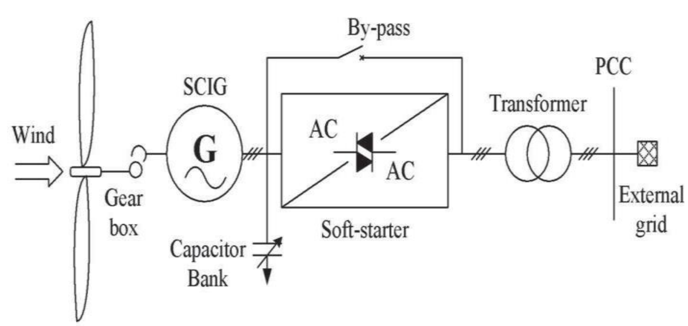


Fig.2.3 Fixed-speed wind turbine with an induction generator.

Variable Speed Generators - Variable speed generators are either DFIG (which is a round rotor machine) or full power converters such as squirrel cage induction generators, permanent magnet synchronous generators, or externally magnetized synchronous generators. Variable speed wind turbines are connected to the grid using power electronic technology and maximize effective turbine speed control. Second type of wind turbine is the Partial Variable Speed Wind Turbine with a variable rotor resistance. The generator for this turbine topology is a Wound Rotor Induction Generator (WRIG) and like in the previous case, it is connected directly to the grid through a soft-starter. As a result, this type of wind turbine offers again low performances with regards to grid codes. A small improvement can be noticed during grid disturbances by connecting the variable resistance in series with the rotor winding. This will allow the increase of speed in the range of 0-10% above synchronous speed. A grid code problem regarding flicker is significant for the first two WT topologies, especially if the WPPs are connected to weaker grids.

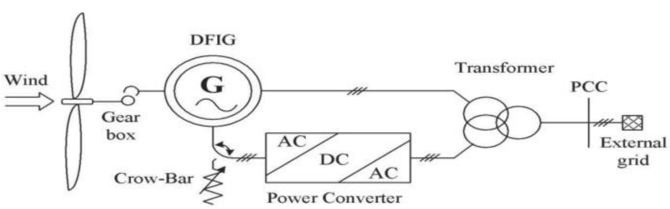


Fig.2.4 Variable-speed wind turbine with a doubly-fed induction generator (DFIG).

III. MODELING OF POWER QUALITY 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 (PCC), the grid connected system in Fig.4.6.7, consists of wind energy generation system and battery energy storage system with STATCOM.

Wind Energy Generating System

In this configuration, wind generations are based on constant speed topologies with pitch control turbine. The induction generator is used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. The power of wind energy system is.

$$P_{Wind} = \frac{1}{2}\rho A V^3_{Wind} \quad \text{.........................(1)}$$

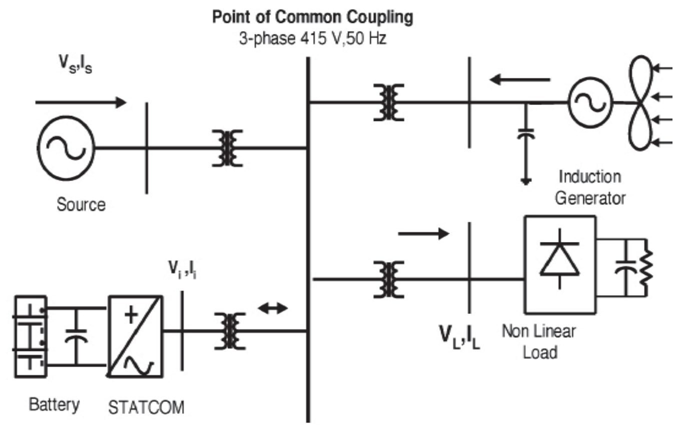


Fig.3.1 Grid connected wind energy system for power quality improvement.

$$P_{Mech} = C_P P_{Wind} \quad \text{................................(2)}$$

Where C_p is the power coefficient, depends on type and operating condition of wind turbine. This coefficient can be express as a function of tip speed ratio and pitch angle. The mechanical power produce by wind turbine is

$$P_{Mech} = \frac{1}{2}\rho \prod R^2 V^3 C_{Wind,P} \quad \text{........................(3)}$$

Where R is the radius of the blade (m).

BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also controls the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the BESS can be used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM [1]. 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.

SYSTEM OPERATION

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 STATCOM compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system. The current control strategy is included in the control scheme that defines the functional operation of the STATCOM compensator in the power system. A single STATCOM using insulated gate bipolar transistor is proposed to have a reactive power support, to the induction generator and to the nonlinear load in the grid system. The main block diagram of the system operational scheme is shown in fig 3.2.

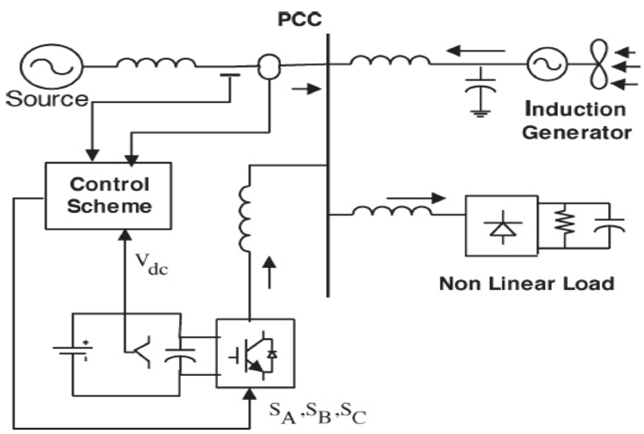


Fig. 3.2 System operational scheme in grid system

Simulation model

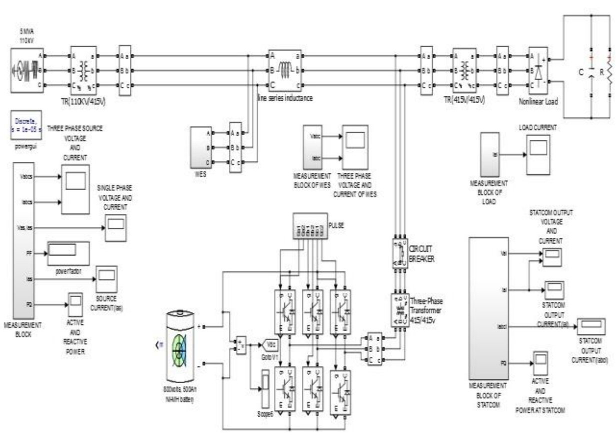


Fig 3.3 Simulation model for statcom control grid connected wind energy system for power quality improvement

CONTROL SYSTEM

The control scheme 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 system scheme for generating the switching signals to the STATCOM is shown in Fig 3.4.The control algorithm needs the measurements of several variables such as three-phase source current, DC voltage, inverter current with the help of sensor. The current control block, receives an input of reference current and actual current are subtracted so as to activate the operation of STATCOM in current control mode.

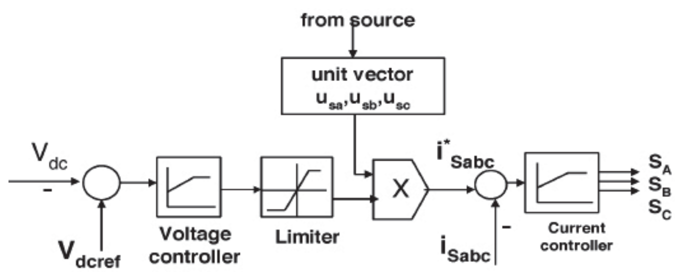


Fig. 3.4 Control system scheme

IV. RESULTS AND DISCUSSION

The wind electricity generating machine is connected with grid having the nonlinear load. The performance of the device is measured by means of switching the STATCOM at time s inside the device and how the STATCOM responds to the step change command for increase in extra load at zero.22s is proven in the simulation. When STATCOM controller is made ON, without alternate in every other load situation parameters, it starts off evolved to mitigate for reactive call for in addition to harmonic modern. The dynamic performance is likewise done via step alternate in a load, whilst applied at zero.22 s. This extra demand is satisfy by STATCOM compensator. Thus, STATCOM can alter the available real electricity from supply. The simulation consequences are shown in the figures beneath.

SIMULATION RESULT

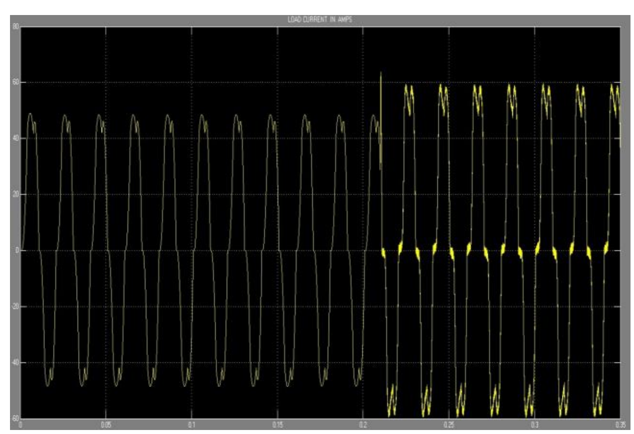


Fig no 4.1 load current without STATCOM

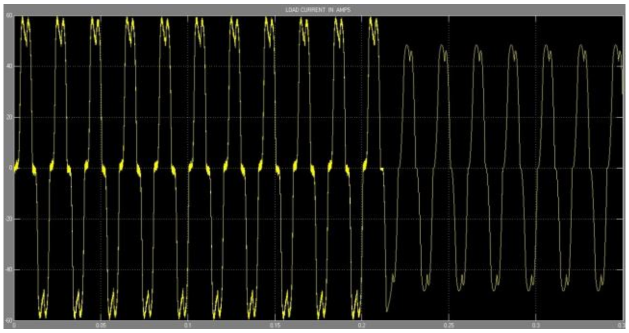


Fig no 4.2 load current with STATCOM

FFT ANALYSIS

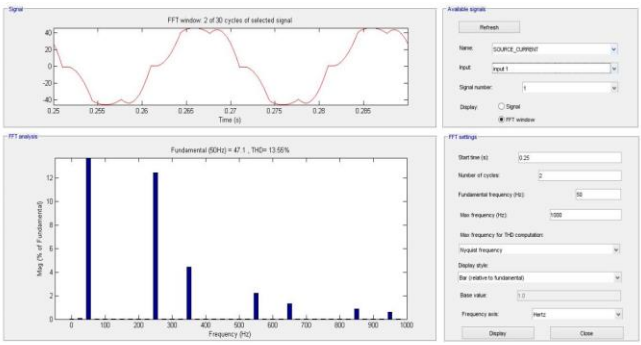


Fig no 4.3 FFT analsysis of without STATCOM

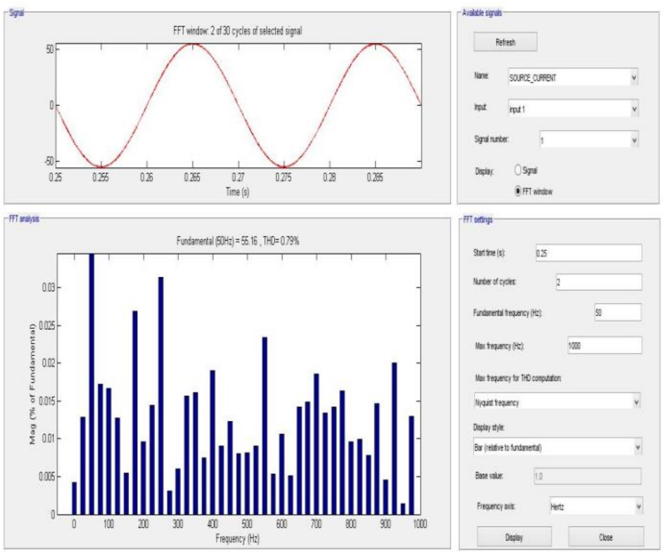


Fig no 4.4 FFT analysis of with STATCOM

According to FFT analysis without STATCOM it is very dip sag and swell in waveform there is lot of harmonics in spectrum the analysis value approximately THD is 13.55 % , 2 of 30 cycle instead of with STATCOM it is very clear to obtain clear spectrum is very smooth and optimistic in nature value that is approximately THD is 0.79% .

ACTIVE & RACTIVE POWER

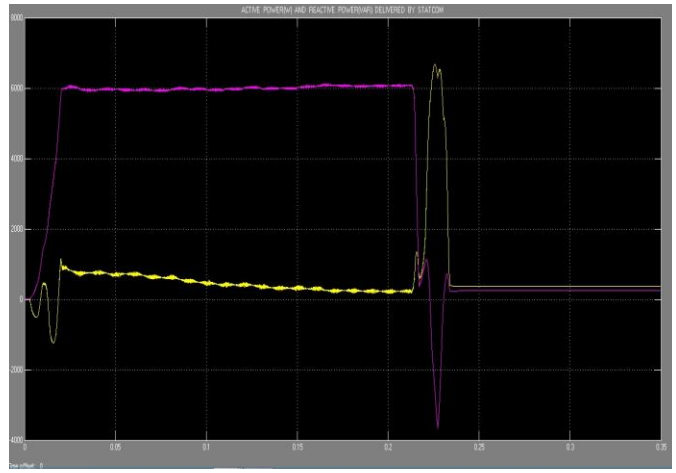


Fig no 4.5 active and reactive power output

the exchange of real power and reactive power of the voltage source converter with AC system is the major required phenomenon for the regulation in the transmission as well as in the distribution system.

CATTERING ANALYSIS OF STACOM OUTPUT VOLTAGE AND CURRENT

Table 5.3 STATCOM output voltage and current

Vref.rybn	239.56	239.56	239.56	239.29	239.29	239.29	239.33	239.33	239.33	239.56	239.56	239.56
Irybn	0.24	0.24	0.24	0.04	0.04	0.04	0.1	0.1	0.1	1.62	1.62	1.62

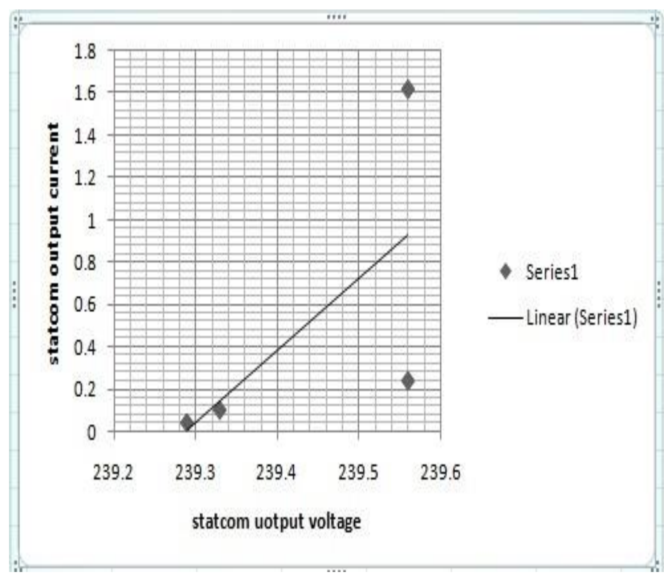
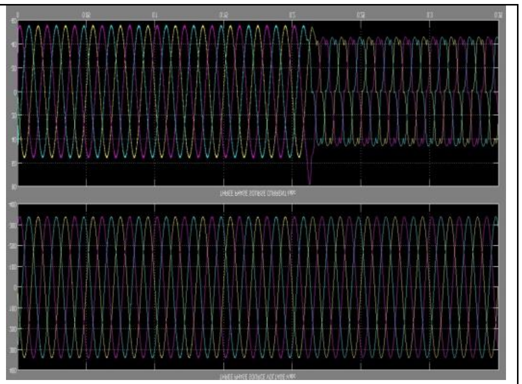
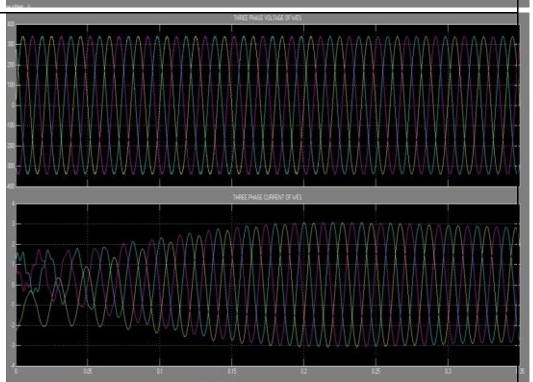
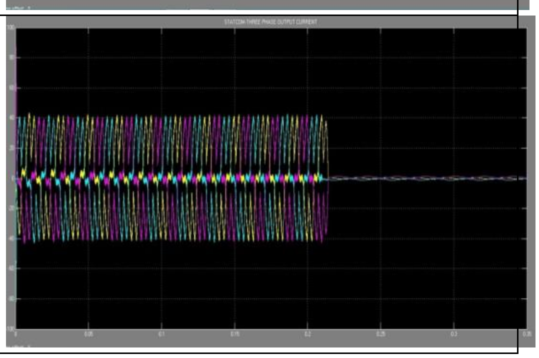
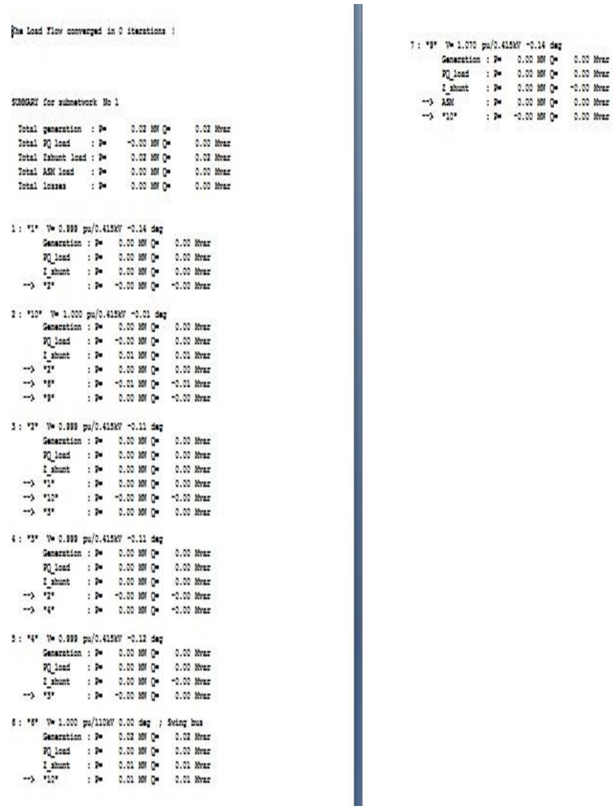


Fig no 4.6 scattering analysis of STATCOM output voltage and current

Table 5.4 TABLE OF DIFFERENT WAVEFORM

1	three phase Voltage and current	
2	Single phase Voltage and current	
3	Three phase voltage of Wind Energy System	
4	STATCOM three phase output current	

LOAD FLOW ANALYSIS



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The Load Flow converged in 0 iterations !

SUMMARY for subnetwork No 1

 Total generation  : P=     0.02 MW Q=     0.02 Mvar
 Total PQ load     : P=    -0.00 MW Q=     0.00 Mvar
 Total Zshunt load : P=     0.02 MW Q=     0.02 Mvar
 Total ASM load    : P=     0.00 MW Q=     0.00 Mvar
 Total losses      : P=     0.00 MW Q=     0.00 Mvar

1 : "1"  V= 0.999 pu/0.415kV -0.14 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.00 MW Q=   0.00 Mvar
  -->  "2"        : P=  -0.00 MW Q=  -0.00 Mvar

2 : "10"  V= 1.000 pu/0.415kV -0.01 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=  -0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.01 MW Q=   0.01 Mvar
  -->  "2"        : P=   0.00 MW Q=   0.00 Mvar
  -->  "6"        : P=  -0.01 MW Q=  -0.01 Mvar
  -->  "9"        : P=   0.00 MW Q=  -0.00 Mvar

3 : "2"  V= 0.999 pu/0.415kV -0.11 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.00 MW Q=   0.00 Mvar
  -->  "1"        : P=   0.00 MW Q=   0.00 Mvar
  -->  "10"       : P=  -0.00 MW Q=  -0.00 Mvar
  -->  "3"        : P=   0.00 MW Q=   0.00 Mvar

4 : "3"  V= 0.999 pu/0.415kV -0.11 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.00 MW Q=   0.00 Mvar
  -->  "2"        : P=  -0.00 MW Q=  -0.00 Mvar
  -->  "4"        : P=   0.00 MW Q=  -0.00 Mvar

5 : "4"  V= 0.999 pu/0.415kV -0.12 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.00 MW Q=  -0.00 Mvar
  -->  "3"        : P=  -0.00 MW Q=   0.00 Mvar

6 : "6"  V= 1.000 pu/110kV 0.00 deg  ; Swing bus
       Generation : P=   0.02 MW Q=   0.02 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.01 MW Q=   0.01 Mvar
  -->  "10"       : P=   0.01 MW Q=   0.01 Mvar

7 : "9"  V= 1.070 pu/0.415kV -0.14 deg
       Generation : P=   0.00 MW Q=   0.00 Mvar
       PQ_load    : P=   0.00 MW Q=   0.00 Mvar
       Z_shunt    : P=   0.00 MW Q=  -0.00 Mvar
  -->  ASM        : P=   0.00 MW Q=   0.00 Mvar
  -->  "10"       : P=  -0.00 MW Q=   0.00 Mvar
```

V. CONCLUSION

It is concluded that this project we gift the FACTS tool (STATCOM) -based manipulate scheme for power fine development in grid connected wind generating machine and with nonlinear load. The electricity best problems and its effects on the purchaser and electric powered utility are presented. The operation of the control gadget evolved for the STATCOM in MATLAB/SIMULINK for keeping the electricity satisfactory is to be simulated. It has a capability to cancel out the harmonic parts of the burden modern-day. It maintains the supply voltage and modern-day in-phase and guide the reactive power demand for the wind generator and load at PCC in the grid machine; hence it gives a possibility to decorate the usage issue of transmission line.

Thus the included wind era and FACTS tool with BESS have shown the superb overall performance in retaining the voltage profile as in keeping with requirement. Thus the proposed scheme in the grid connected machine fulfils the energy nice necessities and maintains the grid voltage unfastened from distortion and harmonics.

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