International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 03, Issue 09, September 2014 ISSN 2319 - 4847

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

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ABSTRACT

Injection if wind power into an electric grid affect the power quality.The performance of the wind turbine and there by power quality are determined on the basis of measurements and the norms followed according to the guideline specified in international electro technical commission standard,IEC-61400.the influence of the wind turbine in the grid system concerning the power quality measurements are the active power, reactive power , variation of voltage, flicker,harmonics, and electrical behaviour of switching operation and these are measured according to national/international guidelines. The paper study demonstrates the power quality problems due to installation of wind turbine with the grid. In this proposed scheme STASTIC COMPENSATOR (STATCOM) is connected at appoint of common coupling with a battery energy system (BESS)to mitigate the power quality issues. 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 system block set. The effectiveness of proposed scheme relives the main supply source from the reactive power demand of load and the induction generator. The development of the grid co-ordination rule and the scheme for improvement in poersuality norms as per IEC standard on the grid has been presented.

Keywords:- Power Quality, Wind Energy, STATCOM, Renewable Energy.

1. INTRODUCTION

Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Amongst the above mentioned sources of energy there has been a lot of development in the technology for harnessing energy from the wind. Wind is the motion of air masses produced by the irregular heating of the earth's surface by sun. These differences consequently create forces that push air masses around for balancing the global temperature or, on a much smaller scale, the temperature between land and sea or between mountains. Wind energy is not a constant source of energy. It varies continuously and gives energy in sudden bursts. About 50% of the entire energy is given out in just 15% of the operating time. Wind strengths vary and thus cannot guarantee continuous power. It is best used in the context of a system that has significant reserve capacity such as hydro, or reserve load, such as a desalination plant, to mitigate the economic effects of resource variability. The power extracted from the wind can be calculated by the given formula:

$$P\ W=0.5\ \rho\pi R$$

The total capacity of wind power on this earth that can be harnessed is about 72 TW. There are now many thousands of wind turbines operating in various parts of the world, with utility companies having a total capacity of 59,322 MW. The power generation by wind energy was about 94.1GW in 2007 which makes up nearly 1% of the total power generated in the world. Globally, the long-term technical potential of wind energy is believed to be 5 times current global energy consumption or 40 times current electricity demand. This would require covering 12.7% of all land area with wind turbines. In the past decades, the wind power generation has experienced a very fast development. It shows the installed wind turbine capacity worldwide at the end of 2002 , although it is obvious that with such a rapid growth in some countries data of this kind become out of date very quickly. The reasons that resulted in the fast development of wind power are quite complex. Important factors include the immense potentials of wind energy on the earth, the political and economic support from the governments and the development of wind turbine technology. 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. 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 2 MW, feeding into distribution network, particularly with customers connected in close proximity. 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.

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

1.3 Wind Energy

Wind (primary renewable natural) power harnesses the power of the wind to propel the blades of wind turbines. These turbines cause the rotation of magnets, which creates electricity. Wind towers are usually built together on wind farms. Wind power is growing at the rate of 21% annually, with a worldwide installed capacity of 238 gigawatts (GW) in 2009, and is widely used in Europe, Asia, and the United States.

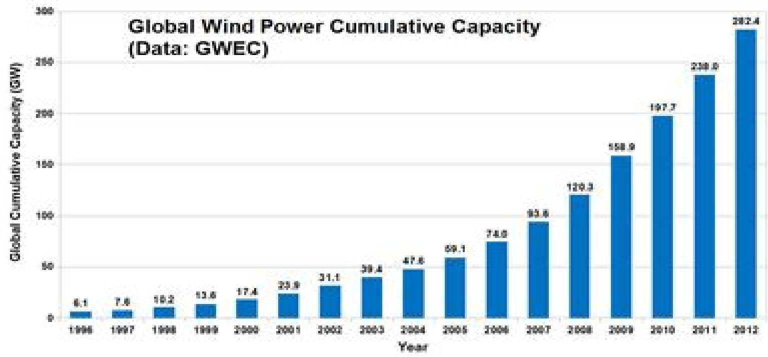

Fig 1.1: Global Wing Power Cumulative Capacity

At the end of 2011, worldwide nameplate capacity of wind-powered generators was 238 gigawatts (GW). Energy production was 430 TWh, which is about 2.5% of worldwide electricity usage. Several countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, 14% in Ireland, and 9% in Germany in 2010. By 2011, at times over 50% of electricity in Germany and Spain came from wind and solar power. As of 2011, 83 countries around the world are using wind power on a commercial basis.

1.4 Hydroelectric Generation:

Fig 1.2: Hydroelectric Power Station

1.5 Solar Power:

Solar (primary renewable natural) power involves using solar cells to convert sunlight in to electricity, using sunlight hitting solar thermal panels to convert sunlight to heat water or air, using sunlight hitting a parabolic mirror to heat water (producing steam), or using sunlight entering windows for passive solar heating of a building. It would be advantageous to place solar panels in the regions of highest solar radiation.

Fig 1.3: Solar Power

Many solar photovoltaic power stations have been built, mainly in Europe. As of April 2012, the largest photovoltaic (PV) power plants in the world are the Charanka Solar Park (India, 214 MW), and the Golmud Solar Park (China, 200 MW).

1.6 Agricultural biomass

Biomass (primary renewable natural) production involves using garbage or other renewable resources such as corn or other vegetation to generate electricity. When gar bagged, the methane produced is captured in pipes and later burned to produce electricity. Vegetation and wood can be burned directly to generate energy, like fossil fuels, or processed to form alcohols. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

Fig 1.4: Sugar Cane can be used as a Bio Fuel

1.7 Geothermal:

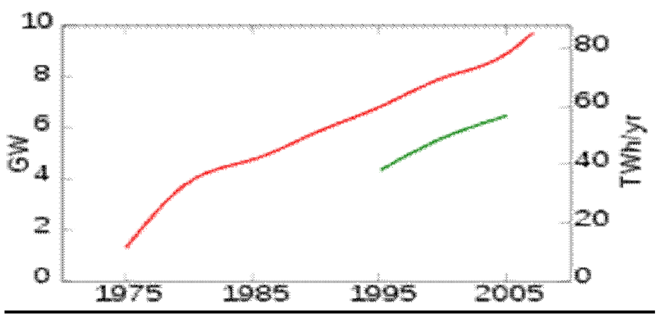

Fig 1.5: Global Geothermal Electric Capacity

1. Red-Installed Capacity 2. Green-Realized Production There are four factors to consider in providing a country's energy from renewable sources - transmission when local resources are greater or less than needed, storage for the same reason, excess capacity to provide sufficient demand, and use of biomass or geothermal to fill in for when wind and solar are insufficient. While the solutions are not fundamentally different from those used with conventional non-renewable sources, the technology is. For example, transmission lines and storage have been used almost since the beginning of electricity use, but as late as 2008 wind power and solar power provided less than 0.25% of total energy (1/400th). A study in Germany by the University of Kassel showed that a combination of wind, solar, storage, and biomass could supply all of Germany's electricity.

1.8 Tidal Power:

Tidal (primary renewable natural) power can be extracted from Moon-gravity-powered tides by locating a water turbine in a tidal current, or by building impoundment pond dams that admit-or-release water through a turbine. The turbine can turn an electrical generator, or a gas compressor, that can then store energy until needed. Coastal tides are a source of clean, free, renewable, and sustainable energy.

Fig 1.6: Tidal Steam Generator

2. WIND TURBINES

2.1 Introduction:

Wind energy is a source of renewable power which comes from air current flowing across the earth's surface. Wind turbines harvest this kinetic energy and convert it into usable power which can provide electricity for home, farm, school or business applications on small (residential), medium (community), or large (utility) scales. Wind energy is one of the fastest growing sources of new electricity generation in the world today. These growth trends can be linked to the multi-dimensional benefits

2.2 Horizontal axis

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Fig 2.1: Horizontal-Axis Wind Turbine

2.2.1 THE ADVANTAGES OF HORIZONTAL-AXIS WIND TURBINES

Wind turbines harvest the power of the wind to create electricity. The wind turns the blades, which spin a shaft, which connects to a generator that supplies an electric current. As of 2010, the two basic types of wind turbines are used in wind energy systems are the traditional farm styled, horizontal--axis turbines and the eggbeater- style vertical turbines. The more common, traditional styled horizontal--axis wind turbines offer some advantages.

1. Blade Adjustment

- Horizontal-axis turbines offer the ability to adjust the pitch of the blades to catch the wind at just the right angle to collect the maximum amount of wind energy for the time of day and season.

2. Efficiency of Operation

- Horizontal-axis wind turbines have blades that are designed perpendicular to the direction of wind. This efficient design increases wind power throughout the entire rotation. In contrast, vertical-axis wind turbines require airfoil surfaces to backtrack against the wind for part of the cycle in a less efficient manner.

2.2.2 The Disadvantages of Horizontal Axis Wind Turbines:

1. Produces 50% less electricity on an annual basis tehn vertical axis wind turbine with the same swept area.
2. Needs higher wind speeds to start generating electricity and less become less efficient at producing power in very hign winds over 90 MPH.
3. They cannot withstand extreme weather conditions due to frost, freezing rain or heavy snow plus heavy winds in excess of 110 MPH.
4. The gearboxes and excessive yawing reduce the lifespan of these HAW turbines.
5. Tend to be visual distraction to the human eye.
6. Birds are injured or killed by the propellers since they are not solid objects so the birds fly into the blades.
7. Cannot be installed in turbulent wind conditions because the flow of wind must be "smooth" to make the HAWT efficient.
8. Blades are too thin to promote graphics or signage for advertising.
9. The propellers on the HAWT design make more noise as the wind speeds increase.
10. More moving parts lead to more service and constant maintenance.
11. Structurally less stable as wind speeds increase do to eccentric loading.

2.3 Vertical axis

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable, for example when integrated into buildings. The key disadvantages include the low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower power coefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modeling the wind flow accurately and hence the challenges of analyzing and designing the rotor prior to fabricating a prototype.

Fig 2.2: Vertical -Axis Wind Turbine

With a vertical axis, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, hence improving accessibility for maintenance. When a turbine is mounted on a rooftop, the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence. It should be borne in mind that wind speeds within the built environment are generally much lower than at exposed rural sites, noise may be a concern and an existing structure may not adequately resist the additional stress.

2.3.1 The Advantages of Vertical Axis Wind Turbines

1. Produces up to 50% more electricity on an annual basis versus conventional turbines with the same swept area.
2. Generates electricity in winds as low as 4.5 mph and continues to generate power in wind speeds up to 150 mph based on the model.
3. Withstands extreme weather such as frost, ice, sand, salt, humidity, and very high wind conditions in excess of 140 mph.
4. Non-polluting through its sealed generator design.
5. Easy on the eyes with non-reflecting surfaces to eliminate shadow strobing effect.
6. Does not harm wildlife as birds can detect a solid object and can be seen on aircraft radar.
7. Can be installed in turbulent wind conditions such as between buildings, alleys, or even downtown urban rooftops with adjacent buildings.

3. GRID CONNECTION REQUIREMENT

3.1 INTRODUCTION

While renewable energy systems are capable of powering houses and small businesses without any connection to the electricity grid, many people prefer the advantages that grid-connection offers. A grid-connected system allows you to power your home or small business with renewable energy during those periods (daily as well as seasonally) when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid. When renewable resources are unavailable, electricity from the grid supplies your needs, eliminating the expense of electricity storage devices like batteries. In addition, power providers (i.e., electric utilities) in most states allow net metering, an arrangement where the excess electricity generated by grid-connected renewable energy systems "turns back" your electricity meter as it is fed back into the grid. If you use more electricity than your system feeds into the grid during a given month, you pay your power provider only for the difference between what you used and what you produced.

3.2 VOLTAGE RISE

When a grid-connected inverter produces ac current, the impedance from the grid and inverter output-circuit conductors causes an increase in voltage at the inverter relative to the utility voltage. This phenomenon is commonly referred to as voltage rise. Voltage rise is essentially a negative voltage drop on the circuit between the inverter and the point of common coupling (POCC) that causes the voltage to increase at the inverter ac bus. Greg Smith, technical training specialist at SMA America, points out: “It isn’t that the inverter must increase the voltage to push current into the grid, but rather the voltage rises *because* the inverter pushes current into the grid.” He explains, “Ohm’s Law that V = I x R applies when current is pushed against the impedance of the grid.” Whether you think of this change in voltage as voltage rise at the inverter ac bus or *voltage drop* between the inverter ac bus and the POCC, the net effect on system performance is negative and must be considered during system design and specification. For example, the percentage of voltage lost due to voltage drop between the inverter and POCC is proportional to the percentage of power, energy and revenue lost, as illustrated by the following relationships: power = voltage x current; energy = power x time; energy = $. Other impacts are not as easy to quantify and predict. Voltage rise at the ac bus can also cause the inverter to disconnect from the grid if the voltage exceeds its upper ac operating voltage limit. Once the inverter trips and ceases to export current, it must monitor the utility source for at least 5 minutes before attempting to reconnect. Therefore, voltage rise is a potential cause of nuisance tripping and may result in unnecessary

3.3 HARMONICS

“Harmonics” means a component with a frequency that is an integer multiple (where n is the order of harmonic) of the fundamental frequency; the first harmonic is the fundamental frequency (50 or 60 Hz). The second harmonic is the component with frequency two times the fundamental (100 0r 120 Hz) and so on. The utilization of electrical power mainly depends up on supply of power with controllable frequencies and voltages, where as its generation and transmission takes place at nominally constant levels. So to convert nominal frequency to variable frequency power electronics circuitry (non-linear loads) is needed, which distorts the voltage and current waveforms. Therefore, the main source of harmonics in the power systems is the non linear loads. The total harmonic distortion (THD), of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Harmonic distortion is caused by the introduction of waveforms at frequencies in multiplies of the fundamental i.e. 3rd harmonic is three multiplied by the fundamental frequency (150Hz). THD is a measurement of the sum value of the waveform that is distorted. The THD is a very useful quantity for many applications. It is the most commonly used harmonic index. However, it has the limitation that, it is not a good indicator of voltage stress within a capacitor because that is related to the peak value of voltage waveform.

4. POWER QUALITY IMPROVEMENT

4.1 INTRODUCTION

The PQ issue is defined as “any occurrence manifested in voltage, current, or frequency deviations that results in failure, damage, upset, or misoperation of end-use equipment.” Today, most of the power quality issues are related to the power electronics equipment which is used in commercial, domestic and industrial application. The applications of power electronics equipment for resident al purposes-TVs, PCs, Refrigerator etc. For business purposes-copiers, printers etc. For industrial purposes-PLCs (Programmable logic controller), ASDs (Adjustable speed drive), rectifiers, inverters etc. Today almost all electrical equipment is based on power electronics which causes harmonics, inter-harmonics, notches and neutral currents. Transformers, motors, cables, interrupters, and capacitors (resonance) are some of the equipment which is affected by harmonics. Notches are produced mainly because of the converters, and they basically affect the electronic control devices. Neutral currents are produced in that equipment which uses switched-mode power supplies, such as printers, photocopiers, PCs, and any triplets' generator. Neutral current affects the neutral conductor temperature and transformer capability. Inter-harmonics are generated because of cyclo-converters, static frequency converters, arching devices and induction motors. The presence of harmonics in the power lines results in greater power losses in distribution, and cause problem by interfering in communication systems and, sometime cause operation failures of electronic equipment, which are more and more critical because it consists of microelectronic control systems, which work under very low energy levels. Because of these problems, the power quality issues delivered to the end consumers are of great concern. International standards concerning electrical power quality impose that electrical equipments should have limitation on the injection of harmonics in the system within a specified limit which has been satisfied by the international standards. Meanwhile, it is very important to solve the problems of harmonics caused by that equipment which is already installed. 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 volt-ages are sensed and are synchronized in generating the cur-rent command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling (POCC), as shown in Fig. 4.1. The grid connected system in Fig. 4.1, consists of wind energy generation system and battery energy storage system with STATCOM.

4.2 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 implicitly, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. The available power of wind energy system is presented as under.

$$P_{\text{wind}} = \frac{1}{2}\rho A V_{\text{wind}}^3$$

where (kg/m) is the air density and A (m) is the area swept out by turbine blade, is the wind speed in mtr/s.

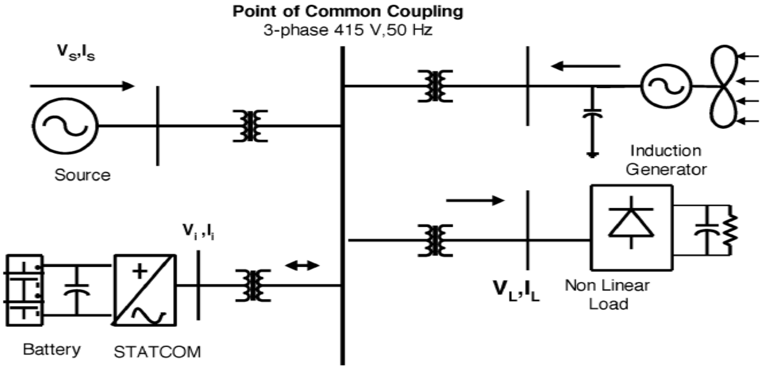

Fig 4.1: Grid connected system for power quality improvement

4.3. STATCOM

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. In general it is solid state switching converter which is capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source at its input terminals. Specifically, the STATCOM considered in this is a voltage-source converter 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 leakage reactance. The dc voltage is provided by an energy-storage capacitor. A STATCOM can improve power-system performance in such areas as the following:

1. The dynamic voltage control in Transmission and distribution systems;
2. The power-oscillation damping in power transmission systems;
3. The transient stability;
4. The voltage flicker control; and
5. It also controls real power in line when it is needed.

Advantages

1) It occupies small areas.
2) It replaces the large passive banks and circuit elements by compact converters.
3) Reduces site work and time.
4) Its response is very fast.

4.4. BESS

Utility-scale energy storage exists since decades in the form of hydro pumped storage. The advantages of this technology are that such storage can respond relatively fast and reliably for power systems' needs. However, the installation sites are limited by the geological conditions. Utility-scale CAES (Compressed Air Energy Storage) is becoming topical. However, special requirements on the installation site apply because of the need of sealed underground air pockets or caverns to store the compressed air. Advanced battery systems are not restricted to geology like hydro pumped storage and have higher energy density than CAES. With the advance of battery technologies, their life cycle has also improved. Another advantage of BESS is that it can provide fast response for power systems' needs such as frequency regulation or other ancillary services. Batteries using lead acid or Li-ion technologies are suitable for such applications. Indeed in some markets in the USA have modified their market rules to allow for the participation of energy storage in the regulation markets. For applications which only require slow charging/discharging, e.g. capacity firming for wind, NaS (Sodium-Sulphur) or NaNiCl (Sodium-Nickel chloride) batteries are suitable. Sodium-based batteries operate in a high temperate environment (300C°). Their advantages are high energy and power density, high efficiency and long life cycle. They are at the moment less costly than Li-ion batteries.

4.5 APPLICATIONS OF BESS

4.5.1 Energy Storage for the Integration of Wind

One of the challenges of integration renewable energy such as wind is the intermittency. The security of supply improves little when adding new wind farm than adding a traditional dispatch able plant. Wind energy exhibits in all time scale, i.e. wind can stop blowing in seconds and the total wind output from a year to the next can be very different. With batteries such as Li-ion which can perform fast charging and discharging, both short-term and longer term fluctuations can be alleviated. In this paper we only focus on longer-term applications, i.e. with a time scale of hours. Therefore the batteries which are suitable technically and economically are NaS or NaNiCl. It is foreseen that the price of Li-ion batteries will drop significantly in the next few years due to the popularity of EV (Electric Vehicles). When that happens, Li-ion will become an interesting option because of its ability of fast charging/discharging. The applications which are considered in this paper are wind energy time-shifting and capacity firming.

4.6 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 phase voltage. The grid connected Wind Generating System model consists of a shunt connected STATCOM with Battery Energy Storage connected at the interface of induction generator and non-linear load. The grid voltages are sensed by the controller and are synchronized to generate the current command for the inverter. The STATCOM injects current for the inverter. The STATCOM injects current into the grid in such a way that the source current is harmonic free and hence power quality is improved.

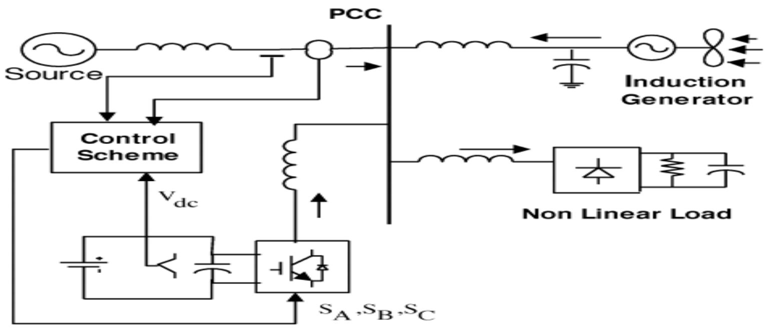

Fig 4.2: System operational scheme in grid system.

4.7 Control Scheme

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. Fig 4.3 presents schematic of BANG-BANG controller used with STATCOM.

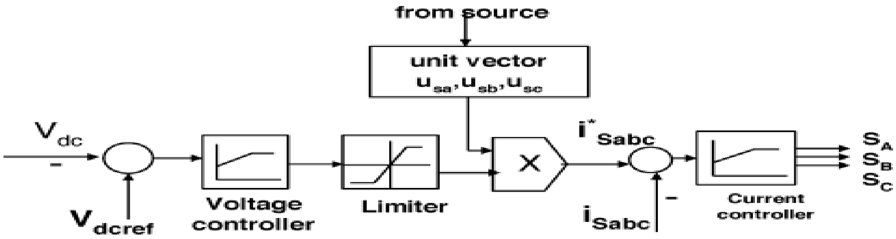

Fig 4.3: Schematic of Bang-Bang Controller

5. SYSTEM SIMULATION & ITS PERFORMANCE

5.1 Introduction:

Simulation model of grid connected wind generating system with STATCOM is shown in the Fig.5.1 and the parameters used for the simulation is listed in Table 1.The system performance of proposed system under dynamic condition is also presented.

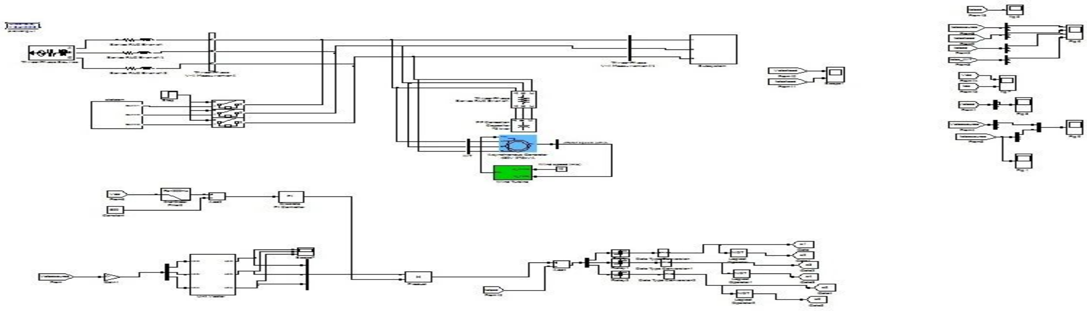

Fig 5.1: Simulation model of grid connected wind generating system with STATCOM

5.4 STATCOM – Performance under Load Variation

The wind energy generating system is connected with grid having the nonlinear load. The performance of the system is measured by switching the STATCOM at time t=0.7 s in the system and how the STATCOM responds to the step change command for increase in additional load at 1.0 s is shown in the simulation. When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate for reactive demand as well as harmonic current. The dynamic performance is also carried out by step change in a load, when applied at 1.0 s. This additional demand is fulfill by STATCOM compensator. Here, the wind farm is connected to the grid. Three phase injected inverter current waveform is shown in 5.4. The source current, load current, inverter injected current and wind generator current are depicted in Fig 5.5. From the Fig 5.5, it is observed that the source current waveform is highly distorted due to the integration of wind generating system with the grid. DC link voltage and current through capacitor are shown in Fig 5.6. The STATCOM output voltage waveform is shown in Fig 5.7. Fig 5.9 presents the FFT analysis for grid connected wind energy system without STATCOM. It shows that the total harmonic distortion for the source current waveform without STATCOM is 4.06%. Here, the STATCOM is connected to the grid connected wind generating system at 0.7s.The supply voltage and current at PCC waveforms for this case are presented in Fig 5.8. It is observed from Fig 5.8 that when the STATCOM controller is switched ON at 0.7s, without change in any other load condition parameters, it starts to mitigate the harmonics present otherwise. Fig 5.10 presents the FFT analysis for grid connected wind energy system with STATCOM. It shows that the total harmonic distortion for the source current waveform with STATCOM is 0.40% which is within the limits imposed by the standards. Thus the performance of the controller designed for STATCOM is satisfactory as it helps in successfully minimizing the source current harmonics introduced by the wind generating systems.

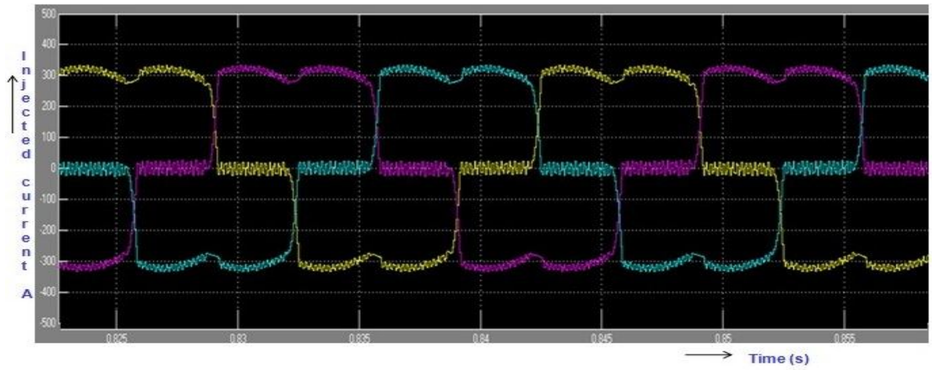

Fig 5.4: Three Phase Injected Inverter Current

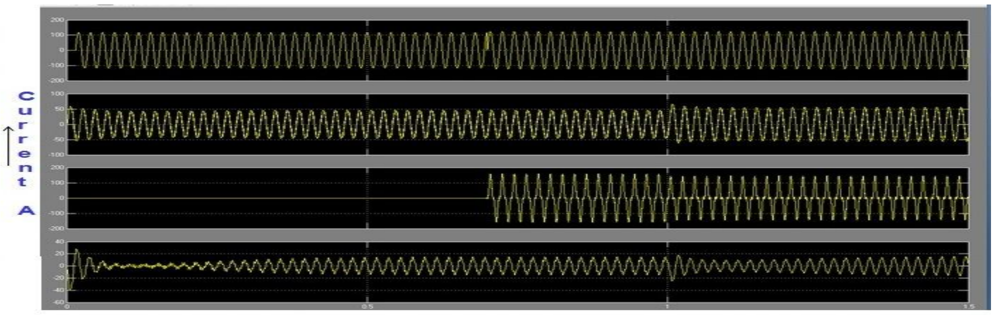

Fig 5.5: (a) Source Current. (b) Load Current. (c) Inverter Injected Current.
(c) Wind generator (Induction generator) current.

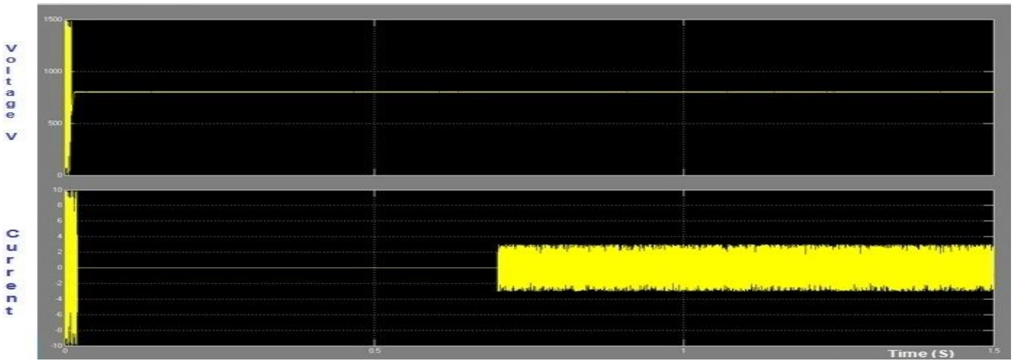

Fig 5.6: (a) DC link voltage. (b) Current through Capacitor

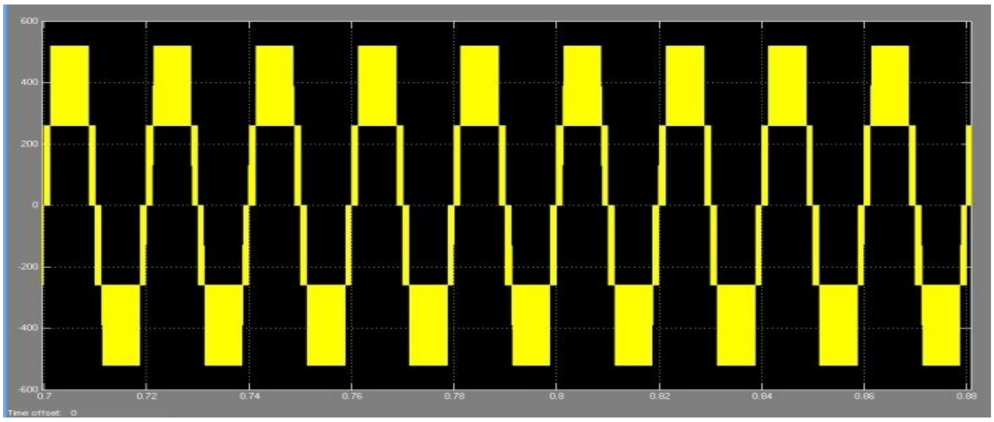

Fig 5.7: STATCOM Output Voltage

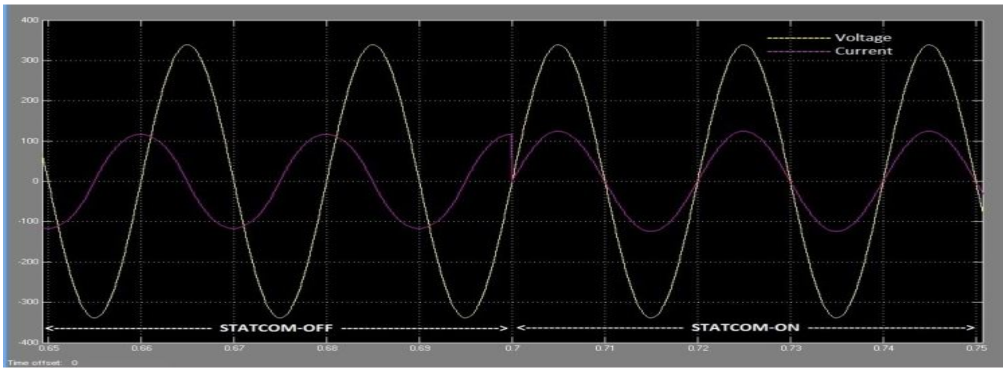

Fig 5.8: Supply Voltage and Current at PCC

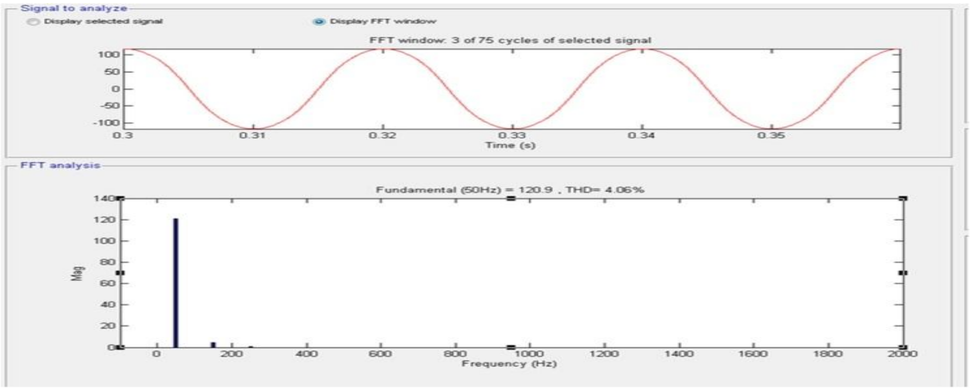

Fig 5.9: With out STATCOM (a) source current. (b) FFT of source current

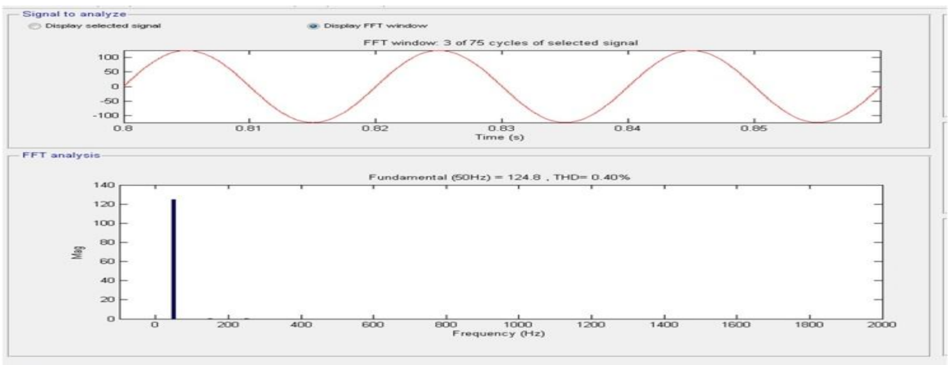

Fig 5.10: With STATCOM (a) source current. (b) FFT of source current

5.5 Power Quality Improvement

It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system. The inverter output voltage under STATCOM operation with load variation is shown in Fig. 5.7. The dynamic load does affect the inverter output voltage. The source current with and without STATCOM operation is shown in Fig. 5.8. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation. The current waveform before and after the STATCOM operation is analyzed. The Fourier analysis of this waveform is expressed and the THD of this source current at PCC without STATCOM is 4.06%, as shown in Fig. 5.9. The power quality improvement is observed at point of common coupling, when the controller is in ON condition. The STATCOM is placed in the operation at 0.7 s and source current waveform is shown in Fig. 5.10 with its FFT. It is shown that the THD has been improved i.e., 0.40% considerably and within the norms of the standard. The above tests with proposed scheme has not only power quality improvement feature but it also has sustain capability to support the load with the energy storage through the batteries.

6. CONCLUSION

In this paper, the effect of integrating the wind generator with the electric grid was addressed. A test system for grid connected wind generating system with non-linear load and STATCOM connected at point of common coupling (PCC) was developed in MATLAB/SIMULINK environment. A controller based on hysteresis current control scheme was devised for the STATCOM and its effectiveness in minimizing the harmonics in the source current waveform from was studied by investigating the waveform before and after STATCOM operation. It was observed from the simulation results that the THD in the source current waveform has been reduced from 4.06% to 0.40% with the use of STATCOM.

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