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STUDY ABOUT POWER QUALITY ENHANCEMENT OF GRID CONNECTED WIND ENERGY SYSTEM USING STATCOM

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Abstract: Renewable energy sources are alternative energy source, can bring new challenges when it is connected to the power grid. Generated power from wind energy system is always fluctuating due to the fluctuations in the wind. The wind power generation have a considerable effect on the power quality, voltage profile and power flow for customers and electricity suppliers. Due to presence of fluctuation in wind, the power injected through wind generator affects most part of power quality. The influence of the wind sources in a grid system concerns the power quality such as the active power, reactive power, harmonics, voltage variation and electrical behaviour in switching operation. Demonstration of a grid side connected wind turbine is considered here with the problem arise due to the above system. At the point of common coupling a Static Synchronous Compensator with Battery Energy Storage System can regulate four-quadrant active and reactive power which is an ideal scheme to solve problems of wind power generation. The power generated through wind generator can be stored in the batteries at low power demand hours and give it back at pike load time. The control strategy used here can coordinate charging of batteries with compensation of reactive power through STATCOM, also it balance the capacity of batteries. Thus the configuration of wind generation with STATCOM in such mode can gives low harmonics and balanced continuous power output. In this STATCOM is used with energy storage system (BESS) to reduce the power quality problems.

I. INTRODUCTION

A rapid development of wind power generation has been seen in a global scale. As with increasing the size of wind turbines and wind farms, a large amount of wind power is injected to the power system. Due to random nature of wind energy a huge penetration of power may cause important problems and also affect the characteristics of the wind generators. The consolidation of wind energy into present existing power system creates technical challenges, which require consideration of stability, voltage regulation related power quality problems.

The power quality problems can be seen in accordance to wind generation, transmission and distribution system, such as voltage sag, flickers, voltage swells, harmonics etc. Due to change in voltage, flicker and harmonics failure of devices like microprocessor based controller, programmable logic controller (PLC), variable speed drives, light source flickering and screen occurs[1]. It also may cause to tripping of contactor, failure of protection device, sensitive equipments stoppage like computers, programmable logic control (PLC) system and also may halt the process or even may damage of some sensitive equipments. In transmission and distribution system power quality of supply is very importance measure to be considered. So considering in wind generation system this power quality issues become so much important measure. As the technology developing in the power generation field the wind power generation developing very quickly. To reduce the disturbances produced by variation in wind flow[2], we use induction generator and connect it directly to the grid system. This induction generator is simple and robust in construction and having reactive power for excitation. However, in induction generators to produce magnetization the reactive power support is required. The major drawback in induction generators is active, reactive power and the terminal voltage varies due to fluctuating wind. A sophisticated control scheme requires in wind generation system when operating normally making proper control of active power production. The new technology in wind generation system use STATCOM based control scheme for improvement of the quality of power. Additionally the wind flow is unpredictable in nature so if there is some disturbance occurs the battery energy storage system(BESS) mitigate the fluctuation of power into the system. Voltage or current source inverter based flexible AC transmission systems (FACTS) use devices such as static var compensator (SVC), dynamic voltage restorer (DVR), static synchronous compensator (STATCOM) and unified power flow controller (UPFC) makes power flow flexible, provide secure loading and damp the oscillations in line. The new developed technology uses some of energy storage system (ESS) for battering the power handling capability of the source. So as a result of such development the FACTS device combined with energy storage system (ESS) have recently developed promising device combination in power system applications. From this development the work carried out here is use a STATCOM from FACTS devices and use battery storage for energy storing purpose for wind power application.

II. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. *International Electro Technical Commission Guidelines*

The guidelines are provided for measurement of power quality of wind turbine. The International standards are developed by the working group of Technical Committee-88 of the International Electro-technical Commission (IEC), IEC standard 61400-21, describes the procedure for determining the power quality characteristics of the wind turbine.

The standard norms are specified.

1) IEC 61400-21: Wind turbine generating system, part-21. Measurement and Assessment of power quality characteristic of grid connected wind turbine

2) IEC 61400-13: Wind Turbine—measuring procedure in determining the power behaviour.
3) IEC 61400-3-7: Assessment of emission limits for fluctuating load IEC 61400-12: Wind Turbine performance. The data sheet with electrical characteristic of wind turbine provides the base for the utility assessment regarding a grid connection.

B. *Voltage Variation*

The voltage variation issue results from the wind velocity and generator torque. The voltage variation is directly related to real and reactive power variations. The voltage variation is commonly classified as under:

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

The voltage flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly.

C. *Harmonics*

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

D. *Wind Turbine Location in Power System*

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

E. *Self Excitation of Wind Turbine Generating System*

The self excitation of wind turbine generating system (WTGS) with an asynchronous generator takes place after disconnection of wind turbine generating system (WTGS) with local load. The risk of self excitation arises especially when WTGS is equipped with compensating capacitor. The capacitor connected to induction generator provides reactive power compensation. However the voltage and frequency are determined by the balancing of the system. The disadvantages of self excitation are the safety aspect and balance between real and reactive power.

F. *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. STATCOM COMBINED WITH BESS

STATCOM Technology

This shunt connected static compensator was developed as an advanced static VAR compensator where a voltage source convertor (VSC) is used in- stead of the controllable reactors and switched capacitors. Although VSCs require self-commutated power semiconductor devices such as GTO, IGBT, IGCT, MCT, etc (with higher costs and losses) unlike in the case of variable impedance type SVC which use thyristor devices, there are many technical advantages of a STATCOM over a SVC.

The principal benefit of the STATCOM for transient stability enhancement is direct through rapid bus voltage control. In particular, the STATCOM may be used to enhance power transfer during low-voltage conditions, which typically predominate during faults, decreasing the acceleration of local generators. An additional benefit is the reduction of the demagnetizing effects of faults on local generation. STATCOM behave analogously to synchronous compensators, except that STATCOM have no mechanical inertia and are therefore capable of responding much more rapidly to changing system conditions. When compared to synchronous machines, they do not contribute to short circuit currents and have no moving parts. However, the system has a symmetric lead-lag capability and can theoretically go from full lag to full lead in fraction of cycles.

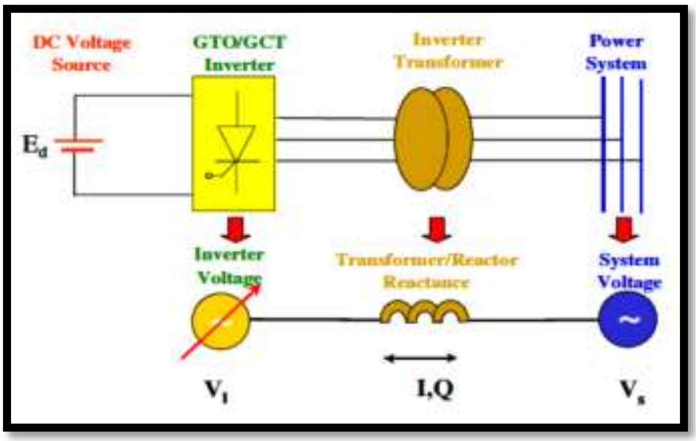

Fig. 1 STATCOM arrangement in power system

A STATCOM, connected in shunt, with the system is capable of improving transient stability by compensating the reactive power at the point of common connection. The ultimate objective of applying reactive shunt compensation in a transmission system is to increase the transmittable power during transients. This is achieved by increasing (decreasing) the power transfer capability when the machine angle increases (decreases). The key benefits of Statcom are:-

(a) Faster response
(b) Requires less space as bulky passive components (such as reactors) are eliminated
(c) Inherently modular and relocatable
(d) It can be interfaced with real power sources such as

battery, fuel cell or SMES (superconducting magnetic energy storage)

(e) A STATCOM has superior performance during low voltage condition as the reactive current can be maintained constant (In a SVC, the capacitive reactive current drops linearly with the voltage at the limit of capacitive susceptance). It is even possible to increase the reactive current in a STATCOM under transient conditions if the devices are rated for the transient overload. In a SVC, the maximum reactive current is determined by the rating of the passive components – reactors and capacitors.

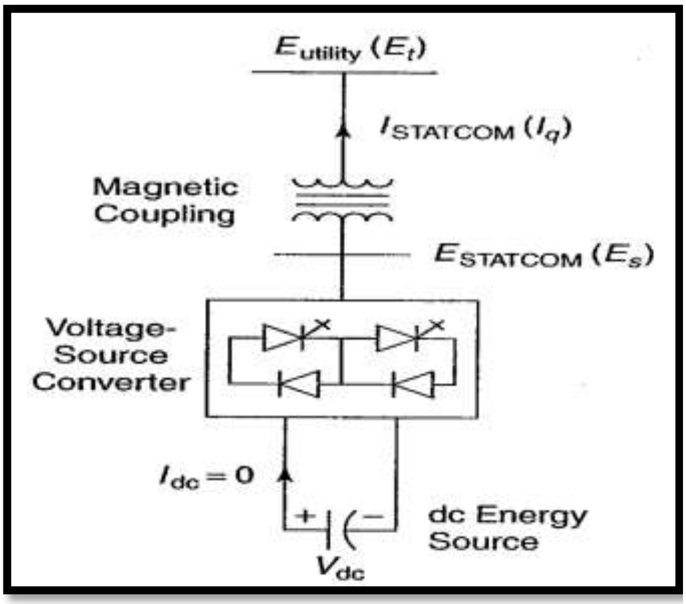

Fig.2 Single Line Diagram of STATCOM

Figure-2 shows the single line diagram of a STATCOM. In this configuration the VSC is connected with utility system through magnetic coupling. By controlling the converter output voltage Es, the reactive power exchange from converter to ac system can achieve easily. That is if the amplitude of output voltage is increased above that of the utility bus voltage, Et, then a current flows through the reactance from the converter to the ac system and the converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system. If the output voltage equals the ac system voltage, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state. If the DC capacitor voltage, Vdc, is increased from its nominal value, the STATCOM is "overexcited" (capacitive mode) and generates reactive power. If the voltage of the DC capacitor bank is decreased below the nominal value, the STATCOM is "under excited" (inductive mode) and absorbs reactive power from the system. This is completely analogous to increasing or decreasing the field voltage of a synchronous compensator.

Adjusting the phase shift between the converter-output and the ac system voltage can similarly control real-reactive power exchange between the converter and the ac system. The converter can supply real power to the ac system from its dc energy storage if the converter-output voltage is made to lead the ac-system voltage. On the other hand, it can absorb real power from the ac system for the dc system if its voltage lags behind the ac-system voltage. Although reactive power is generated internally by the action of converter switches, a dc capacitor must still be connected across the input terminals of the converter. The primary need for the capacitor is to provide a circulating current path as well as a voltage source. The magnitude of capacitor is chosen so that the dc voltage across its terminals remains fairly constant to prevent it from contributing to the ripples in the dc current. The VSC output voltage is in the form of a staircase wave into which smooth sinusoidal current from the ac system is drawn, resulting in slight fluctuations in the output power of the converter. However, to not violate the instantaneous power equality constrains at its input and output terminals, the converter must draw a fluctuating current from its dc source.

IV. BESS Technology

enewable energy sources like solar power and wind power often produces fluctuating power due to varying natural conditions. However, this generated power cannot inject directly to the existing system because of strict conditions placed by power regulation committee. The issue of power fluctuation and active, reactive power production or absorption, waveform distortion of supply produces due to non linear elements of plan. Fluctuating wind speed also causes the system frequency to deviate from the 50 Hz standard, as many protection relays have the frequency margin of 1%, which causes the malfunction of the power system protection equipment.

As a result, it has become the major concern for the Transmission System Operators (TSO) or the utility companies to resolve the wind power smoothing issue. Energy Storage System (ESS) is needed to smooth the intermittent output power fluctuations of the wind farm. A lot of choices for the ESS are present nowadays in the market e.g. Pumped Hydro Energy Storage (PHES), Compressed Air Energy Storage (CAES), Flywheel, Super capacitors Energy Storage (SES), Hydrogen Energy Storage System (HESS), Batteries Energy Storage System(BESS), etc., which are used to overcome the fluctuated wind farm output power. The choice of the ESS in the electric system network depends upon the desired application. To meet the electric power quality problems, energy storage with fast response rate and ability to charged/discharged many times is needed. For the time scale of seconds-to minutes, a suitable energy storage system is needed to have a good ramp rates, as discussed earlier, flywheel, super capacitors, batteries might be a good option. Besides that, the chosen energy storage system should be able to provide rated power for longer periods. However, for the longer time scales, the charging/discharging rate becomes less important and the choice of the ESS depends upon the amount of stored energy and the power capacity. Currently, the Pumped Hydro Storage System (PHSS) is the most common storage technology for longer time scales applications. Different types of batteries are presented as the substantial choice for the ESSs which are Sodium Sulfur (NaS), Lithium-Ion (Li-ion), Nickel Metal, Nickel Cadmium and Lead Acid type's batteries. Among different types of batteries, Lead Acid is the most popular and oldest technology. It has low capital investment and has the vast experience of usage. Lead-acid batteries requires frequent maintenance, they have short life (often 3-5 years), risk of explosions, acid leaking and are not environment friendly. They are majorly used as backup sources nowadays. Nickel Cadmium type battery appears as an alternative for the lead-acid battery. They have longer life time, less temperature dependent and high charge rates. They have a disadvantage of crystallization; it decreases the capacity of the battery when the battery is idled. Nickel metal type hybrid battery has higher energy density as compared to the lead acid and nickel cadmium, but they need a special charging control. Sodium-Sulfur (NaS) type battery system has a modular structure. It is the most recent technology among other technologies of the batteries. NaS uses the molten metal and operates at temperature above 250º C. They have very high power densities and works good for storing bulk amount of power. They have longer life time i.e. 15 years and they are relatively inexpensive.

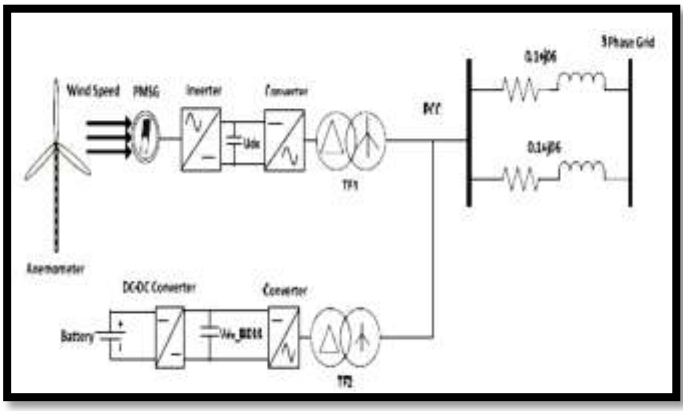

Fig. 3 BESS Configuration with Converter

The BESS has non-linear characteristics therefore the proper representation of BESS and it's controllers is challenge. The simplest and most commonly used model of a battery consists of the constant internal resistance in series with the variable DC voltage source. Previous studies of the STATCOM are limited only up to the reactive power compensation, but with the recent advancement of the BESS, it is possible to control the real power as well using BESS integrated with STATCOM system on the DC side. Thus allows us the controlling of the real and reactive power independently. Studies shows that the BESS integrated with STATCOM could solve the power fluctuation problems besides that it also improves the stability of the wind farms during the short circuit disturbances by supplying the adequate reactive power support to the system. Besides that, it also has other possible applications, e.g. voltage control, frequency regulation, and power oscillation damping.

V. Proposed Work

The STATCOM based current control voltage source inverter injects the current into the grid 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. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), for grid connected system in Fig.4.

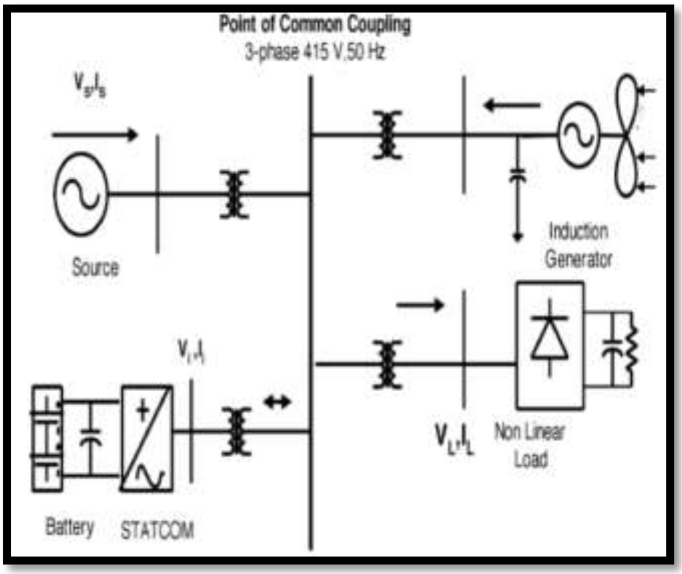

Fig.4. Grid connected system for power quality improvement

Control Scheme…

It is possible to improve the STATCOM response by employing the PID control method by choosing kp, ki and kd. It is a time consuming process but response speed, settling time and proper overshoot rate all guarantees the system stability.

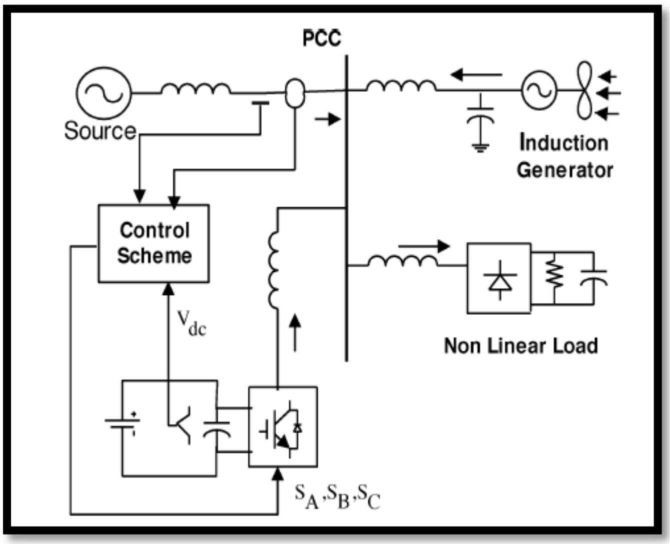

Fig. 5 System operational scheme in grid system Wind Power Generation Model

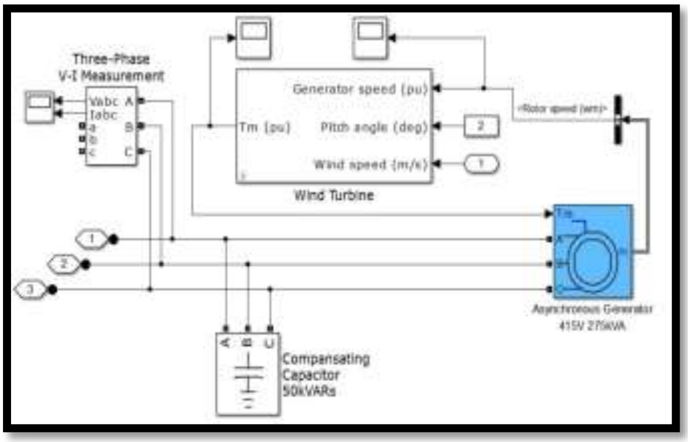

Fig.6 Wind Generating System Model

The wind generation system contains a pitch angle control type wind turbine which produces the mechanical power in reference of wind speed and current generator speed. This mechanical torque (T_m) is given to asynchronous generator which produces the electrical power equal to mechanical power given. Here the asynchronous type induction generator is used so that it requires reactive power support to avoid excessive lagging power, this can be done using a capacitor bank connected parallel to the line.

VI. SIMULATION RESULTS

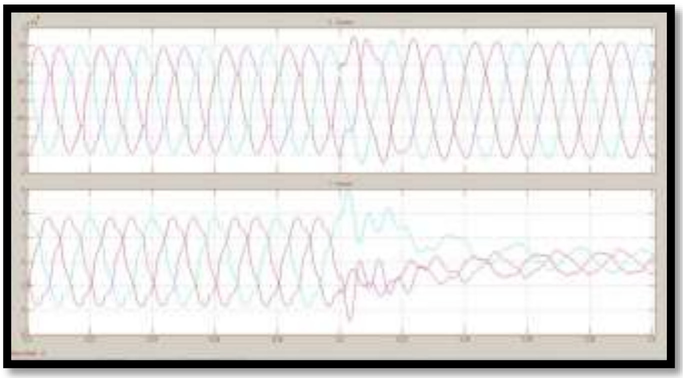

Fig.7 Source side voltage and current

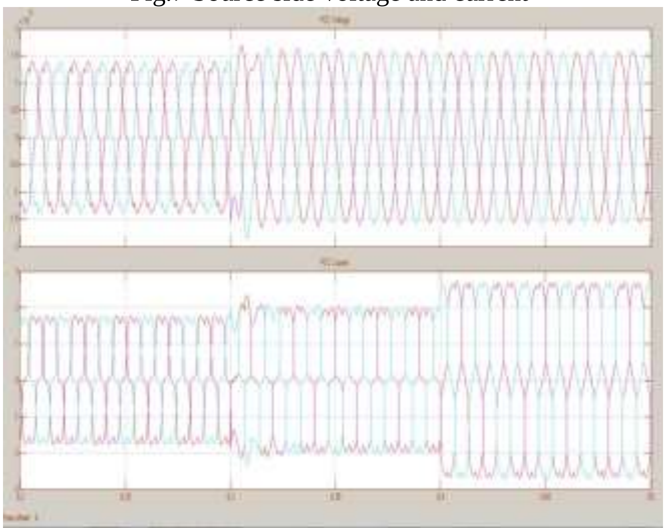

Fig-8 Voltage and Current at point of common coupling (PCC)

VII. CONCLUSION

Various parts of this paper has been showed and discussed with precision and proper details. Based on that we can conclude that the wind generation power integration with existing grid can be possible by using STATCOM converter and the power supply provide by this converter reduces the system harmonics and improve the power quality. Also it shows that change in load has significant effect on power system voltage and current. Change in load can produce some of power quality problems which are undesirable but it is due to distribution network and totally depending on power consumers. So the harmonics production due to load change can't be avoid but it can reduce by using prescribed system. Also one major part of this thesis work is excess power of wind generation can store using high capacity batteries so that the power exchange with grid can be constant and the energy can be utilize during pike load time. This gives power saving of base load plant and provide a non polluting power time to time. Thus the concept is another step in the field of non polluting energy and reduction in carbon footprint.

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