Grid Power Quality Improvement in Wind Energy System using STATCOM Combined with BESS

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Abstract— The sources such as wind power and solar power are expected to be promising energy sources when it is connected to the power grid. The wind generators have a significant impact on the power quality, voltage profile and the power flow for customers and electricity suppliers. The power exhausted from above energy sources varies due to environmental conditions. Due to the fluctuation in nature of the wind, the wind power injection into an electric grid affects the power quality. The influence of the wind sources in the grid system concerns the power quality such as the reactive power, active power, voltage variation, harmonics and electrical behaviour in switching operation[1]. At the point of common coupling a Static Synchronous Compensator with Battery Energy Storage System-STATCOM/BESS, can regulate four-quadrant active and reactive power, which is an ideal scheme to solve problems of wind power generation. As the power from wind generation varies with time so the battery energy storage used to maintain constant real power comprehensively from varying wind power. The power generated through wind generator can be stored in the batteries at low power demand hours[2-4]. The combination of battery storage with wind energy generation system will synthesize the output waveform by absorbing or injecting reactive power and enable the real power flow required by the load. The control strategy can coordinate charge or discharge of batteries with reactive power compensation of STATCOM, and balance the batteries capacity. If required, amount of energy consumed or given to the grid can be observed through an online smart meter connected in the circuit.

Key words: Power Quality, Statcom, Wind Energy, BESS, Wind Turbine, Energy Storage System

I. INTRODUCTION

Recently a rapid development of wind power generation has been experiencing in a global scale. As with increasing the size of wind turbines and wind farms, a large amount of wind power is injected into 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[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 issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. 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[2-4].

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. The power quality is an essential measure and is greatly affected by the operation of a distribution and transmission network. So as the power quality problem is of great importance to the wind turbine generation.

II. POWER QUALITY PROBLEMS

Power quality describes the current, voltage and frequency within the power system. As the most power system equipment has been capable to run successfully with comparatively wide variation of the considered three parameters, so the power quality term did not so critically meant prior to last decade. However within last decade of time the large numbers of electrical equipments (computers, microprocessors, power system equipments like as the adjustable speed drives) have been added to the power system which is not so much tolerant in nature of power quality.

A. Voltage Variation and Voltage Deep:

If a large proportion of the grid load is supplied by wind turbines, the output variations due to wind speed changes can cause voltage variation, flicker effects in normal operation. The voltage variation can occur in specific situation, as a result of load changes, and power produce from turbine. These can expected in particular in the case of generator connected to the grid at fixed speed. The large turbine can achieve significantly better output smoothing using variable speed operation, particularly in the short time range. The speed regulation range is also contributory factor to the degree of smoothing with the large speed variation capable of suppressing output variations. The start up of wind turbine causes a sudden reduction of voltage. Voltage sag is a phenomenon in which grid voltage amplitude goes below and then returns to the normal level after a very short time period.

B. Switching Operation and Harmonics:

The harmonics distortion caused by non-linear load such as electric arc furnaces, variable speed drives, large concentrations of arc discharge lamps, saturation of magnetization of transformer and a distorted line current. The current generated by such load interact with power system impedance and gives rise to harmonics. The effect of harmonics in the power system can lead to degradation of power quality at the consumer’s terminal, increase of power losses, and malfunction in communication system. The harmonics voltage and current should be limited to acceptable level at the point of wind turbine connection in the system. The harmonic measurement at the wind turbine is problem due to the influence of the already existing harmonic voltage in the grid. The wave shape of the grid voltage is not sinusoidal. There are always harmonics voltages in the grid such as integer harmonic of 5th and 7th order which affect the measurements. Today's variable speed turbines are equipped with self commutated PWM inverter system.

C. Flickers and Reactive Power:

Flicker is the one of the important power quality aspects in wind turbine generating system. Flicker has widely been considered as a serious drawback and may limit for the maximum amount of wind power generation that can be connected to the grid. Flicker is induced by voltage fluctuations, which are caused by load flow changes in the grid. The flicker emission produced by grid-connected variable-speed wind turbines with full-scale back-to-back converters during continuous operation and mainly caused by fluctuations in the output power due to wind speed variations, the wind shear, and the tower shadow effects. As a consequence, an output power drop will appear three times per revolution for a three bladed wind turbine. There are many factors that affect flicker emission of grid connected wind turbines during continuous operation, such as wind characteristics and grid conditions. Variable-speed wind turbines have shown better performance related to flicker emission in comparison with fixed-speed wind turbines.

Traditional wind turbines are equipped with induction generators. Induction generator is preferred because they are inexpensive, rugged and requires little maintenance. Unfortunately induction generators require reactive power from the grid to operate. The interactions between wind turbine and power system network are important aspect of wind generation system. When wind turbine is equipped with an induction generator and fixed capacitor are used for reactive compensation then the risk of self excitation may occur during off grid operation.

III. STATCOM AND BESS OVERVIEW

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. STATCOMs behave analogously to synchronous compensators, except that STATCOMs 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.

The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has current injection in such a way that it reduces the current harmonics as well as makes the source voltage at its desired value by adjusting the phase angle. 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. The grid connected system consists of wind energy generation system and battery energy storage system with STATCOM.

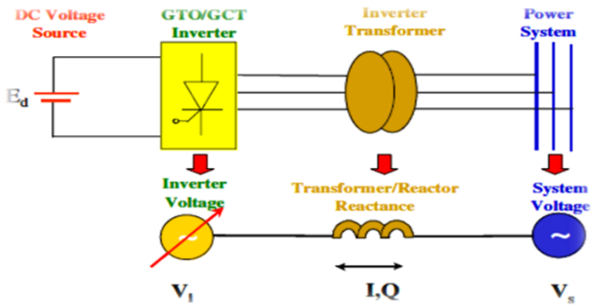

Fig. 1

Renewable energy sources often produce power and voltage varying with natural conditions (wind speed, sun light, etc). However, electric utility grid systems cannot readily accept connection of new generation plant without strict conditions placed on voltage regulation due to real power fluctuation and reactive power generation or absorption, and on voltage waveform distortion resulting from harmonic currents injected by nonlinear elements of the plant. 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.

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.

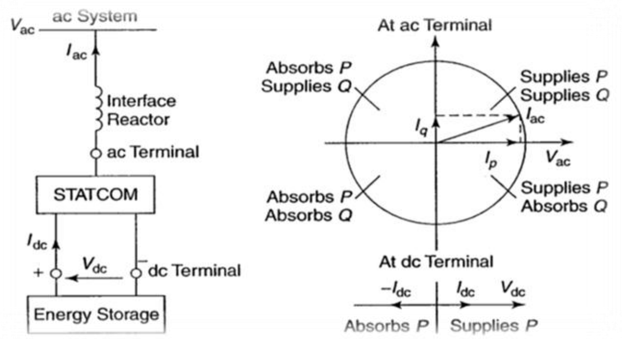

Fig. 2:

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. 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.

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.

IV. STATCOM WITH BESS CONFIGURATION

FACTS with energy storage system (ESS) have recently emerged as more promising devices for power system applications. This work focuses on STATCOM incorporated with battery energy storage system (BESS), i.e., STATCOM/BESS topology for wind power application. Figure-3 presents typical architecture of connected STATCOM with BESS to electric utility system. The static synchronous compensator, or STATCOM, is a shunt-connected power electronic converter-based FACTS device. Unlike static var compensator (SVC), the STATCOM does not employ capacitor or reactor banks to produce reactive power. The major disadvantage of a traditional STATCOM without energy storage is that it has only two possible steady-state operating modes, namely, inductive mode (lagging) and capacitive mode (leading). Typically, the STATCOM converter voltage is maintained in phase with the PCC voltage, thus ensuring that only reactive power flows from the STATCOM to the system.

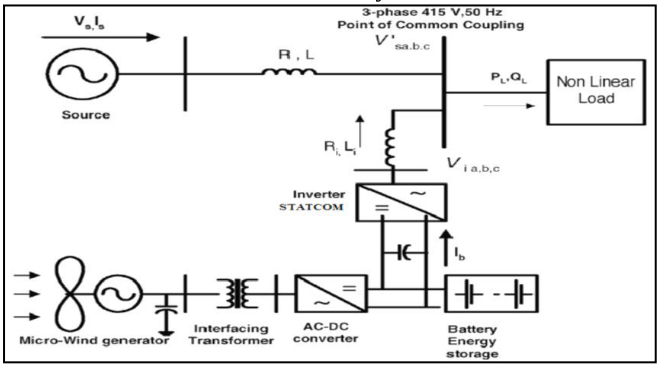

Fig. 3:

V. CONTROL STRATEGY

The control scheme with battery storage and micro wind generation system utilizes the dc link to extract the energy from the wind. The wind generator is connected through a step up interfacing transformer and to the rectifier bridge so as to obtain the dc voltage. Also a lead acid cell battery is used for maintaining the dc bus voltage constant. Thus the inverter is implemented successfully in the distributed system. The control scheme approach is based on injecting the current into the grid using hysteresis band current controller. Using such techniques controller keeps the control system variables between the boundaries of hysteresis area and thus gives correct switching signals for the inverter operation. Fig. 4 shows the control scheme for generating the switching signals to the inverter.

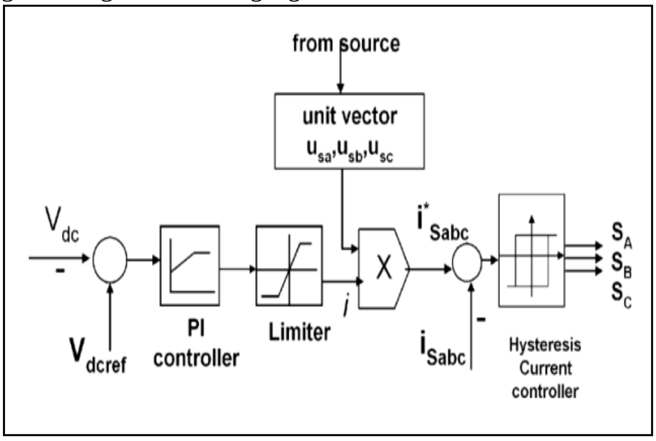

Fig. 4:

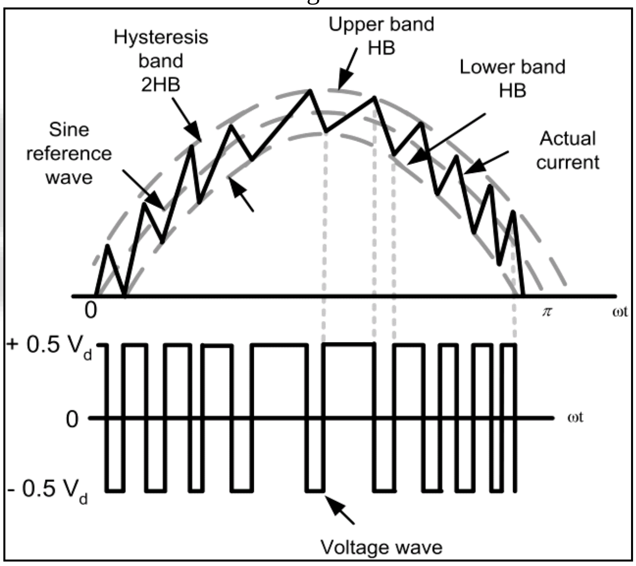

Fig. 6:

The control algorithm needs the measurement of several variables such as three-phase source current i_{Sabc} for each phases, dc bus voltage V_{dc}, and inverter current i_{iabc} with the help of measurement sensors. The current control unit receives an input of reference current i^*_{Sabc} and actual current i_{Sabc} is measured from each phases respectively, which are subtracted so as to activate the operation of the inverter in current control mode.

VI. MATLAB SIMULATION AND RESULTS

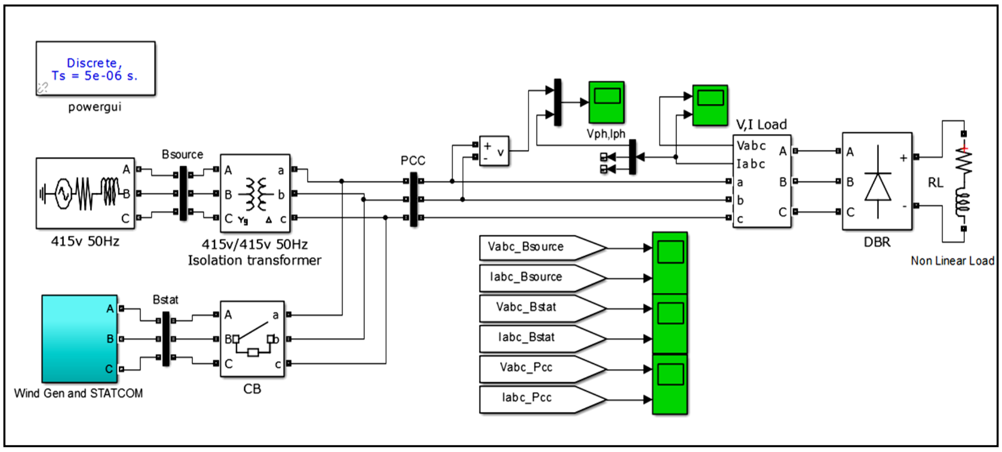

Fig. 7:

The test system shown here is covering all the sections of the dissertation work. Here a power system is connected with wind generating system with converter STATCOM and battery energy storage system. The source side power can be analyzed by 'Bsource' measurement block. The two of system one is wind generation system and external system is connected at the point of common coupling (PCC) and the voltage and current is observed with PCC measurement block. The voltage at the common coupling point should be free from harmonics even though the nonlinear load is connected at load side.

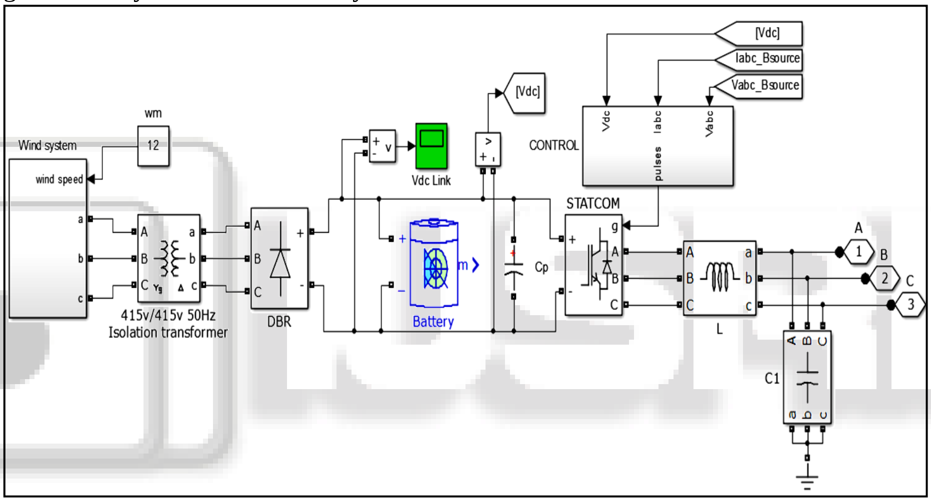

Fig. 8:

This subsystem is converter section for wind generating power. Here the power from wind turbine is firstly isolated by isolation transformer (415/415V) so that the switching harmonics can be avoided to penetrate into generation system. The first stage of power conversion is done through diode bridge rectifier (DBR) and the converted dc supply is feed to intermediate battery storage. This battery makes the capacitor voltage constant during the fluctuation in power generation also store excess power generation during high wind flow. Now in the next stage this dc power is converted into ac supply through voltage source converter type STATCOM. This converted ac power exchange through line reactance and filtering capacitor.

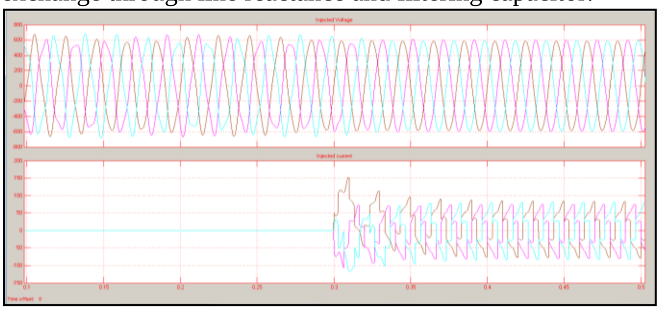

Fig. 9: STATCOM Injected Voltage and Current

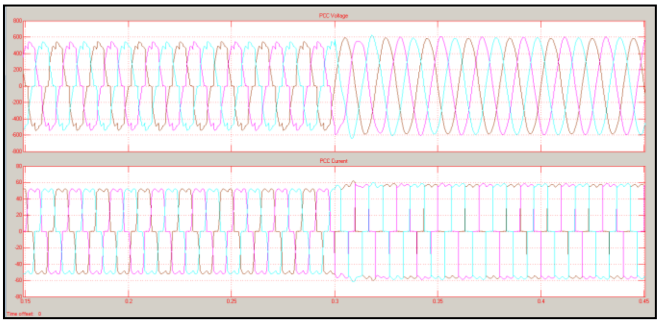

Fig. 10: At PCC Point Voltage and Current

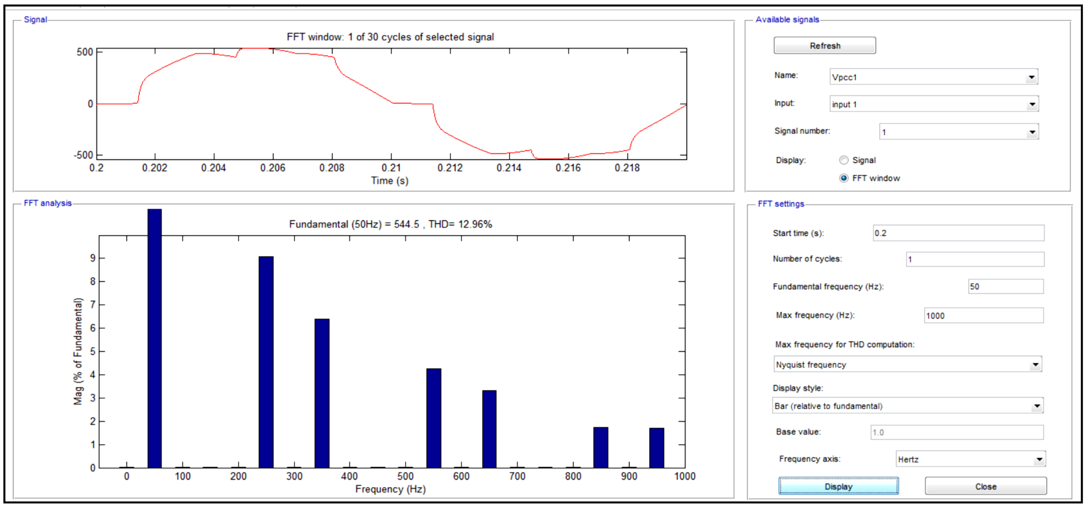

Fig. 11: THD without STATCOM (12.96%)

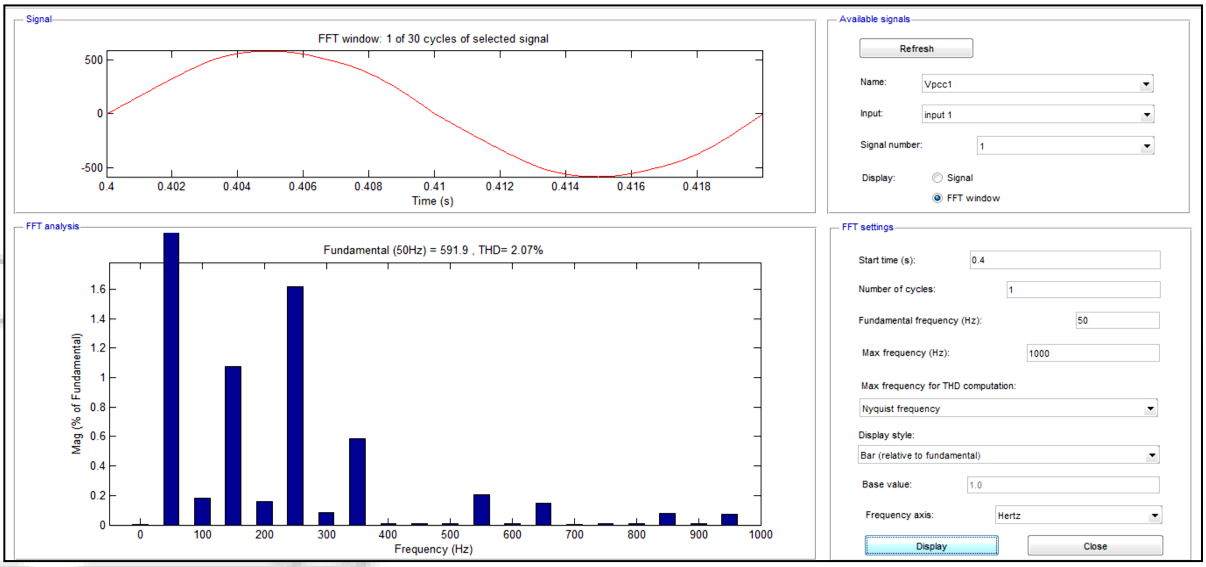

Fig. 12: THD with STATCOM (2.07%)

Here the voltage and current get distorted during first 0.3sec of time due to nonlinear load and the STATCOM and wind generation system is isolated. As at 0.3sec the breaker is operated and the system get connected to the existing system the STATCOM removes the voltage harmonics and makes it smooth sinusoidal.

VII. Conclusion

Various parts of this project 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 is 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.

VIII. Acknowledgment

The completion of any project brings with it a sense of satisfaction, but it is never complete without thanking those people who made it possible and whose constant support has crowned our efforts with success. My deepest gratitude to Almighty God for holding my hands and guiding me throughout our lives. I wish to express my deep sense of gratitude to all the faculty members of Electrical Department in Government Engineering College, Bhuj for their invaluable and precious guidance and continuous encouragement and motivation. I would also like to thank my family and my friends at Government Engineering College, Bhuj for their support and help during the course of seminar work.

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