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Improvement in power quality in grid connected Wind energy system and non-linear load using STATCOM

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ABSTRACT

Power quality in electric network is one today's most concerned areas of electric power system. The power quality has serious economic implications for consumers utility and electrical equipment manufactures. Power quality is a set of electrical boundaries that allow a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. Power quality problem is an occurrence manifested as a nonstandard voltage, current and frequency that result in a failure of end user equipment. The impact of power quality problem is increasingly felt be industrial, commercial and even residential. One of the major problems faced by consumers is voltage fluctuation. With voltage quality problems in the utility distribution systems, industrial loads and sensitive load etc. get suffered. Therefore, power engineers and researchers are continuously finding the ways to encounter such problems. This report deals with the use of the STATCOM, a custom power device for the industrial system to mitigate the voltage fluctuations. The fast response of STATCOM corrects the voltage sag, swell and Interruptions. Therefore, modelling and simulation of STATCOM for improving the power quality under load variations would be studied.

I. INTRODUCTION

To have sustainable growth and social progress, Energy required can be achieved by utilizing the renewable energy resources like co-generation, wind, hydro, biomass. The key paradigm in sustainable energy system are energy conversation and the use of renewable source. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant [19]. In recent years very high growth and development in exploitation of wind energy has been reported. Each unit can generate upto a large capacity of 2 MW. These days, all over the world more than 28000 wind generating turbines are running successfully. 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 continuous variable output power is produced by fixed speed wind turbine during normal operation.

These variations in power are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. So, for such fluctuations the network needs to be managed. In wind generation, transmission and distribution network, Power Quality issues encompass (include) a wide range of disturbances such as voltage sags, swells, harmonics distortion, flicker, notching, and interruptions. Induction generator can be directly connected to the grid system to run a wind generating system. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. To improve the power quality to manage the power level of wind turbines a STATCOM based technology is used.

II. LITERATURE SURVEY

Ganesh.Harimanikyam., [1] introduced that the STATCOM system reduces THD in the supply currents for non-linear loads. Rectifier-based non-linear loads generated harmonics are eliminated by STATCOM. When single-phase rectifier loads are connected, STATCOM currents balance these unbalanced load currents.

S. Rajesh Rajan., [2] demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme Static Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator. The proposed system maintains the grid voltage free from distortion and harmonics.

Mis.Rubeena M. Shaikh.,[3] proposed that Injection of the wind power into an electric grid affects the power quality. The generated wind power is always not constant due to its time varying nature and causing stability problems. This weak interconnection of wind generating source in the electrical network affects the power quality and reliability. In this paper the power quality problem due to installation of wind turbine with the grid is determine. In this proposed scheme Static Compensator (STATCOM) is connected at a point of common coupling to reduce the power quality problems.

G.Srinivas, T. Santosh Chaitanya.,[4] This paper presents the grid connected wind energy system for power quality improvement by using STATCOM. In this proposed scheme to eliminate the harmonic content of the load current the STATCOM-BESS control system is used. So that power quality is maintained at the point of common coupling. The shape of the grid current is almost sinusoidal and the % THD has been improved from 1l.08 % to 5.78 % after compensation.

V. Amarnath Reddy, P. Harshavardhan Reddy., [5] presents the FACTS device (STATCOM) -based control scheme for power quality improvement in wind generating system on integration to the grid and with nonlinear load. The operation of the control system developed for the STATCOM in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It maintains the source voltage and current in-phase and load at PCC in the grid system, thus it enhance the utilization factor of transmission line.

B.T.RAMAKRISHNARAO, L.NARENDRA.,[6] presents the grid connected wind energy system for power quality improvement by using STATCOM. The power quality problems, its consequences and their mitigation techniques are presented here. In this proposed scheme to eliminate the harmonic content of the load current the STATCOM-BESS control system is used.

Sk. Baji babu, M. Balasubba Reddy.,[7] addressed reactive power compensation and harmonic reduction in a low voltage distribution networks for integration of wind power to the grid. It proposes a control scheme based on instaneous Pq theory for compensating the reactive power requirement of a three phase grid connected wind driven induction generator as well as the harmonics produced by the non linear load connected to the PCC using STATCOM.

Sharad W.Mohod et al., [8] presented the power quality problem due to installation of wind turbine with grid. They proposed STATCOM based scheme connected with a BESS to mitigate the power quality issues. It includes the STATCOM control schemes simulated with grid using MATLAB/SIMULINK. This also presented the development of grid co-ordination rule and schemes for improvement in power quality norms as per IEC-STD on the grid side.

B.Ronner et al., [9] introduced operational experiences of STATCOMs for Wind Park. It describes the principles of operation of a medium voltage STATCOM and value adding additional functions of STATCOM is named.

A.H.Kasem et al., [10] introduces a methodology to enhance the quality of power and voltage, and minimize the flicker produced from constant speed direct connected wind turbines. The method uses an electrolyser/fuel cell combination to be connected to the PCC via limiting rating converters. The control schemes is designed to keep the power ramp rate and voltage fluctuation within their limits and minimize the rating of converters used. The incorporation of STATCOM and its effect on the generated power and flicker level have been investigated.

J.A.Barrado et al., [11] presented a STATCOM with a self-oscillating bidirectional dc-dc converter for interfacing battery energy storage in stand-alone induction generator system. The self oscillation mode is based on relay feedback control with

hysteresis. The proposed control allows that the previous electronic converters, with an additional resistive dump load, compensate all disturbances in self-excited induction generator.

Sharad W.Mohod et al., [12] proposed the control schemes for VSI in a current control mode to inject the compensating current into the power system at a PCC. A hysteresis current controller has been implemented to generate the inverter switching signals using reference from source voltage. This ensures that wind turbine system will inject current through inverter to maintain unity power factor.

A.Arulampalam et al., [13] proposed a new hybrid STATCOM-BES control technique for improving the stability and power quality to fixed speed induction generator, wind turbine. The variation of the network voltage , active and reactive power with fluctuation of wind generation is studied. A WES with STATCOM-BES unit and the new control simulated and the results demonstrate that both power quality and stability margin can be improved.

Sharad W.Mohod et al., [14] introduces a micro-wind energy conversion system with BES is used to exchange the controllable real and reactive power in the grid and to maintain the quality of power as per IEC at PCC. The generated micro wind power can be extracted under varying wind speed and can be stored in the batteries at low power demand hours. The system provides rapid response to critical load. The system reduces the burdun on
conventional source and constraints.

Z.Saad-Saoud et al., [15] investigate how STATCOM could be used with fixed speed winturbine, which use induction generators, to improve both steady -state and dynamic impact of a wind farm on the network. An optimal power flow model based on loss minimization was developed and used to show that operation of a wind farm at unity power factor is unlikely to allow maximum penetration of wind energy into a weak distribution circuit. The results of simulation show that use of a STATCOM improves the steady state stability limit of the
network.

B.Singh et al., [16] presented a review on the state-of-the-art STATCOM technology and further research. This also includes the development of STATCOM controller employing various solid-state converter topologies, magnetic configurations, control algorithms, switching techniques and so on.

Ben-Sheng Chen et al., [17] this paper include a novel controller with fixed modulation index (MI) and variable dc capacitor voltage reference to minimize voltage and current harmonics is presented for a distribution static synchronous compensator (STATCOM). The STATCOM with the proposed controller consists of a three-phase voltage-sourced inverter and a dc capacitor and is used to provide reactive power compensation and regulate
ac system bus voltage with minimum harmonics**.** With the proposed STATCOM controller, harmonic distortions in the inverter output current and voltage can be reduced.

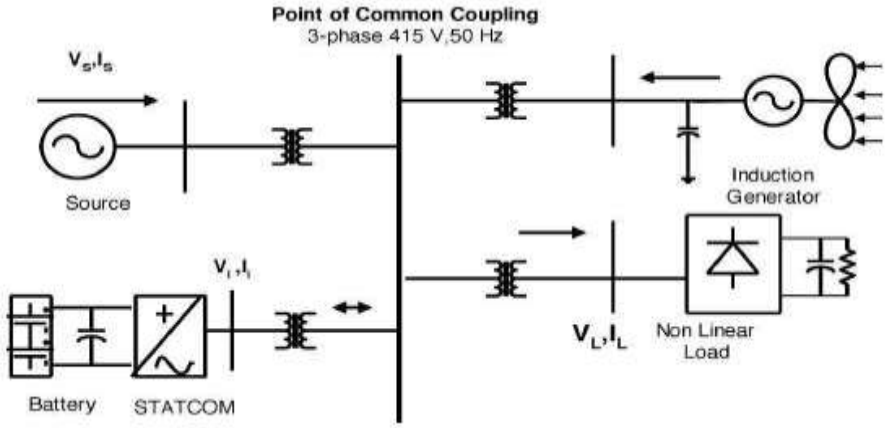
G. Elsady, et al., [18] they investigated application of STATCOM to improve performance of Power Grid with Wind Farms. So they developed dynamic model of Power System having Wind Farm controlled by proposed STATCOM, result proved the effectiveness of proposed STATCOM in restoring power system stability.

A. Karthikeyan et al., [19] proposes a hybrid, open-loop exciter for the wind turbine-driven induction generator for low power applications. The hybrid exciter comprises one set of fixed capacitor bank and a parallel connected three-phase fixed frequency pulse width modulation (PWM) inverter fed from a battery. This hybrid exciter inherently adapts to the changes in the rotor speed or load on the generator while maintaining a near constant voltage and frequency at the load terminals. The whole system including the PWM inverter is operated in an open loop, without the need for any sensors other than the low speed cut-in and high-speed cut-out mechanisms on the wind turbine. Results from simulations and laboratory tests show that the dynamic reactive power compensation of the generator is inherent in the proposed open-loop system.

III. QUALITY IMPROVEMENT IN GRID CONNECTED WIND ENERGY SYSTEM AND NON-LINEAR LOAD USING STATCOM

The renewable sources of energy integrated in the local grid have been increased because of reduction in gaseous emission, energy efficiency or use of energy, deregulation or competitive policy, and variegation of energy resources. Renewable Sources such as wind energy, hydro, tidal, solar, etc. are intermittent in nature. Due to ruggedness, low cost, less maintenance and no backup short circuit Induction generators are used for wind energy conversion. But reactive power requirement of induction generators are to be met from the source. In these to control the voltage at common coupling point a controlled reactive power source is used. During connection and disconnection of integrated system may lead voltage sag.

During connection high inrush current by incoming generator may cause significant voltage drop. And during disconnection, operating at full load may lead to significant, if infrequent, voltage drops.

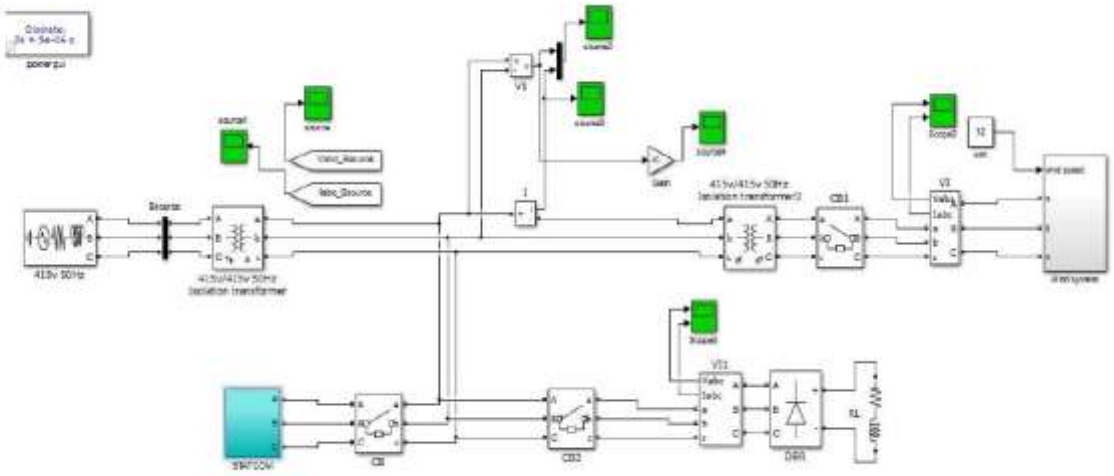


REASONS FOR CHOOSING A STATCOM

The advantage of using STATCOM over a thyristor based SVC is that it's compensating current is not dependent on the voltage level at the connection point. The compensating current does not lowered as the voltage drops. The output of the wind power plants and the total load vary continuously throughout the day. To maintain the power system reactive power compensation is used. The power system can be seriously affected by Reactive power imbalances. These imbalances can be reduced by using reactive power compensation devices as STATCOM. Even at lower voltages these reactive power compensation devices can operate at its full capacity and thus contribute to low voltage ride through requirement.

IV. RESULT & ANALYSIS

The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented. 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.



MATLAB Simulation model

Performance of System with Grid Connected SEIG and Non-linear Load

With MATLAB SIMULATION results are obtained for i.e. system without SEIG and Non-Linear load in Fig. 1, and system with Non-Linear in Fig.2 and system with both Non-Linear load and SEIG in Fig.3, it is observed that system voltage at PCC is purely sinusoidal and 1 p.u. In Fig 2 it is observed that when a Non-Linear load connected to the system the voltage waveform is not purely sinusoidal and contain harmonics, means Non-Linear load injects harmonics to the system. Now when we connected SEIG also to the system in Fig.3, at 0.1 sec the system voltage becomes dip (0.8 p.u) due reactive power support to SEIG by the system. Hence, when both SEIG and Non-Linear connected to the system the voltage waveform is distorted and also decrease at PCC.

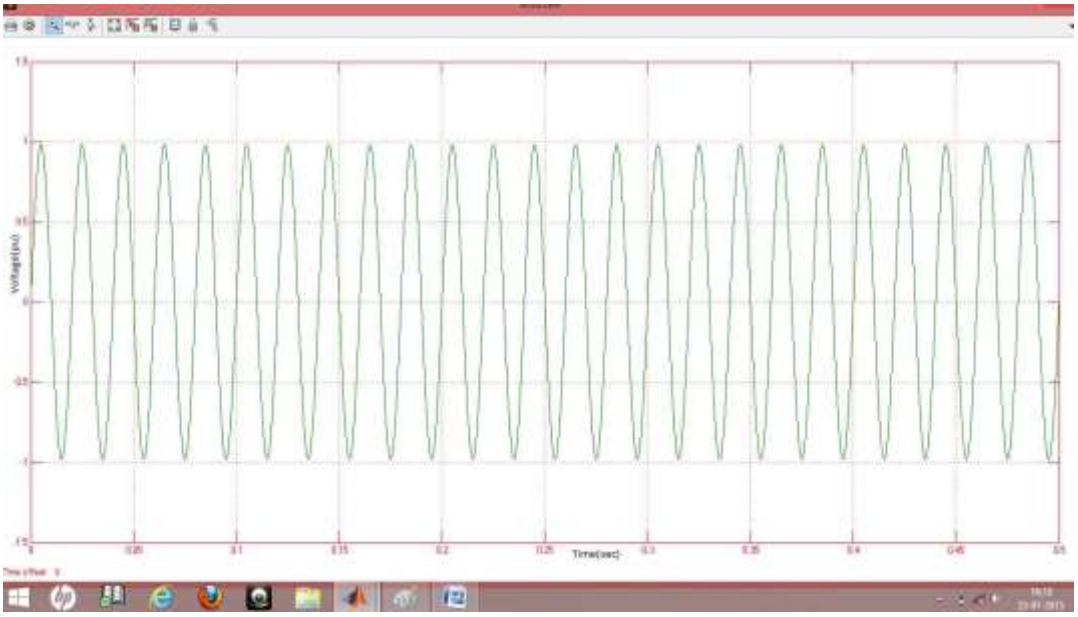


Fig 1. Voltage at PCC

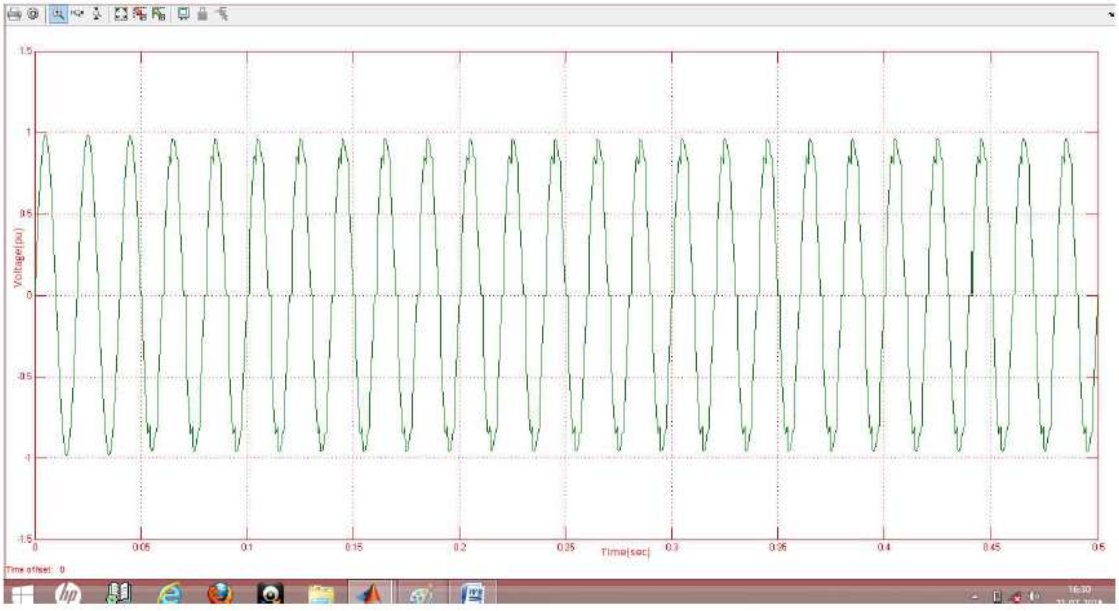


Fig 2. Voltage at PCC when only Non-Linear load connected

As shown in the figure above after connecting of non-linear load waveform distorted hence harmonics present in the system voltage.

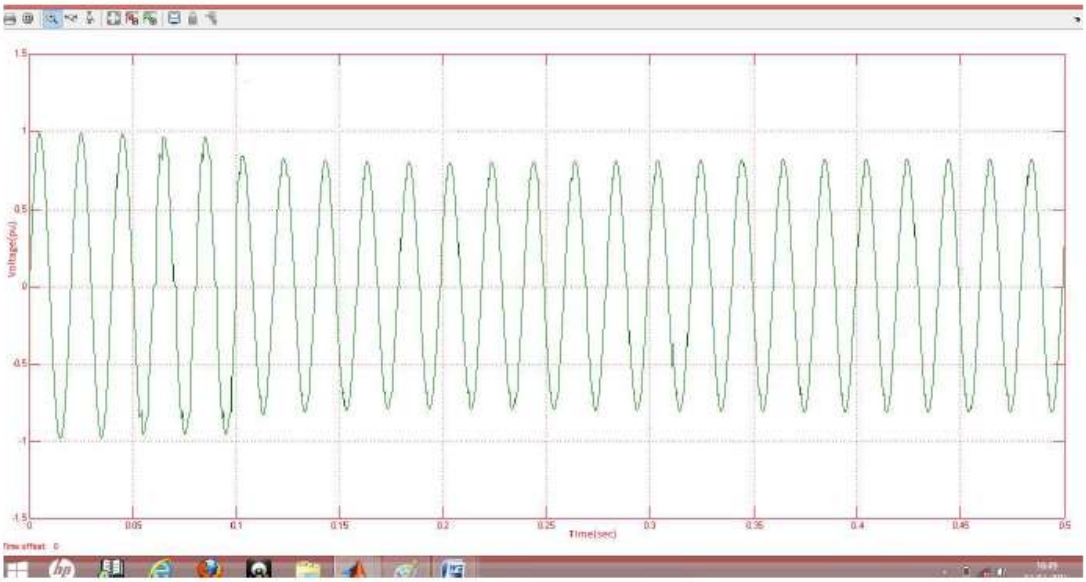


Fig 3. Voltage waveform when wind and non-linear load connected at PCC

As shown the wind connected induction generator connected at 0.1 sec after this there is voltage dip. Hence due to interconnection of non-linear load and SEIG voltage at PCC is distorted and decreased.

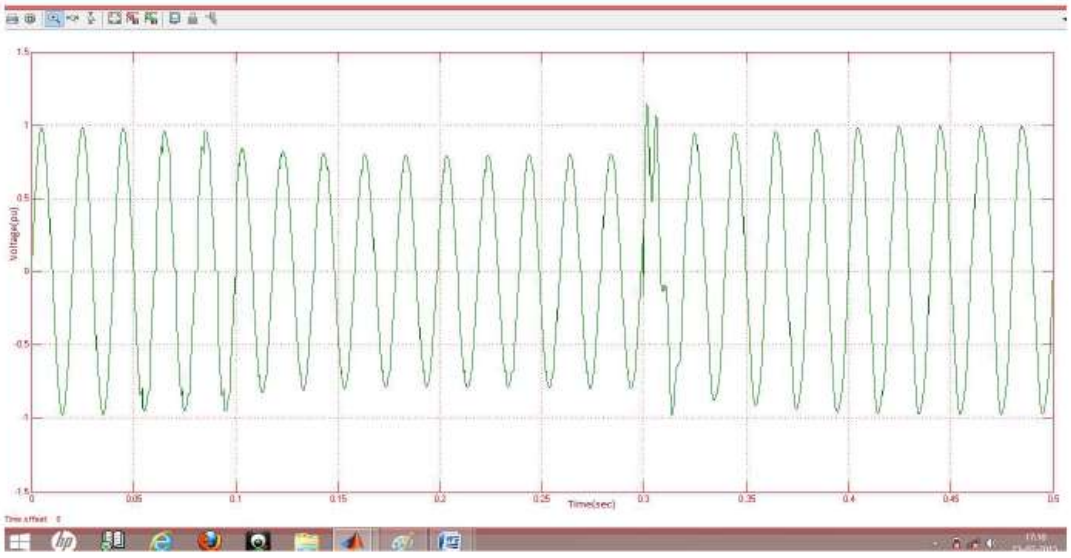


Fig 4. Voltage at PCC after STATCOM connected

As shown in the Fig. above the STATCOM is connected at 0.3 sec to the system which increase the voltage and also shape of waveform improve i.e. reduction of harmonics at PCC. Hence, power quality is improved by STATCOM.

CONCLUSION

A pressing demand for more electric power coupled with the depleting natural resources have led to an increased need for energy production from renewable sources such as wind and solar energy. Wind power has seen increased penetration in the recent past and certain stringent grid interconnection requirements have been developed. The induction generator has inherent advantages of cost effectiveness and robustness. The advantages of self-excited induction generators (SEIG) have led to them being chosen as suitable candidates for the energy supply in rural communities and remote areas, where these machines can be driven by using diesel engines or some renewable energy resources, such as wind energy or micro

hydropower. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. On the other hand Non-linear load connected at PCC effect the quality of power at PCC, mainly by injecting harmonics in the system. Therefore both the Grid Connected SEIG and Non-linear load effect the quality of power i.e Grid connected SEIG decrease the voltage level at PCC due absorption of reactive power from system to provide active power to system and Non-linear load increase the harmonics level at PCC ,so that Voltage waveform distorted. Hence both the voltage decreases and waveform distorted, causes the poor power quality at PCC.STATCOM based power conditioner shows effectiveness to improve the quality of power at PCC, which reduce the harmonics presented to system by Non-linear load and maintain the voltage reduced by grid connected SEIG by providing reactive power support to the system. The performance of system is analysed, which shows that proposed technique maintain the voltage and harmonics distortion level at PCC within permissible limits.

FUTURE SCOPE

In this thesis, simulation studies show that the power quality is improved with the use of a STATCOM in Grid connected SEIG and Non-linear load. This work may be extended as:
The wind turbine here is modelled as individual turbine, which could be extended to represent a wind farm by modelling them as single equivalent wind turbine.
1. Present study has been based on the performance for Grid connected SEIG that could be extended to various type of wind turbine generator.
2. Here STATCOM is used for improving the quality of power another FACTS device search for techniques for other FACTS devices for power quality improvement.

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