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Energy Storage Equipped STATCOM for Power Quality Improvement in Grid Integrated Wind System

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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. According to the guidelines specified in IEC-61400 standard (International Electro-technical Commission) provides some norms and measurements. The performance of the wind turbine, power quality is determined. The power quality measurements are-the active power, reactive power, voltage sag, voltage swell, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national/international guidelines. The paper clearly shows the existence of power quality problem due to installation of wind turbine with the grid. In this STATCOM is used with energy storage system (ESS) to reduce the power quality problems. Simulation results are presented to demonstrate the impact of integration of wind generating system with the grid and the effectiveness of the STATCOM control scheme in minimizing the impact.FFT analysis carried out for the source current shows that the THD is considerably reduced and is clearly within limits imposed by standards with STATCOM connected at point of common coupling(PCC). The STATCOM control scheme for the grid connected wind energy generation system to improve the power quality is simulated using MATLAB/SIMULINK in power system block set.

KEYWORDS: Power Quality, Wind Generating System (WGS), STATCOM, ESS.

I. INTRODUCTION

The need to integrate the renewable energy like wind energy into power system is to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents requires the consideration of voltage regulation, stability, 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 [1].

The need for providing reliable and secure power supply arises with an ever increasing demand for electricity. In recent years, the use of non-conventional sources for electricity generation has been gaining popularity and one such source is wind energy. The success of wind energy generating system lies in the capability of wind technology to be integrated into existing power system. However, the fluctuating nature of wind and the comparatively new types of its generators affect the power quality when the wind power is injected into the grid. In order to address the power quality issues that arise due to the integration of wind turbine with the grid, the grid operators have imposed stringent regulations requiring the wind turbines and wind farms to full fill power plant properties. This necessitates the use of highly sophisticates and flexible technology [2]. The performance of the wind turbine and thereby power quality are assessed through the guidelines specified by IEC-61400 standard. 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. However the wind generator introduces disturbances into the distribution network. 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 then power quality which can technically manages the power level

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associates with the commercial wind turbines. A simple control scheme based on hysteresis current control is developed for the STATCOM with the following objectives:

- Unity power factor at the source side.
- Minimize the percentage THD in source current waveform.

The paper is organized as fallows. The Section II introduces the power quality standards, issues and its consequences of wind turbine. The Section III describes system development The Sections IV, V, describes the simulation results and conclusion respectively.

II. POWER QUALITY ISSUES AND ITS CONSEQUENCES

(A) Harmonics

The harmonic results due to the switching 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 [10].

(B) Voltage Sag (Or Dip)

A decrease of normal voltage level between 10 to 90% of the nominal rms voltage level at power frequency for duration of 0.5 cycles to one minute. It occurs due to connection of heavy loads and start-up of large motors.

(C) Voltage spikes

Very fast variation of the voltage values for durations from a several microseconds to few milliseconds. It occurs due to disconnection of heavy loads.

(D) Voltage Swell

Momentary increase of voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds. It is caused due to badly regulated transformers (mainly during off-peak hours).

(E) Voltage fluctuation

A series of voltage changes or a continuous variation of the R.M.S voltage . It is caused due to frequent start/stop of electric motors (for instance elevators), Oscillation in loads.

(F) Very Short Interruption

Total interruption of electrical supply for duration from few milliseconds to one to two seconds . It is caused due to insulation failure, lightning and insulator flashover.

(G) Long Interruptions

Total interruption of electrical supply for duration greater than 1 to 2 seconds. It occurs due to equipment failure in the power system network.

(H) Consequences of the issues

The voltage variation, flicker, harmonics causes the mal-function of equipment namely microprocessor based control system, programmable logic controller. It may lead 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 degrades the power quality in the grid [3].

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III. SYSTEM DEVELOPEMENT

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.

The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC),for grid connected system in Fig

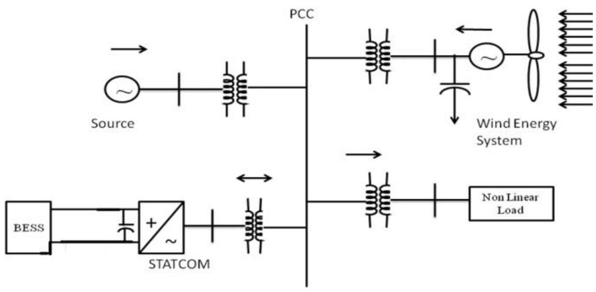

Fig.1. Grid connected system for power quality improvement.

(A) Wind Energy Generating System

In this configuration, wind generations are based on constant speed topologies with pitch control turbine. The induction generator is used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. The available power of wind energy system is presented as under in (1).

$P_{mech} = C_p * P_{wind}$ (1)

$P_{wind} = 0.5*p*AV^3$ (2)

Where ρ (kg/m) is the air density and A (m) is the area swept out by turbine blade, V wind is the wind speed in mtr/s. It is not possible to extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient *Cp* of the wind turbine.

(B) ESS-STATCOM

The energy storage system (ESS) is used as an energy storage element for the purpose of voltage regulation. The ESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also control the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the ESS can be used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM [4]–[5].

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the Point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling.

(C) 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

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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.

(D) 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 2 presents schematic of BANG-BANG controller used with STATCOM.

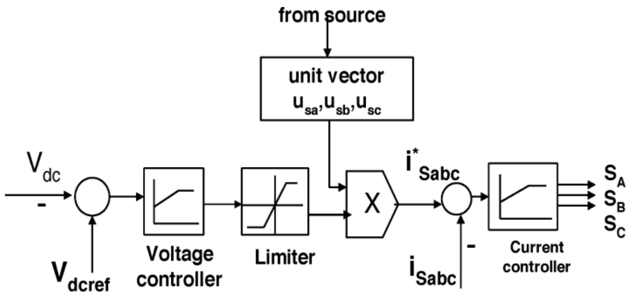

Fig 2: Control scheme of STATCOM.

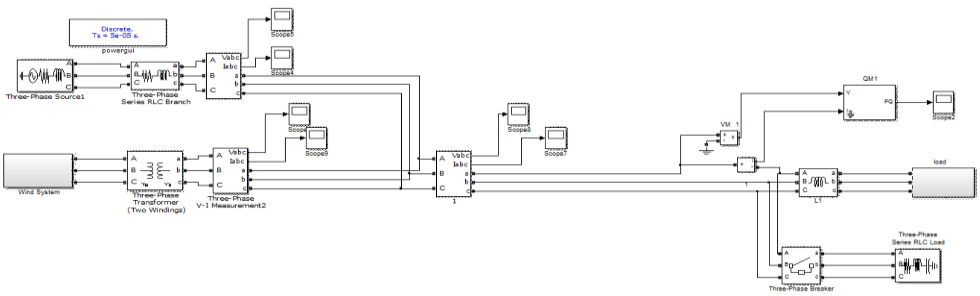

Figure 3: Simulation model of grid connected wind system without STATCOM.

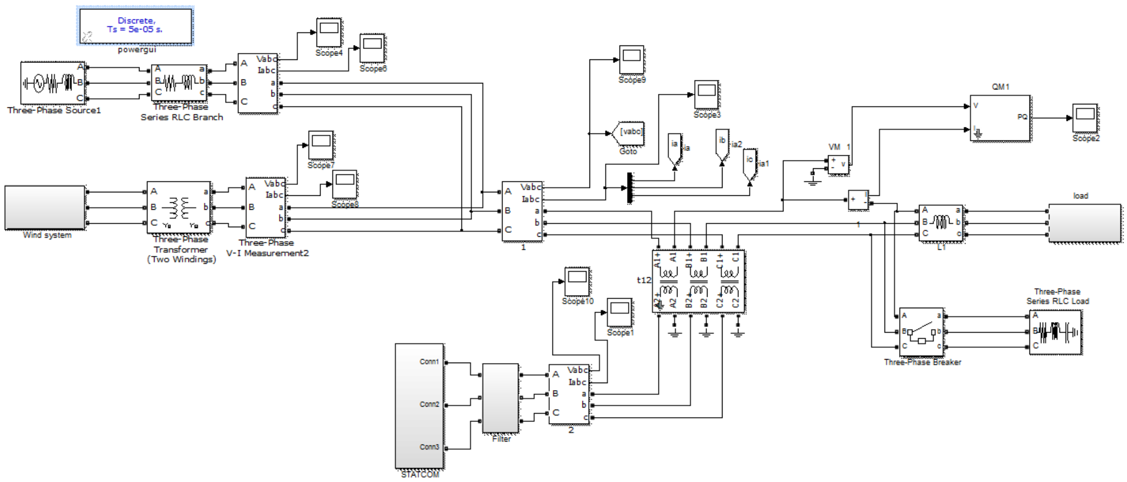

Figure 4: Simulation model of grid connected wind system with STATCOM

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Simulation model of grid connected wind generating system with STATCOM is shown in the Fig.3 and the parameters used for the simulation is listed in Table 1.

Table 1: System parameters

S.N.	Parameters	Ratings
1	Grid Voltage	3-phase ,415V,50 Hz
2	Induction Motor/Generator	3.35 kVA,415V, 50 Hz, P = 4, Speed = 1440 rpm, Rs = 0.01Ω, Rr=0.015Ω,Ls =0.06H,Lr=0.06H
3	Line Series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage = 800V, DC link Capacitance = 100 μF. Switching frequency = 2 kHz,
5	IGBT Rating	Collector Voltage =1200V, Forward Current =50A,Gate voltage =20V, Power dissipation = 310W
6	Load Parameter	Non-linear Load 25kW.

IV. SIMULATION RESULT AND DISCUSSION

In this paper various results are analyze with the help of system performance with and without STATCOM

In this system when wind energy system is connected to the grid then it brings the variations in the power which may affect the power quality of the system. When wind system is connected to the grid without STATCOM then it greatly affects the voltage and current of the system. It injecting voltage variations and power fluctuations also impact of harmonics on the system.

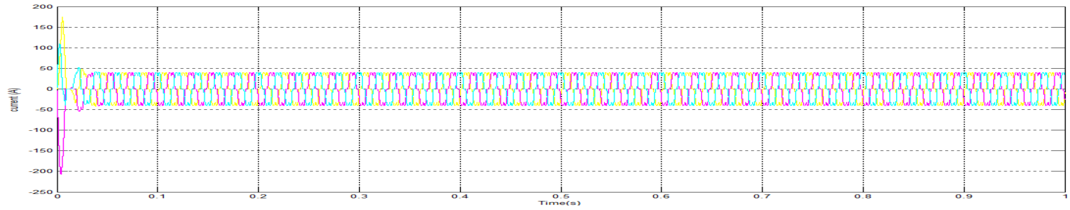

Figure 5: Current at PCC without STATCOM

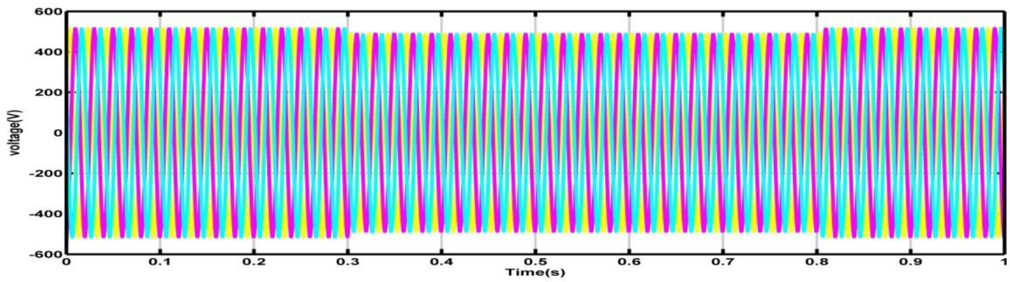

Figure 6: Voltage at PCC without STATCOM

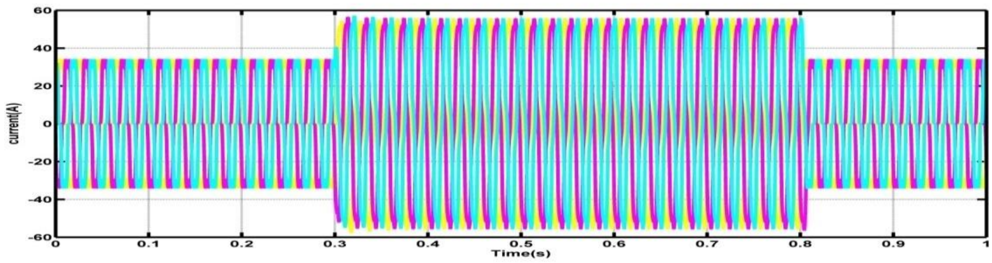

Figure 7: Current at PCC without STATCOM

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When extra non-linear load is connected to the system without STATCOM at time t= 0.3s to t= 0.8s then the system voltage has dip and hence it greatly disturb power quality of system. Also the FFT analysis of the system without STATCOM are 19.99% and 18.87% respectively. when system is compensated with energy equipped storage STATCOM then voltage at PCC is compensated and restored to the nominal voltage. Also the THD of current at PCC with STATCOM is greatly reduced to the 8.35% which is at acceptable levels.

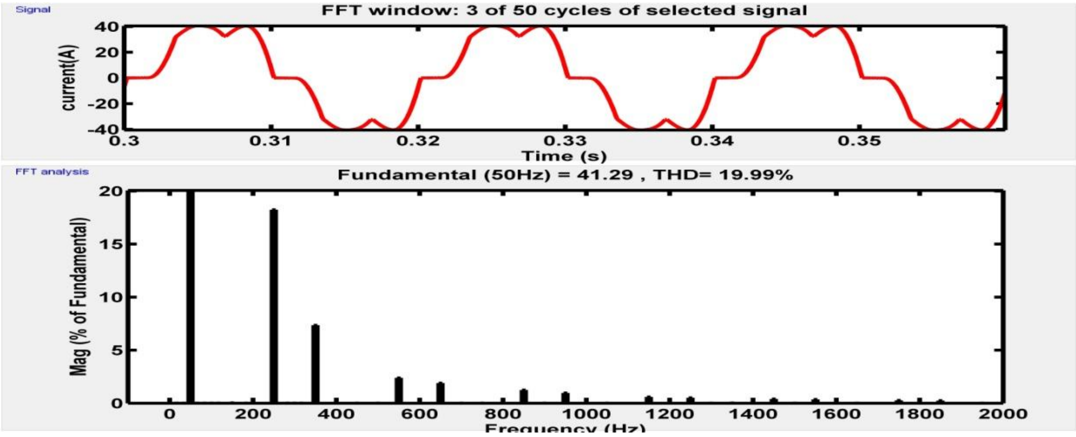

Figure 8: FFT analysis of current at PCC of system without STATCOM

The FFT analysis are shown in the above diagram for current at PCC and source side. The analysis shows that the THD percentage of current at PCC is 19.99% and THD percentage of current at source side is 18.87% which is beyond the limits of the standards and norms set by IEC and IEEE standards committee.

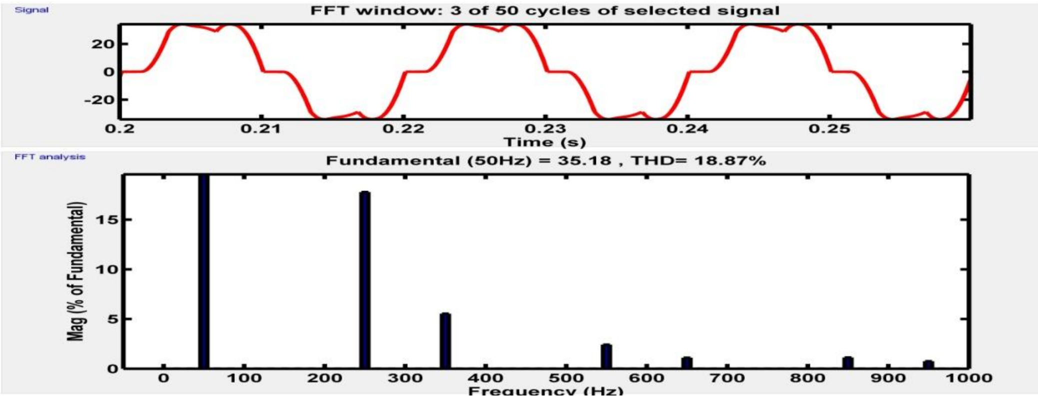

Figure 9: FFT analysis of source current of system without STATCOM

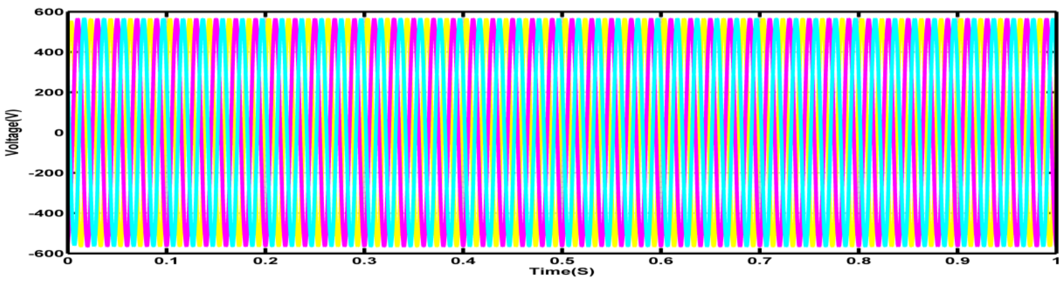

Figure 10: Voltage at PCC with STATCOM

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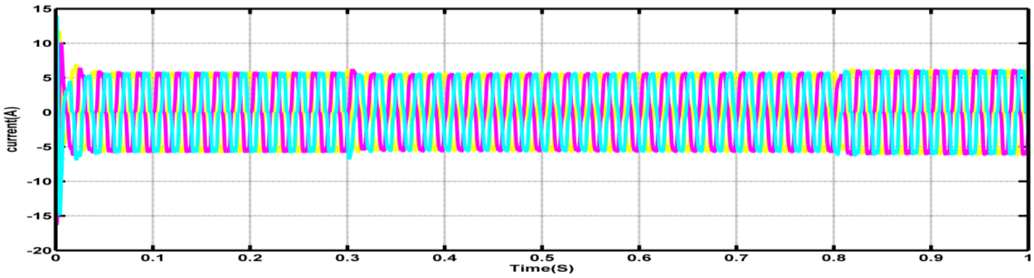

Figure 11: Current at PCC with STATCOM

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 0.3 to 0.8s in the system and how the STATCOM responds to the step change command for increase in additional load at 0.3 to 0.8s 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.

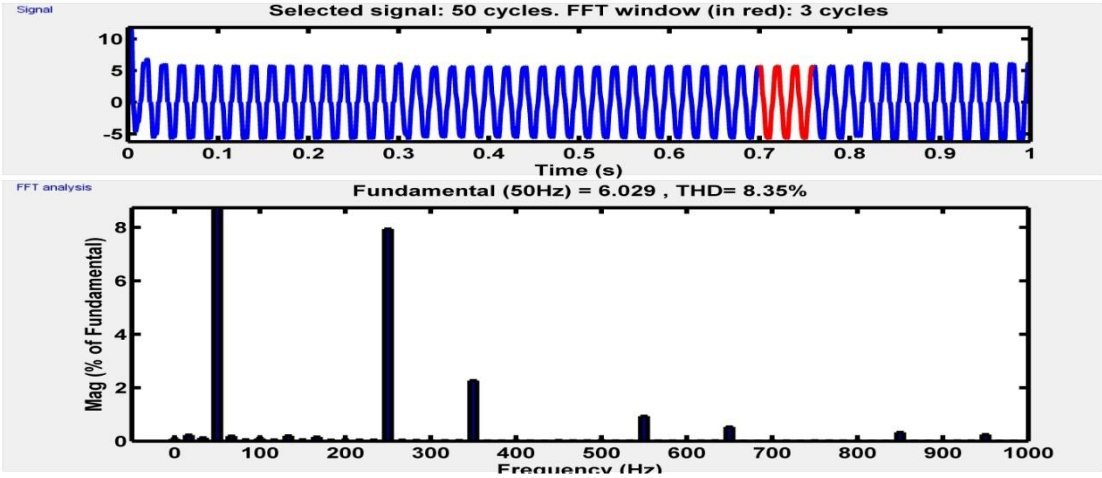

Figure 12: FFT analysis of current at PCC of system with STATCOM

The dynamic performance is also carried out by step change in a load, when applied at 0.3 s. This additional demand is fulfil by STATCOM compensator. Thus, STATCOM can regulate the available real power from source

VI.CONCLUSIONS

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 greatly reduced from 19.99% to 8.35% with the use of STATCOM. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it enhance the utilization factor of transmission line. The integrated wind generation and FACTS device with ESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfils the power quality norms as per the IEC standard 61400-21.

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