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# Power Quality improvement of grid connected wind energy system using STATCOM

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***Abstract-*** The Power Quality of the system is degraded when it is connected to a non conventional energy system. The injection of power degrades the grid performance. The proposed PI control scheme improves the system performance by injecting the compensation signal using STATCOM for maintaining the unity power factor at the source side, reactive power support to wind Generator and Load. The proposed PI controller improves the system dynamic performance. The proposed PI control improves the grid power quality by generating the counter signal to the harmonic signal, incompliance with IEEE standards

***Keywords—*** STATCOM, Power Quality, PI controller, BESS.

## I. INTRODUCTION

With increase in the demand for electricity due to increase in population and industrialization, the generation of power was really a challenge now a days. If we want to increase the power generated in conventional way i.e., by mean of non-renewable energy sources like coal, diesel, natural gases and similar fossil fuels, the pollution the pollution increases which degrades the environment and human life style. 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. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid 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. 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.

- Source side unity power factor
- Burden on grid decreases as reactive power issupplied by STATCOM to wind generator and Load.
- Reduce grid side current harmonics due to non linear load.

## II. POWER QUALITY ISSUES

*A. Power Quality Standards:*

*1. 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 thepower quality characteristics of the wind turbine [4]. The standard norms are specified.

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

b. IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.

c. IEC 61400-3-7: Assessment of emission limit for fluctuating load IEC 61400-12: Wind Turbine performance.

*2. 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.

*A.Voltage rise*

The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power Smax of the turbine, the grid impedances R and X at the point of common coupling and the phase angle , given in Eq.1.

$$\Delta u = S_{max}\,(R\cos\Phi - X\sin\Phi)/U^2 \quad (1)$$

Where $\Delta u$—voltage rise,
$S_{max}$ —max. apparent power,
Φ—phase difference,
U—nominal voltage of grid.The Limiting voltage rise value is <2 %

*B.Voltage dips (d)*

The voltage dips is due to startup of wind turbine and it causes a sudden reduction of voltage. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

$$d = K_u S_n/S \quad (2)$$

Where d is relative voltage change, $S_n$ is rated apparent power, $S_k$ is short circuit apparent power, and $K_u$ is sudden voltage reduction factor. The acceptable voltage dips limiting value is <3%.

*C.Flicker*

The measurements are made for maximum number of specified switching operation of wind turbine with 10- min period and 2-h period are specified, as given in Eq. 3.

$$P_{lt} = c(\psi k) S_n/S_k \quad (3)$$

Where $P_{lt}$ —Long term flicker.
c (ψk ) —Flicker coefficient
The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 h

*D. 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.

The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point of common connection. The total harmonic voltage distortion of voltage is given as in Eq. 4.

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1}}\, 100 \quad (4)$$

Where Vn is the nth harmonic voltage and $V_1$ is the fundamental frequency (50) Hz. The THD limit for 132 KV is < 3%. THD of current ITHD is given as in Eq. 5

$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_n^2}{I_1}}\, 100 \quad (5)$$

WhereIn is the nth harmonic current and *I*1is the fundamental frequency (50) Hz. The THD of current and limit for 132 KV is <2.5%.

*E. Grid Frequency*

The grid frequency in India is specified in the range of 47.5–51.5 Hz, for wind farm connection.

## III. POWER QUALITY IMPROVEMENT TOPOLOGY

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.1.

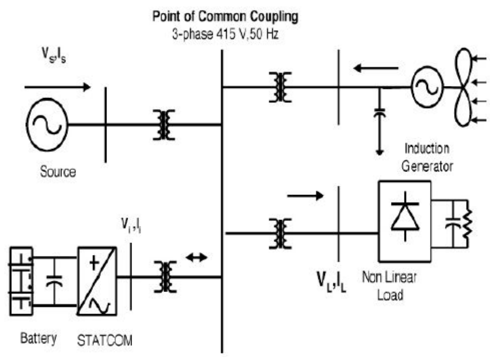


Fig.1.Grid Connected system for enhancement of power quality

*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

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3 \quad (6)$$

Where ρ(kg/m)is the air densityandA(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,and is given in Eq.7

$$P_{mech} = C_p P_{wind} \quad (7)$$

Where *Cp* is the power coefficient, depends on type and operating condition of wind turbine.This coefficient can be express as a function of tip speed ratio γ and pitch angle θ. The mechanical power produce bywind turbine is given in Eq.8.

$$P_{mech} = \frac{1}{2}\rho\Pi R^2 V_{wind}^3 C_p \quad (8)$$

Where R is the radius of the blade (m)

*B. BESS-STATCOM*

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS 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 BESS 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.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.

## IV. PI CONTROL SCHEME

It is possible to improve the STATCOM response by employing the PI controlmethod..Application of the PI involves choosing the *KP*, *KI* that provide satisfactory closed-loop performance. But the main method is based on trialand error, although time consuming. To achieve equilibrium among range control parameters, response speed, settling time and proper overshoot at all of which guarantee the system stability, and the PI is employed in Fig.2.

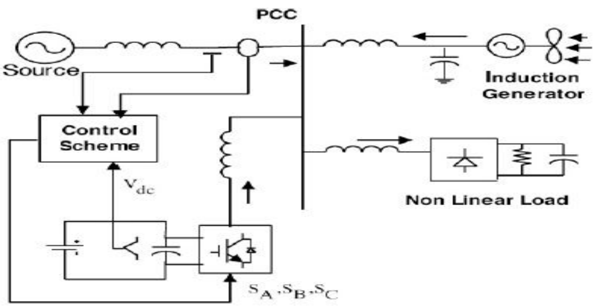


Fig.2. Operational Scheme

## V.SYSTEM PERFORMANCE

*A. Voltage Source Current Control—Inverter Operation*

The three phase injected current into the grid from STATCOM will cancel out the distortion caused by the nonlinearload and wind generator. The IGBT based three-phase inverter is connected to grid through the transformer. The generation of switching signals from reference current is simulated with PI controller. The choice of the current injection depends on the operating voltage and the interfacing transformer impedance. The compensated current for the nonlinear load and demanded reactive power is provided by the inverter. The real power transfer fromthe batteries is also supported by the controller of this inverter.

*B.STATCOM—Performance under Load Variations*

The wind energy generating system is connected with grid having the nonlinear load. The performance of the system ismeasured by switching the STATCOM at time s in the system and how the STATCOM responds to the step changecommand 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.

*C.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 source current waveforms without and with STATCOM are shown in Fig 4 and Fig.5. The simulation parameters are tabulated in Table- I.

| S.No | Parameters | Ratings |
|---|---|---|
| 1 | Grid voltage | 3-Phase, 415V,50Hz |
| 2 | Induction generator | 3.35KVA, 415V,Hz,P=4,Speed=1440rpm,Rr=0.01Ω , Rs=0.015Ω,Ls=Lr=0.06H |
| 3 | Line series Inductance | 0.05mH |
| 4 | Inverter Parameters | DC Link Voltage=800V, DCLink Capacitance=100μF, Switching Frequency=2kHz |
| 5 | IGBT rating | Collector Voltage=1200V, Forward Current=50A,GateVoltage=20V,Power Dissipation=310w |
| 6 | Load Parameter | Non-Linear Load=25kw |

**TABLE. I. System Parameters**

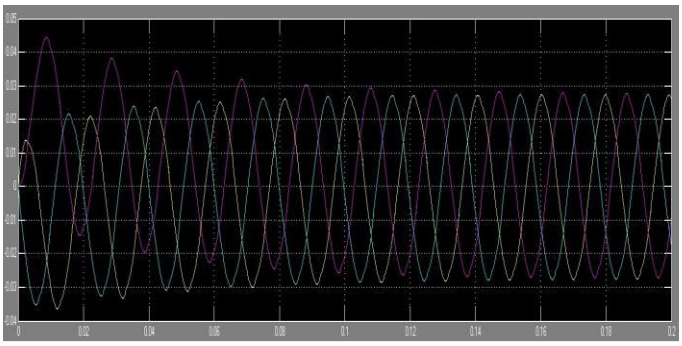

Fig.4. Current waveform without STATCOM

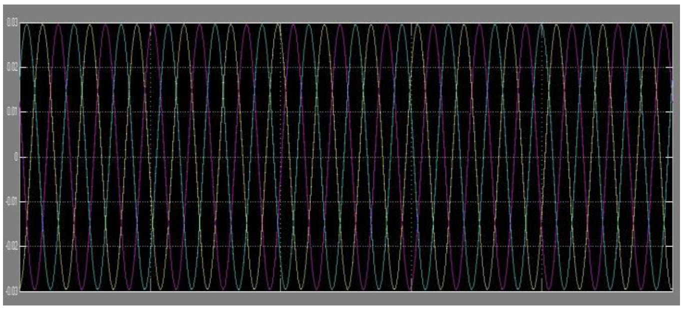

Fig.5. Current waveform with STATCOM

The THD of the proposed system with the employment of STATCOM and without STATCOM are shown in Fig.6 and Fig.7. The THD is reduced to 0.45%

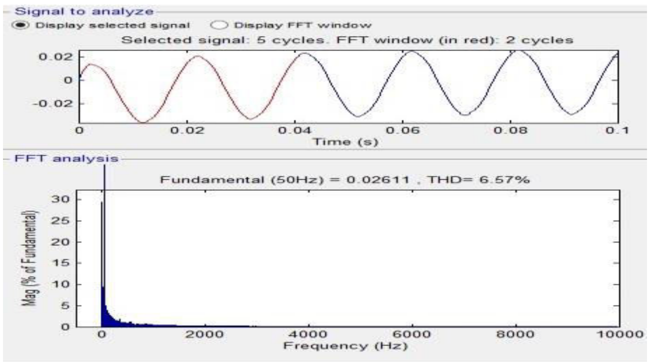


Fig.6. FFT Analysis without STATCOM

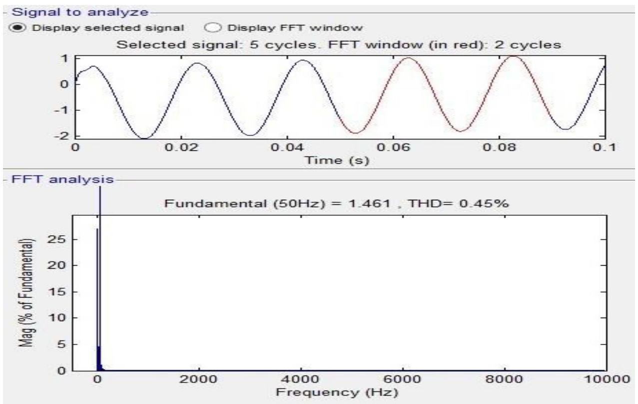


Fig.7. FFT Analysis with STATCOM

## VI.CONCLUSION

This paper enumerates the STATCOM with PI based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The power quality issues and its effects on the grid and electric utility are discussed. The proposed PI controller is modeled in MATLAB/SIMULINK environment. The proposed control algorithm effectively compensates the current harmonics by generating equal and opposite compensation signal to maintain the grid power quality. 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 the integrated wind generation and STATCOM with BESS have shown the outstanding performance in maintaining therated voltage profile and harmonic less source current. Thus the proposed PI control scheme in the grid connected system fulfils the power quality requirements in compliance with IEEE 519 and IEC 61400-21 standard.

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