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Performance Evaluation of Static Compensation for Grid Connected System for Power Quality Improvement Features

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ABSTRACT- Renewable energy sources, which are expected to be a promising alternative energy source, can bring new challenges when connected to the power grid. Like conventional power plants, wind power plants must provide the power quality required to ensure the stability & reliability of the power system. Increasing amount of wind turbine is connected to electrical power system in order to mitigate the negative environmental consequence of conventional electricity generation. While connecting wind turbine to grid it is important to understand source of disturbance that affect the power quality. In general voltage & frequency must be kept as stable as possible. This stability can be obtained by using FACTS devices. Recently voltage-source or current-source inverter based various FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillation. Some of those are used also to improve transient & dynamic stability of wind power generation system (WPGS). The power arising out of the wind turbine when connected to a grid system concerning the power quality measurements, are: active power, reactive power, voltage sag, voltage swell, flicker, harmonics, and electrical behavior of switching operation. This paper proposes a control scheme based on instantaneous 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 The FACTS Device (STATCOM) control scheme for the grid connected wind energy generation system to improve the power quality is simulated using MATLAB/SIMULINK.

Keywords- wind power, distribution network, induction generator, STATCOM, reactive power, harmonics, Power quality.

I.INTRODUCTION

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. 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. The integration of wind energy [1] into existing power system presents technical challenges and that requires 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. The issue of power quality is of great importance to the wind turbine [2]. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28 000 wind generating turbines are successfully operating all over the world. 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. 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.

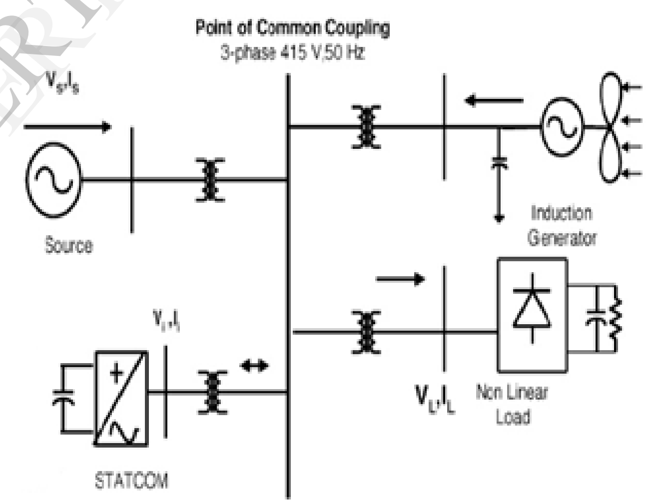

Fig. 1. Grid connected system for power quality improvement.

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 [3] 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 [4]. 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[6]. A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency. It changes the shape of the current waveform from a sine wave to some other form and also create harmonic currents in addition to the original (fundamental frequency) AC current. The most used unit to compensate for reactive power in the power systems are either synchronous condensers or shunt capacitors, the latter either with mechanical switches or with thyristor switch, as in Static VAR Compensator (SVC). The disadvantage of using shunt Capacitor is that the reactive power supplied is proportional to the square of the voltage. Consequently, the reactive power supplied from the capacitors decreases rapidly [9] when the voltage decreases [3] .To overcomes the above disadvantages; STATCOM is best suited for reactive power compensation and harmonic reduction. It is based on a controllable voltage source converter (VSC).

Static Synchronous Compensator (Statcom):

The STATCOM is a shunt-connected reactive-power compensation device that is capable of generating and/ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals. Specifically, the STATCOM, which is a voltage-source converter which when fed from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor.

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.

A STATCOM can improve power-system Performance like:

1. The dynamic voltage control in transmission and distribution systems,
2. The power-oscillation damping in power- transmission systems,
3. The transient stability;
4. The voltage flicker control; and
5. The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both Capacitive and inductive) power.

II. WIND DRIVEN INDUCTION GENERATOR WITH STATCOM

The STATCOM is a three-phase voltage source inverter having a capacitor connected to its DC link. Fig 2 shows a neutral clamped topology of VSI for STATCOM application.

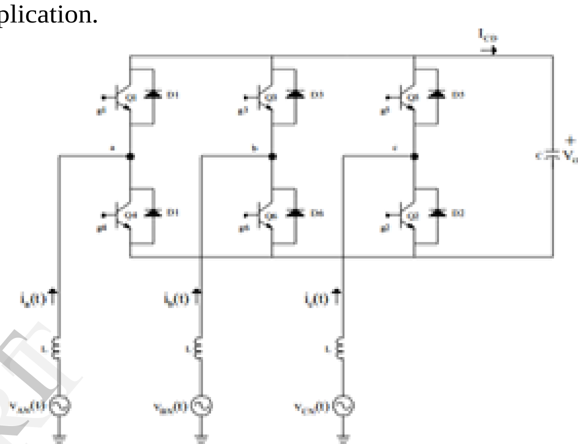

Fig 2.Six Pulse VSI STATCOM

But in the proposed system with STATCOM, reactive power requirement of induction generator and load is supplied by the STATCOM instead of grid. The STATCOM injects a compensating current of variable magnitude and frequency component at the PCC [8]-[10]. The shunt connected ST A TCOM is connected to the PCC through interfacing inductors. The induction generator and load is also connected to the PCC [13]. The STATCOM compensator output is controlled, so as to maintain the power quality norms in the grid system.

REFERENCE CURRENT GENERATION FOR STATCOM:

Reference current for the ST ATCOM is generated based on instantaneous reactive power theory [7]-[l0]. A STATCOM injects the compensation current which is a sum of reactive component current of IG, non-linear load and harmonic component current of non-linear load.

Pq theory gives a generalized definition of instantaneous reactive power, which is valid for sinusoidal or non sinusoidal, balanced or unbalanced, three-phase power systems with or without zero sequence currents and/or voltages.

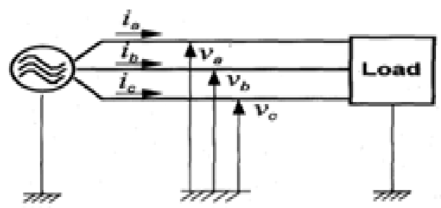

Fig .3 Three phase power system

Fig.3 shows the three phase power system, instantaneous Voltages, V_a, V_b, V_c in volts and instantaneous currents, ia,ib,ic in amps of a three phase system are expressed as instantaneous space vectors ' v' and 'i' given by (1)

$$v = \begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} \qquad i = \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \tag{1}$$

'p' is the instantaneous active power of a three-phase circuitin Watts, given by (2)

$$P = v.\, i \tag{2}$$

Instantaneous active power of a three-phase circuit ' p' is the scalar product of instantaneous voltage and current. It is the product of the sum of three phase voltages and current, given by (3)

$$P = V_a + V_b + V_c \tag{3}$$

Instantaneous active power consists of average component and oscillatory component as given by (4)

$$P = P_{dc} + P_{ac} \tag{4}$$

'Pdc' is the average component of instantaneous active power in watts and 'Pac' is the oscillatory component of instantaneous active power in watts. ' q' is the instantaneous reactive power of a three-phase circuit in VAR, given by (5)

$$q = \| v \times i \| \tag{5}$$

Instantaneous reactive power of a three-phase circuit ' q' is the vector product of instantaneous voltage and current, given by (6)

$$q = \begin{pmatrix} q_a \\ q_b \\ q_c \end{pmatrix} = \begin{pmatrix} \begin{vmatrix} v_b & v_c \\ i_b & i_c \end{vmatrix} \\ \begin{vmatrix} v_c & v_a \\ i_c & i_a \end{vmatrix} \\ \begin{vmatrix} v_a & v_b \\ i_a & i_b \end{vmatrix} \end{pmatrix} \tag{6}$$

Total current is the sum of instantaneous active, reactive and harmonic component of current given by (7)

$$i = i_p + i_q + i_h \tag{7}$$

'i_p', 'i_q' and 'i_h' are of instantaneous active, reactive and harmonic component of current respectively. 'i_p' is the instantaneous active component current in amps given by (8)

$$i_p = \frac{p_{dc} . v}{v_a{}^2 + v_b{}^2 + v_c{}^2} \tag{8}$$

Since it is a non linear load reactive component and harmonic component current are used as a reference current for STATCOM. The reference current for the three phases as given by (9),(10),(11).

$$i_{af^*} = i_{ap^*} - i_{as^*} = i_{aq} + i_{ah} \tag{9}$$

$$i_{bf^*} = i_{bp^*} - i_{bs^*} = i_{bq} + i_{bh} \tag{10}$$

$$i_{cf^*} = i_{cp^*} - i_{cs^*} = i_{cq} + i_{ch} \tag{11}$$

'i_{af}'' , 'i_{bf}'' and 'i_{ef}'' are the STATCOM reference current of three phases respectively.' i_{ap}*', 'i_{bp}*' and 'i_{ep}'' are fundamental active component current of three phases Respectively. Similarly 'i_{as}''' 'i_{bs}'' and 'i_{cs}'' are the STATCOM source current of three phases respectively. 'iaq', 'ibq' and 'ieq , are the sum of instantaneous reactive Component current of induction generator and load of three phases respectively. 'i_{aq}', 'i_{bq}' and 'i_{eq}' are the instantaneous harmonic component current load of three phases respectively.

III. HYSTERESIS CONTROLLER

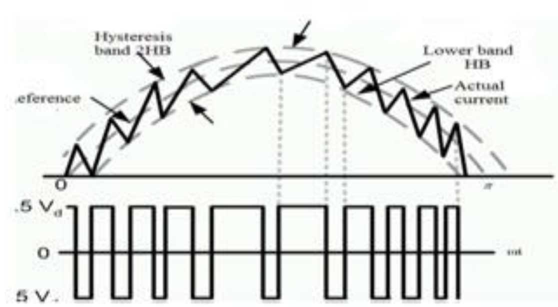

Fig.4. Hysteresis current Modulation

With the hysteresis control, limit bands are set on either side of a signal representing the desired output waveform [11-12]. The inverter switches are operated as the generated signals within limits. The control circuit generates the sine reference signal wave of desired magnitude and frequency, and it is compared with the actual signal. As the signal exceeds a prescribed hysteresis band, the upper switch in the half bridge is turned OFF and the lower switch is turned ON. As the signal crosses the lower limit, the lower switch is turned OFF and the upper switch is turned ON. The actual signal wave is thus forced to track the sine reference wave within the hysteresis band limits.

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IV.MATLAB MODELEING AND SIMULATION RESULTS

Here Simulation results are presented for two cases. In case one load is balanced non linear with Battery Energy Storage System (BESS) case two load is balanced non linear with PV energy system for regulating the voltage.

Case 1: Balanced non linear with Battery Energy Storage System (BESS):

Performance of STATCOM connected to a weak supply system for power factor correction and load balancing. The variation of performance variables such as supply voltages (*v*sa, *v*sb and *v*sc), terminal voltages at PCC (*v*ta, *v*tb and *v*tc), supply currents (*i*sa, *i*sb and *i*sc), load currents (*i*la, *i*lb and *i*lc), STATCOM currents (*i*ca, *i*cb and *i*cc) and DC link voltage (*V*dc) are shown below.

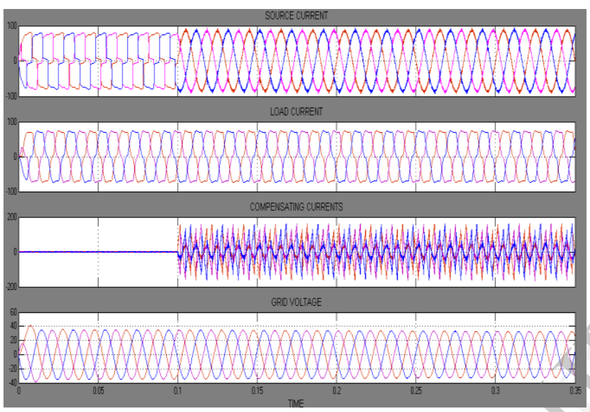

Fig.5. Simulation results for Balanced Non Linear Load with BESS (a) Source current. (b) Load current. (c) Inverter injected current. (d) grid voltage.

Figure 5 shows the source current, load current and compensator current and grid voltage plots respectively. Here compensator is turned on at 0.1 seconds.

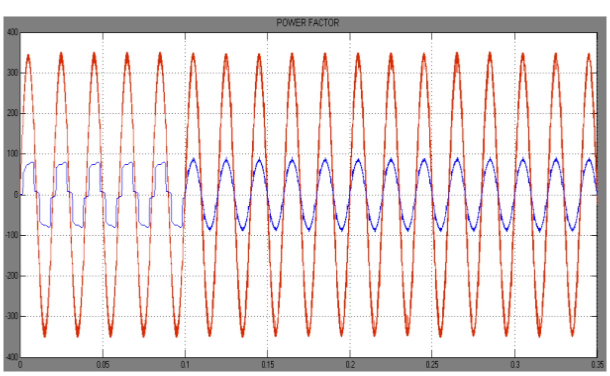

Fig.6. Simulation results power factor for Non linear Load

Figure 6 shows the power factor it is clear from the figure after compensation power factor is unity.

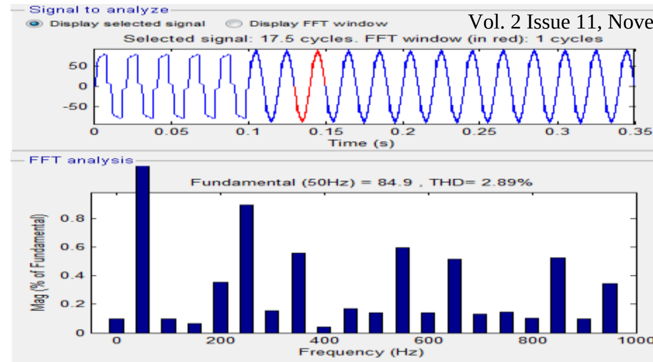

Fig.7 FFT Analysis of Phase A Source Current

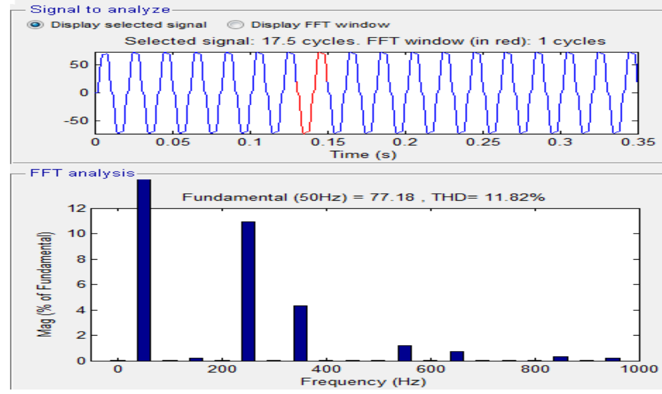

Fig. 8 FFT Analysis of Phase A Load Current.

Figure 7, 8 shows the FFT Analysis of Source Current & Load Current with Balanced Non-Linear Load with BESS.

Case 2: Balanced non linear with PV Energy System:

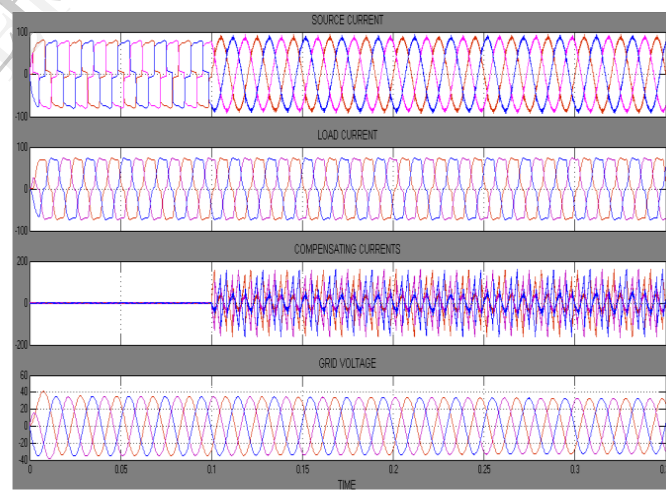

Fig.9. Simulation results for Balanced Non Linear Load with PV Energy System (a) Source current. (b) Load current. (c) Inverter injected current. (d) grid voltage.

Figure 9 shows the source current, load current and compensator current and grid voltage plots respectively. Here compensator is turned on at 0.1 seconds with PV interfaced to compensate the active power as well as reactive power in the power system network to balance the system parameters.

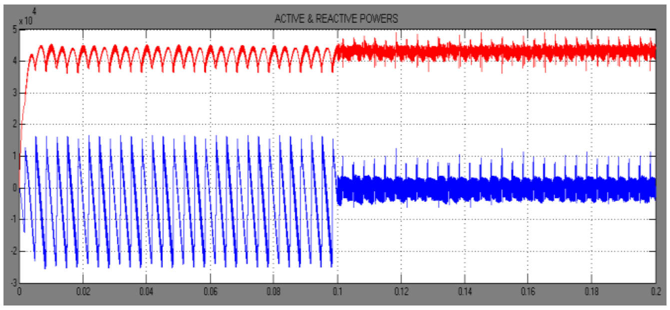

Fig. 10 Active & Reactive Power

Figure 10 shows the Active & Reactive Power of System, as before 0.1 sec our compensator is in off condition that's why power are changed to different values, whenever compensator turn on, we get constant power to maintain system in balance condition.

V. CONCLUSION

STATCOM system is an efficient mean for mitigation of PQ disturbances introduced to the grid by STATCOM compensator is a flexible device which can operate in current control mode for compensating voltage variation, unbalance and reactive power and in voltage control mode as a voltage stabilizer. The latter feature enables its application for compensation of dips coming from the supplying network. The simulation results show that the performance of STATCOM system has been found to be satisfactory for improving the power quality at the consumer premises. STATCOM control algorithm is flexible and it has been observed to be capable of correcting power factor to unity, eliminate harmonics in supply currents and provide load balancing. It is also able to regulate voltage at PCC by using interfaced PV system. The control algorithm of STATCOM has an inherent property to provide a self-supporting DC bus of STATCOM. It has been found that the STATCOM system reduces THD in the supply currents for non-linear loads within limits provided by IEEE.

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BIOGRAPHY

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