PQ Theory Controlled Statcom for Grid Connected Wind Driven Induction Generator for Power Quality Improvement

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ABSTRACT- Now a days Power electronic converters, ever more widely used in industrial, commercial, and domestic applications, suffer from the problem of drawing non-sinusoidal current and reactive power from the source. Like conventional power plants, wind power plants must provide the power quality required to ensure the stability & reliability of the power system. 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 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. Finally PQ theory is proposed and applied to statcom for power quality improvement. Proposed concept simulated and verified by using Matlab/simulink software.

Keywords- PQ theory, wind power, distribution network, induction generator, STATCOM, reactive power, harmonics and 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.

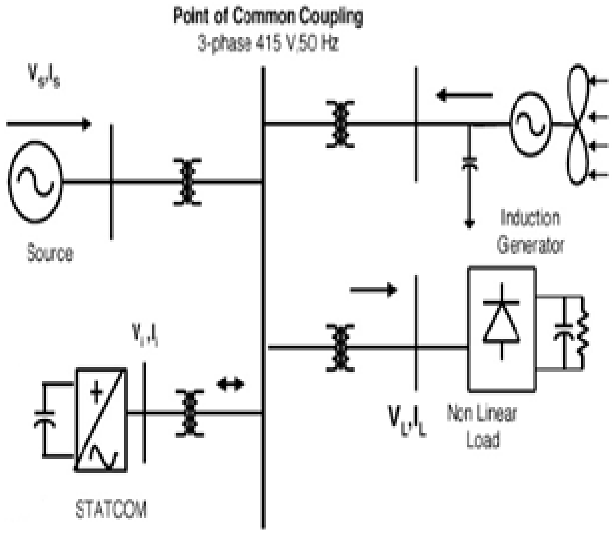

Fig.1. Grid connected system for power quality improvement.

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.

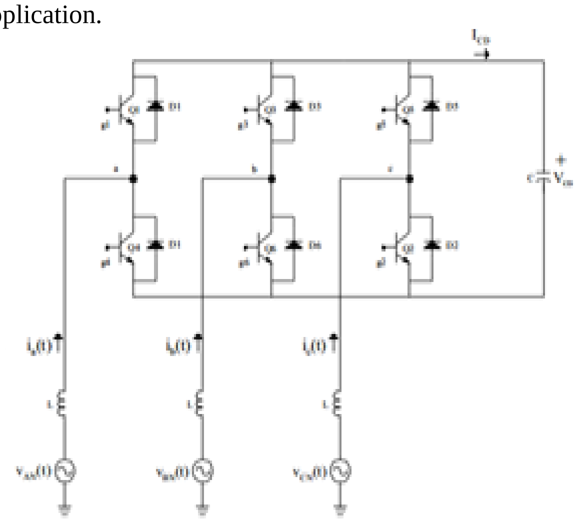

Fig 2.Six Pulse VSI STATCOM

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 [10]. The STATCOM compensator output is controlled, so as to maintain the power quality norms in the grid system.

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.

III. PQ THEORY

Reference current for the ST ATCOM is generated based on instantaneous reactive power theory. 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

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systems with orwithout zero sequence currents and/or voltages.

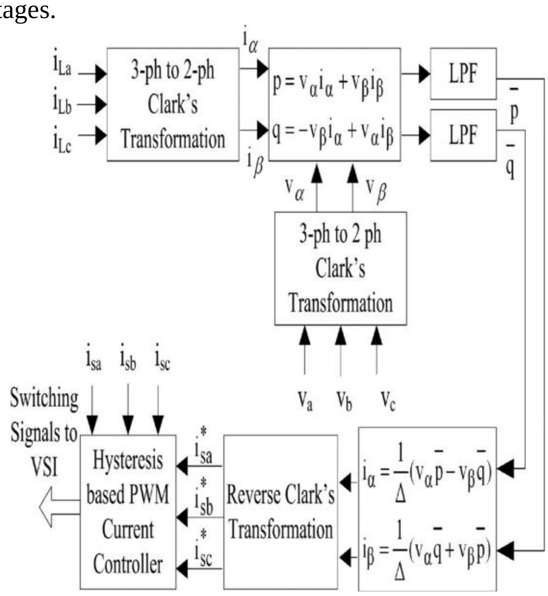

Fig.3Block diagram of the reference current extraction using IRP theory.

IRP theory was initially proposed by Akagi. This theory is based on the transformation of three-phase quantities to two-phase quantities in α–β frame and the calculation of instantaneous active and reactive power in this frame.

A basic block diagram of this theory. Sensed inputs *va*, *vb*, and *vc*and *iLa*, *iLb*, and *iLc*are fed to the controller, and these quantities are processed to generate reference current commands (i^*sa, i^*sb, and i^*sc), which are fed toa hysteresis-based pulse width modulated (PWM) signal generate final switching signals fed to the DSTATCOM; therefore, this block works as a controller for DStatcom.

va=Vmsin(ωt)

vb=Vmsin(ωt− 2π/3)

vc=Vm sin(ωt− 4π/3) (3)

and the respective load currents are given as

iLa =$ILan$ sin {n(ωt) –θan}

ILb =$ILbn$sin {n(ωt− 2π/3) − θbn}

iLc=$ILcn$sin {n(ωt− 4π/3) − θcn} .

In a–b–c coordinates, a, b, and c axes are fixed on the sameplane, apart from each other by 2π/3. The instantaneous space vectors va and iLa are set on the "a" axis, and their amplitude varies in positive and negative directions with time. This is true for the other two phases also. These phasors can be transformed into α–β coordinates using Clark's transformation as follows where α and β axes are the orthogonal coordinates. Conventional instantaneous power for three-phase circuit can be defined as

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix}$$

p = $v\alpha i\alpha$+ $v\beta i\beta$(5)

where$p$ is equal to conventional equation

p = $vaia$+ $vbib$+ $vcic$. (6)

Similarly, the IRP is defined as

q = −$v\beta i\alpha$+ $v\alpha i\beta$. (7)

IV POWER QUALITY ISSUES

A. 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.

B.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. The rapid switching gives a large reduction in lower order harmonic current com- pared 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 [9]. The total harmonic voltage distortion of voltage is given as in (8)

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1}} 100 \quad (8)$$

Where Vn is the nth harmonic voltage and V1 is the fundamental frequency (50) Hz. The THD limit for 132 KV is < 3 %.THD of current ITHD is given as in (9)

$$I_{THD} = \sqrt{\sum \frac{I_n}{I_1}} 100 \quad (9)$$

Where In is the nth harmonic current and I1 is the fundamental frequency (50) Hz. The THD of current and limit for 132 KV is <2.5%.

C.Reactive Power

Traditional wind turbine is equipped with induction generator. 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. Thus the sensitive equipments may be subjected to over/under voltage, over/under frequency operation and other disadvantage of safety aspect. The effective control of reactive power can improve the power quality and stabilize the grid. The suggested control technique is capable of controlling reactive power to zero value at point of common connection (PCC).

D.Wind Turbine Location in Power System

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

V.MATLAB MODELEING AND SIMULATION RESULTS

Here Simulation results are presented follows it 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.

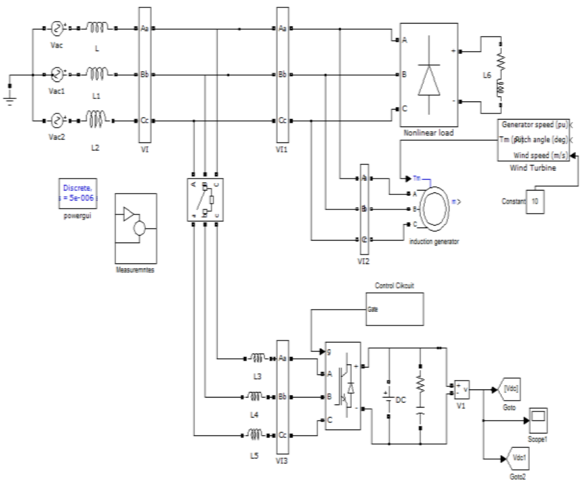

Fig.4 Matlab/simulink model of three phase separately excited induction generator feeding non linear load

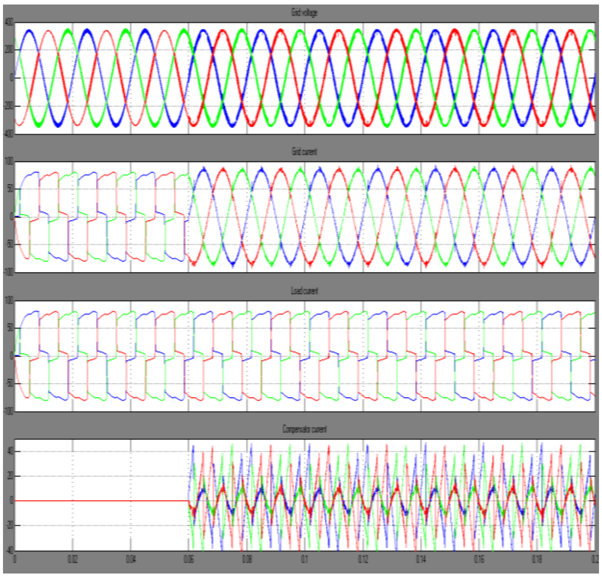

Fig.5 Three phase Grid voltage, grid current, load current, compensator current

Above figure 5 shows the Statcom ON and OFF conditions are presented 0 to 0.06 Statcom OFF and the reaming is ON condition the variation shown in above figure 5.

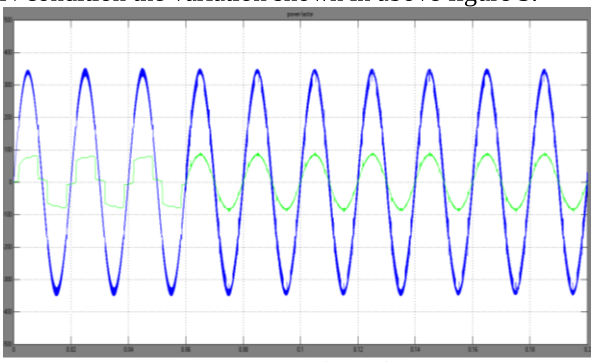

Fig.6. Simulation results power factor for Non linear Load

In above figure shows the power factor for non-linear load in this Statcom 0 to 0.06 Statcom OFF and the reaming is ON

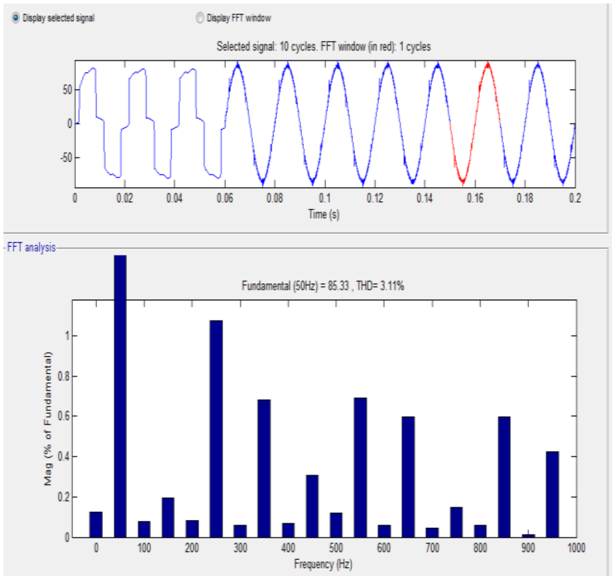

Fig.7 FFT Analysis of Phase A Source Current Using pq theory

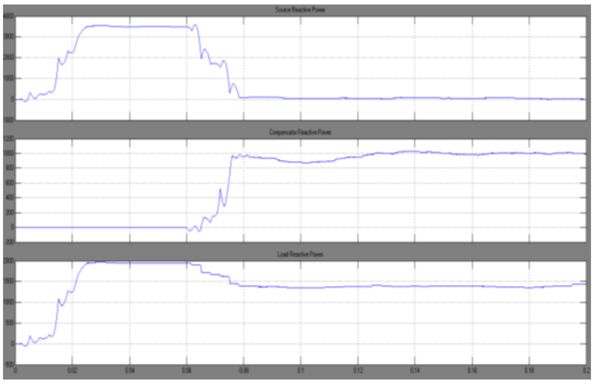

Fig.8 Source reactive power, compensator reactive power, load reactive power

VI. CONCLUSION

This concept working on control technique is PQ theory applied to the proposed system. 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. 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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