

Shunt Connected STATCOM Control Grid of Wind Turbine System for Balanced and Unbalanced Non Linear Loads

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ABSTRACT

Injection of wind power into the grid affects the power quality resulting in poor performance of the system. 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 reactive power theory for compensating reactive power requirements of wind turbine generator as well as the harmonics produced by balanced and unbalanced non linear loads. The proposed control scheme is simulated using MATLAB/SIMULINK in power system block set

Keywords -STATCOM, Wind Turbine Generator, Instantaneous Reactive power (IRP), Hysteresis Control

I. INTRODUCTION

Injecting wind power into the power system grid effects power quality problems such as reactive power compensation, voltage regulation, harmonics produced in the grid. We know that induction generators reactive problems may come due to non linear loads balanced and unbalanced loads some kind of power electronic devices such as arc lamps welding machines etc. this all are switching actions harmonics will present in the system so that complete grid effects and also it effects on source side. Thus, the network needs to manage for such 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 affects power quality [1]. 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 [2]. 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. Fig 1 shows the block diagram of grid connected system. In this 3-phase separately excited induction generator feeding non linear load has been presented. A STATCOM is connected at the point of common coupling with this system in order to compensate the reactive power requirements of induction generator as well as load and also to reduce harmonics produced by the non linear load

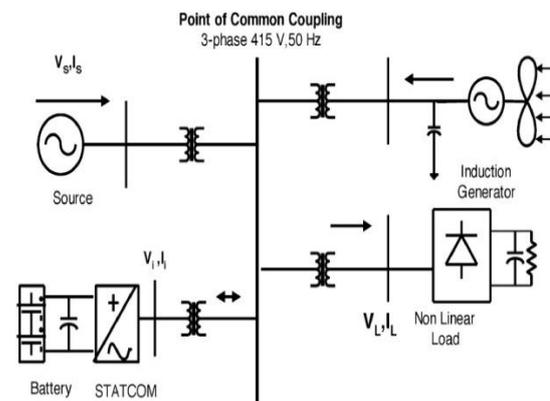


Fig.1 Schematic diagram of grid connected wind energy systems

The proposed scheme Shunt Connected STATCOM Control Grid of wind Turbine System for Balanced and Unbalanced Non linear Loads to improve power quality has following objective.

- It supplies the reactive power required wind turbine system
- Maintain unity power factor source side
- Harmonics are eliminated by STATCOM and produced by balanced unbalanced non linear loads

This paper is organized as follows. Section II discusses Shunt connected reactive power compensation device (STATCOM). Section III, IV and V discuss wind Turbine generator, STATCOM control scheme and hysteresis current controller for STATCOM respectively. Section VI and VII discusses simulation results and conclusion respectively

II. SHUNT CONNECTED REACTIVE POWER COMPENSATION DEVICE (STATCOM)

The STATCOM is a shunt connected reactive power compensation device that is capable of generating and absorbing reactive power and in which the output can be varied to control the specific parameters of a grid. It's three phase voltage source inverter having capacitor connected to its DC link in earlier case reactive power requirements of induction generator and load supplied by the grid but proposed system with STATCOM reactive power requirement of induction generator and load I supplied by the STATCOM instead of grid. The STATCOM injects a compensation current of variable magnitude and frequency component at the PCC [4].

A STATCOM based control technology has been proved for improving the power quality which can technically manages 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
5. The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

III. WIND TURBINE GENERATOR

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 under in (1)

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

Where ρ (kg/m) is the air density and A (m²) 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 C_p of the wind turbine, and is given in(2)

$$P_{mech} = C_p P_{wind} \quad (2)$$

Where C_p 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 and pitch angle. The mechanical power produced by wind turbine is given in (3)

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

IV. The Instantaneous reactive power (IRP)

The Instantaneous reactive power (IRP) p- q Theory is based on the Clarke Transform of voltages and currents in three-phase systems into alpha and beta orthogonal coordinates. Its development was a response to the demand to instantaneously compensate the reactive power originally this theory was formulated by Akagi Kanaazawa and Nabae for the active power filter control [7]-[8].

Power properties of three phase system are described by the IRP p-q theory in two orthogonal alpha and beta coordinates in terms of two p and q instantaneous powers. They are referred to as the instantaneous real and the imaginary power or more commonly as the instantaneous active and reactive powers according to Authors the instantaneous imaginary (reactive) power q was introduced on the same basis as the conventional real power p in three phase circuits and then the instantaneous reactive power in each phase was defined with the focus on the physical meaning and the reason for naming. Because of it the IRP p-q Theory has become a very attractive theoretical tool not only for the active power filter control but also for analysis and identification of power properties of three phase systems with no sinusoidal voltages and currents [9]-[10].

As long as the IRP p-q Theory is considered only as a controller then, the interpretation of power phenomena as suggested by this theory is irrelevant. It is sufficient for an to be acceptable that it enables us to reach the control objectives. However To be considered as a power theory the IRP p-q Theory should also satisfy other expectations first, it should provide a credible interpretation of power properties and phenomena in power systems power properties of here phase system are expressed by the IRP p-q Theory in terms of only two, active and reactive, p and q Theory in terms of only two active and reactive p and q powers.

V. STATCOM Control scheme

The control scheme approach is based on injecting the currents into the grid 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 system operation scheme block diagram shown Fig.2

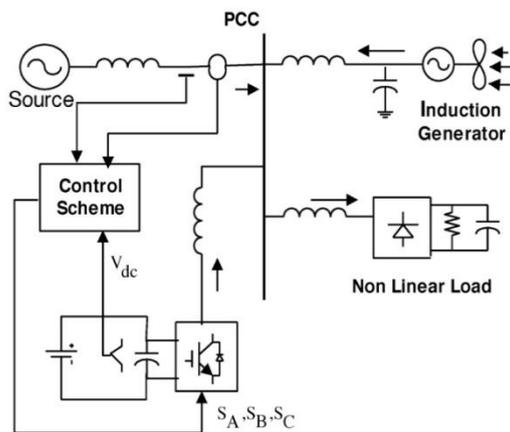


Fig.2 System operational scheme in grid system

The controller need to measure of several variables such as three-phase source current i_{sabc} , DC voltage V_{dc} , inverter current i_{sabc} with the help of sensor. The current control block, receives an input of reference current i_{sabc}^* and actual current i_{sabc} are subtracted so as to activate the operation of STATCOM in current control mode. In three-phase balance system, the RMS voltage source amplitude is calculated at the voltage source amplitude is calculated at the sampling frequency from the source phase voltage (V_{sa}, V_{sb}, V_{sc}) and is expressed, as sample template V_{sm} , sampled peak voltages [6].

VI. Hysteresis current controller for STATCOM

A controlled current inverter is required to generate this compensating current. Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current waveform [11]-[12]. This method controls the switches in an inverter asynchronously to ramp the current through an inductor up and down so that it tracks a reference current signal. Hysteresis current control is the easiest control method to implement. A hysteresis current controller is implemented with a closed loop control system and is shown in diagrammatically Fig.3

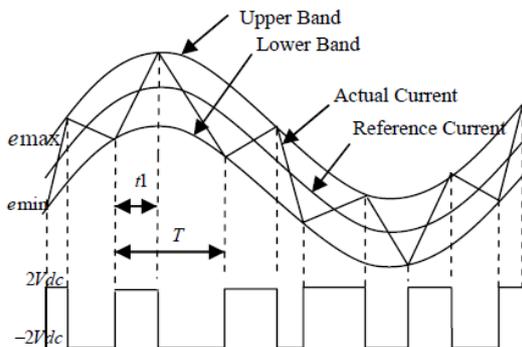


Fig.3 Hysteresis current modulation

An error signal, $e(t)$, is used to control the switches in an inverter. This error is the difference between the desired current, $i_{ref}(t)$, and the current being injected by the inverter, $i_{actual}(t)$. When the error reaches an upper limit, the transistors are switched to force the current down. When the error reaches a lower limit the maximum and minimum values of the error signal are e_{min} and e_{max} respectively.

VII. MATLAB/SIMULINK MODELING OF STATCOM

A. Power Circuit Modeling

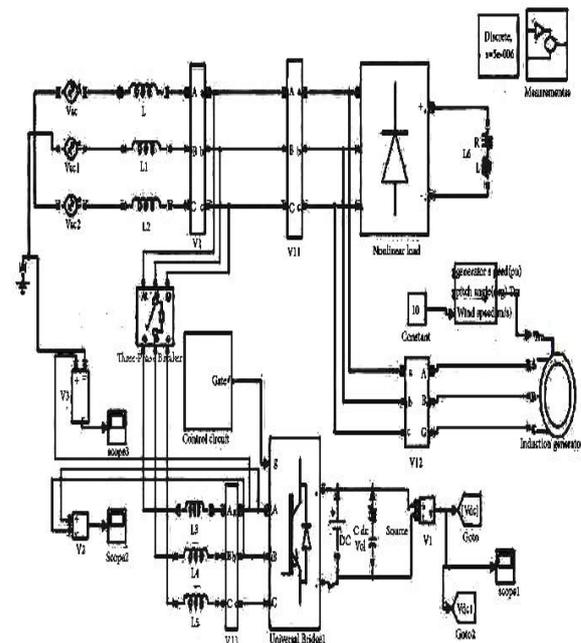


Fig.4 Matlab/Simulink Model of STATCOM power circuit

Fig.4 shows the complete MATLAB model of STATCOM along with control circuit. The power circuit as well as control system are modeled using Power System Blockset and Simulink. The grid source is represented by three-phase AC source. Three-phase AC loads are connected at the load end. STATCOM is connected in shunt and it consists of PWM voltage source inverter circuit and a DC capacitor connected at its DC bus. An IGBT-based PWM inverter is implemented using Universal bridge block from Power Electronics subset of PSB. Snubber circuits are connected in parallel with each IGBT for protection. Simulation of STATCOM system is carried out for linear and non-linear loads. The linear load on the system is modeled using the block three-phase parallel R-L load connected in delta configuration. The non-linear load on the system is modeled using R and R-C circuits connected at output of the diode rectifier. Provision is made to connect loads in parallel so that the effect of sudden load addition and removal is

studied. The feeder connected from the three-phase source to load is modeled using appropriate values of resistive and inductive components.

B. Control Circuit Modeling

Fig. 5 shows the control circuit of STATCOM with two PI controllers. One PI controller regulates the DC link voltage while the second PI controller regulates the terminal voltage at PCC. The in-phase components of STATCOM reference currents are responsible for power factor correction of load and the quadrature components of supply reference currents are to regulate the AC system voltage at PCC.

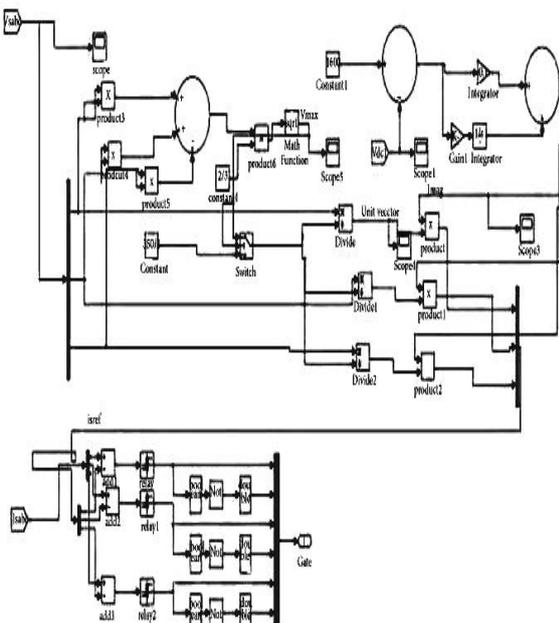


Fig.5 Matlab/Simulink Model of Control circuit

The output of PI controller over the DC bus voltage (I_{spdr}) is considered as the amplitude of the in-phase component of supply reference currents and the output of PI controller over AC terminal voltage (I_{spqr}) is considered as the amplitude of the quadrature component of supply reference currents. The instantaneous reference currents (i_{sar} , i_{sbr} and i_{scr}) are obtained by adding the in-phase supply reference currents (i_{sadr} , i_{sbrd} and i_{scdr}) and quadrature supply reference currents (i_{saqr} , i_{sbqr} and i_{scqr}). Once the reference supply currents are generated, a carrier less hysteresis controller is employed over the sensed supply currents (i_{sa} , i_{sb} and i_{sc}) and instantaneous reference currents (i_{sar} , i_{sbr} and i_{scr}) to generate gating pulses to the IGBTs of STATCOM. The controller controls the STATCOM currents to maintain supply currents in a band around the desired reference current values. The hysteresis controller generates appropriate switching pulses for six IGBTs of the VSI working as STATCOM.

VIII. Simulation Results

Here Simulation results presented for two cases

Case 1: Balanced & unbalanced non liner load without STATCOM

Performance of without STATCOM Fig.5.This plot shows 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}).

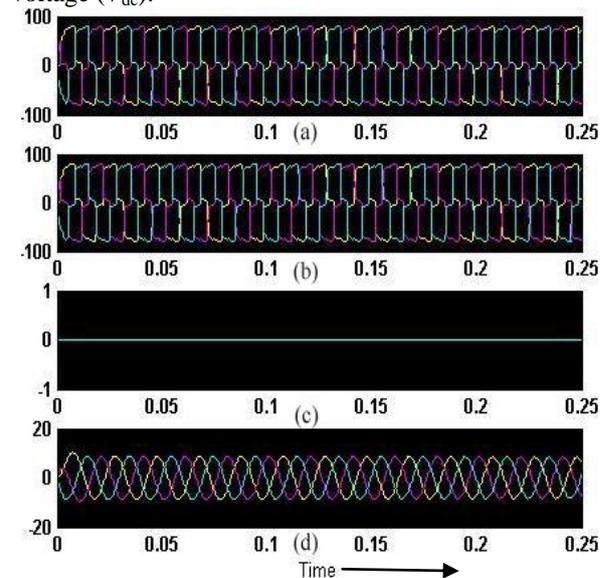


Fig.6 Simulation results for three phase non liner loads without STATCOM. (a) Source current. (b) Load current (c) compensator current (d) grid voltage.

Fig.6 shows the source current load current and compensator currents and grid voltage plots respectively. Here compensator is turned off

Case 2: Balanced & unbalanced non liner load with STATCOM

Performance of with STATCOM Fig.5.This plot shows 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}).

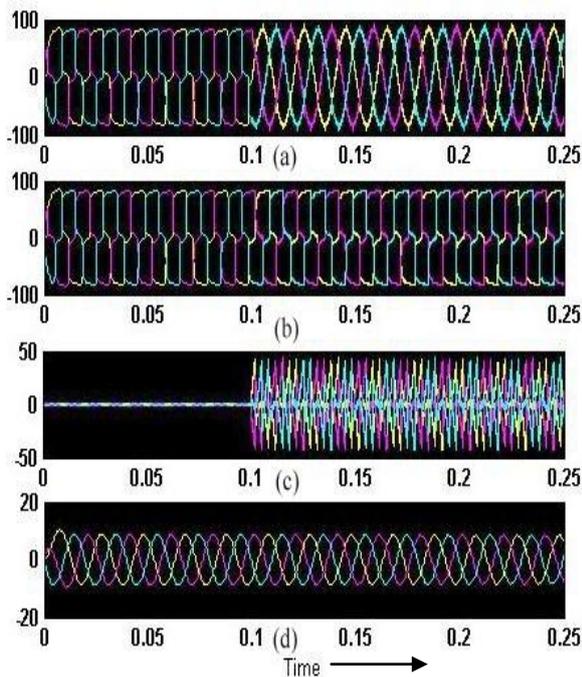


Fig.7 Simulation results for three phase nonlinear loads with STATOCM.(a) Source current (b) Load current (c) compensator current (d) Grid voltage

Fig.7 shows the source current load current and compensator currents and grid voltage plots respectively. Here compensator is turned on at 0.1 seconds.

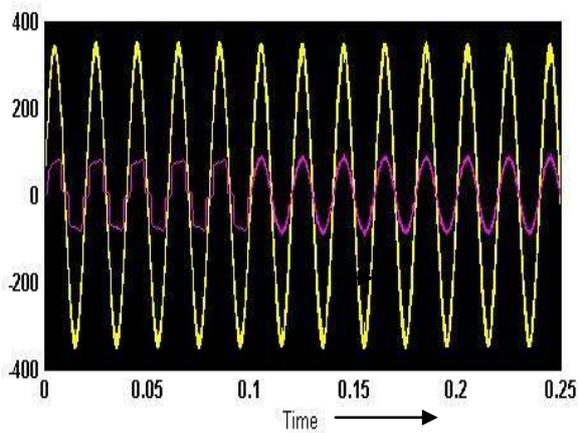


Fig.8 Simulation results power factor Non linear Load

Fig.8 shows the power factor it is clear from the figure compensation power factor is unity.

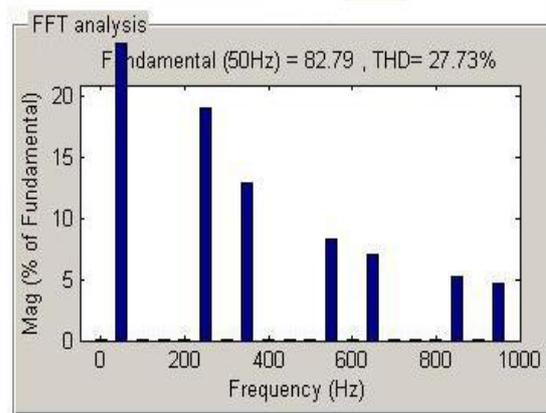


Fig.9 FFT analysis of source current before compensation

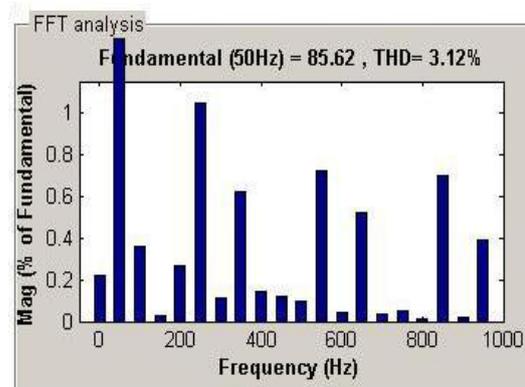


Fig.10 FFT analysis of source current after compensation

IX. Conclusion

This paper presents shunt connected STATCOM Control Grid of wind Turbine System for Balanced and Unbalanced Non linear Loads. The control system for the STATCOM is simulated using MATLAB/SIMULINK. The Simulation results shows the grid voltage and current are in-phase, making the power factor unity, which implies that the reactive power demand of Induction generator and load is no longer, fed by the grid rather it is supplied by the STATCOM. Also the shape of the grid current is almost sinusoidal and the % THD has been reduced from 27.73 % to 3.12 % after compensation. The proposed control scheme has improved the power quality requirement of a low voltage grid connected wind driven IG system feeding a non-linear load

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