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Power Quality Improvement in Distribution System Using STATCOM Fed With IRP Control

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Abstract - *A current condition of renewable energy source is helpful part in electrical power generation. The renewable energy source is interface to point of common coupling (PCC), because of increase electrical power generation. In this case we are interface renewable energy source to grid to full fill the demand. This paper presents Static Compensator (STATCOM) with Interfacing wind energy source (WES) modelled in the MATLAB SIMULINK toolbox for the mitigation of the power quality issues in the distribution system. STATCOM is one of the custom power device used in distribution system for power conditioning. STATCOM is developed for the compensating reactive power demanded by non-linear and unbalanced load. Also power factor of the source is improved and the Total Harmonic Distortion in the source currents is reduced. STATCOM can correct voltage harmonics by injecting the reactive current into the system. Instantaneous reactive power theory is used for obtaining reference source current for controlling STATCOM. The performance of the STATCOM by using the IRP theory for unbalanced and nonlinear load is demonstrated with the MATLAB simulation results.*

Key Words; **STATCOM, Instantaneous reactive power (IRP), wind energy source (WES), Point of common coupling (PCC)**

1.INTRODUCTION

To customer demand is to continuous quality and reliable of electrical power supply. Present condition electrical power demand of customer is increases but another side electrical power generation is decreases. Because electrical power generation use coal, fuel, etc. Cost of this source is more, which is limited sources also. So customer demand is not equal to generation of electrical power. Above condition solution is use to renewable energy source in electrical generation. Renewable energy source many advantage. It is cost less, abundantly available in nature, pollution free. In renewable energy source solar, wind, etc use for electrical power generation. The proposed system we use wind energy source. In this paper wind energy source is interface to electrical power grid. Wind energy source same problem is occurs. In wind blades natural air is not continuously flow. In this case speed of wind turbine is not constant. Speed of wind turbine is varies than automatically speed of generator is also continuously varies. Result of this condition is output of wind generator is not constant. So this situation wind power generation system (WPGS) is not possible to interface the electrical grid, because power quality problem occurs in the point of common coupling (PCC). We use novel idea using FACT devices and interface wind energy source to grid, proposed system FACT devise use as STATCOM. STATCOM is use for absorption of current and injection of reactive current at point of common coupling. As compare to other FACT devises STATCOM is less cost, faster in operation, small size and ability to provide active and reactive power.

Control schemes reported in the literature for controlling of the STATCOM are synchronous reference frame (SRF) theory, current compensation using DC bus regulation, instantaneous reactive power(IRP) theory, a scheme based on the neural network technique. Out of all these techniques most commonly used the theories are synchronous reference frame (SRF) theory and instantaneous reactive power (IRP) theory.In this paper MATALAB based simulation of the STATCOM is carried out using instantaneous reactive power (IRP) theory for compensation of the reactive power, unbalance, reducing total harmonic distortion (T.H.D) and improving power factor of the system.

2. THE PROPOSED SYSTEM

A distribution feeder connected to unbalanced and nonlinear load is shown in the below Fig. 1. Working performance of the wind energy base STATCOM using instantaneous reactive power theory (IRP) is analyzed by the modeling system shown in Fig.1 in MATLAB Simulink tool.

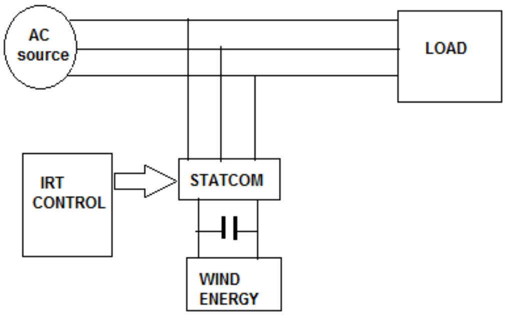

Fig-1: The proposed system

3.WIND POWER GENERATION SYSTEM (WPGS)

Wind energy is a renewable, clean, and free energy source for energy production. Wind energy system (WES) requires no connection to an existing power source, and they could be combined with other power sources to increase system reliability and could be installed and upgraded as wind firm; more wind turbine could be added as power demand increases

In this case we use wind power generation system. Wind energy source output is variable. We use induction generator. Induction generator is not requiring separated filed circuit. It is variable input and output accepts. Available wind power is

$$P_w = \frac{1}{2}\rho a V_w^3$$

Where

ρ is air density Kg/m3,

a,is area swept out by turbine blade m^2,

v_w= Wind speed mtr/s.

Kinetic energy of wind is not possible to extract. It is extract a fraction of power in wind called as power co-efficient (Cp) of wind turbine.

$$P_m = C_p P_{wind}$$

Power co-efficient can be expressing a function of tip speed ratio and pitch angle. Wind turbine produce mechanical power is given by

$$P_{mech} = C_p \frac{1}{2}\rho\pi r^2 V_w^3$$

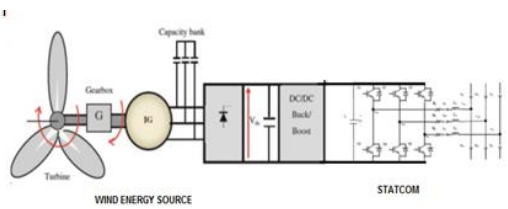

Fig-2: STATCOM with wind energy source

We use novel idea using FACT devices and interface wind energy source (WES) to grid, proposed system FACT devise use as STATCOM. STATCOM is use for absorption of current and injection of reactive current at point of common coupling. As compare to other FACT devises STATCOM is less cost, faster in operation, small size and ability to provide active and reactive power.

4 INSTANTANEOUS REACTIVE POWER THEORY

The P-Q theory was introduced by H.Akaqi in 1983.The speed response of converter is used and they generate reactive power and harmonic component to compensate for harmonics or reactive power. The conventional approaches to the analysis of power are not sufficient in terms of RMS or average value of variables. Time domain analysis has evolved a new manner to analyse and understand the energy flow in nonlinear circuit. The p-q theory is based on the set of instantaneous power defined in time domain. No restrictions are imposed on the voltage or current waveform and it can be applied on the three phase system with or without neutral. The p-q theory uses Clarks' transformation to converter from a-b-c coordinates to α-β-0 coordinates for both three phase currents and voltages and then defines instantaneous powers on these coordinates. The p-q theory uses Clarke transformation or α-β-0 transformation which consists of a real matrix that transforms three phase components into α-β-0 stationary reference frames. In this method reference current is generated from the instantaneous active and reactive power of the non-linear load.

4.1 CLARKE TRANSFORMATION

The three phase current or voltage waveforms from *a-b-c* coordinates system transforms to α-β-*0* coordinates. It corresponds to an algebraic transformation, known as *Clarke* transformation, where coordinates α-β are orthogonal to each other, and coordinate corresponds to the zero-sequence component.

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_{ca} \\ V_{cb} \\ V_{cc} \end{bmatrix}$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix}$$

4.2 INVERSE CLARKE TRANSFORMATION

The α-β-*0* coordinate system is again transformed to three phase *a-b-c* coordinates system. This corresponds to an algebraic transformation, known as Inverse Clarke transformation.

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix}$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \\ V_o \end{bmatrix}$$

4.3 INSTANTANEOUS POWER

The conventional instantaneous power on the three phase circuit can be defined as

Where p is equal to the conventional equation

$$p = v_\alpha i_\alpha + v_\beta i_\beta$$

The Instantaneous Reactive power q is defined as

$$q = v_\alpha i_\beta - v_\beta i_\alpha$$

The Instantaneous active power p and reactive power q are defined as

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

P and q can resolved a mean value and an alternating value.

$$q = \bar{q} + \tilde{q}$$

$$p = \bar{p} + \tilde{p}$$

$\bar{p}$ and $\bar{q}$ are created from positive sequence components of the load current and $\bar{p}$ and $\bar{q}$ from the harmonic components of load current.

The oscillating components of p and the entire q should be supplied by the active power filter. So the required compensating currents can be calculated as

4.4 CALCULATION OF REFERENCE COMPENSATING CURRENTS I_{CA*}, I_{CB*}, I_{CC*}

Compensating current $i_{c\alpha}$ and $i_{c\beta}$ is obtain by the Instantaneous active power p and reactive power q

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} \bar{P} \\ q \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \bar{P} \\ q \end{bmatrix}$$

Instantaneous active current on the α axis $i_{c\alpha*}$

$$i_{c\alpha*} = \frac{v_\alpha}{v_\alpha^2 + v_\beta^2} \bar{p} - \frac{v_\beta}{v_\alpha^2 + v_\beta^2} q$$

Instantaneous reactive current on the β axis $i_{c\beta*}$

$$i_{c\beta*} = \frac{v_\beta}{v_\alpha^2 + v_\beta^2} \bar{p} + \frac{v_\alpha}{v_\alpha^2 + v_\beta^2} q$$

The Instantaneous reactive currents $i_{c\alpha*}$, $i_{c\beta*}$ are transformation into the three phase reference compensating currents i_{ca*}, i_{cb*}, i_{cc*}

$$\begin{bmatrix} i_{ca*} \\ i_{cb*} \\ i_{cc*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha*} \\ i_{c\beta*} \end{bmatrix}$$

The three phase reference compensating currents $i_{ca*}, i_{cb*}, i_{cc*}$ are given to hysteresis current controller

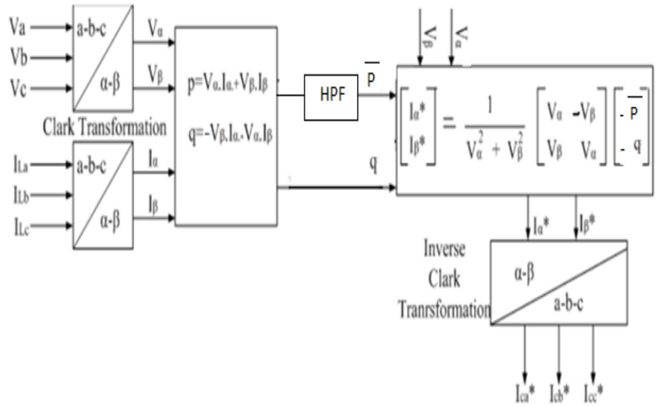

Fig-3: calculation of reference compensating currents $i_{ca*}, i_{cb*}, i_{cc*}$

Harmonics are generated by nonlinear loads and are injected into power system. The calculated compensating three phase currents using instantaneous reactive power theory $i_{ca*}, i_{cb*}, i_{cc*}$ are used as reference currents for hysteresis current controller. The Hysteresis current controller will generate pulses given to the controller switches. Finally controller will generate compensating currents $i_{ca*}, i_{cb*}, i_{cc*}$ and injected into power system. Therefore reactive power demand in the power system decreases. By the way, with the reduction in reactive power demand, the Harmonics in the system are reduced. The value of THD is decreased and power factor is improved

5. SIMULATION RESULTS

Case1: with out statcom

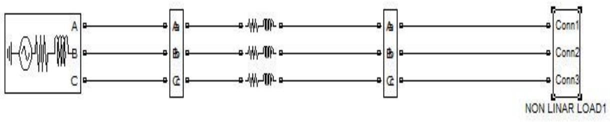

Fig-4: with out STATCOM

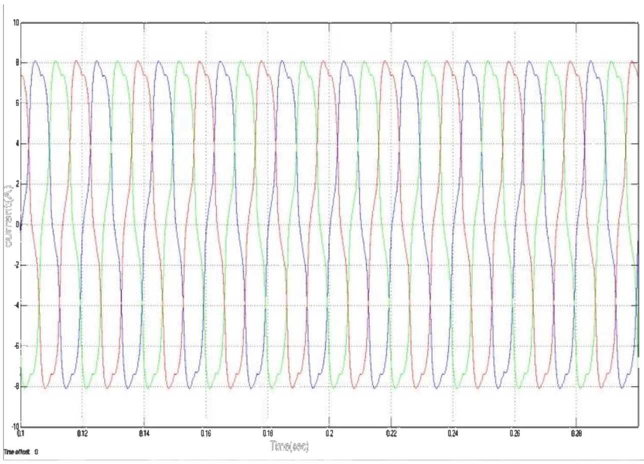

Fig-5: current wave form at the source with out STATCOM

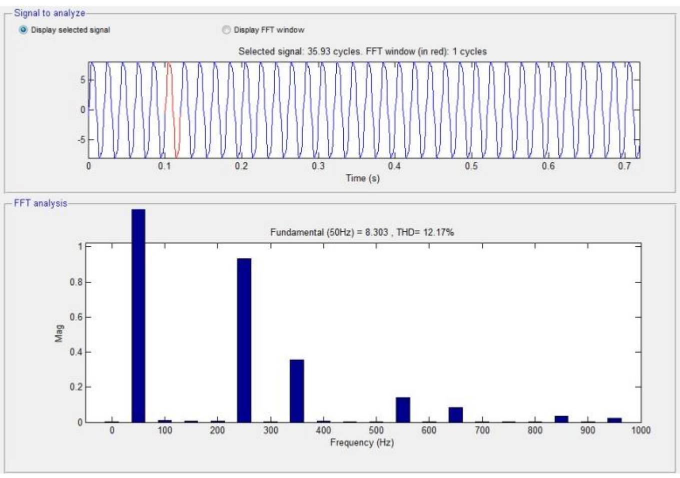

Fig-6: FFT analysis for current wave form at the source with out STATCOM

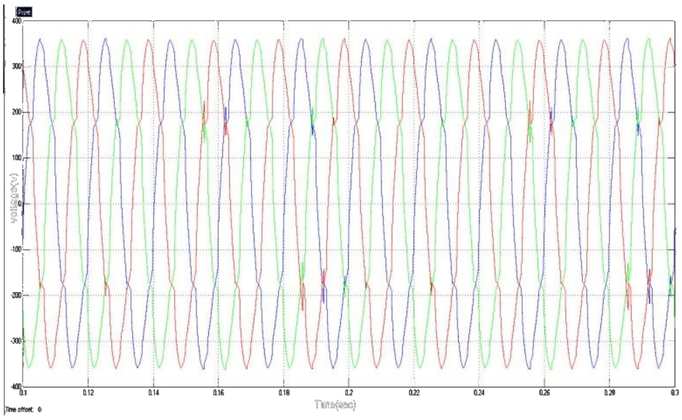

Fig-7: voltage wave form at the source with out STATCOM

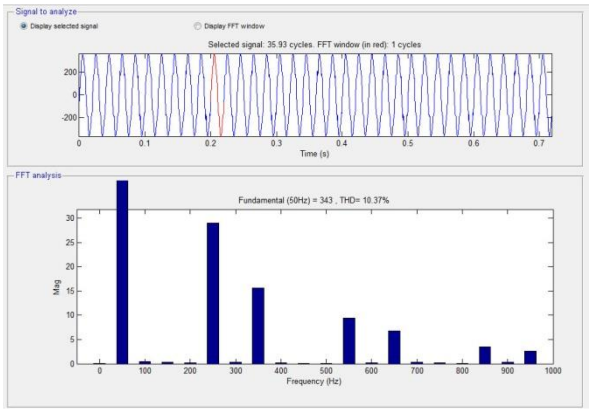

Fig-8: FFT analysis for voltage wave form at the source with out STATCOM

Case 2 with STATCOM

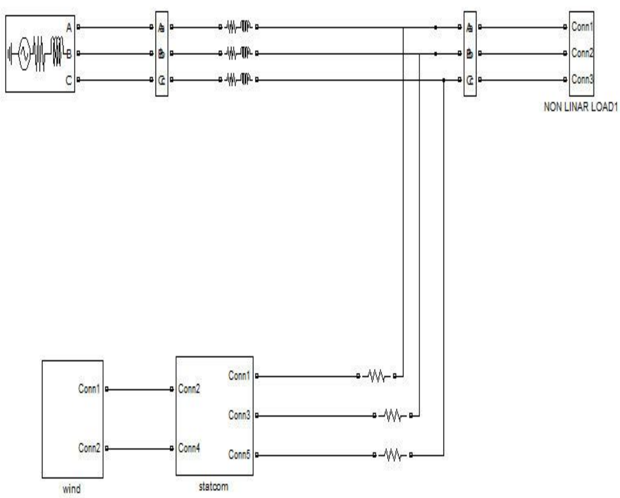

Fig-9: with STATCOM

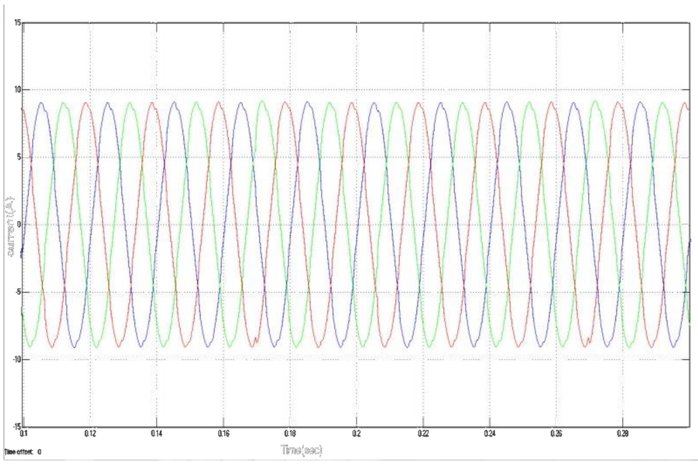

Fig-10: current wave form at the source with STATCOM

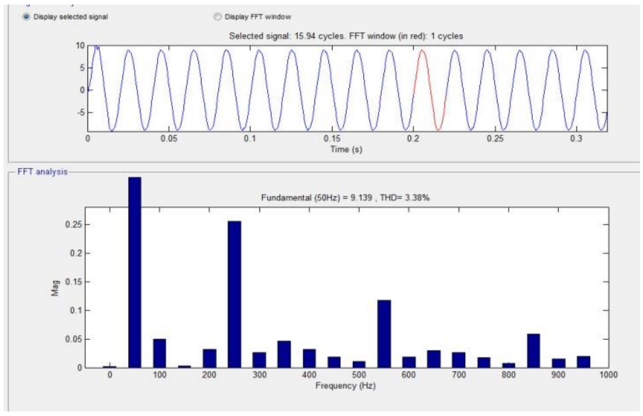

Fig-11:FFT analysis for current wave form at the source with STATCOM

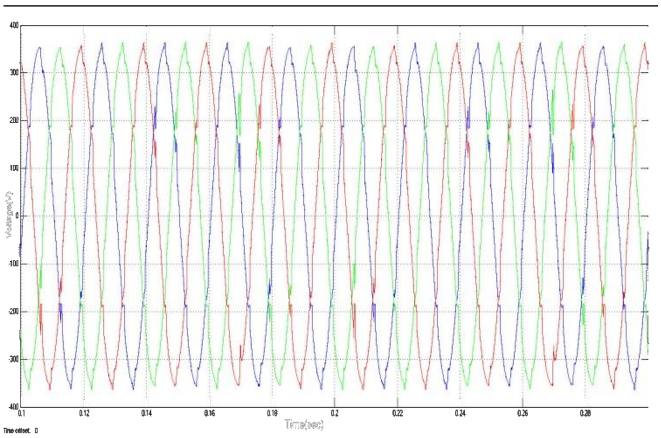

Fig-12:voltage wave form at the source with STATCOM

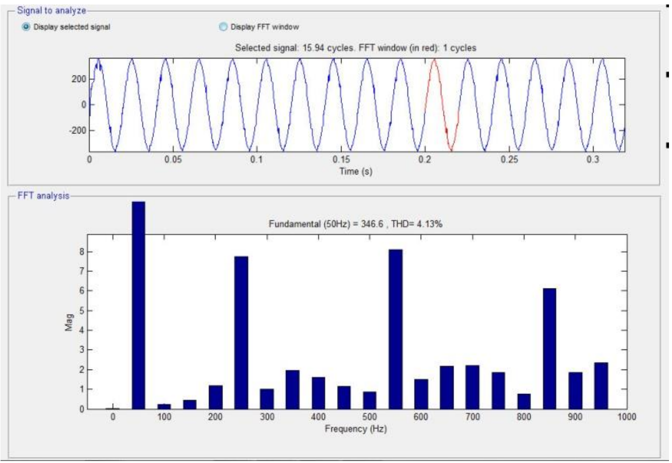

Fig-13:FFT analysis for voltage wave form at the source with out STATCOM

Results

Table: 5.1 comparison of results with and with out STATCOM

Power quality issues	Without STATCOM	With STATCOM
THD –I (current)	12.17	3.38
THD –v (voltage)	10.37	4.13
REACTIVE POWER	801	256.7
POWER FACTOR	0.91	0.99

6.CONCLUSION

In this system we are use FACT device STATCOM and improve power quality at point of common coupling. Also using STATCOM for to maintain constant voltage of wind energy system and interface between electrical power grids. Custom power devices can be used for power quality improvement in the distribution system, IRP theory for controlling the STATCOM reduces the voltage and current harmonic components are also reduced. Power factor of the system is improved and maintained equal to unity.

7.REFERENCE

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