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ANALYSIS OF VOLTAGE AND CURRENT RELAETD POWER QUALITY IN HYBRID SOLAR P-V /WIND SYSTEM USING UPQC

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ABSTRACT

The real problems in diminution of power quality occurs due to the rapid growth of non-linear load that leads to sudden decrease of source voltage for a few seconds i.e sag, swell, harmonics in source and load current, voltage unbalance etc. All these problems can be compensated by using Unified Power Quality Controller (UPQC) and the operation of UPQC depends upon the available voltage across capacitor present in DC link. If the capacitor voltage is maintained constant then it gives satisfactory performance. The proposed research is basically on designing of Photo Voltaic (PV) /Wind energy fed to the DC link capacitor of UPQC so as to maintain proper voltage across it and operate the UPQC for power quality analysis. The said model is simulated in Matlab and results are verified by using FFT analysis. The proposed PV/ Wind energy-UPQC is design in Matlab simulation for reduction of voltage sag, swell, interruption of voltage, harmonics in load current and compensation of active and reactive power.

Keywords: Capacitor, diode, efficiency, Photo Voltaic, resistance, Unified Power Quality Controller (UPQC), voltage, wind turbine.

INTRODUCTION

The use of electricity is increasing very rapidly, so the necessity of renewable energy-based source is required for interconnection to the distribution network. The main drawbacks of the renewable sources are that the power generation is not continuous and it is season-based. To overcome these disadvantages, numbers of renewable sources are to be interconnected. The

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compensation principle and different control strategies of the UPQC in detail and performance of UPQC is examined by considering a diode rectifier feeding an RL load (non-linear load) that acts as a source of harmonics. The theory, modeling and application of a unified power quality conditioner has been described by [4]. The coordinated and integrated control of solar PV generators with the maximum power point tracking (MPPT) control and battery storage control to provide voltage, frequency (V-f) and P-Q control, respectively, with PV generator and battery storage support to an islanded Microgrid. Femia *et al*. have developed a scheme for maximum power point tracking (MPPT) of solar PV system using perturb and observe method. Gaeid *et al.* have designed a unified power quality conditioner (UPQC) including a series and a shunt active power filter (APF) to compensate harmonics in both the distorted supply voltage and non-linear load current. In the series, there is APF control scheme and a proportional-integral (PI) controller. Meanwhile a PI controller is designed in the shunt APF control scheme to relieve harmonic currents produced by non-linear loads. The major disadvantage of UPQC is that it cannot compensate the voltage interruption but proposed method can perform all the function as UPQC can and also compensate the voltage interruption.

PV/ WIND ENERGY INTEGRATED UPQC CIRCUIT AND ITS FUNCTIONS

We propose the design and development of a PV/Wind energy-UPQC system. By using instantaneous d-q control theory techniques along with PI and hysteresis band controller, the mitigation of voltage sag and swell under different balance and unbalanced load conditions are simulated. The use of a PV array and wind energy for retaining fixed DC link voltage is another distinguishing feature of the PV/Wind energy-UPQC system. With these functions, the proposed method is suitable for connecting at PCC. The proposed configuration with UPQC is shown in Figure 1. There is voltage interruption reimbursement and active power injection to the Point of Common Coupling (PCC) in addition to the other regular UPQC operation.

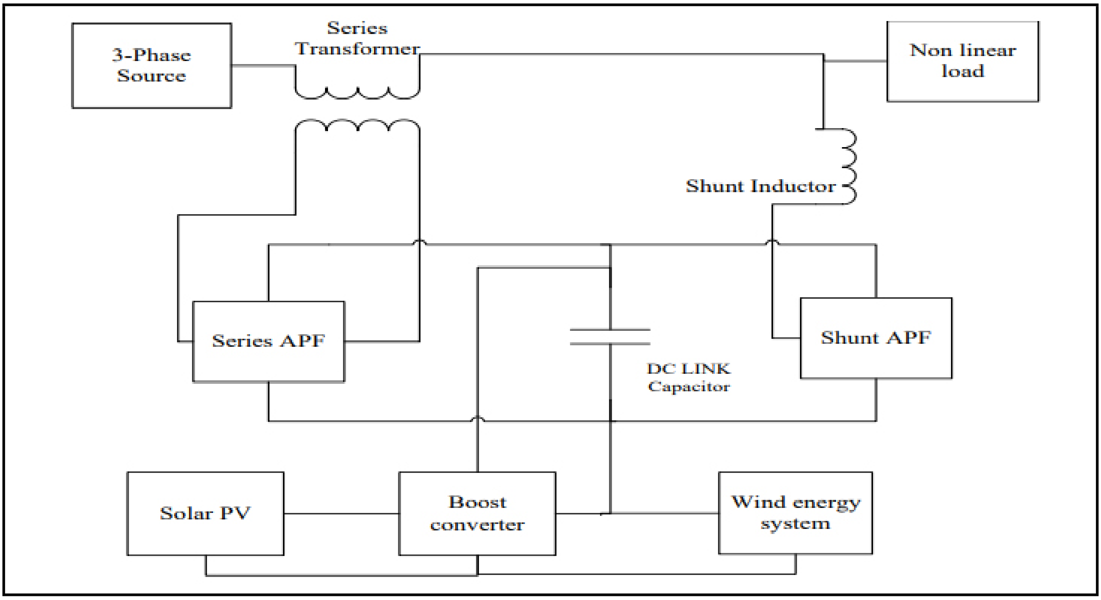
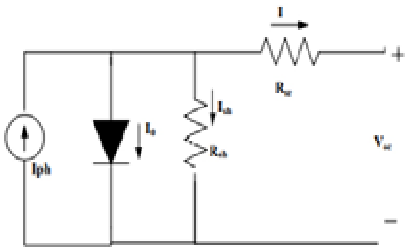


Figure 1: Basic Block diagram for PV/ Wind energy - UPQC system

Modeling of Solar PV

Solar photo-voltaic system works on the principle that when a light energy falls on solar cell, it converts the same to electrical energy. Figure 2 shows an equivalent model of solar PV system representing single diode model. It consist of a photo current Iph which depends on temperature and irradiation, the series resistance represents the internal resistance due to which current 'I' flows and the shunt resistance describe the flow of Ish which is a leakage current.



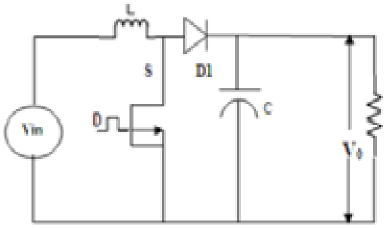


Figure 2:Solar cell single diode model **Figure 3: Basic circuit for Boost converter**

The load current, photo current and other equation are summed up below:

$$I = I_{Ph} - I_0 - I_{sh} \tag{1}$$

$$I_{Ph} = [I_{sc} + K_i(T_k - T)] \times \frac{G}{1000} \tag{2}$$

$$I_{RS} = \frac{I_{sc}}{[exp(q \times V_{OC}/N_S \times k \times A \times T) - 1]} \tag{3}$$

$$I_0 = I_{RS}\left[\frac{T}{T_r}\right]^3 exp\left[\frac{q \times E_{go}}{Ak}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}\right] \tag{4}$$

$$I_{PV} = N_P \times I_{Ph} - N_P \times I_0\left[\exp\left\{\frac{q \times V_{PV} + I_{PV}R_{se}}{N_S \times AkT}\right\} - 1\right] \tag{5}$$

Where,

I_{PV}-Diode photo current

I_O-Reverse saturation current of diode

V_{pv}-Diode voltage

V_{oc}-Open circuit voltage

R_{se}-Series Resistance

R_{sh}-Shunt resistance

MPPT

The solar panel efficiency is increased by the use of the MPP technique. The MPPT is the application of maximum power transfer theorem which says that the load will receive maximum power when the source impedance is equal to load impedance. The MPPT is a device that extracts highest power from the solar cell and changes the duty ratio of boost converter so as to match the load impedance to the source.

P and O MPPT

There are many method of MPPT out of which P & O technique is mostly used by the researcher due to its simplicity and cost effectiveness. This method works on an algorithm that first PV panel terminal voltage and current are calculated and related value of power is measured denoted by P (k-1). The detailed algorithm is shown in flow chart at Figure 4 which describes the algorithm for designing the MPP system using P&O by Matlab simulation.

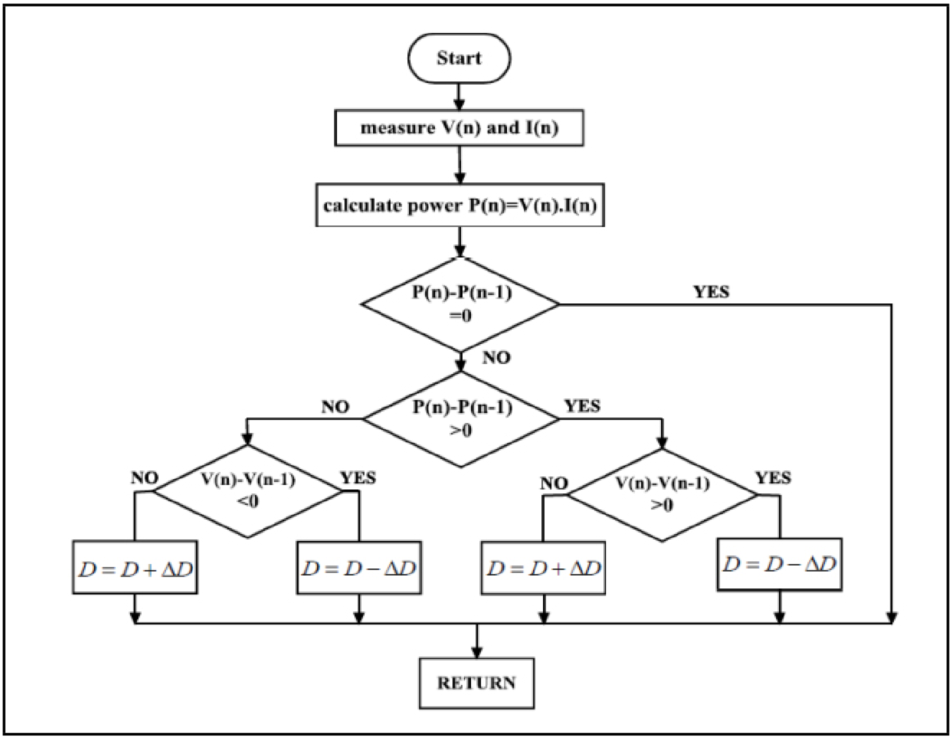


Figure 4: Flowchart of P & O MPPT algorithm

DC/DC Step up Converter

A step up DC/DC converter is a boost converter which increases the solar voltage to desired output voltage as required by load. The configuration is shown in Figure 4 which consists of an inductor L, switch S, diode D1, capacitor C for filter, load resistance R and DC input voltage V_{in} When the switch S is turned ON by using switching pulse, the boost inductor stores the energy fed from the input voltage source. During this time, the load current is maintained by the charged capacitor so that the load current should be continuous. During the switch off period, the input voltage and the stored inductor voltage will appear across the load hence the load voltage is increased. The load voltage depends upon whether switch S is in ON or OFF mode and this depends upon the duty ratio D. The switch conducts with a duty ratio D and then the output DC voltage is given by equation 6:

$$\frac{V_0}{V_s} = \frac{1}{1-D} \tag{6}$$

The minimum value of duty cycle D_{min} and maximum value of duty cycle D_{max} used for a zero-loss boost converter is given by the following equation:

$$D_{max} = 1 - \frac{V_{in-min}}{V_o} \times \eta \tag{7}$$

Where, D_{max} is the maximum duty ratio required to keep the converter in Continuous Conduction Mode (CCM)

$$D_{min} = 1 - \frac{V_{in\ max}}{V_o} \times \eta \tag{8}$$

Where, D_{min} is the minimum duty cycle required to keep the converter in CCM

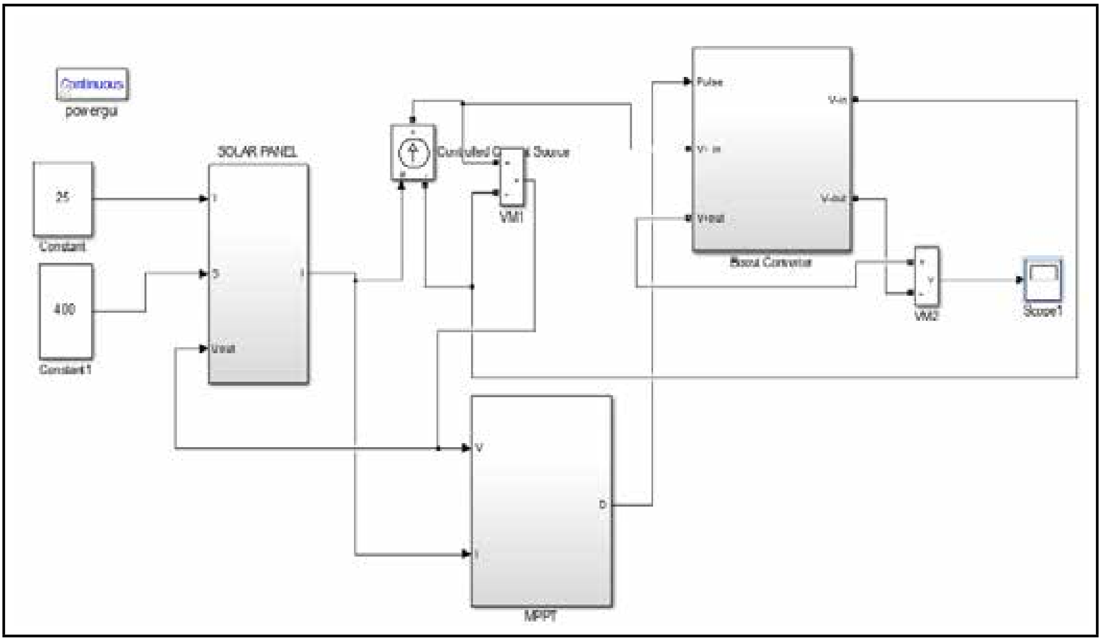
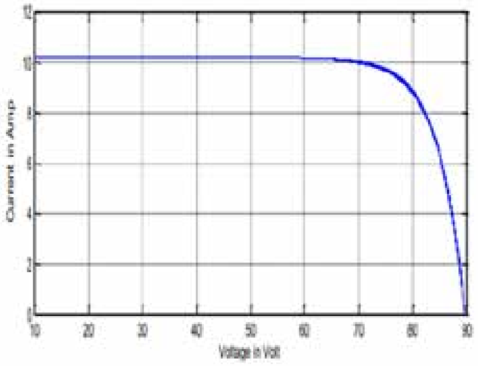


Figure 5: Simulation of Solar PV with MPPT and Boost converter

Matlab/Simulation of PV System

In general, the efficiency of a PV unit is extremely low; therefore it is essential to operate it at the peak power point so that the highest power can be provided to the load irrespective of continuously varying environmental conditions. This improved power makes it well again for the use of the solar PV unit. A DC/DC converter which is located next to the PV unit extracts maximum power by matching the impedance of the circuit to the impedance of the PV unit. Impedance matching is possible by changing the duty ratio of the boost converter. The simulation of solar PV with P&O MPPT and Boost converter is shown in Figure 5.

The P-V and I-V characteristic of PV module is shown in Figure 7 and Figure 6.



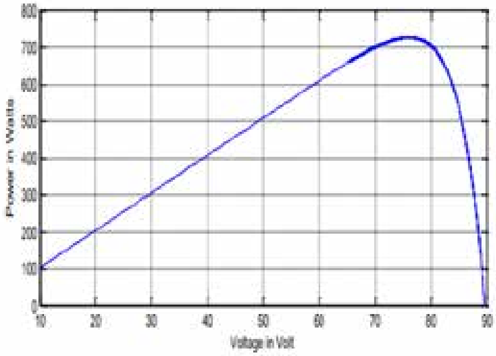


Figure 6: I-V Characteristics of PV module **Figure 7: P-V Characteristics of PV module**

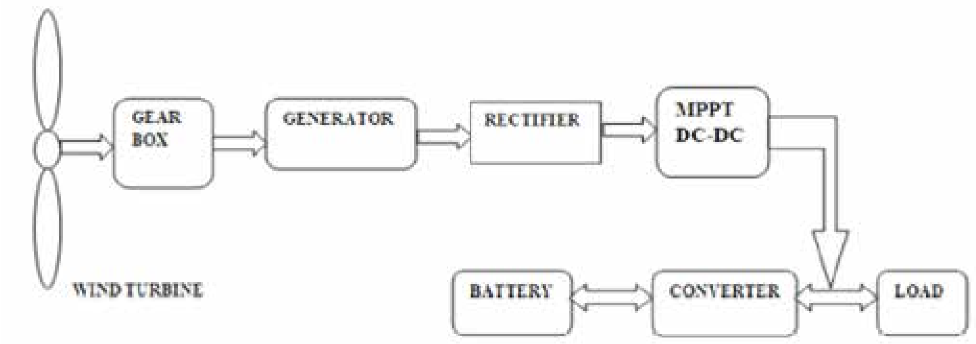


Figure 8: Wind energy system block diagram

WIND ENERGY SYSTEM

The diagram shown in Figure 8 is the basic wind energy conversion system model. The wind kinetic energy IS first converted to rotational motion and by the use of gear box it matches the speed of turbine and generator. The function of generator is to convert the mechanical energy of turbine to electrical energy. A rectifier is used to convert the AC voltage to DC and a battery is connected in such a way that it can be charged in both the way i.e. a bidirectional converter is used to charge the battery.

Modeling of Wind Turbines

The kinetic energy of wind is converted to rotational motion i.e. wind power to mechanical power conversion is done with the help of wind turbine blade in contact with wind speed. So different equations are given for power generation from wind.

$$Pm = \frac{1}{2}\pi\rho Cp(\lambda,\beta)R^2V^3 \tag{9}$$

Where, P_m – Mechanical power, ρ−Air density, β –Pitch angle, R–Blade Radius–Speed of the wind λ is the tip-speed ratio, given by λ = ΩR/ V. Where, Ω - Rotor speed of rotation (in rad/sec) and C_p can be expressed as the function of the tip-speed ratio (λ)

$$C_p = \frac{1}{2}\left(\frac{116}{\lambda_1} - 0.4\beta - 5\right) exp^{\frac{-165}{\lambda_1}} \quad (10)$$

$$\lambda_1 = \left(\frac{1}{\frac{1}{\lambda+0.089} - \frac{0.035}{\beta^3+1}}\right) \quad (11)$$

where C_p –Power coefficient of turbine and λ_1–Any constant

Permanent Magnet Synchronous Generator (PMSG)

In case of (PMSG) permanent magnet synchronous generator, the magnetic field is stationary and the flux is produced by permanent magnet not by electromagnet, therefore a separate supply is not required for creation of magnetic field and the field flux remain constant. Another advantage of PMSG is that there is no requirement of slip ring. All other construction remains same as that of normal synchronous generator. The e.m.f induced in a synchronous generator.

$$E = 4.44 \emptyset_m t\, f \quad (12)$$

Where, f - Frequency in Hz, Φm - maximum flux in Wb and t- Number of turns.The simulation of wind turbine with generator and rectifier is shown in Figure 9.

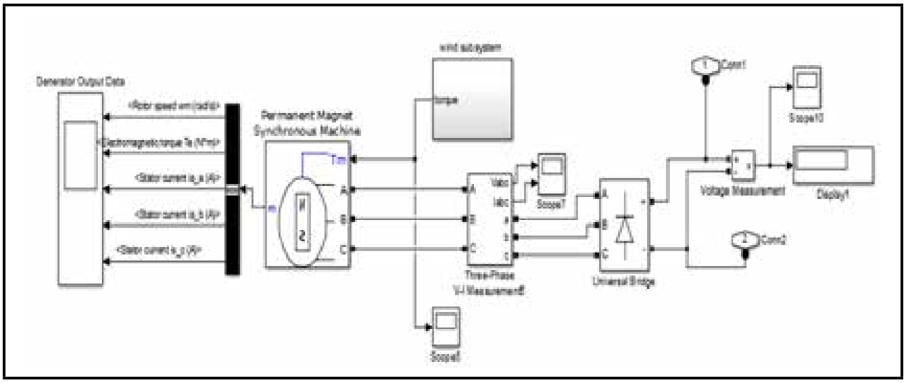


Figure 9: Simulation of wind system with PMSG and Rectifier

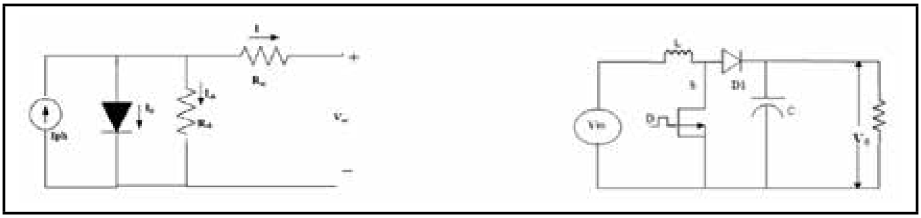
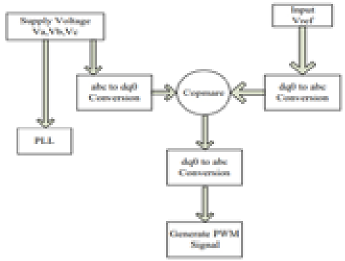


Figure 10: Block diagram of UPQC



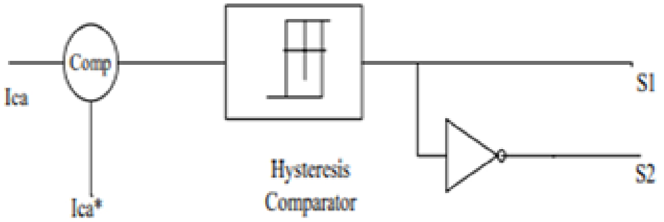


Figure 11: Control scheme of series Active Filter **Figure 12: Principle of hysteresis current controller**

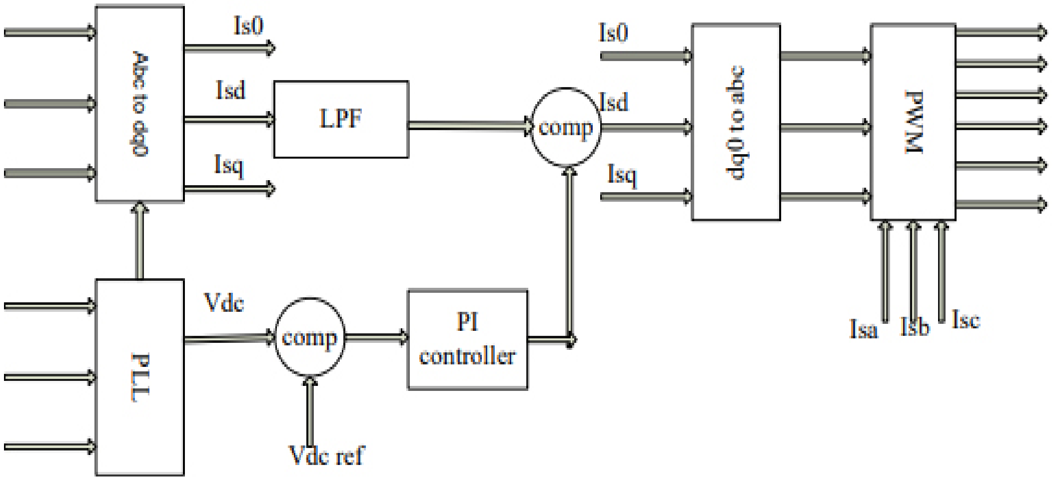


Figure 13: Control scheme of Shunt Active Power Filter

CONTROL STRATEGIES OF THE UPQC SYSTEM

There are several control strategies available to find out the reference values of the voltage and the current of UPQC. Figure 10 shows the block diagram for control strategies of UPQC system. The concept of instantaneous active power (p) and reactive power (q) and its application in shunt filter reference current generation, the synchronous reference frame theory, the fuzzy logic control (FLC) for the control of UPQC method are some of the above mentioned control strategies. Based on the above discussion, d-q theory with hysteresis current control mode is suitable for parallel mode operation of UPQC system and d-q theory with PWM voltage control mode is suitable for interruption mode operation. The hysteresis control method is simple to implement and it has enhanced system stability, increased reliability and mitigates power quality problems.

Control Scheme of Series Active Filter

The block diagram for series APF control scheme is shown in Figure 11 where Park's transformation method is used for generation of unit vector signal. The actual voltage and the reference are converted to dq0 from *abc* coordinates and both are compared in *dq0* reference frame. After the comparison both are again converted to *abc* reference frame. From PLL (phase locked loop), Ø can be generated which is required for Park's transformation and inverse Park's transformation. The switching pulses required for VSI conduction are generated from the comparison of selected output voltage (Vc*) with the sensed series APF output voltage (Vc) in a hysteresis voltage controller.

Control Scheme for Shunt Active Power Filter

To eliminate the harmonics, the equal amount of harmonic compensating current is injected in opposite phase w.r.t the harmonic current. The control scheme shown in Figure 13 includes the transfer of source current from a-b-c to d-q frame. In non-linear load, the source current includes both oscillating as well as dc component. The dc component is only positive sequence component but the oscillating component includes positive, negative and zero sequence components. To maintain the DC link voltage, this active filter will absorb some active power from the power system. The shunt active filter eliminates the harmonics component present in the source current & make the source current wave form pure sinusoidal by acting as a current controlled voltage source inverter.

Design of Shunt Apf

a. *DC link capacitor:* The active and reactive power flow to the system is provided by the link capacitor when it is required.
b. *Voltage source inverter:* The electronics device which converts direct current to alternating current when PWM signal is given to the gates of its IGBT or GTO etc. Here the main function of the VSI is to compensate the source current harmonics present by injecting the equal and opposite compensating current to the system.
c. *Hysteresis Current Controller:* Hysteresis current controller shown in Figure 12 generates PWM signal by comparing the reference signal w.r.t to the actual signal the figure below shows the generation of PWM signal by comparing the two current signals.

SIMULINK MODEL OF SOLAR PV/WIND ENERGY-UPQC SYSTEM

Result Analysis

The simulink models of PV/Wind energy-UPQC are simulated in Matlab which is shown in Figure 14. It consist of series APF, shunt APF, solar PV, wind energy and boost converter. The simulation result shown in Figure 15 is without series filter where voltage sag is clearly shown from 0.1sec. to 0.3sec. When the series active filter injects voltage from 0.1sec.to 0.3sec shown in Figure 16, the load voltage is compensated to actual value as shown in Figure 17. The Figure 18 shows the simulation result load current before compensation and Figure 19 shows the harmonics content i.e. 16.6% by using FFT analysis. When the shunt active filter injects current from 0.1sec.to 0.4sec as shown in Figure 20, the load current harmonics is reduce to2.33% as shown in the FFT analysis in Figure 22 for which the load current is nearly sinusoidal as shown in Figure 21.

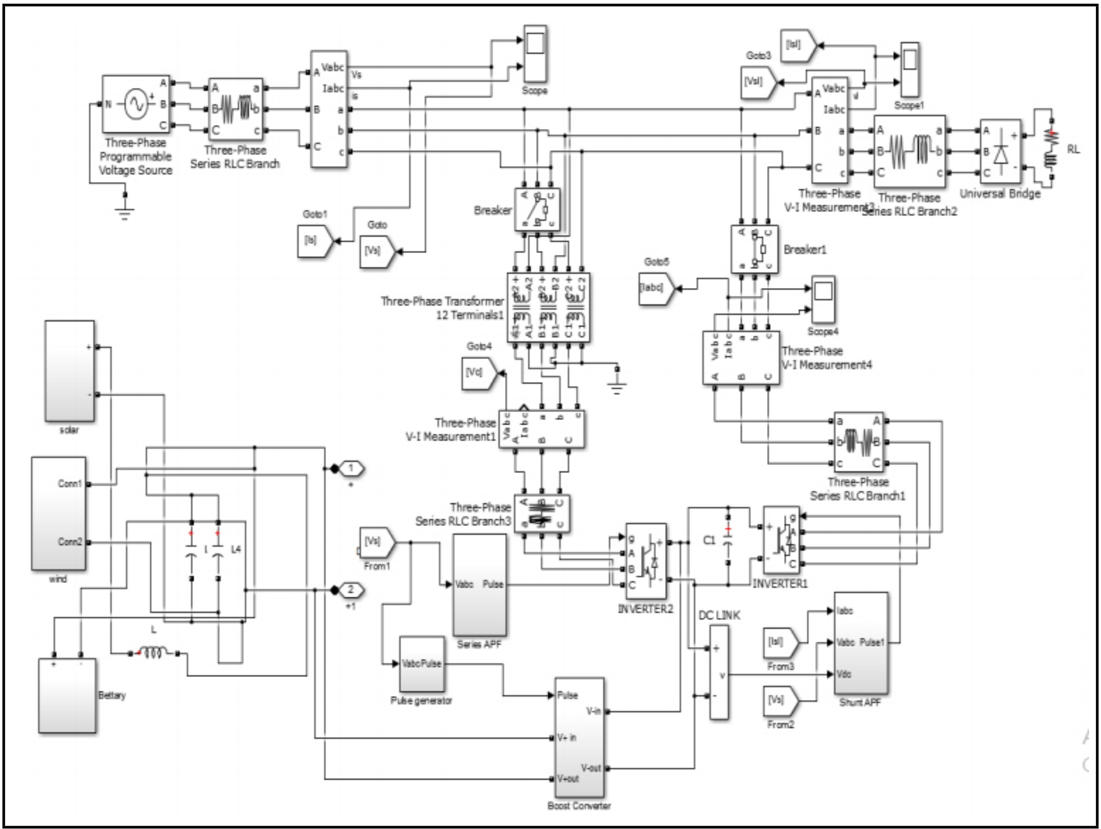


Figure 14: Simulation of PV/Wind –UPQC system

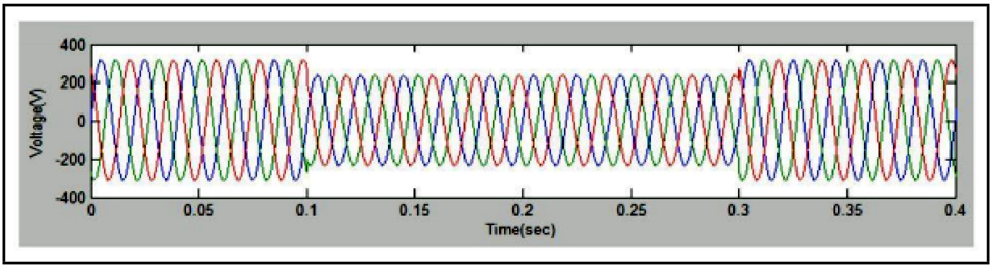


Figure 15: Load Voltage without SAF

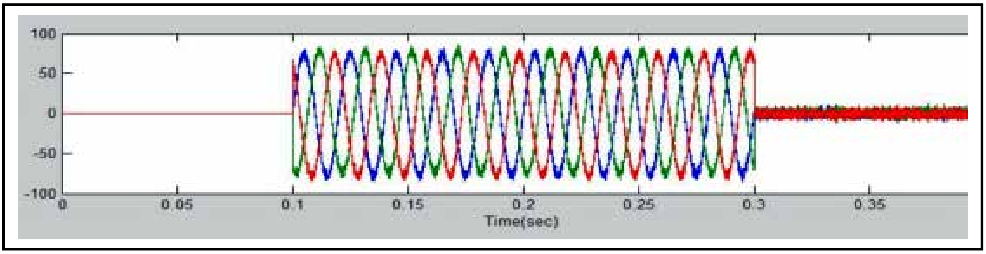


Figure 16: Injected Voltage

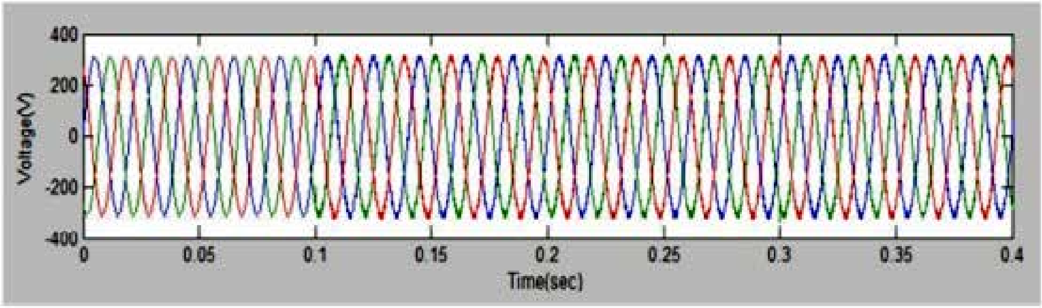


Figure 17: Load Voltage with SAF

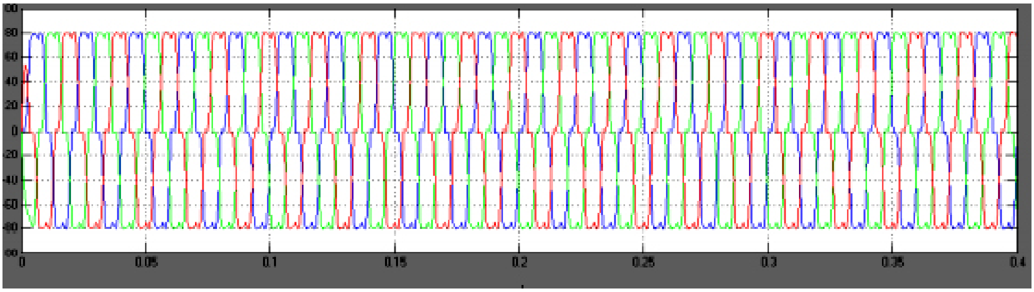


Figure 18: Load current before compensation

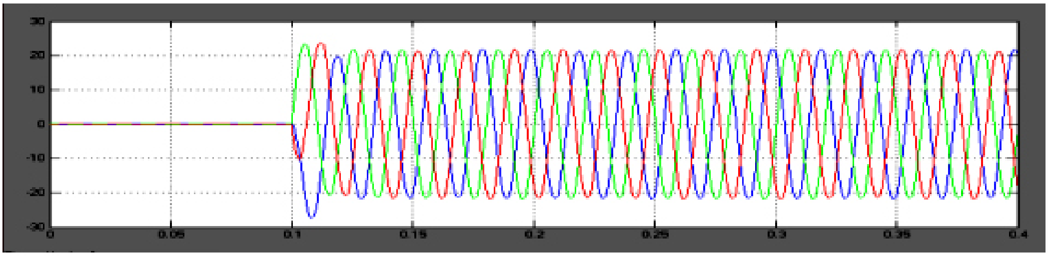


Figure 19: Current Injected by shunt active filter

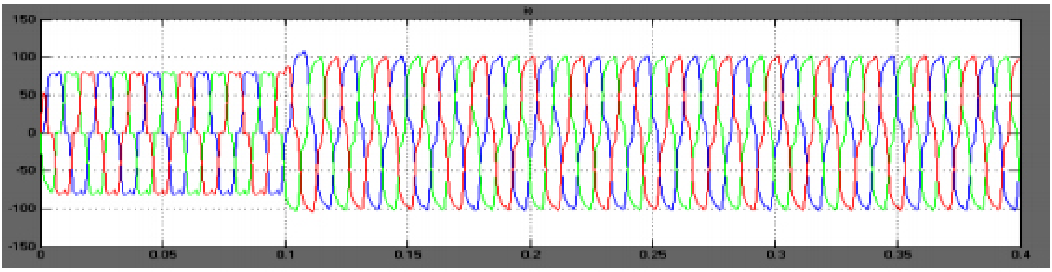
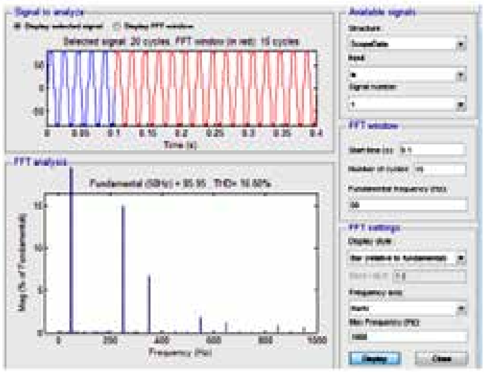


Figure 20: Load current with shunt APF



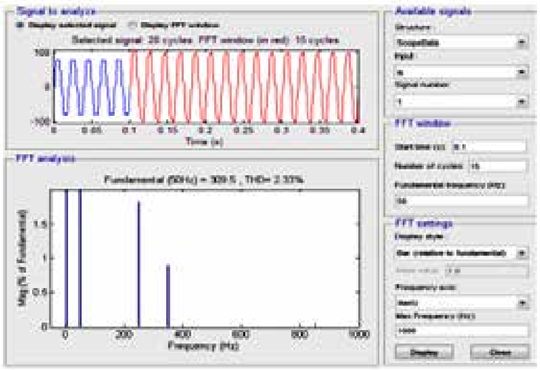


Figure 21:Harmonics analysis without shunt APF **Figure 22: Harmonics analysis with shunt APF**

CONCLUSION

The advantage of Photo Voltaic / Wind energy System is to retain a constant voltage of 700 volts across the DC-Link capacitor. In this work the solar PV with boost converter output is obtaining 700V and Wind energy with boost converter output is also 700V and simulation of PV/ Wind energy -UPQC maintains constant voltage of 700V when Sag, Swell and Interruption occur. It also reduces the harmonics content to 2.33% if any nonlinear load is associated. Hence the proposed scheme can regulate active and reactive power injection to the grid and compensate voltage interruption in addition to the other usual operation of UPQC.

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