Design, Modeling and Simulation of UPQC system with PV array

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Abstract

This work deals with design, modeling and simulation of UPQC system to improve the power quality in multibus system. The UPQC system is modeled using the elements of Simulink and it is simulated using MATLAB. A sag is created by applying a heavy load at the receiving end. The sag is compensated by using the UPQC. The harmonics required at the receiving end are supplied by the inverter part of UPQC. The DC required by the UPQC is supplied by Solar cell and Boost converter system. The simulation results are compared with theoritical results.

Keywords: *FACTS, MATLAB, UPQC, SOLAR CELL*

1. Introduction

One of the comparative structures of the electric power is back to back converter. In respect to controlling structure, these converters may have various operations in compensation. For example, they can operate as series or shunt active filters for compensating the load current harmonics and voltage oscillation [2]. This is called Unified Power Quality Conditioner (UPQC) [3].

UPQC is greatly studied by [1], [5], [8] as a basic device to control the power quality. The duty of UPQC is to reduce perturbations which affect the operation of sensitive loads. UPQC is able to compensate voltage using shunt and series inverters. In spite of this issue, UPQC is not able to compensate voltage interruption and active power injection to grid, because in its DC link, there is no energy source.

The attention to Distributed Generating (DG) sources is increasing day by day. The reason is their important roll they likely play in the future of power system [6];[4]. Recently, several studies are accomplished in the field of connecting DGs to grid using power electronic converters. Here, grid's interface shunt inverters are considered more where the reason is low sensitive of DGs to grids parameters and DG power transferring facility using this approach. Although DG needs more controls to reduce the problems like grid power quality and reliability, Photovoltaic array (PV) energy is one of the distributed generation sources which provides a part of human required energy nowadays and will provide in the future. The greatest shares of applying this kind of energy in the future will be its usage in interconnect systems. Nowadays, European countries have shown inter – connected systems development in their countries by choosing supporting policies. In this study, UPQC and PV combined system has been presented. UPQC introduced by [7], it has the ability to compensate voltage sag voltage swell, harmonics and reactive power.

In Fig.1, the general structure of grid connected PV systems is shown. The advantage of proposed combined system is voltage interruption compensation and active power injection to grid in addition to the mentioned abilities. Also, this proposed system has higher efficiency and functioning ability compared with other common PV's and cause reduction in system's total cost. Simulation results, using MATLAB software show that this proposed system operates correctly.

In this study, a new structure is proposed for UPQC, where, PV is connected to DC link and UPQC acts as energy source.

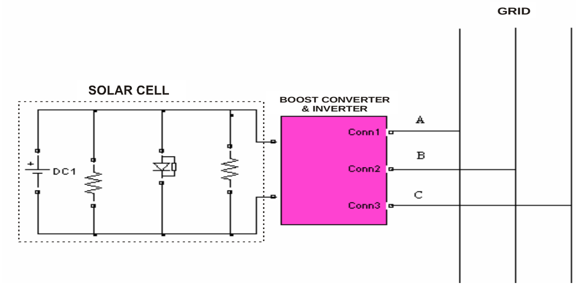

Figure 1.
General structure of grid connected PV system

2. UPQC SYSTEM

UPQC has shunt and series voltage source inverters which are 3-phase 3-wire shunt inverter connected to point of common coupling (PCC) by shunt transformer. The series inverter stands between source and coupling as current source and it operates as voltage source.

The equations for real and reactive power through the line are as follows:

$$P = \frac{V_S V_R}{X} \sin(\delta_1 - \delta_2) \qquad \text{...... (1)}$$

$$Q = \frac{V_R}{X}(V_S - V_R) \qquad \text{...... (2)}$$

These equations are given by neglecting the resistance of the line.

UPQC is able to compensate current harmonics, to compensate reactive power, voltage distortions and control load flow but cannot compensate voltage interruption because of non availability of sources.

Common interconnected PV systems structure shown in Fig 2 is composed of PV array, DC/DC and DC/AC converters.

The equations for the boost converter are by using the following equations.

$$V_o = \frac{V_i}{(1-\delta)}$$

Inductance and capacitance are calculated by using the following equations

$$L = \frac{V_i \delta}{f \Delta I} \qquad \text{...... (3)}$$

$$C = \frac{\delta}{2 f R} \qquad \text{...... (4)}$$

In this case, UPQC finds the ability of injecting power using PV to sensitive load during source voltage interruption. Two operational modes of UPQC care as follows:

2.1. Interconnected mode:

Where, PV transfers power to load and source.

2.2. Islanding mode:

Where, the source voltage is interrupted and PV provides a part of load power separately.

2.3. Controller designing:

The controlling structure of proposed system is composed of three following parts:

2.3.1. Shunt inverter control.

2.3.2. Series inverter control

2.3.3. DC/DC converter.

Capacitor voltage controlling loop is used here by applying PI controller.

The above literature does not deal with modeling & simulation of UPQC using matlab simulink. This work presents the simulink model and results of UPQC system with PV array.

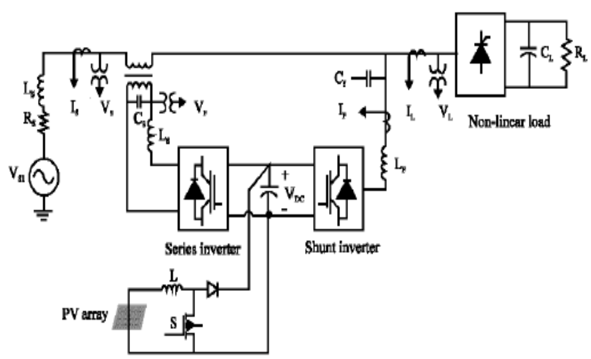

Figure 2. Configuration of UPQC with PV array

Controlling strategy is designed and applied for two interconnected and islanding modes. In interconnected mode, source and PV provide the load power together while in islanding mode, PV transfers the power to the load lonely. By removing voltage interruption, system returns to interconnected mode.

2.4. Shunt inverter control:

In this study, shunt inverter undertakes two main duties. First is compensating both current harmonics generated by nonlinear load and reactive power, second is injecting active power generated by PV system.

The power loss caused by inverter operation should be considered in this calculation. Also, shunt inverter control undertakes the duty of (stabilizing) DC link voltage during series inverter operation to compensate voltage distortion.

3. Simulation results.

L & C are designed by assuming $\Delta I = 0.4$A, f = 3 kHz & R = 1K Ω.

L & C for boost converter worksout to be 7.5 mH & 12 µF; T_{ON} : 0.25ms ; T_{OFF} : 0.08 ms.

The circuit model of UPQC system is shown in figure 3.

The inverter of DVR used in the UPQC is triggered at 50 Hz. All the switches are operated with pulses of width 10ms. The pulses given to the other two switches are displaced by 10ms. The output of inverter is filtered by using LC filter. This will reduce heating since harmonics are reduced. The inverter switches of active filter are triggered at 250Hz. In Fig.5 the circuit consists of two inverters. The DC required by the DC link is supplied using solar cell and boost converter. This circuit is shown in Fig 5. The output of solar cell is not sufficient to drive the capacitor at the input of the inverter. Therefore the output of solar cell is boosted by using a boost converter. The boost converter uses boost inductor, capacitor and blocking diode. The output voltage is controlled by using a MOSFET. Fig.6 shows the variation of output voltage (in volts) with time in milli seconds. The voltage across loads 1 and 2 are shown in Fig 6. An additional load is applied at t=0.2 seconds. The total load current increases and the drop in the line impedance increases. The receiving end voltage is reduced. At t =0.3 seconds, the voltage

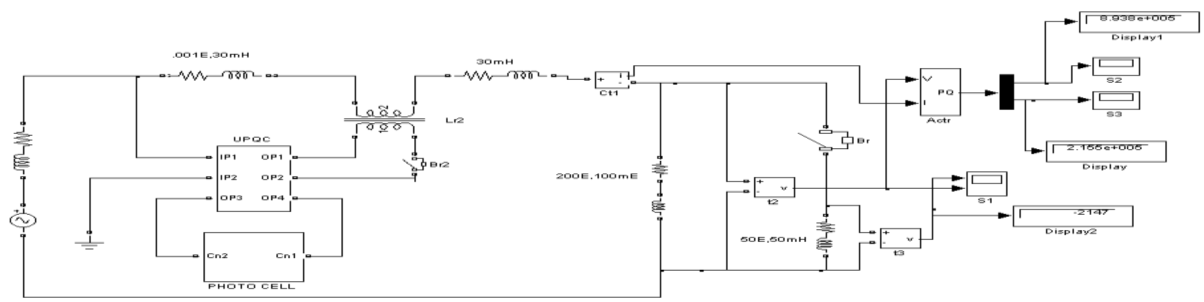

Figure 3. Circuit model of UPQC

Scopes are connected to measure receiving end voltage, receiving end current, real power and reactive power. The generator is represented as series combination of R,L&E. Line is represented by series impedance. The load at the receiving end is series combination of resistance 200Ω and inductance of 100 mH. The parameters of the additional load are 50Ω and 50mH. DC required by UPQC is applied from a photo cell. The output of UPQC is injected using a series transformer. The circuit inside the UPQC block is shown in Fig 4.

is injected by the UPQC to bring the receiving end voltage to the normal value. From the waveform of V_{L1}, it can be seen that the sag is compensated by using the DVR part of UPQC. The voltage V_{L2} is zero up to 0.2 seconds, since the breaker is open. The waveforms of real and reactive powers are shown in Figures 7 and 8 respectively. The real and reactive powers increase at t = 0.2 seconds due to the increase in the load. This increases further at t = 0.3seconds, due to the injection of the voltage by UPQC.

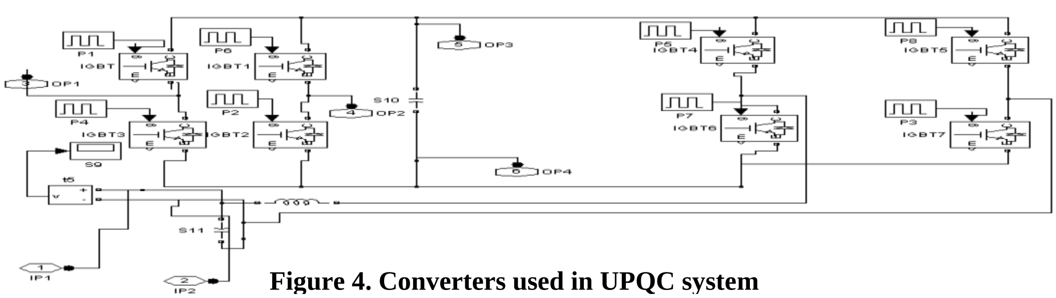

Figure 4. Converters used in UPQC system

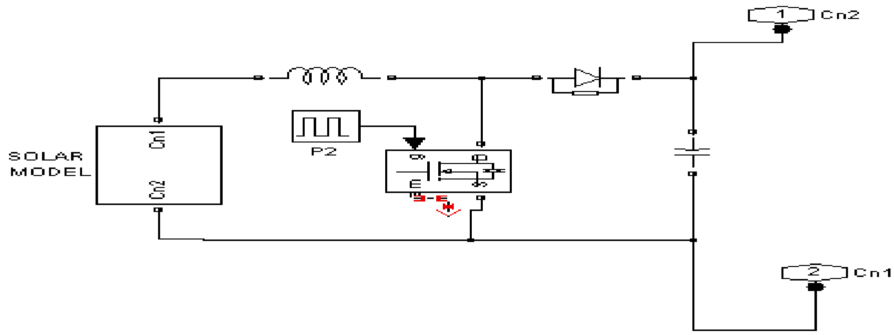

Figure 5. Boost converter circuit

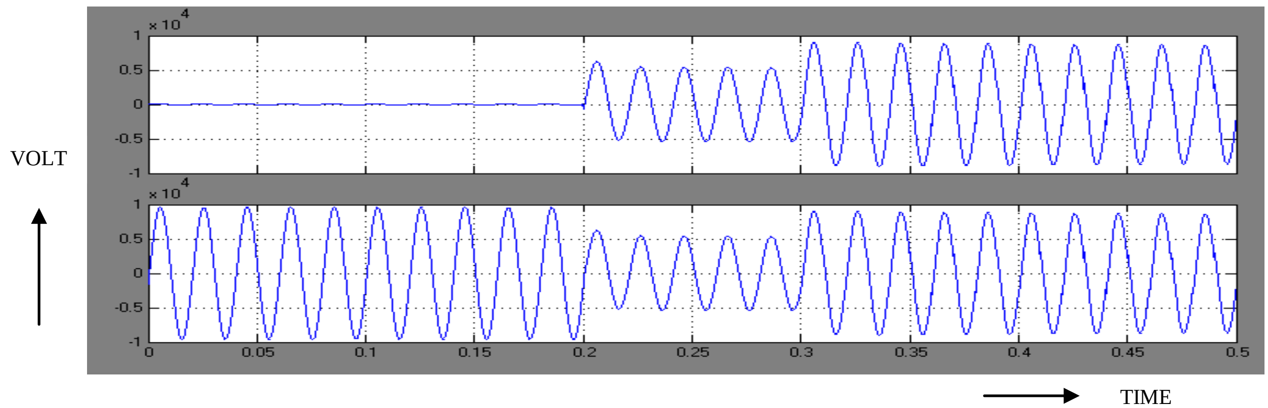

Fig .6 Voltages across load-2 and load-1

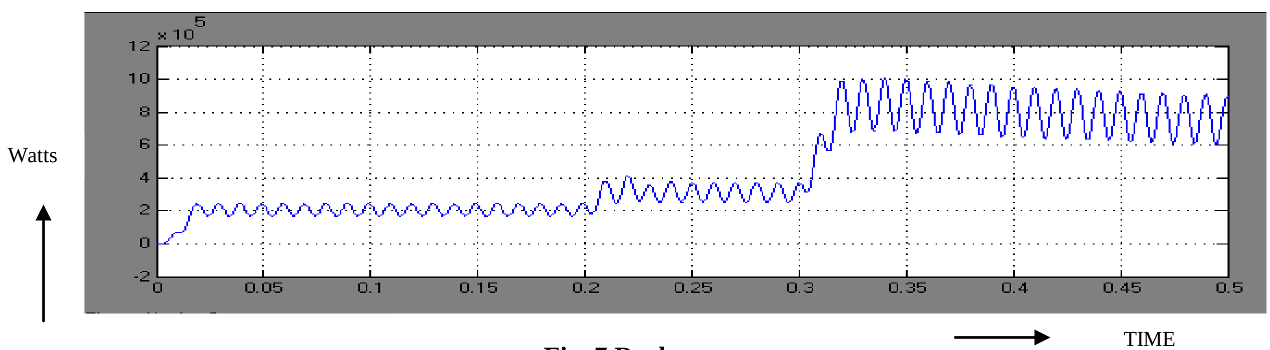

Fig. 7 Real power

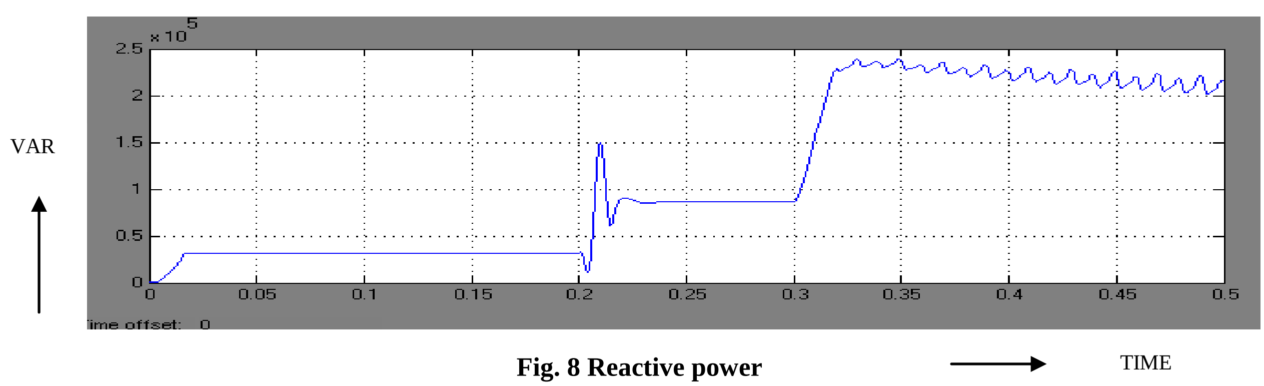

Fig. 8 Reactive power

4. Conclusion.

The UPQC system is successfully designed and modelled using the circuit elements of simulink. The sag in the voltage is created by applying an additional heavy load at the receiving end. This sag is compensated by using DVR part of UPQC. The simulation results are in line with the predictions. The THD in the output is reduced by using UPQC.

The scope of this work is the modelling and simulation of UPQC system. The hardware implementation is yet to be done. The simulation can be extended to multi bus system.

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