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DESIGN, MODELLING AND SIMULATION OF UPQC IN FOURTEEN BUS SYSTEM

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ABSTRACT

This work deals with design, modelling and simulation of UPQC in Fourteen bus system to improve the power quality in a multi bus system. The UPQC system is modelled 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 of fourteen bus system are presented in time domain.

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

1. INTRODUCTION

The modern power distribution system is becoming highly vulnerable to the different power quality problems {1-2}. The extensive use of non-linear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small / large-scale renewable energy systems based on wind energy, solar energy, fuel cell, etc., installed at distribution as well as transmission levels is increasing significantly.

Unified power quality control was widely studied by many researchers as an eventual method to improve power quality of electrical distribution system {1-3}. The function of unified power quality conditioner is to compensate supply voltage flicker / imbalance, reactive power, negative sequence current and harmonics.

In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. Therefore, the UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker / imbalance {2}. The UPQC consisting of the combination of a series active power filter (APF) and shunt APF can also compensate the voltage interruption if it has some energy storage or battery in the DC link {3}. The shunt APF is usually connected across the loads to compensate all current-related problems such as the reactive power compensation power factor improvement, current harmonic compensation, and load unbalance compensation (3,4) whereas the series APF is connected in a series with the line through series transformers. It acts as controlled voltage source and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc.

The proposed control technique has been evaluated and tested under non-ideal mains voltage and unbalanced load conditions using Matlab / simulink software. The above mentioned literature does not deal with modelling and simulation of fourteen bus system with UPQC. This work proposes UPQC to improve the power quality of fourteen bus system. This work presents the simulink model of UPQC based 14 bus system.

2. UPQC SYSTEM

Structure of grid connected PV system is shown in figure 1. Configuration of UPQC with PV array is shown in figure 2. UPQC has shunt and series voltage source inverters which are 3-phase 3-wire shunt inverters 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:

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

$$Q = \frac{V_R}{X}\left(V_S - V_R\right) \qquad (2)$$

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 design of the boost converter is done by using the following equations.

$$V_o = \frac{V_i}{\left(1-\delta\right)} \qquad (3)$$

Inductance and capacitance are calculated by using the following equations

$$L = \frac{V_i \delta}{f \Delta I} \qquad (4)$$

$$C = \frac{\delta}{2\, fR} \qquad (5)$$

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.

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.

Design is done using the equations given in the previous section.

L & C are designed by assuming ΔI = 0.4A, 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.

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 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.

14 bus system is modelled using the elements of matlab simulink and the simulation results are presented in this section. The line impedances are shown as series combination of

resistance and inductance. There are three generator buses and five load buses. The load at each bus is represented as series combination of load resistance and inductance. The circuit of Fourteen bus system without UPQC is shown in Fig. 3(a). The load 2 is connected in parallel with the load 1. The breaker is connected in series with load 2. Additional load is applied by closing the breaker at t=0.2 sec. The real and reactive powers at bus 7 and bus 3 are shown in Figs. 3(b) and 3(c) respectively. The real and reactive power increases at t=0.2 sec, since the current drawn is increased. The voltage across load 1 and load 2 is shown in Fig. 3(d). At t=0.2 sec, the voltage across loads 1 and 2 decreases due to the addition of heavy load.

The circuit of Fourteen bus system with UPQC is shown in Fig. 4(a) and 4(b). The network of 14 bus system is represented as a sub-system here. The real and reactive powers at bus 7 and bus 1, 3 are shown in Figs.4(d), 4(e) and 4(f) irrespectively. The load is applied at t=0.2 sec. The DVR part of UPQC injects voltage at t=0.3 sec. The real and reactive power at bus 1 decreases and that of bus 3 increases due to the transfer of power from bus 1 to bus 3. The voltage across load 1 and 2 are shown in Fig. 4(c). The voltage decreases at t=0.2 sec. and resumes to its normal value at t=0.3 sec. This is due to voltage injected by the UPQC. The summary of real and reactive powers at various buses are shown in Table 1.

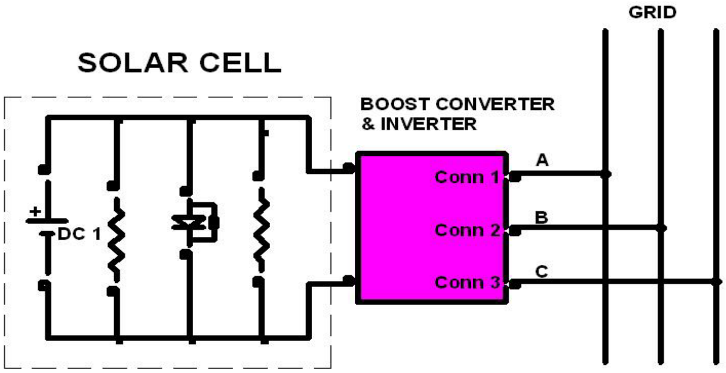

Figure 1. General Structure Of Grid Connected PV System

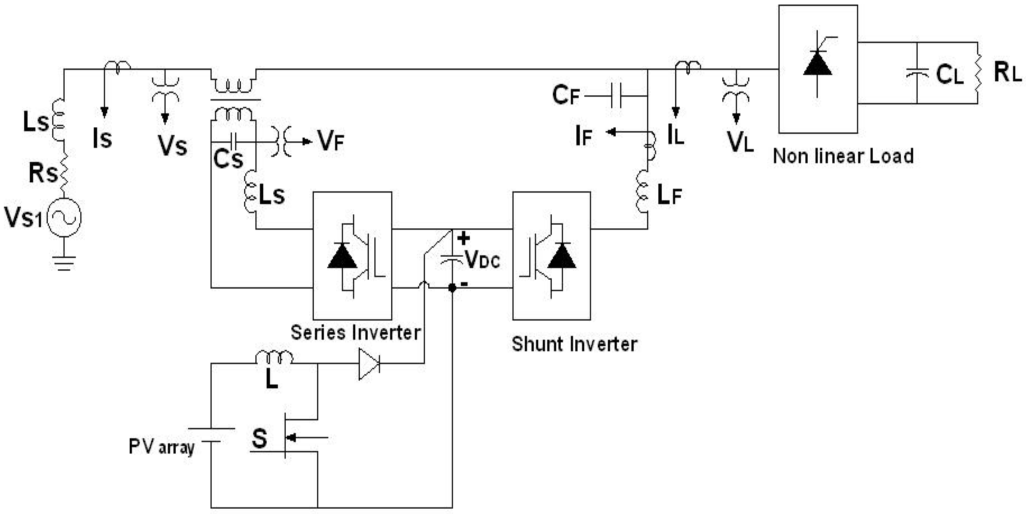

Figure 2. Configuration Of UPQC With PV Array

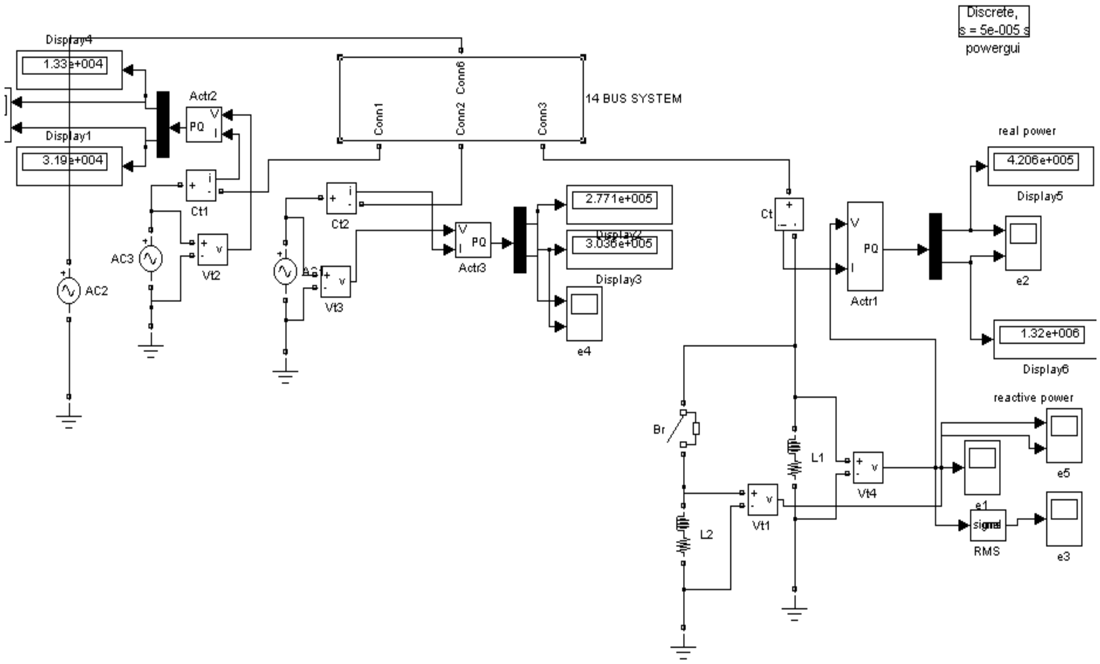

Fig. 3(a). 14 Bus System Without UPQC

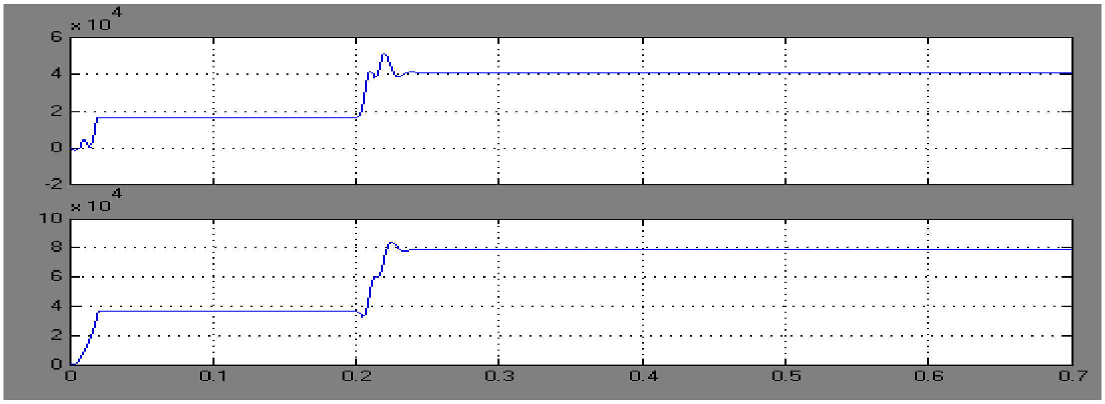

Fig. 3(b). Real And Reactive Power Across Bus-7

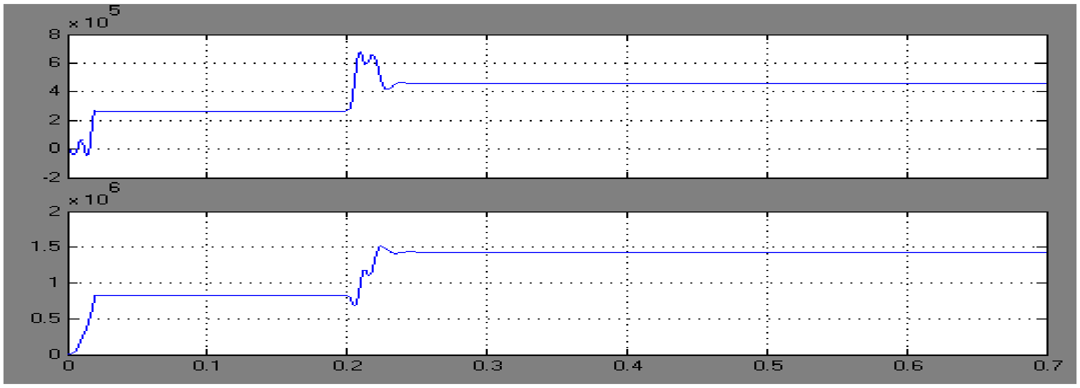

Fig. 3(c). Real And Reactive Power Across Bus-3

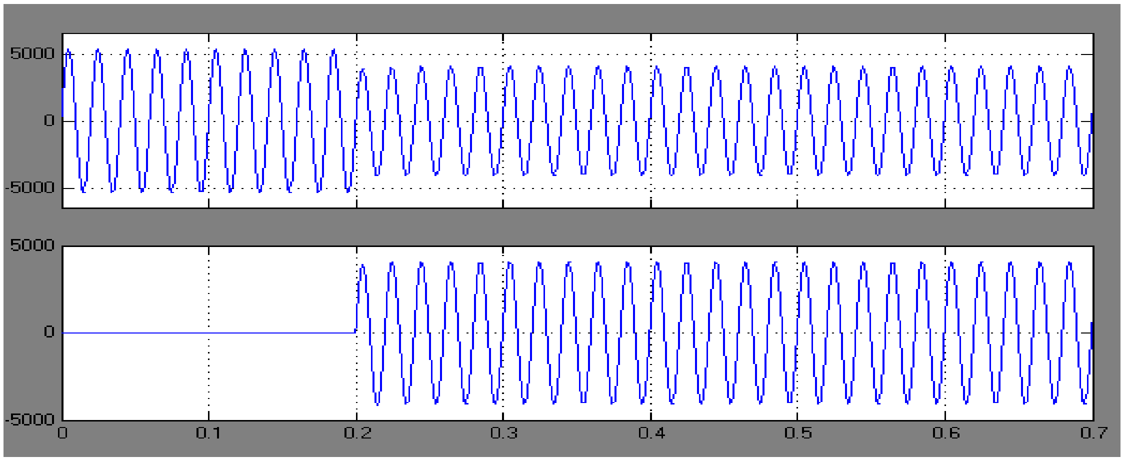

Fig. 3(d). Voltage Across Load-1 And Load-2

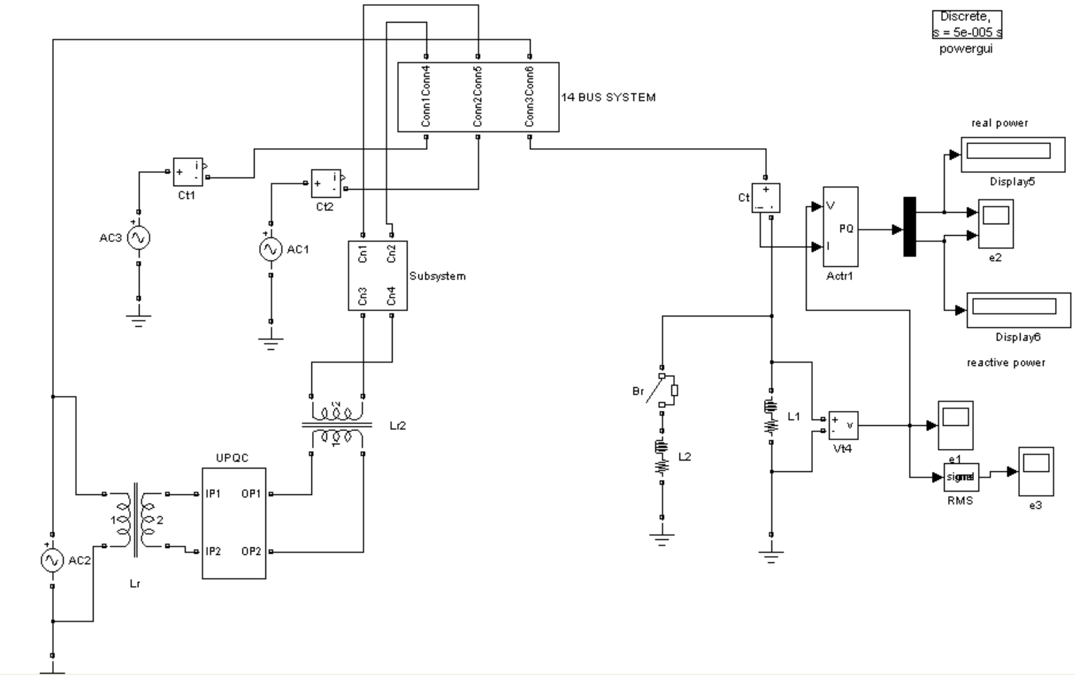

Fig. 4(a). Block Diagram Of 14 Bus System With UPQC

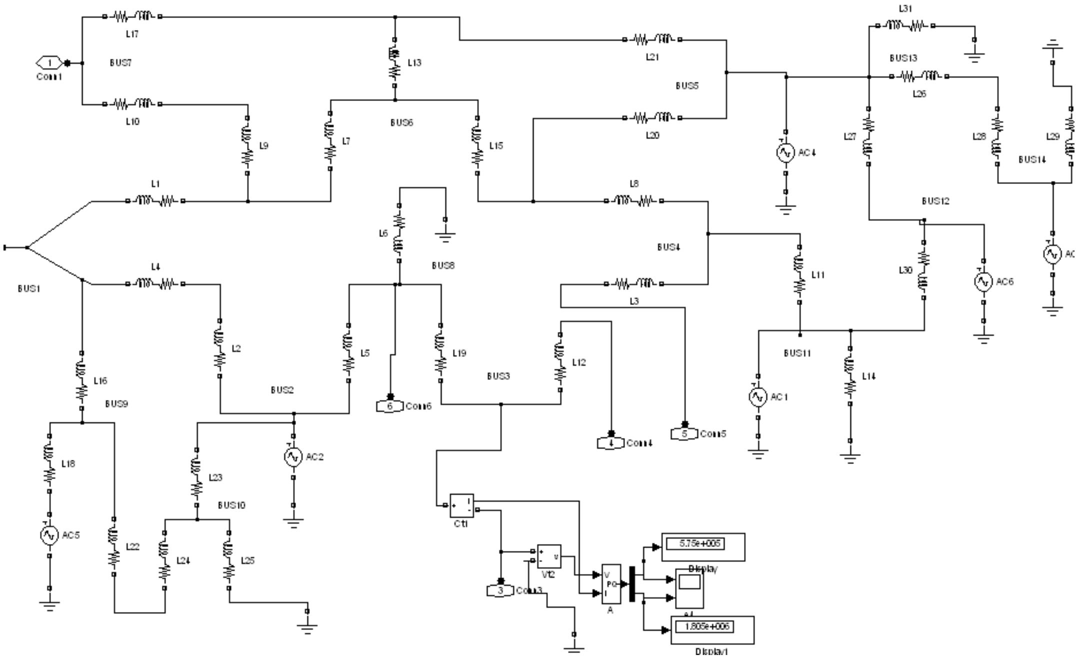

Fig. 4(b). Circuit Model Of 14 Bus System

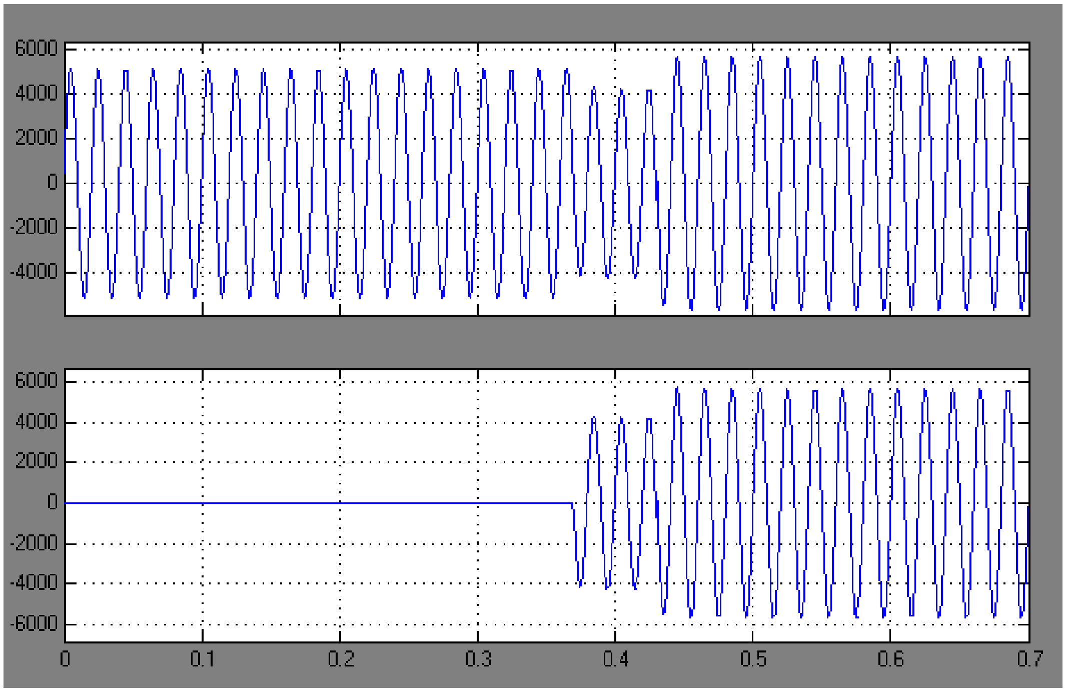

Fig. 4(c). Voltage Across Load-1 And Load-2

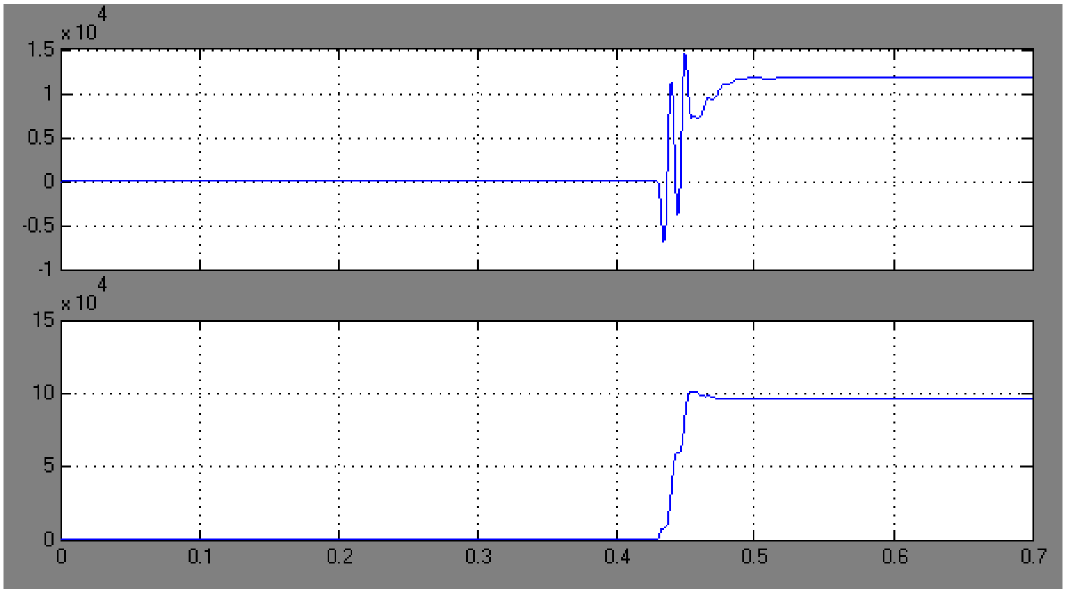

Fig. 4(d). Real And Reactive Power Across Bus-7

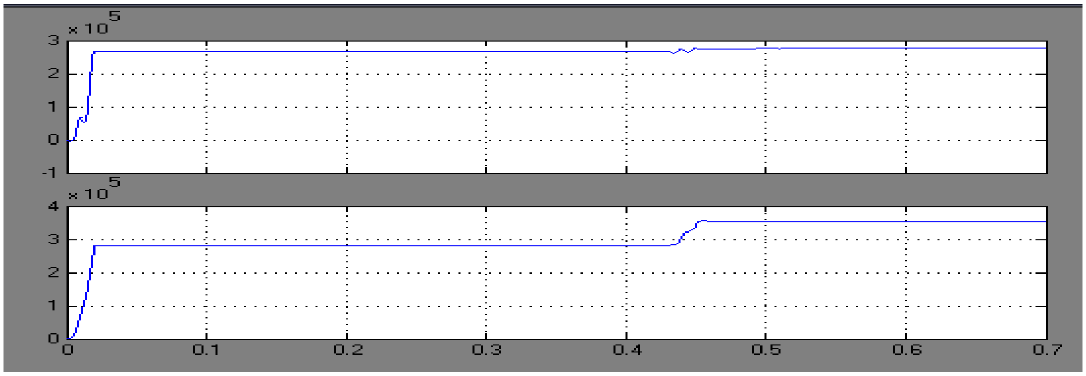

Fig. 4(e). Real And Reactive Power Across Bus-1

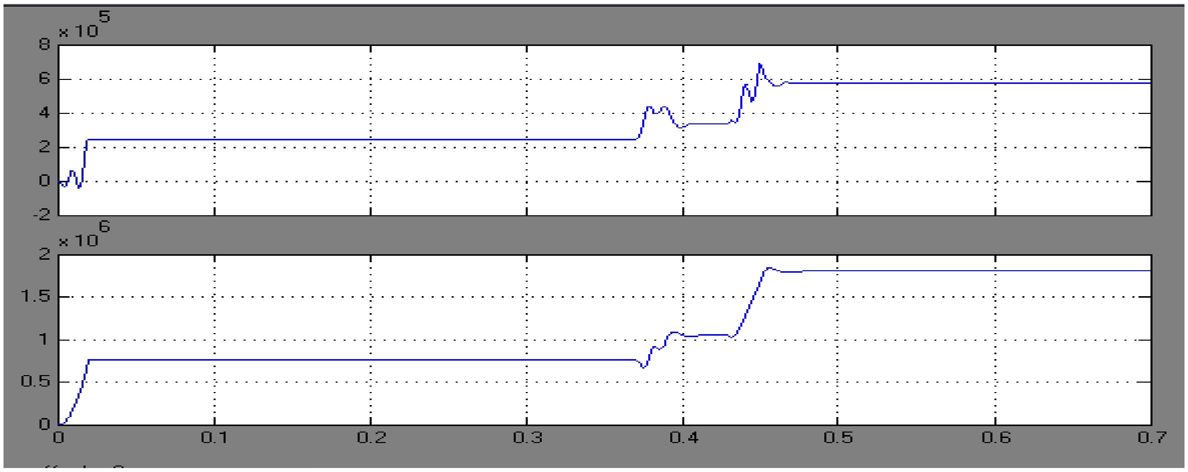

Fig. 4(f). Real And Reactive Power Across Bus-3

Table 1 : Summary Of P & Q.

BUS NO	REAL POWER WITHOUT UPQC (MW)	REAL POWER WITH UPQC (MW)	REACTIVE POWER WITHOUT UPQC (MVAR)	REACTIVE POWER WITH UPQC (MVAR)
BUS-7	0.0013	0.0117	0.0032	0.0096
BUS-1	0.277	0.275	0.304	0.352
BUS-3	0.42	0.575	1.32	1.801
BUS-11	3.20	3.21	3.35	3.36

4. CONCLUSION.

The Fourteen bus system with UPQC 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 THD in the output is reduced by using UPQC. The simulation results are in line with the predictions.

The scope of this work is the modelling and simulation of Fourteen bus system. Simulation of thirty bus system is yet to be done. Closed loop system may be simulated by using neural network or hysteresis control.

REFERENCES.

[1] C. Sankaran, Power Quality, Boca Raton: CRC Press, (2002) p:202.
[2] R.A.Walling, R.Saint, R.C.Dugan, J.Burke and I.A.Kojovic, "Summery of Distributed Resources Impact on Power Delivery Systems", IEEE Trans, Power Delivery, Vol.23, No:3, (July 2008), pp:1636-1644.
[3] H.Akagi, and H.Fujita, "The unified power quality conditioner. The integration of series and shunt-active filters," IEEE Trans. Power Electron., Vol.13, No:2, (Mar, 1998) pp: 315-322. "A new power line conditional for harmonic compensation in power systems," IEEE Trans. Power Del., Vol.10, No.3, (Jul, 1995) pp:1570-1575.
[4] H.Akagi, E.H.Watanabe and M.Aredes, Instantaneous Power Theory and Applications to Power Conditioning. Wiley-IEEE Press. (April 2007)
[5] D.Graovac, A.Katic, and A.Rufer, "Power Quality Problems Compensation with Universal Power Quality Conditioning System, IEEE Transaction on Power Delivery, Vol.22, No.2. (2007)
[6] B.Han, B.Bae, H.Kim, and S.Back, "Combined Operation of Unified Power Quality Conditioner with Distributed Generation," IEEE Transaction on Power Delivery, Vol.21, no.1, (2006) pp.330-338.
[7] M.Aredes, "A combined series and shunt active power filter," in Proc. IEEE/KTH Stockholm Power Tech Conf., Stockholm, Sweden, (June 1995), pp.18-22.
[8] Y.Chen, X.Zha, and J.Wang, "Unified Power Quality conditioner (UPQC): The theory, modeling and application," Proc. Power System Techlogy Powr Con Int. Conf., Vol.3, (2000), pp1329-1333.
[9] F.Z. Peng, J.W. McKeever, and D.J. Adams, "A power line conditioner using cascade multilevel inverters for distribution systems," IEEE Trans.Ind.Appl., vol.34, no.6, Nov./Dec. 1998, pp.1293-1298,
[10] G.M.Lee, D.C.Lee and J.K.Seok, "Control of series active power filter compensating for source voltage unbalance and current harmonics," IEEE Transaction on Industrial Electronics, vol.51, no.1, (Feb.2004), pp.132-139.
[11] V.Khadkikar, A.Chandra, "A New Control Philosophy for a Unified Power Quality

Conditioner (UPQC) to Coordinate Load – Reactive Power Demand between Shunt and Series Inverters," IEEE Trans. on Power Delivery, Vol.23, no.4, (2008), pp.2522-2534.

[12] M. Aredes, H.Akagi, E.H.Watanabe, E.V.Salgado, L.F. Encarmacao, "Comparisons between the p-q and p-q-r Theories in Three Phase Four-Wire Systems," IEEE Transactions on Power Electronics, vol.24, no.4, (April, 2009), pp.924-933.

[13] A.Esfandiari, M.Parniani, A.Emadi, H.Mokhtari, "Application of the Unified Power Quality Conditioner for Mitigating Eletric Arc Furnace Disturbances," International Journal of Power and Energy Systems, Vol.28, no.4, (2008), pp.363-371.

[14] Mariun N., A.Alam, S.Mahmod, H.Haizam, Review of Control Stategies for powe quality conditioners, power and energy conference proceedings, vol.2, (2004), pp.1515-1520.

[15] L.F.C. Monteiro, M.Aredes, and L.A.M. Neto, "A control stategy for unified power quality conditioner," in Proc. IEEE Int. Symp. Ind. Electron., Vol.1, (Jun.2003), pp.391-396.