Power Quality Improvement of Supply System using UPQC Dual Compensating Scheme

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Abstract— The behavior of the system under the condition of non-linear loading like micro-controller, micro-processor based load laptop, computers digital signal processor etc power electronic based loading has been analysed. The analysis has been undertaken to mitigate harmonics in the supply system generated due to nonlinear loading conjointly reduction in power loss under such condition is taken care off. a power conditioner has been designed to boost voltage and current quality which is Unified Power Quality conditioner (UPQC).UPQC is featured with dual compensation strategy such it employs 2 converters One is connected serial through a coupling transformer Another is parallel connected at load side.

Keywords: Unified Power Quality Conditioner (UPQC), Custom Power Devices (CPD), Low Pass Filter (LPF), High Pass Filter (HPF), Phase Lock Loop

I. INTRODUCTION

The PQ issues originate from completely different events like non-linear loads, switch on/off of large equipment at the end user or from faults on transmission and distribution lines. These PQ issues are classified by 5 main events: sags, swells, harmonics, interruptions and transients. These events will cause degradation in services, which might cost financial losses to each service supplier and customers [2].Power electronic based sensitive equipments also are another root reason behind answer is also hidden in correct design and control mechanism of Power electronic componenet to mitigate PQ connected issues [1], [2].once converters are properly designed and properly placed within the system they're the best solution for PQ issues. Technically Power electronic components which are used to mitigate PQ problem and improves the performance of the distribution systems are termed as custom power devices (CPD).Distribution side quality of power will be increased by putting in CPD at load terminals. One such customized device is Unified Power Quality Conditioner (UPQC), that is seemingly suggested at the customer-end.it will recuperate the voltage profile distorted due to abnormality in operation and non-linear loading. UPQC systems will perform, at the same time, the series–parallel active power-line compensation by using each series and parallel converters. Thus, for overcoming utility PQ issues, UPQCs are used supported different ideas and solutions [10] comprising single-phase systems or in three-phase applications, considering three-phase three-wire (3P3W) systems [1], [3], [9] or three-phase four-wire (3P4W) systems [2], [4], [8] consequently, in most UPQC-based applications, the series and parallel active power filter (APFs) are controlled as non-sinusoidal sources by using non-sinusoidal references to regulate voltage- current quantities [1], [6]–[10].Hence improving the ability quality at customer end sinusoidal reference frame based mostly UPQC system has been designed. The analysis has been undertaken to mitigate harmonics within the supply system generated due to nonlinear loading additionally reduction in power loss under such condition is taken care off. a power conditioner has been designed to enhance voltage and current quality which is Unified Power Quality conditioner (UPQC). UPQC is featured with dual compensation strategy such that it employs 2 converters.

One is connected serial through a coupling transformer another is in parallel connected at load side. In this work also one such converter particularly UPQC has been customized to enhance PQ of the supply system.

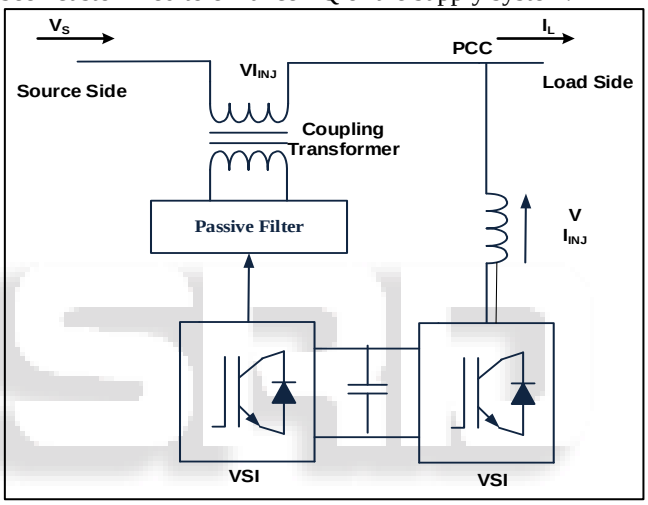

Fig. 1: Schematic diagram of Grid connected UPQC system.

II. CONTROL OF UPQC

Conventionally UPQC are controlled nonsinusoidally. It is difficult to develop control algorithm for APF which are nonsinusoidal. Additional control is desired to improve the performance of such system. In this work UPQC are controlled sinusoidally hence less effort is required to control shunt and series APF. Such type of control is called synchronous reference frame (SRF). SRF control resembles the instantaneous control theory. The characteristics property of this strategy is that only load current is essential here for the generation of reference current and hence disturbances present in source or distortions present in voltage have will leave no negative impact on the performance of the designed UPQC system. In the proposed topology, the three phase voltage or current signals are sensed and to develop the control signal they are transformed from abc to rotating dq0 frame using parks transformation. The transformation angle ωt is rotating at constant speed and is synchronized with the 3-Ø ac voltage using PLL. After this, currents having same magnitude but with reverse phase is produced and injected to the proposed system for compensating neutral current, harmonics, and reactive power. In the stationary reference frame abc

coordinates are stationary, while in the SRF, d−q−0 coordinate is rotating in synchronism with supply voltages. This is presented in Figure 2.

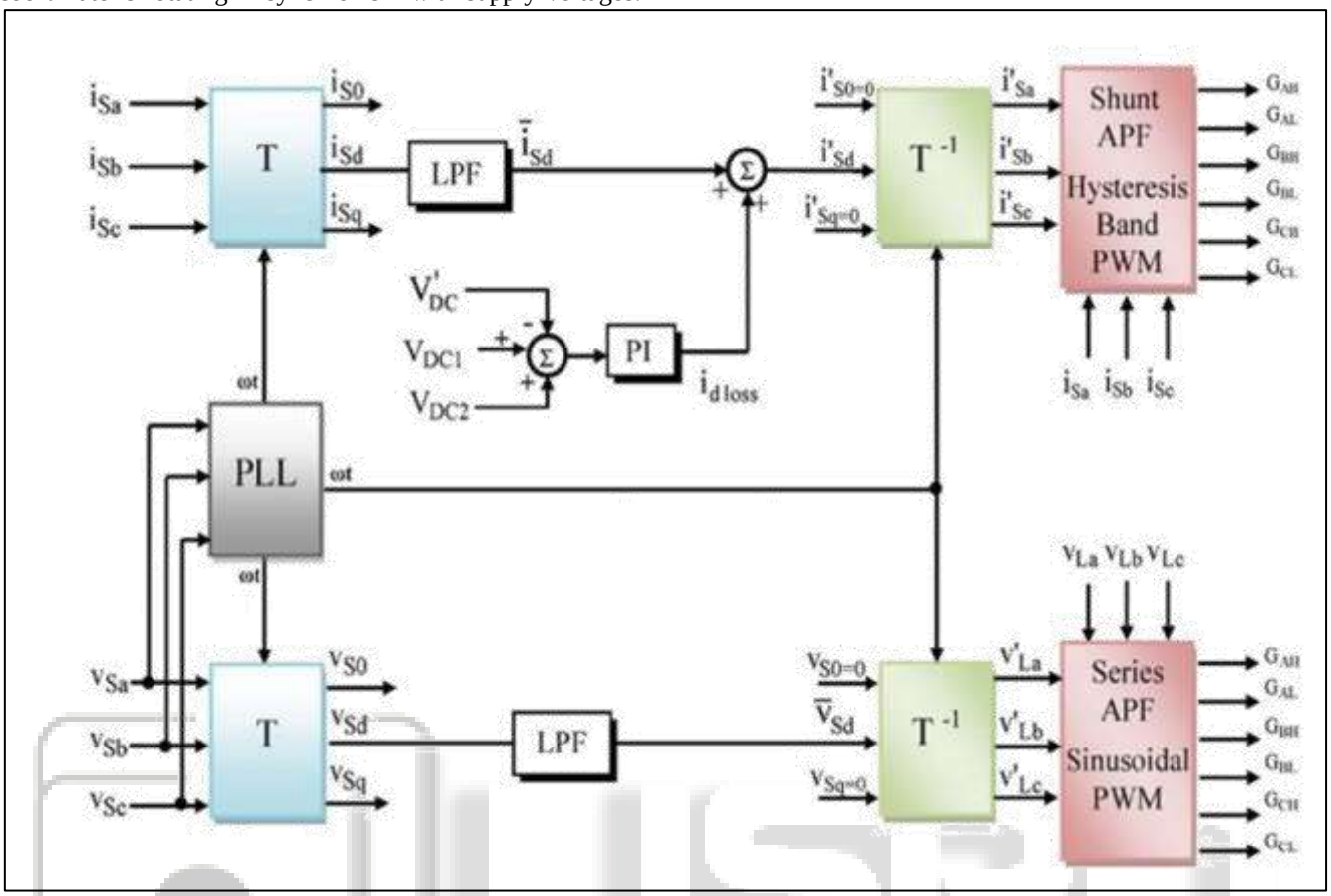

Fig. 2: SRF control for UPQC operation

From figure 2 it is clear that two controls are developed; one for series APF and another for shunt APF. The series APF acts as a controlled sinusoidal current source whose three phase current is transformed into dq0 using park's transformation as in equation (1)

$$\begin{bmatrix} Iso \\ Isd \\ Isq \end{bmatrix} = T \begin{bmatrix} Isa \\ Isb \\ Isc \end{bmatrix} \quad (1)$$

Where,

$$T = \sqrt{\frac{2}{3}} \begin{vmatrix} \frac{1}{\sqrt{2}} & \sin(\omega t) & \cos(\omega t) \\ \frac{1}{\sqrt{2}} & \sin(\omega t - 120°) & \cos(\omega t - 120°) \\ \frac{1}{\sqrt{2}} & \sin(\omega t + 120°) & \cos(\omega t + 120°) \end{vmatrix} \quad (2)$$

The reference current is again obtained from inverse park's transform.

The shunt APF acts as a sinusoidal voltage source. The supply voltage is sensed and then it is transformed into d-q-0 frame of reference by the following transformation matrix:-

$$\begin{bmatrix} Vso \\ Vsd \\ Vsq \end{bmatrix} = T \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix}$$

Both the measured and reference source current are compared now and are synthesized using PI controller for getting the gating signals for operation of shunt and series APF in the given UPQC model and hence mitigating all the current related problem from the system.

III. UPQC DESCRIPTION

In general UPQC can be designed by connecting two VSIs as shown in figure 1. The logic behind this is two mitigate voltage and current abnormalities simultaneously. A series converter is connected source side using coupling transformer and parallel transformer is directly shunted load side. In the proposed work as shown in figure 2, PI based series and parallel voltage source inverter (VSI) is used for series and parallel conditioning. While designing UPQC filters plays very important role in mitigating load as well as source voltage-current harmonics. In the proposed work three types of non-linear loading is tested for with and without UPQC designed and Their %THD Value has been Comparative analysed.

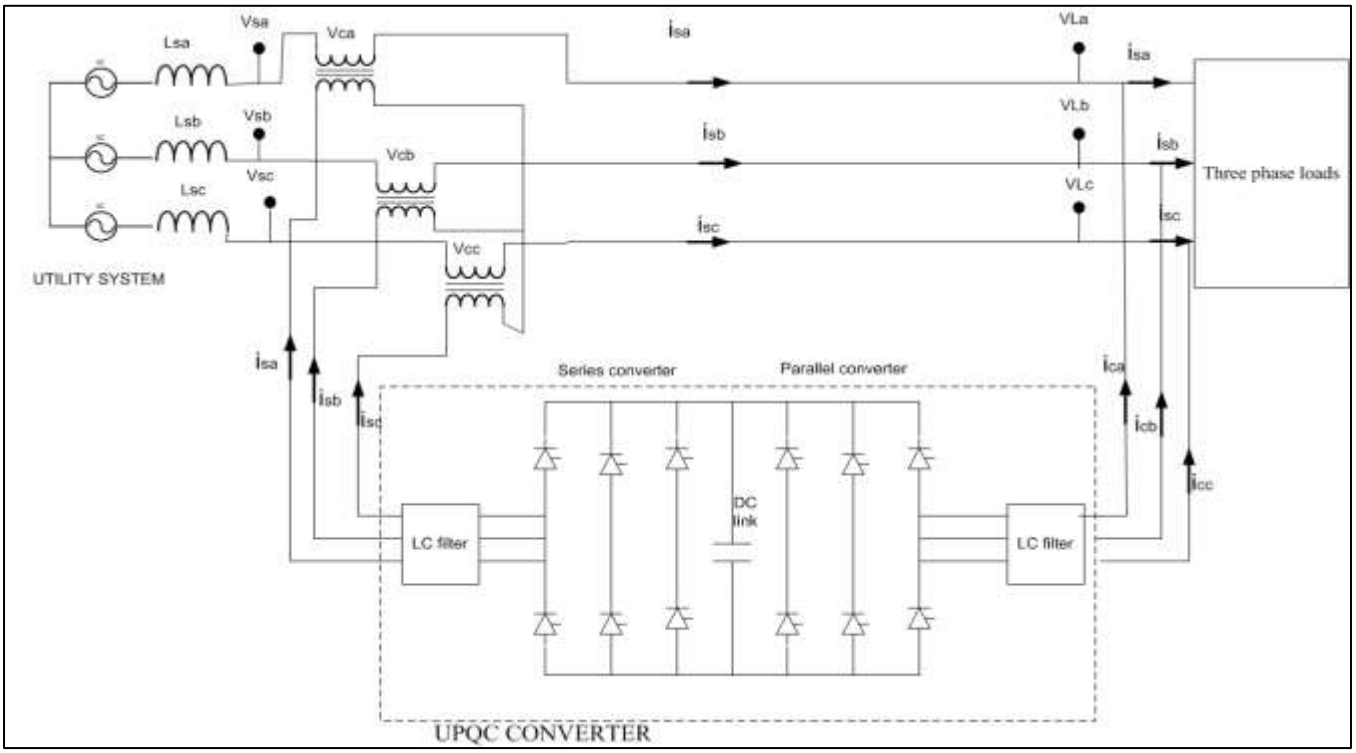

Fig. 3: Proposed UPQC system.

IV. PROPOSED WORK

In this Praposed work a dual compensating scheme based UPQC (Unified Power Quality Conditioner) controller has been designed for compensating source condition for all non-linear loading. Three types of loading has been tested in the proposed work through three phase and single phase rectifier as shown in Table 1. The focus of the research is to mitigate harmonics in the supply system generated because of nonlinear loading and maintain the supply profile at all adverse conditions. A PI controller is used to generate a control signal for triggering inverter. In place of using three PI controller for three phase system only one controller is used. This could be possible by converting three phase abc into two phase dq0 system. A phase lock loop controller is used to synchronize the UPQC with the utility system whose reference signal could be obtained either from three phase grid voltage or current. The system parameters are presented in table 2. Firstly a three phase three wire distribution is designed for operating the below mentioned three types of loading without connected UPQC. Than a UPQC is connected and again results are obtained for the mentioned loading conditions. As mentioned earlier designing of an UPQC filer design is a very important consideration. The system is designed in MATLAB software using Simulink tool-kit. The source and load side voltage and current waveforms are analysed.

Unbalanced three phase loads	Phase A	Phase B	Phase C
Three single phase rectifier with RL loading (load-1)	R=8.1 ohm L=380mH	R=10.12 ohm L=346mH	R=13.5 ohm L=357mH
Three single phase rectifier with RLC loading (load-2)	ohm C=940 micro F	ohm L=346mH	ohm L=380mH
Balanced loading connected via three phase full wave rectifier (load-3)	R=17.7 ohm		

Table 1: Operating conditions

Effective nominal voltage of the utility (line to neutral)	Vs a , b , c = 127 V
Switching frequency of the converters	20 KHz
Nominal utility grid frequency	fs = 50 Hz
Dispersion inductance of the series coupling transformer	0.42mH
Resistance of series coupling transformer	0.26Ω
Transformation ratio of the series coupling transformers	n = 1
dc-bus voltage	Vd c = 400 V
dc-bus capacitance	Cd c = 9400 µF

Table 2: System parameters

LOADING	FILTER
Load-1	Ls=1.5mH,Rs=0.15Ω Lp=1mH,Cp=59mF, Rp=0.12Ω
Load-2	Ls=1.5mH,Rs=0.15Ω Lp=1mH,Cp=59mF, Rp=0.12Ω
Load-3	Ls=1.5mH,Rs=0.15Ω Lp=1mH,Cp=700µF, R=0.12Ω

Table 3: Filter Parameters

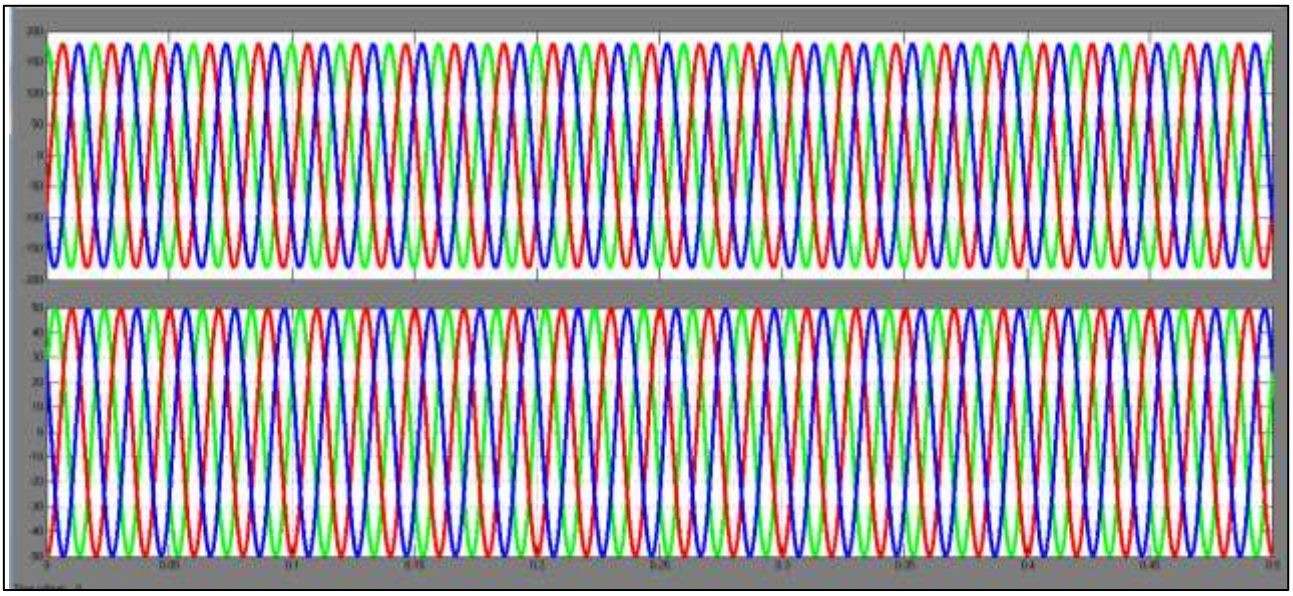

Fig. 3: Voltage and current source side for RL load for proposed UPQC system.

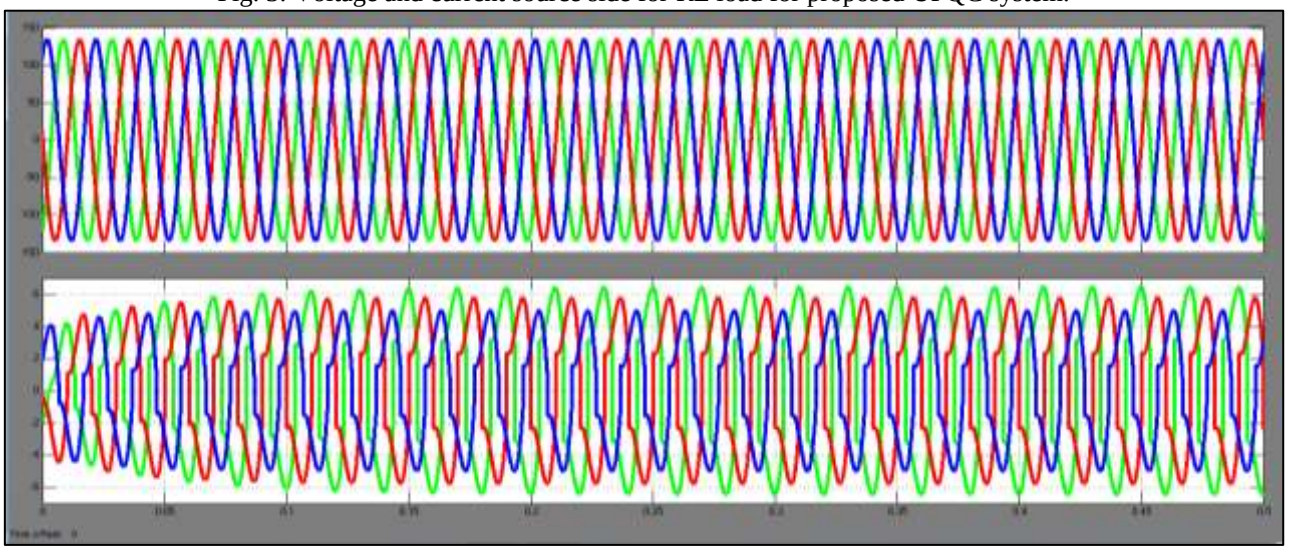

Fig. 4: Voltage and current load side for RL load for proposed UPQC system

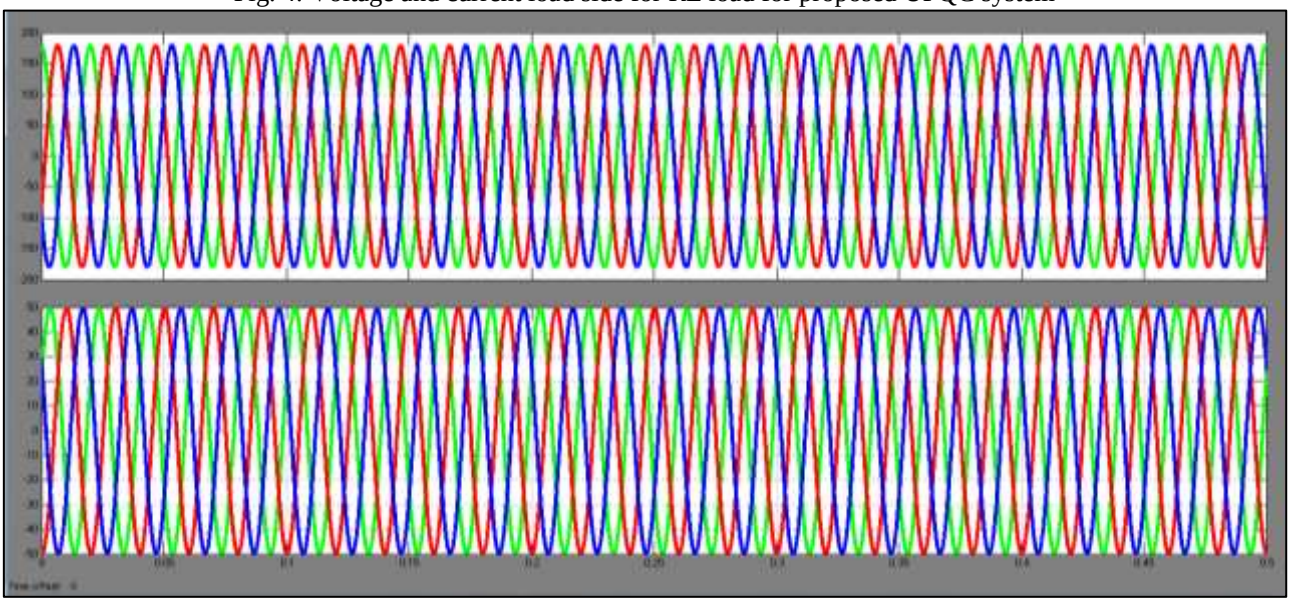

Fig. 5: Voltage and current source side for RLC load for proposed UPQC system

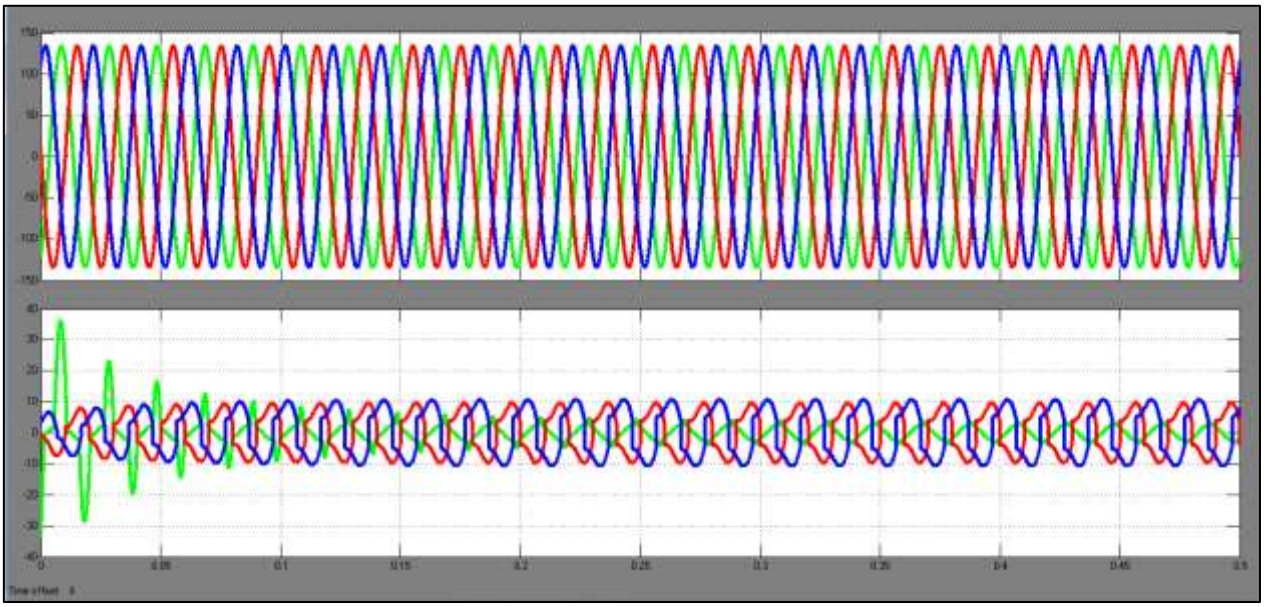

Fig. 6: Voltage and current Load side for RLC load for proposed UPQC system

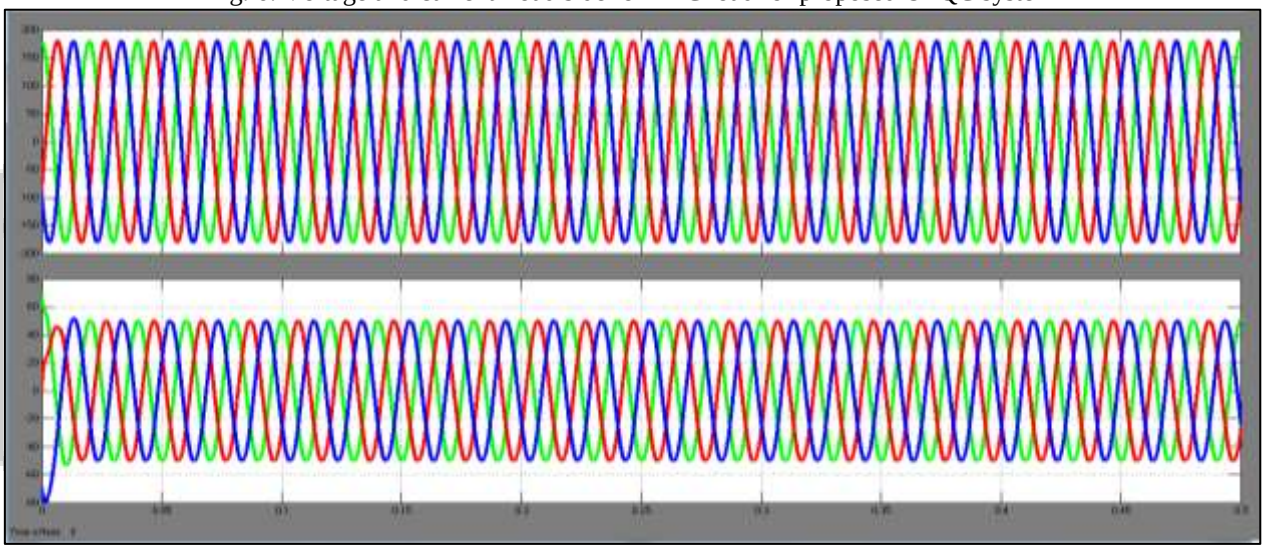

Fig. 7: Voltage and current source side for balanced non-linear R-load for proposed system

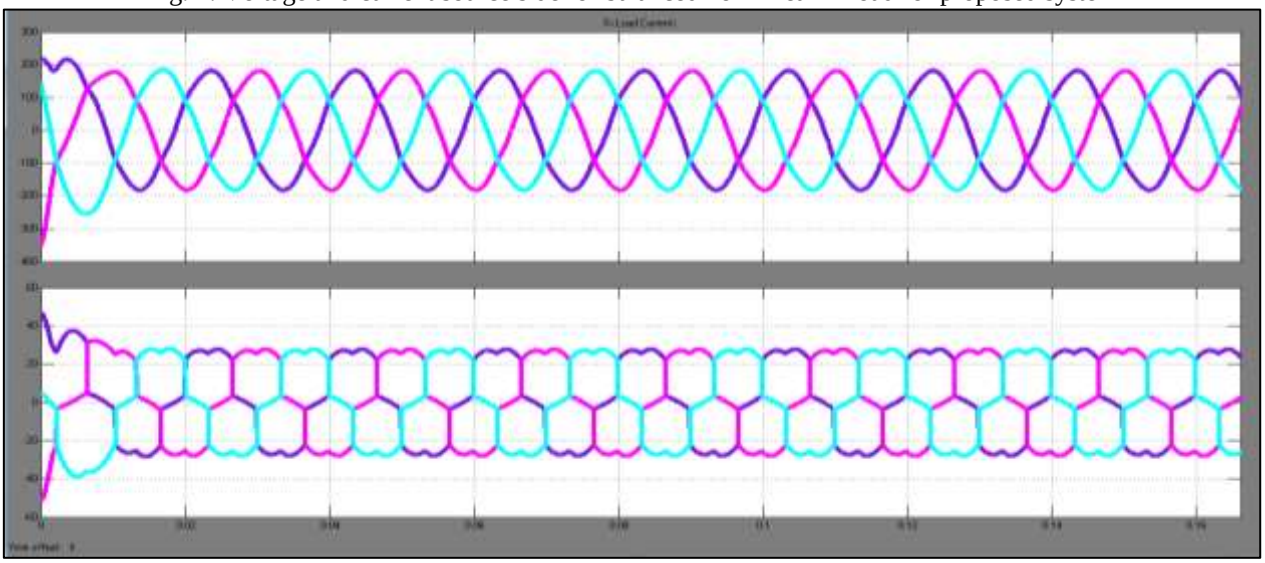

Fig. 8: Voltage and current load side for balanced non-linear R-load for proposed system

V. RESULT DISCUSSION

The system is analyzed with and without UPQC connected. The duo controllers namely series and parallel are synchronized with grid using PLL and the signals are extracted from the grid voltage three phase reference values. The PI control designs the gating signals for inverter circuit. The UPQC successfully regulates the load voltage and load current harmonics and maintains the grid profile. The performance of the proposed system has also been analysed for Three types of loading For With And Without UPQC and their comparative analysis of Source current THD, source voltage THD and Load current THD is presented in Table 3, 4 and 5 respectively.

	THD%					
Three Phase Load	Without UPQC			With UPQC		
	i_{Sa}	i_{Sb}	i_{Sc}	i_{Sa}	i_{Sb}	i_{Sc}
Three single-phase full-wave rectifiers (unbalanced load 1)	45.64	45.25	45.66	0.00	0.00	0.00
Three single-phase full-wave rectifiers (unbalanced load 2)	46.67	40.09	57.94	0.00	0.00	0.00
Balanced three-phase load Three-phase full-wave Rectifier (17.7 ohm)	28.45	28.50	28.7	1.00	0.99	0.99

Table 3: Comparison of Source Current THD with and without UPQC

	THD%					
Three Phase Load	Without UPQC			With UPQC		
	V_{Sa}	V_{Sb}	V_{Sc}	V_{Sa}	V_{Sb}	V_{Sc}
Three single-phase full-wave rectifiers (unbalanced load 1)	0.61	0.52	0.40	0.00	0.00	0.00
Three single-phase full-wave rectifiers (unbalanced load 2)	0.00	0.52	0.61	0.00	0.00	0.00
Balanced three-phase load Three-phase full-wave Rectifier (17.7 ohm)	0.40	0.31	0.44	0.00	0.00	0.00

Table 4: Comparison of Source Voltage THD with and without UPQC

	THD%					
Three Phase Load	Without UPQC			With UPQC		
	I_{La}	I_{Lb}	I_{Lc}	I_{La}	I_{Lb}	I_{Lc}
Three single-phase full-wave rectifiers (unbalanced load 1)	45.65	45.25	45.66	24.54	22.93	19.36
Three single-phase full-wave rectifiers (unbalanced load 2)	46.67	40.09	57.94	25.85	22.93	24.83
Balanced three-phase load Three-phase full-wave Rectifier (17.7 ohm)	28.4	28.5	28.7	22.06	21.90	22.01

Table 5: Comparison of Load Current THD with and without UPQC

VI. CONCLUSION

From Result it can be concluded that

- Harmonics in voltage and current can be efficiently reduced IN Source side by this method.
- With UPQC, THD in source current is low as compared to Without UPQC THD in Source current for all three types of Non Linear Loading.
- With UPQC, THD in Source Voltage is low as compared to Without UPQC THD in Source Voltage for all three types of Non Linear Loading.
- With UPQC, THD in Load current is low as compared to Without UPQC THD in load current for all three types of Non Linear Loading.

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