International Journal of Engineering Research and General Science Volume 3, Issue 3, Part-2 , May-June, 2015
ISSN 2091-2730

Power Quality Improvement by UPQC in Distribution System

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Abstract— The quality of electrical power supply is adversely affected by the use of power electronic based equipment. Power quality problems raised are reduced by using Custom Power Devices (CPD).Unified Power Quality Conditioner (UPQC), is a device which allow the mitigation of voltage and current disturbances that could affect sensitive electrical loads. UPQC is a combination of Series Active Power Filter (APF) that compensates voltage harmonics of the power supply, and Shunt APF that compensates harmonic currents of a non-linear load. This paper presents realization of UPQC using PWM-VSI inverter in MATLAB/Simulink tool. A dqo transformation based PWM controller is used to derive gating pulses for the IGBT switch. Comparison of voltage and current level in different operating condition, along with the level of Total Harmonic Distortion (THD) with and without UPQC and faulted condition.

Keywords— Power Quality, UPQC, APF, THD, dqo transformation, FACTS, Shunt Controller, Series Controller.

INTRODUCTION

In modern power distribution system the use of nonlinear loads is increased. Many non-linear loads like electric arc furnaces, power electronic convertors etc. introduces current and voltage harmonics. Proper functioning of sensitive loads like computers, micro-controllers depend upon the quality of power supplied. Various electrical power quality problems such as voltage sag, swell, harmonics, noise, voltage unbalance, etc are found. For the mitigation of current as well as voltage based distortions, various Custom Power devices can be used. Different CPD such as Dynamic Voltage Regulator (DVR), Distribution Static Compensator (DSTATCOM), and UPQC are also reported for the effective mitigation of voltage sag/swell, while compensation capability of UPQC is better.

The UPQC is a combination of series and shunt active filters connected in cascade via a common DC link capacitor. Both the devices are fired by gating signals. The gate pulses are generated by control technique used. It is the control strategy which decides the efficiency of a particular system. The main purpose of a UPQC is to compensate for supply voltage and current. UPQC can absorb active power or inject active power. The shunt connected converter balance the source currents by injecting negative and zero sequence components and control the power factor by injecting the required reactive current. The series connected converter balance the voltages at the load bus by injecting negative and zero sequence voltages and regulate the magnitude of the load bus voltage by injecting the required active and reactive components.

This paper deals with the effectiveness of UPQC for distribution network with nonlinear load under normal and faulted conditions. The proposed control technique has been evaluated under different load conditions using MATLAB software.

UNIFIED POWER QUALITY CONDITIONER

UPQC is the integration of Series APF and shunt APF, active power filters, connected back-to-back on the dc side, sharing a common DC capacitor. The series component of the UPQC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance etc. It injects currents in the ac system such that the source currents become balanced sinusoids and in phase with the source voltages. The overall function of UPQC mainly depends on the series and shunt APF controller. The integrated controller of the series and shunt APF of the UPQC to provide the compensating voltage reference V_c and compensating current reference $I_{c..}$The system configuration of a UPQC is shown in the Figure given below.

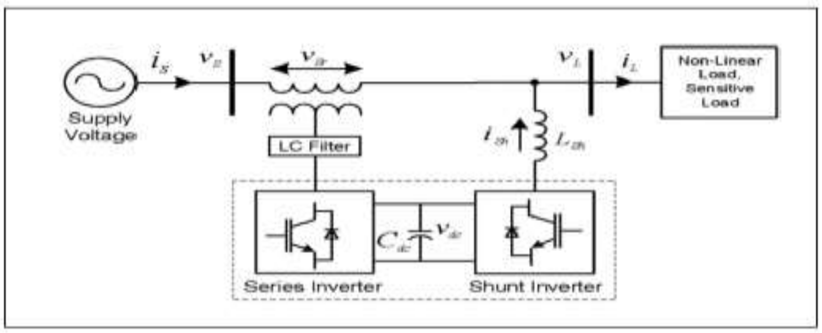

Figure 1. Block Diagram of UPQC

The equivalent circuit of UPQC is shown in the figure 2. An ideal controlled voltage source is connected in series in the circuit and current source is connected in shunt of the circuit so that the circuit works same as that of the UPQC.It is controlled in such a way that the voltage at load bus is always sinusoidal and at desired magnitude. Therefore the voltage injected by series active power filter must be equal to the difference between the supply voltage and the ideal load voltage. Thus the series active power filter acts as controlled voltage source. The function of shunt active power filter is to maintain the dc link voltage at constant level. In addition to this the shunt active power filter provides the VAR required by the load, such that the input power factor will be unity and only fundamental active power will be supplied by the source.

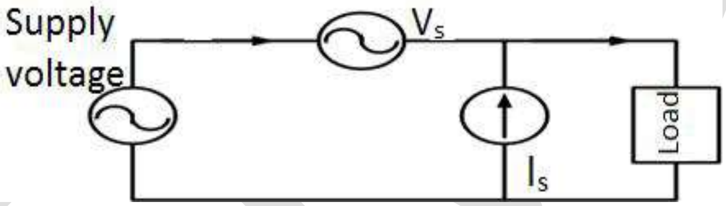

Figure 2. Equivalent Circuit of UPQC

CONTROL STRATEGY OF UPQC

The control strategy proposed here aims to generate reference signals for both shunt and series APFs of the UPQC. The proposed control technique is capable of extracting most of the load current and source voltage distortions. The series APF is controlled to eliminate the supply voltage harmonics; whereas the shunt APF is controlled to the supply current harmonics and negative sequence current. In this paper, d-q frame theory is used to control both series and shunt controller.

A. Description of Implementation of Series Controller

The control strategy of series controller is shown in figure 3, in which voltage from the load and source is converted to its equivalent dq0 components, by using the angles from the discrete three phases PLL. The angles for the calculation are generated by using load voltage. The resultant voltage is then transferred back to the 3 phase component using reverse transformation. The resultant abc component is the fed to the discrete Pulse With Modulation generator (PWM) to produce gate pulses. The dq0 transformation is done by parks transformation. The same formula can be used for current transformation. Inverse parks transformation for the generation of reference signal.

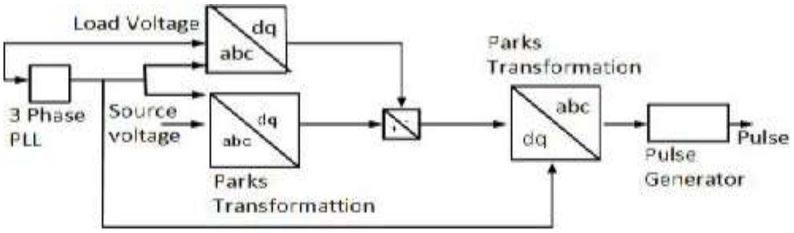

Figure 3. Control Strategy for Series Controller

B. Description of Implementation of Shunt Controller

The control strategy of shunt controller is shown in figure 4. It is same as that for series controller, the difference lies in the fact that input in place of control voltage wave having magnitude of 1 p.u controlled by the angles drawn from the PLL (phase locked loop). Load current is given as input to PLL.The angles for the calculation is generated by using load current using parks transformation equation. Resultant reference signal is fed to PWM generator, which produce gate signal.

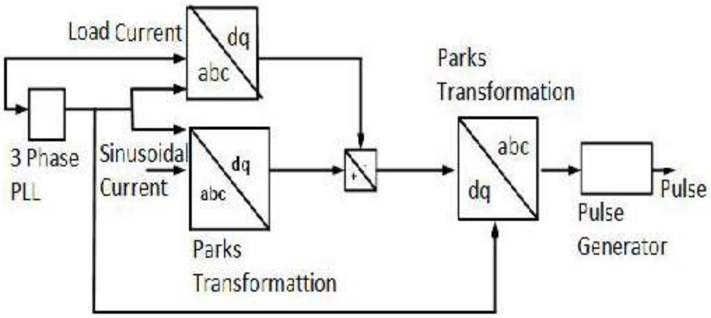

Figure 4. Control Strategy for Shunt Controller

SIMULATION MODEL OF UPQC

In this model, the load is fed from the utility of 200V and 50 Hz as a source. A step up transformer is used to step up the utility voltage of 200V to 440V. A non-linear load is chosen for the purpose of investigation of single line to ground fault and double-line to ground fault. The series and shunt compensator of UPQC is connected through an inductor so that to remove the harmonics from the injected voltage and to remove the distortions in the injected current. Here, two compensators of UPQC works as Dynamic Voltage Restorer (DVR) and Distribution Static Compensator (DSTATCOM), the series compensator works as DVR and the shunt compensator works as DSTATCOM.

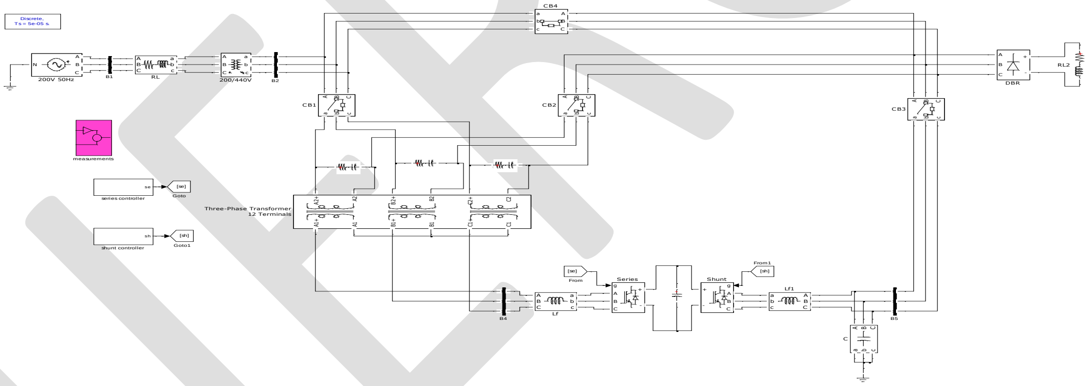

Figure 5. Matlab/Simulink model of UPQC

SIMULATION RESULTS

Based on above proposed model of UPQC, the system is analyzed for normal conditions and fault conditions. Results for simulation without using UPQC are also given for comparison.

A. Simulation results in normal operating conditions

a. Simulation results Without Using UPQC

Model as shown in figure 5, with test parameters is connected to a non-linear load. Load voltage and load current waveforms are shown in figure 6 and 7. Fast Fourier Transform (FFT) analysis is also done to determine the difference in percentage of Total Harmonic Distortion (THD).

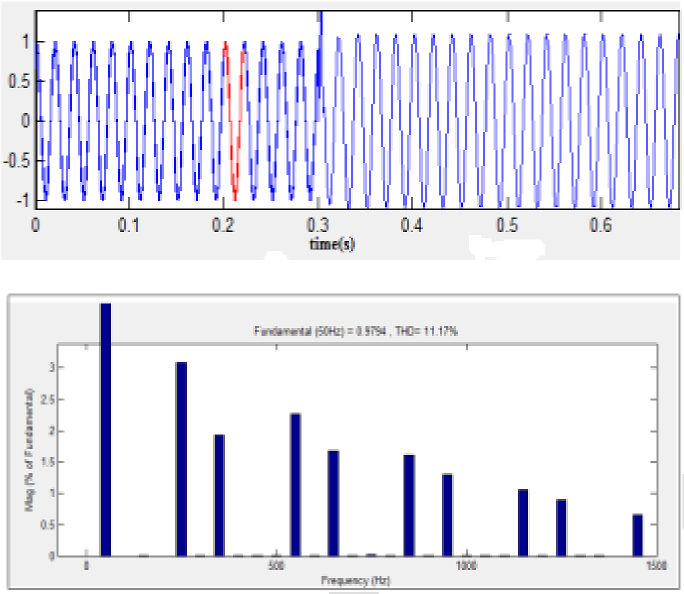

Figure 6. Load Voltage Waveform without UPQC

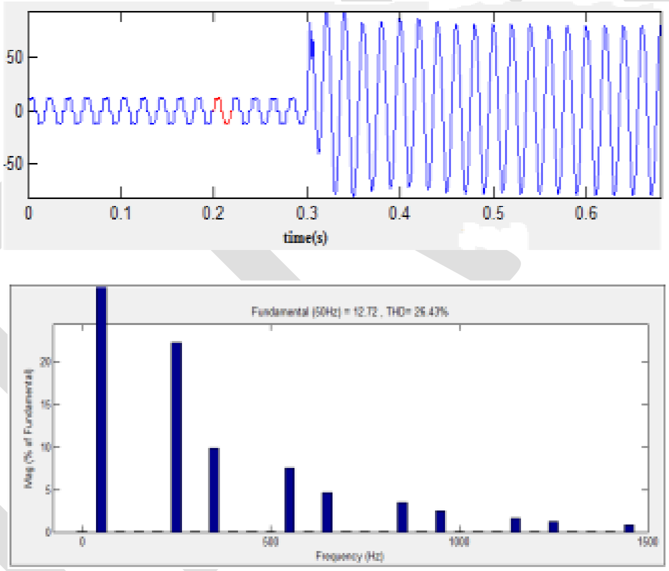

Figure 7. Load Current Waveform without UPQC

Figure 6 and 7 shows the harmonic level with THD.The harmonic level of voltage is 11.17% and the magnitude is 0.9794 p.u and the harmonic level of current is 26.43% and the magnitude level is 12.72 p.u.

b. Simulation results Using UPQC

Load voltage and load current waveforms of test system using UPQC are shown in figure 8 and 9. The harmonic distortion of voltage is reduced to 2.11% and that of current is reduced to 2.92%.

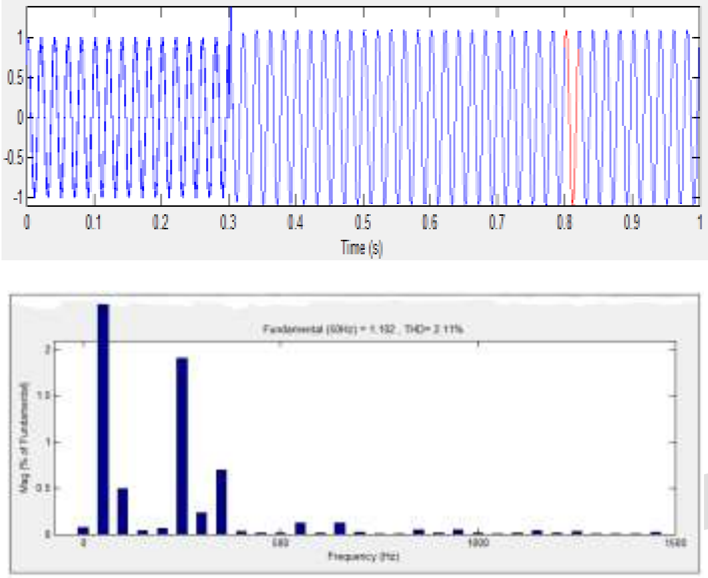

Figure 8. Load Voltage Waveform using UPQC

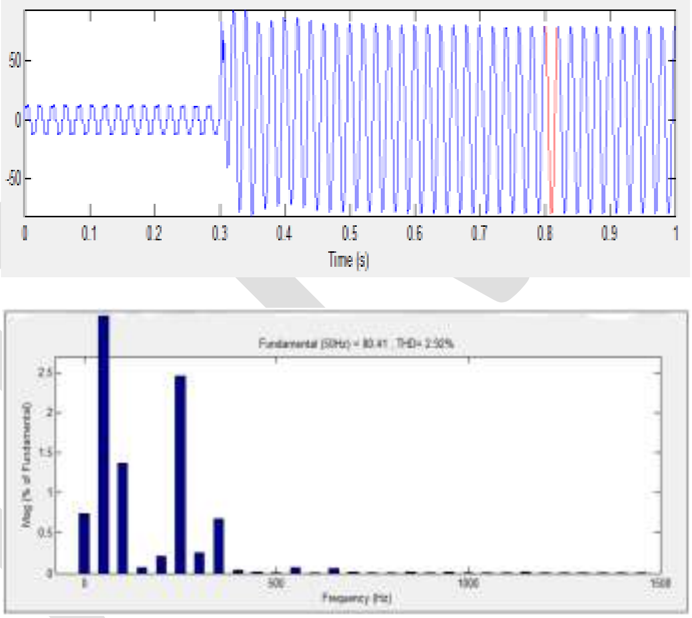

Figure 9. Load Current Waveform using UPQC

The value of total harmonic distortion in both cases signifies the use of UPQC in distribution system.

B. Simulation results in faulted operating conditions

a. Simulation results Without Using UPQC

To check faulted operating condition a single line to ground fault is introduced in the circuit near the load. The fault transition time is chosen between 0.1-0.3 second. It can be seen that voltage level during the transition time is reduced considerably and the current level is increased.

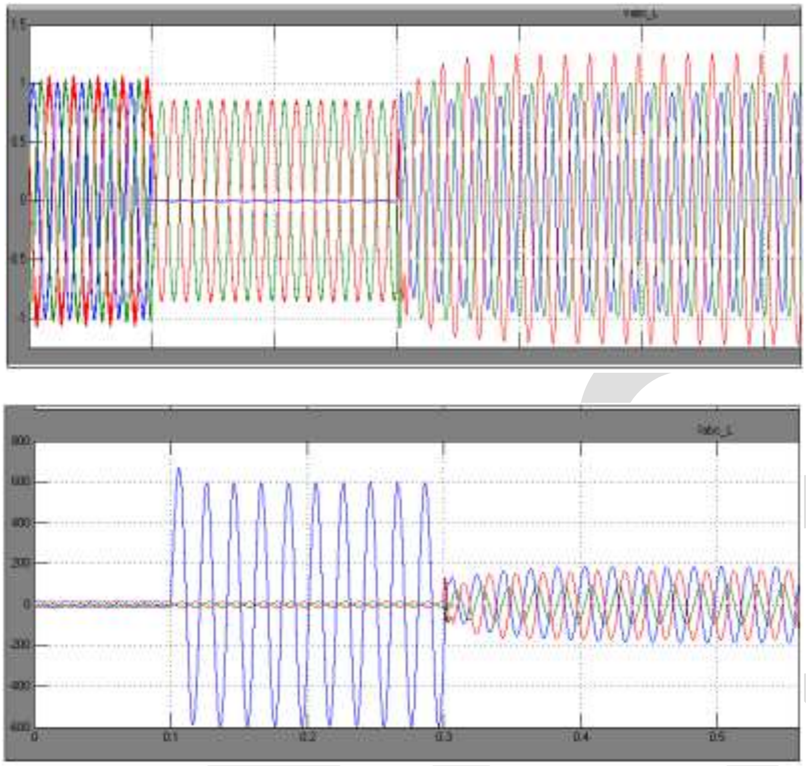

Figure 10. Voltage & Current level during Transition time

At this condition, FFT analysis is done. Figure 11 &12 shows the results for the same.

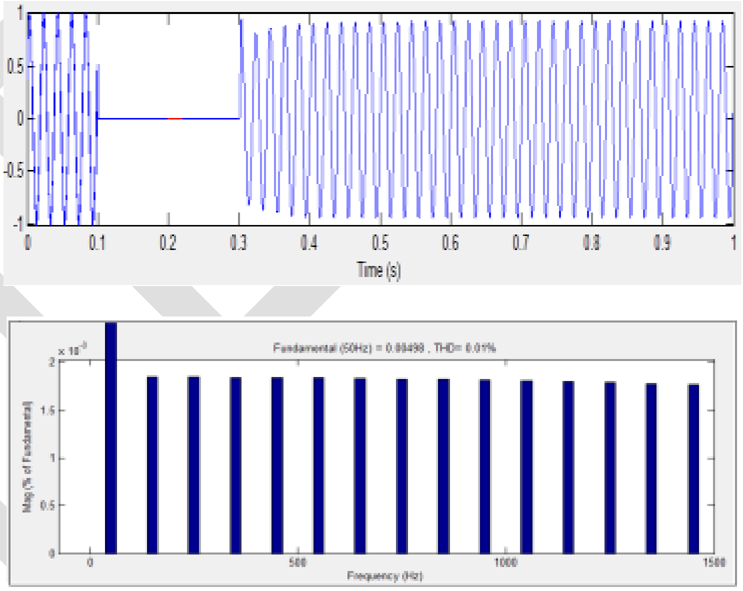

Figure 11. Load Voltage Waveform without UPQC

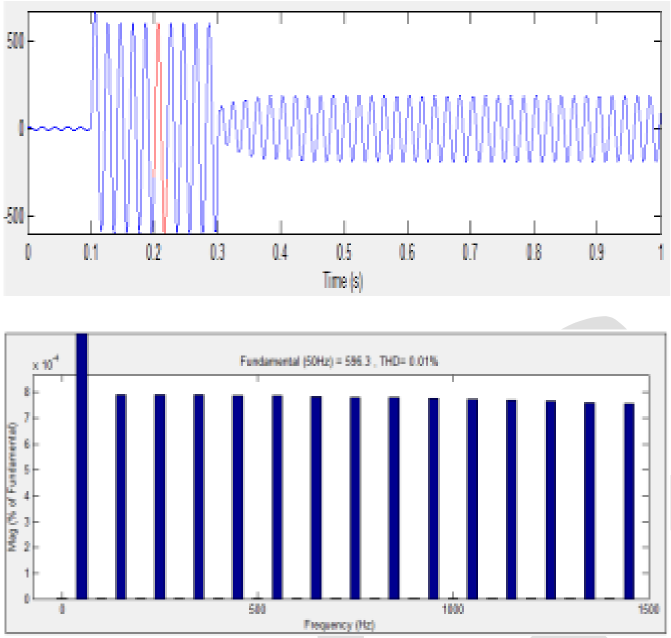

Figure 12. Load Current Waveform without UPQC

b. Simulation results Using UPQC

Wave forms and FFT analysis during UPQC compensation is shown in figure 13 & 14. Voltage and current levels are maintained at permissible limits and the harmonic distortion is considerably reduced below 5%. The harmonic distortions for voltage and current were 1.98% and 1.70% respectively.

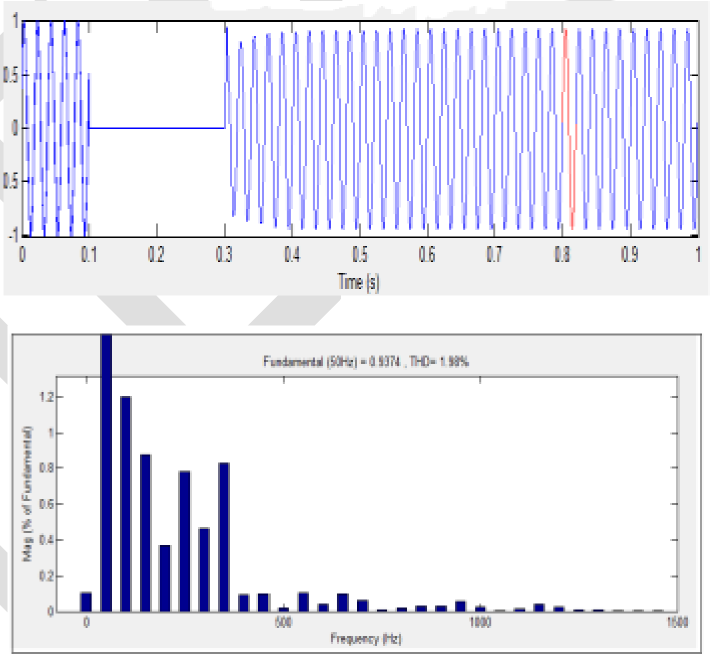

Figure 13. Load Voltage Waveform using UPQC

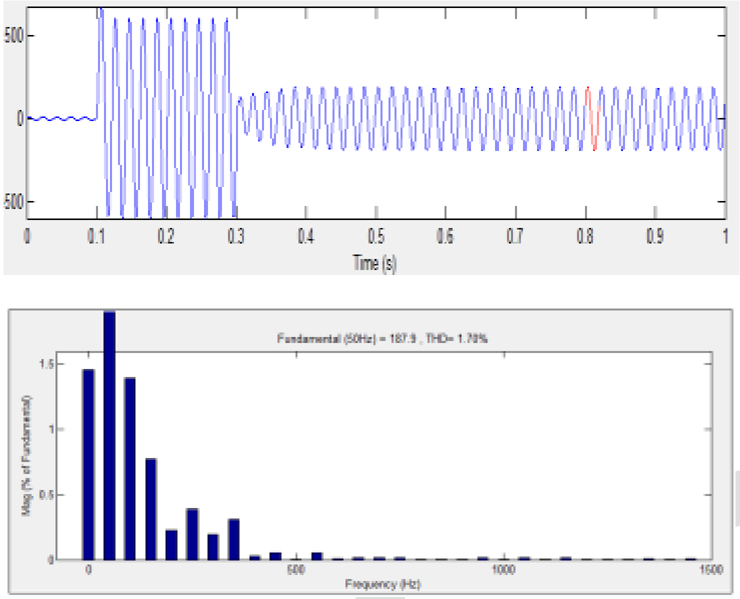

Figure 14. Load Current Waveform using UPQC

Similarly, the waveforms for double line to ground fault can also be observed.

CONCLUSION

In this paper the UPQC is tested under various load condition and single line to ground fault in MATLAB/simulink. It is seen that by designing the model with & without UPQC and analyzing the Fast Fourier transform results, the device is capable to maintain voltage and current in permissible limit and distortion level under 5% of standard.

REFERENCES:

[1] Narain Hingorani & L. Gyugi, “Understanding FACTS, Concepts and Technology of Flexible AC Transmission System”, IEEE Press, 2000.

[2] Jos Arrillaga, Neville R. Watson, and S.Chen “Power System Quality Assessment”, John Wiley & Sons,2000.

[3] K.R.Padiyar “FACTS Controller in Power Transmission & Distribution”. New Age International Publisher, 2007.

[4] I.J.Nagrath and D.P.Kothari “Modern Power System Analysis”, McGraw-Hill, New York, 2011.

[5] Hideaki Fujita and Hirofumi Akagi “The Unified Power Quality Conditioner: The Integration of Series-and Shunt-Active Filters”, IEEE transactions on power electronics, vol. 13, no. 2, March 1998.

[6] Bhim Singh, Kamal Al-Haddad “A Review of Active Filters for Power Quality Improvement”, IEEE transactions on industrial electronics, vol. 46, no. 5, October 1999.

[7] Kolhatkar Y. Y. and Das S. P., “Experimental investigation of a single-phase UPQC with minimum VA loading,” IEEE Trans. Power Deliv., vol. 22, no. 1, pp. 373-380, 2007.

[8] Malabika, B., Das, S., Dubey, G. “Investigation on the performance of UPQC-Q for voltage sag mitigation and PQ improvement at a critical load point”. IET Generation, Transmission and Distribution, Vol. 2, Issue 3, pp. 414-423. 2008.

[9] Ahmet Teke, Lütfü Saribulut, and Mehmet Tümay “A Novel Reference Signal Generation Method for Power-Quality Improvement of Unified Power-Quality Conditioner”, IEEE Transactions On Power Delivery, Vol. 26, No. 4, October 2011.

[10] Khadkikar, V., “Enhancing Electric Power Quality Using UPQC: A Comprehensive Overview”, Power Electronics,IEEE Transactions, vol. 27, no. 5, pp. 2284-2297, May 2012.

[11] Yash Pal, A. Swarup and Bhim Singh, “A Novel Control Strategy of Three-phase, Four-wire UPQC for Power Quality Improvement”, Journal of Electrical Engineering & Technology Vol. 7, No. 1, pp. 1~8, 2012.

[12] Ankush Malhar and Parag Nijhawan “Improvement of Power Quality of Distribution Network with DTC Drive Using UPQC”, International Journal of Emerging Trends in Electrical and Electronics (IJETEE – ISSN: 2320-9569) Vol. 5, Issue. 2, July-2013.

[13] Sumaya Banu, Dr. Sidheswar Prasad, “Study on Three-Phase Four-Wire UPQC device for Power Quality Improvement”, IJEDR,Volume 2, Issue 3,2014