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Comparison of Two Inductor Boost Converter and Interleaved Boost Converter Based Unified Power Quality Conditioner

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Abstract: *In recent times, UPQC is an attractive system between sending end and receiving end. This work deals with identification of suitable boost converter between photo voltaic system and capacitor of UPQC. Two Inductor Boost Converter (TIBC) and Interleaved Boost Converter (ILBC) are considered for comparison purpose. The principle of operation and case studies are presented in this paper. The results of TIBC based system are compared with those of ILBC based system. The Hardware for ILBC based UPQC is fabricated and tested in the laboratory. The ILBC is proposed for UPQC system since it gives superior performance. The MATLAB results show an improved performance with ILBC between PV system and inverter. The Comparison is made in terms of ripple in output voltage, real power and reactive power.*

Keywords - *Unified Power Quality Conditioner, Two Inductor Boost Converter, Inter Leaved Boost Converter, Total Harmonic Distortion, Dynamic Voltage Regulator, Active Filter*

I. INTRODUCTION

In modern power systems, distribution utilities mandate the connected loads to satisfy the strict power quality standards. This is to improve the reliability of the distribution system to meet the needs of critical loads and sensitive automation systems.

The major requirements to maintain good quality power are: 1) Fundamental reactive power requirements of the connected loads 2) Voltage sags and swells at the point of common coupling (PCC) due to connection and disconnection of large industrial loads and reactive power compensating capacitors 3) Voltage and/or current harmonic distortion due to the presence of nonlinear loads. Active power filters (APFs) are the most promising and widely used solutions for improving the power quality (PQ) at the distribution level [1],[2]. These APFs can be classified as Shunt APF, Series APF, and Hybrid APF. The combination of both series and shunt APFs, to reduce all of the voltage and current related PQ problems, is a unified power quality conditioner (UPQC). Superior performance and the capacity to reduce almost all major PQ problems make UPQC the most attractive system for PQ improvement in spite of its high cost, complex structure, and control [1]-[3]. The system configuration of a UPQC is shown in Fig.1.

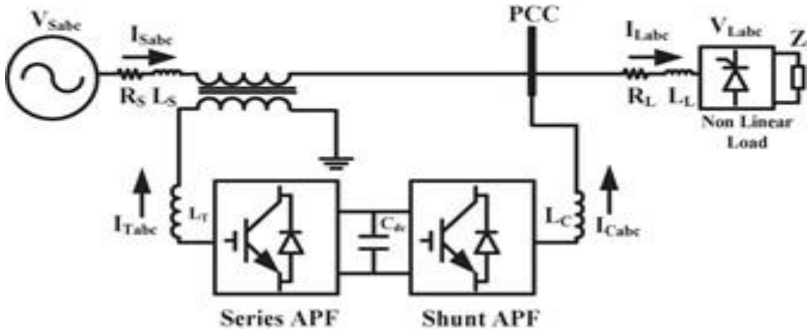

Fig.1: Schematic diagram of the Unified Power Quality Conditioner (UPQC)

Current trends in the area of UPQC are directed toward operating the UPQC with minimum volt ampere (VA) loading to reduce the overall system losses [3]-[12]. However, all of the reported work are based on minimizing the VA loading during voltage sag conditions [3],[4], [7]-[12]. The sizing aspect of the UPQC system (including the shunt inverter, series inverter, and series transformer) considering individual shunt and series inverter VA loading under different operating conditions are discussed.

In [3]-[2], several methods have been proposed for the optimization of total instantaneous VA loading of UPQC (i.e., algebraic sum of VA loadings of shunt and series inverters). In [9] and [10], the authors have used an offline optimization method to compute the optimum angle δ (displacement angle between source and load voltages) that ensure the minimum instantaneous VA loading of UPQC for the given percentage of voltage sag and load power factor. An “80 X 80” matrix-based 2 – D look up table is computed and used for the control of the series inverter during the voltage disturbance (sag/swell) conditions. This algorithm minimizes the total UPQC VA loading at any given operating condition; however, it dos not include the variation in individual VA loadings of series and shunt inverters under different operating conditions.

In [11] and [12], along with load power factor, load current, and percentage of voltage sag, the authors have included the allowable Total Harmonic Distortions (THD’S) of load voltage and source current as variables in the optimization problem. A Particle Swarm Optimization (PSO) based technique is used to compute the instantaneous optimum angle. However, its impact on VA ratings of series and shunt inverters, and series transformers is not considered.

After examining different techniques for minimizing the VA loading of UPQC [3]-[12], it is clear that all the techniques directly or indirectly control the displacement angle. The satisfactory results supporting minimum VA loading claims, at a particular operating point, are found in the literature. It should be noted that obtaining minimum UPQC VA loading at a certain condition (such as voltage sag) does not guarantee minimum VA ratings of the shunt inverter, series inverter, series transformer, and, thus, overall UPQC system.

Although general voltage sags and swells exist only for short durations, the UPQC sizing should be carried out considering the voltage sag/swell as steady state operation for an uninterrupted operation of critical loads in the events of large duration sags/swells.

The above literature does not deal with TIBC/ILBC based UPQC systems. The above papers do not report comparison of TIBC and ILBC based UPQC systems. This work proposes ILBC based UPQC for power quality improvement. The ILBC is proposed between PV source and shunt capacitor.

II. SYSTEM CONFIGURATION

Block Diagram

Block diagram of existing system is shown in Fig.2.1. A large battery is used to charge the capacitor of UPQC.

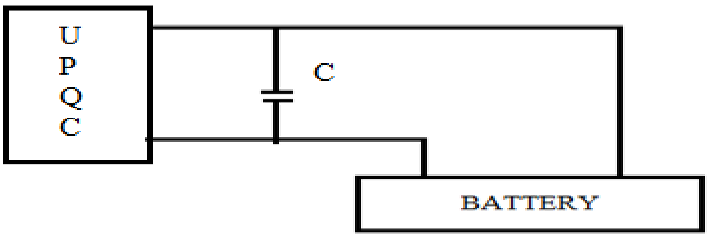

Fig.2.1: Block Diagram of Existing System

The block diagram of proposed system is shown in Fig.2.2. The capacitor of UPQC is charged by the Output of TIBC or ILBC. The output voltage of PV is boosted using TIBC or ILBC.

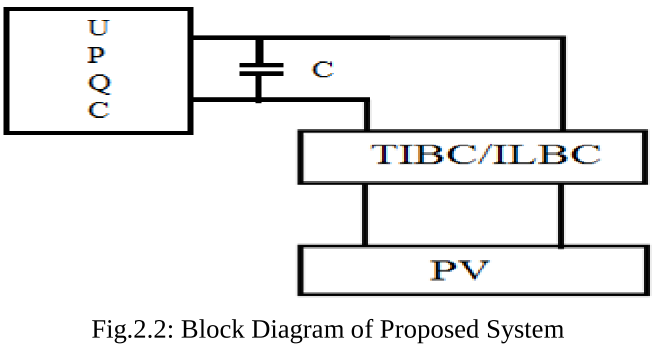

Fig.2.2: Block Diagram of Proposed System

The Battery is replaced by a PV system & ILBC/TLBC to produce the voltage required to charge the capacitor. ILBC/TIBC is preferred to single boost converter due to reduced input current ripple.

Design of UPQC System

Design is done by obtaining the values of V_1, I_1 and frequency of MOSFET. Based on required capacitor voltage, the duty ratio is calculated using the equation

$$V_0 = \frac{V_1}{(1-a)} \qquad (1)$$

Efficiency of the converter to calculate the output current is

$$\eta = \frac{V_a I_a}{V_1 I_a} \qquad (2)$$

The values of L & C are calculated by assuming ΔI & ΔV are

$$\Delta V = \frac{V_1 D}{f L} \qquad (3)$$

$$\Delta I = \frac{I_a D}{f C} \qquad (4)$$

Voltage to be injected is equal to IZ. The active filter is designed to supply fifth harmonic. The value of C_5 is assumed and L_5 is calculated with formula

$$f_5 = \frac{1}{2\pi (L_5 C_5)^{\frac{1}{2}}} \qquad (5)$$

Pulse width for switches of DVR inverter is $\frac{T_0}{2}$. Pulse width for switches of AF inverter is $\frac{T_5}{2}$.

III. SIMULATION RESULTS

3.1 TIBC based UPQC System

SIMULINK model of UPQC system with TIBC is shown in Fig.3.1. A Two Inductor Boost Converter is used between PV cell and capacitor of UPQC. Solar model of TIBC based is shown in Fig.3.2. Output power is product of output voltage and current.

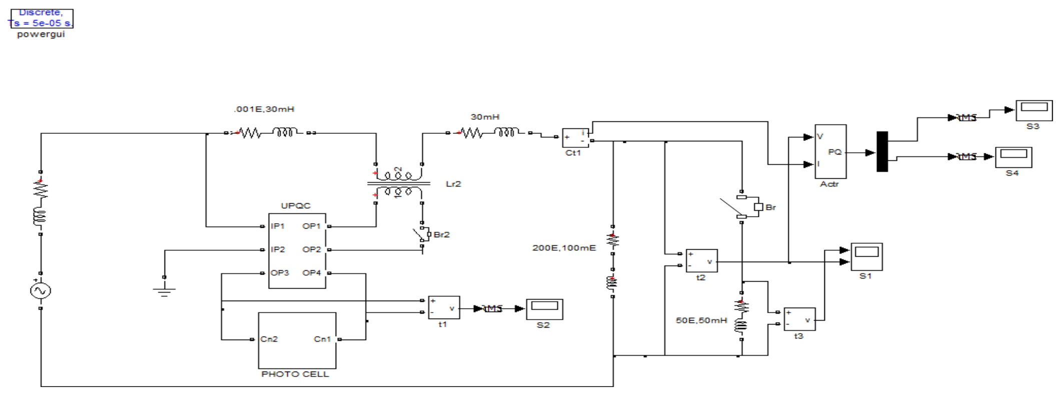

Fig.3.1: UPQC with Two Inductor Boost Converter

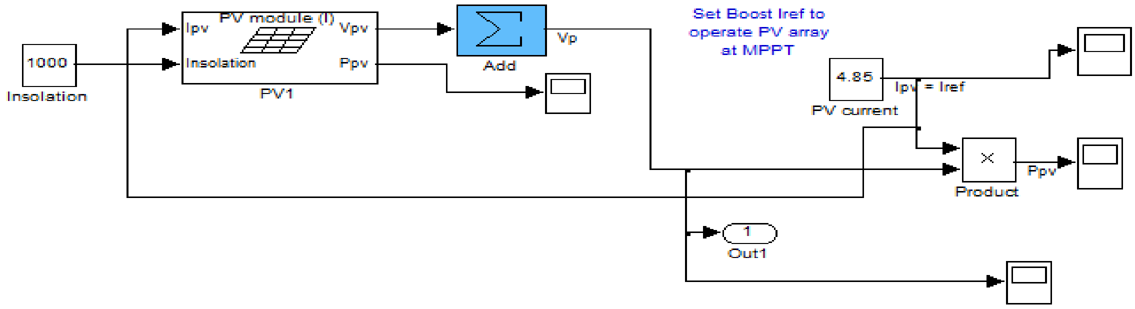

Fig.3.2: Solar model for TIBC

Two Inductor Boost Converter circuit is shown in Fig.3.3. The input current ripple is reduced since the pulses given to M_2 are shifted by 180^0 w.r.to M_1. Output voltage of Two Inductor Boost Converter is shown in Fig.3.4 and its value is 700V.

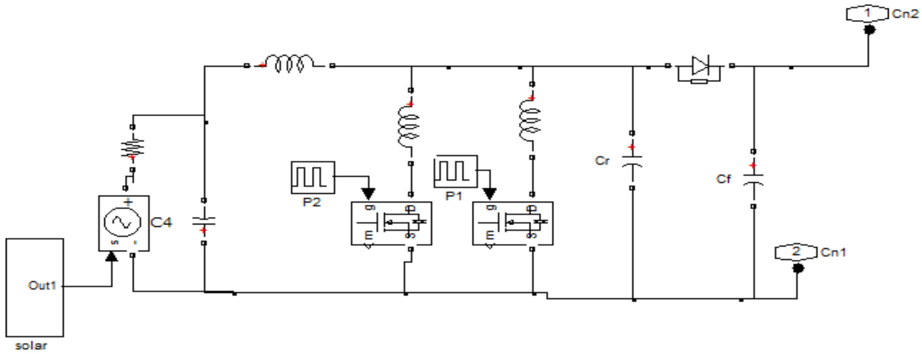

Fig.3.3: TIBC circuit for UPQC based System

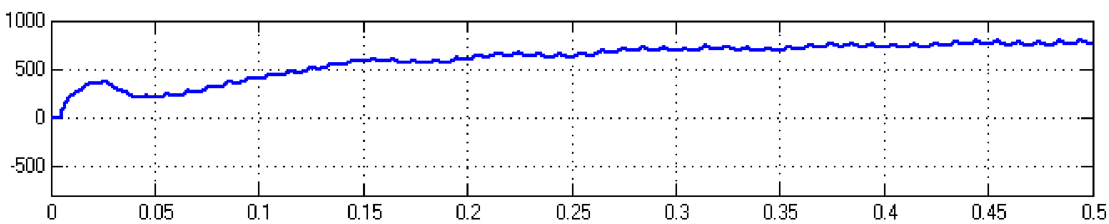

Fig.3.4: Output Voltage of TIBC based UPQC System

Ripple in Output Voltage of TIBC is shown in Fig.3.5. The peak to peak ripple is 50V. Voltage across loads 1 & 2 are shown in Fig.3.6. The peak value of voltage is 5000V. Real & Reactive powers are shown in Fig's 3.7 & 3.8 respectively. Real power is $3*10^5$ w and reactive power is $6.1*10^5$ VAR.

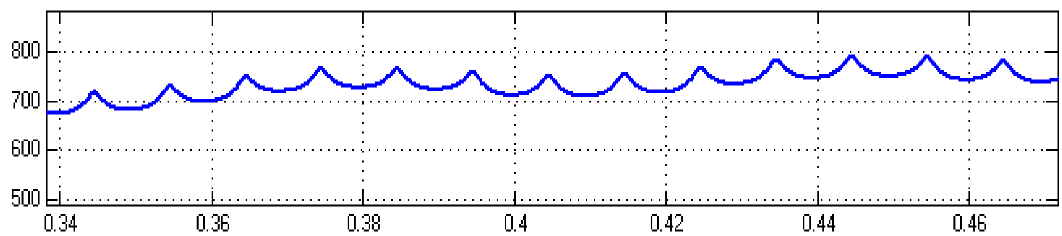

Fig.3.5: Ripple in Output Voltage

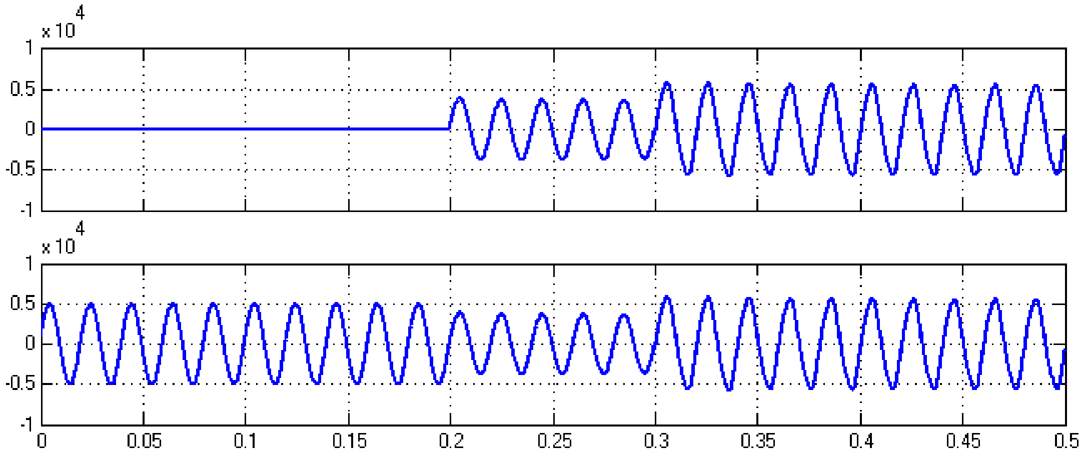

Fig.3.6: Voltage across Load – 1 and Load -2

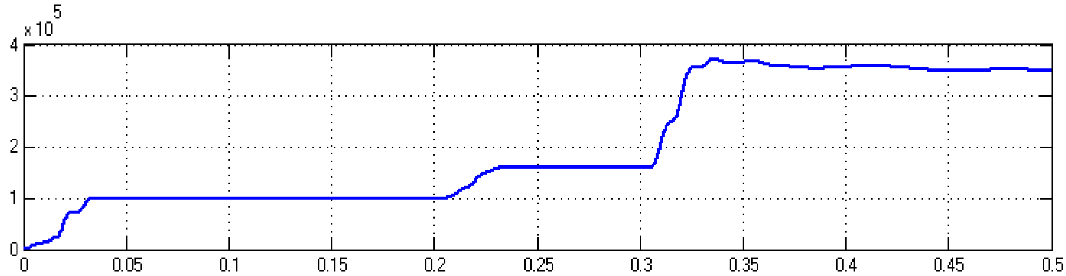

Fig.3.7: Real Power

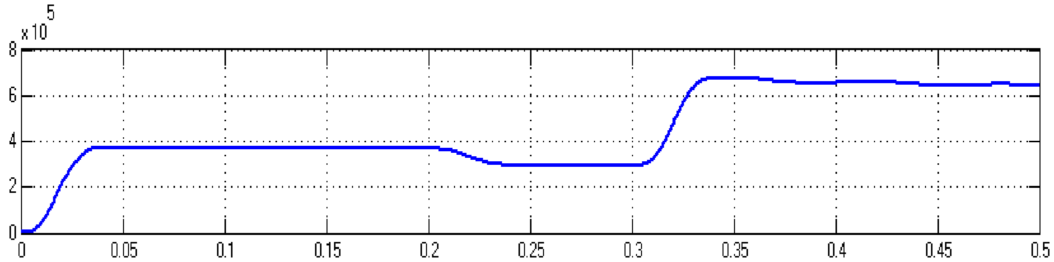

Fig.3.8: Reactive Power

3.2. ILBC based UPQC System

Proposed Inter Leaved Boost Converter based UPQC is shown in Fig.3.9.The TIBC is replaced with ILBC. Inter Leaved Boost Converter Circuit is shown in Fig.3.10.

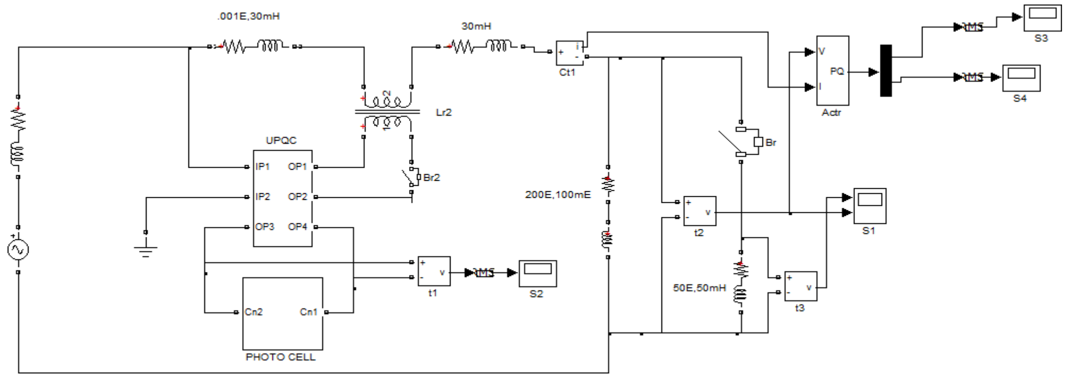

Fig.3.9: UPQC using Inter Leaved Boost Converter

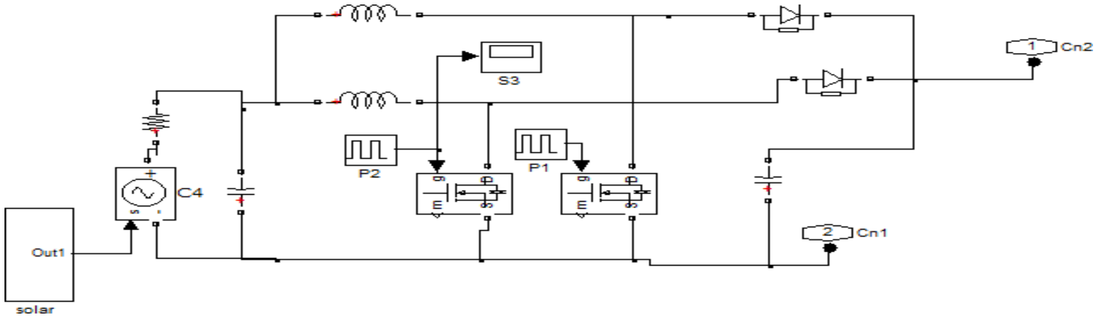

Fig.3.10: ILBC circuit for UPQC system

Output Voltage of ILBC is shown in Fig.3.11. The output voltage is 1100V. Ripple in output voltage is shown in Fig.3.12. The peak to peak ripple is 40V.

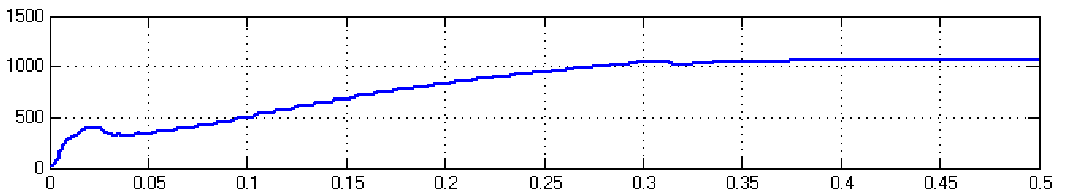

Fig.3.11: Output voltage of ILBC

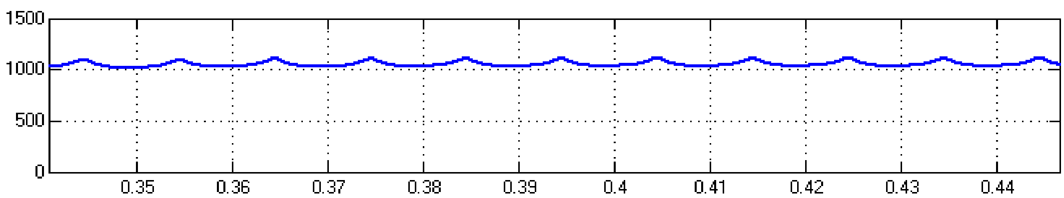

Fig.3.12: Ripple in Output Voltage

Voltage across loads 1 & 2 are shown in Fig.3.13. Peak Voltage is 500V. Real &Reactive powers are shown in Fig.3.14 & 3.15. Real Power is $4*10^5$ W and reactive power is $7*10^5$ VAR.

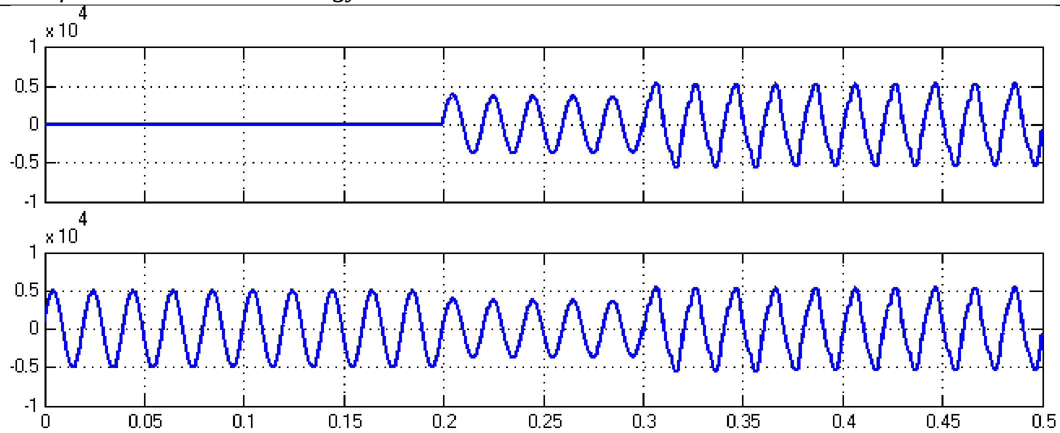

Fig.3.13: Voltage across Load – 1 and Load -2

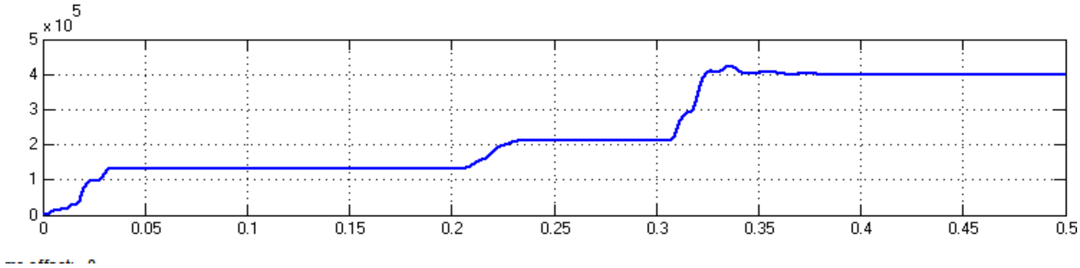

Fig.3.14: Real Power

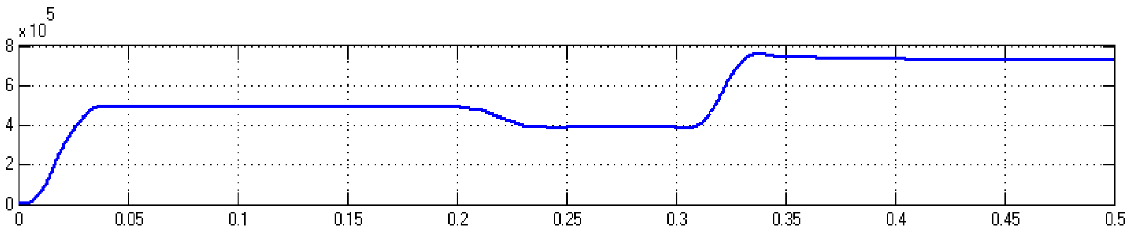

Fig.3.15: Reactive Power

IV. HARDWARE RESULTS

The Hardware of UPQC System is fabricated and tested in Laboratory. The Hardware consists of control board, Active filter board & DVR board. The pulses are generated using PIC 16F84. They are amplified using driver IC 2110. Implementation of the ILBC with UPQC is shown in Fig.4.1.

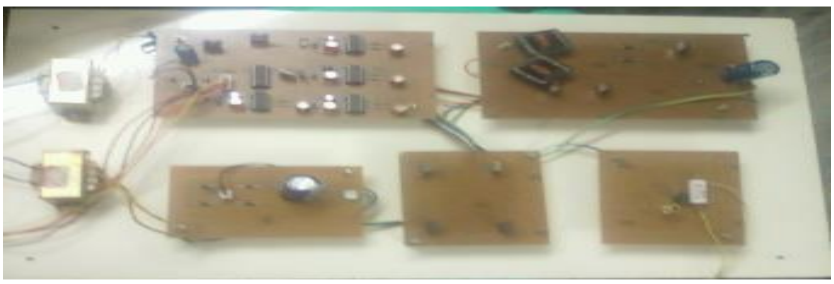

Fig.4.1: Implementation of ILBC based UPQC

The DC input voltage to the ILBC is shown in Fig.4.2. Switching Pulse for the MOSFET of the ILBC is shown in Fig.4.3.

Fig.4.2: DC Input Voltage to the ILBC

Fig.4.3: Switching Pulse for ILBC

Switching Pulses for M1 & M2 of the inverter are shown in Fig's 4.4 and 4.5 respectively.

Fig. 4.4: Switching Pulse for M1 of the Inverter

Fig. 4.5: Switching Pulse for M2 of the Inverter

Driving pulse for the MOSFET of the ILBC is shown in Fig.4.6. Output voltage of the ILBC is shown in Fig.4.7. Output voltage of DVR is shown in Fig.4.8.

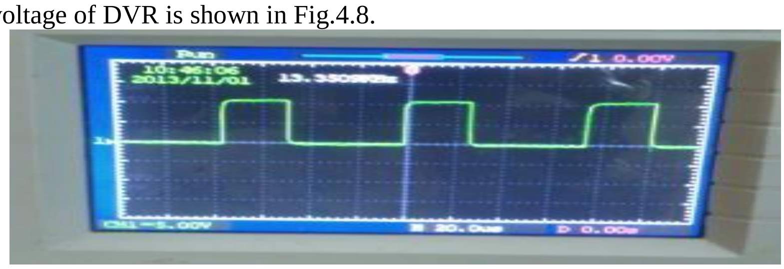

Fig.4.6: Driving Pulse for the MOSFET of ILBC

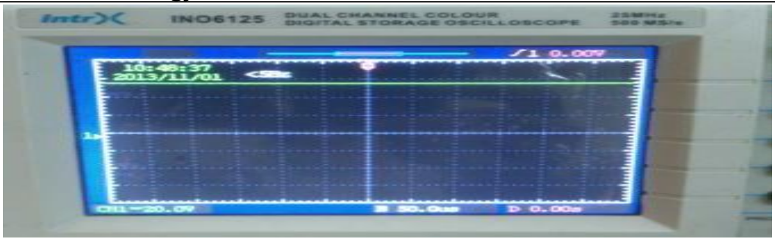

Fig.4.7: Output Voltage of the ILBC

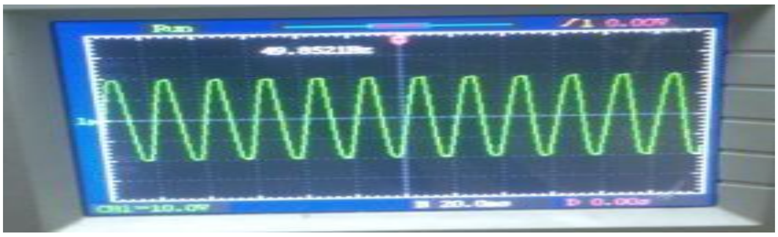

Fig.4.8: DVR Output Voltage with the LC Filter

The Table 4.1 represents comparison between TIBC and ILBC based UPQC with respect to real power, reactive power and ripple voltage. Real power and reactive power are higher in case of ILBC based UPQC system. Real power with ILBC is 0.403 MW and ripple voltage is reduced to 8 V.

Table: 4.1 Summary of TIBC & ILBC based UPQC Systems

UPQC	Real power (MW)	Reactive power (MVAR)	Ripple Voltage(Volts)
TIBC	0.364	0.605	25
ILBC	0.403	0.725	8

V. CONCLUSIONS

TIBC & ILBC based UPQC systems are successfully modelled and simulated using MATLAB and the results are presented. The investigations indicate that the performance of ILBC system is better than that of TIBC system. Therefore ILBC based UPQC is viable alternate one to the existing UPQC systems. The Hardware for ILBC system is fabricated and experimental results are obtained. The experimental results match with simulation results. The ripple in the output voltage is reduced by 17V. The real power increases by 10.7% and reactive power increases by 19.8% by employing ILBC based UPQC. The advantages of the proposed system are reduced ripple & increased power rating. The disadvantage is that ILBC requires two switches, two inductors and a capacitor.

The scope of the present work is comparison between TIBC & ILBC based UPQC systems. The comparison of High Gain Boost Converter based UPQC with the present system will be done in near future. The reduction in number of PV cells can be studied.

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