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THREE PHASE THREE WIRE SOFT SWITCHING UNIFIED POWER QUALITY CONDITIONER

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ABSTRACT

Three phase three wire soft switching unified power quality conditioner (UPQC) using ZVS is proposed in this paper. In the proposed 3P3W UPQC, all filter switches operate at zero-voltage-switching (ZVS). The proposed UPQC consists of a soft- switching shunt active power filter and a soft-switching series active power filter. The AC source voltage fluctuations can be compensated with the help of soft switching series active filter. It is used to regulate both the under -voltage and over-voltage situations. The soft- switching shunt active power filter compensates the current harmonics. Finally, MATLAB Simulink results are presented for verification.

Keywords: Unified power quality conditioner (UPQC), soft-switching, zero-voltage-switching (ZVS), Active Power Filters (APF).

I. INTRODUCTION

In recent years, Power engineers are increasingly concerned over the quality of the electrical power. Recent industries use precise equipment which is sensitive to even small disturbances. Poor power quality may result in the equipment malfunction or failure.In order to obtain high efficiency and to protect the equipment from malfunctioning, we need to improve power quality. There are two ways to improve power quality one is to compensate current based disturbances and other is to compensate voltage based disturbances. In current based disturbance current harmonics and reactive power are improved. In voltage compensations voltage swell, voltage sag, voltage flickers are mitigated.

Active power filters (APF) are the best way to eliminate power quality problems. Active power Filters are classified in the shunt active power filter and series active power filter. Three phase Unified power quality conditioner is a hybrid active filter which comprises of both series APF and shunt APF coupled with common DC link. The series and shunt APF mitigates voltage and current problems simultaneously hence UPQC is a multifunction device.

The configuration of the commonly used 3P3W UPQC is shown in figure.1. As Series APF and Shunt APF operates simultaneously it not only compensates load voltage it eliminates current harmonics. Hence, the UPQC improves the power quality. Conventional UPQC operates at hard switching. Usually hard switching operates in low switching frequency which results in low performance. Increasing the switching frequency increases the performance of UPQC but with increased high frequency causes problems such as Electromagnetic interference and switching losses. Hence soft switching technique is incorporated.

The proposed three-phase three soft switching UPQC uses zero voltage switching technique to turn on the power electronic switches. The three phase UPQC consists of 12 power electronic switches. These switches are converted into ZV switches using parallel capacitor and diode (Half-wave soft switching). Finally, MATLAB Simulink results are shown to verify the operation of the three phase soft switching UPQC.

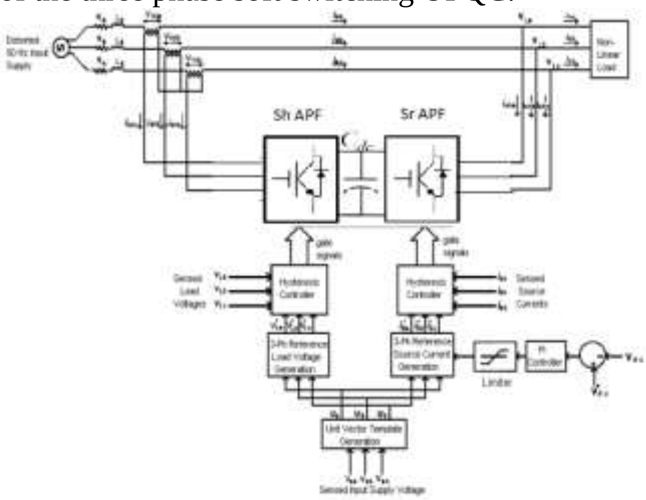

Fig 1: 3P3W Soft Switching UPQC Configuration

II. Proposed Soft-Switching Three-Phase Three-Wire UPQC

A. System Configuration

Fig 2 Shows the Simulink diagram of proposed three phases three wire soft switching UPQC. It consists of ZVS Series APF and ZVS shunt APF. The ZVS series active power filter used to mitigate voltage disturbances like voltage sag, voltage swell etc. Similarly, ZVS shunt active power filter is used to compensate reactive power and eliminates current harmonics. Since both the filter works simultaneously the load voltage is stable.

The Zero Voltage Switching technique is used to turn-on the main filter switches. The voltage across the switches is reduced to zero as the current increases. Due to this, the voltage stress across the main filter switch does not increase. Finally, it increases the efficiency, power density and EMI of the UPQC.

The ZVS shunt and series active power filter is shown in figure 3. The filters are similar to conventional active filters the difference is that the main switches consist of a parallel capacitor and antiparallel diode.

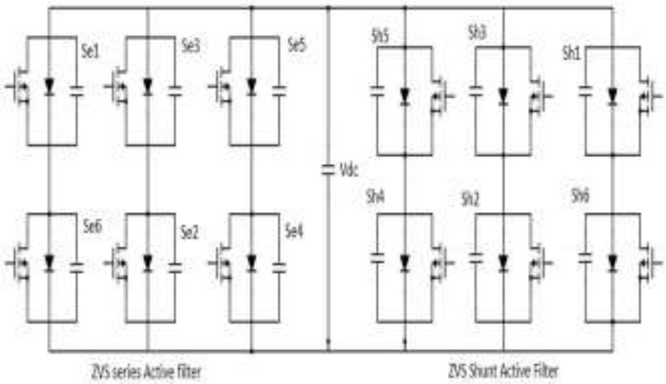

Fig 2: ZVS (Soft Switching) Active Power Filter

The two active power filters are connected with DC link. Each ZVS main switch consists of MOSFET diode and Capacitor.

B. Control Strategy

The control strategy used in this proposed soft switching is d-q transformation technique (Park's transformation). The series APF compensates the voltage disturbance on the source side, which is due to the fault in the transmission line at the PCC. The series APF control algorithm calculates the reference value which is injected by the series APF transformers, comparing the positive-sequence component with the load voltages. The proposed series APF reference voltage signal generation is done by using d-q-o theory. In equation (1), supply voltages V_{sabc} are transformed into d-q-0 coordinates.

$$\begin{bmatrix} V_{S0} \\ V_{Sd} \\ V_{Sq} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin(wt) & \sin(wt-2\frac{\pi}{3}) & \sin(wt+2\frac{\pi}{3}) \\ \cos(wt) & \cos(wt-2\frac{\pi}{3}) & \cos(wt+2\frac{\pi}{3}) \end{bmatrix} \begin{bmatrix} V_{Sa} \\ V_{Sb} \\ V_{Sc} \end{bmatrix} \quad \text{--- (1)}$$

The load side reference voltages V_{Labc*} are calculated. The switching signals are assessed by comparing reference voltages (V_{Labc*}) and the load voltages (V_{Labc}) and via sinusoidal PWM controller. These produced three-phase load reference voltages are compared with load voltages and errors are then processed by sinusoidal PWM controller which is used to generate the required signals for series APF switches.

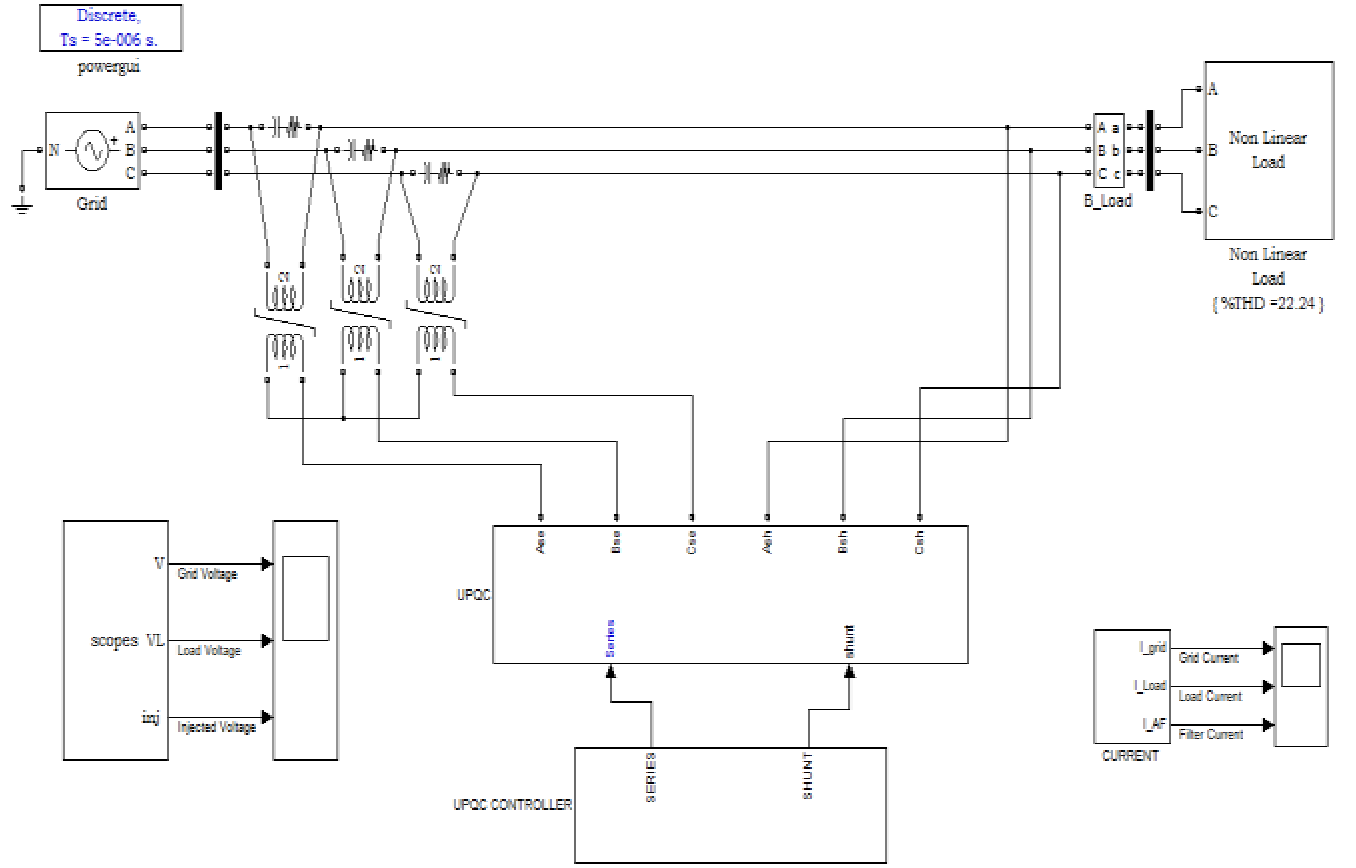

Fig 3: Simulink Diagram of 3P3W Soft switching UPQC

The instantaneous reactive power (p-q) theory is used to control of shunt APF. In this theory, the instantaneous three-phase currents and voltages are transformed to α-β-0 coordinates as shown in equation (2) and

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} i_{Sa} \\ i_{Sb} \\ i_{Sc} \end{bmatrix} \qquad \text{---(2)}$$

These reference source current signals are then compared with sensed three-phase source currents, and the errors are processed by PWM controller to generate the required switching signals for the shunt APF switches.

C. OPERATION PRINCIPLE

The operation principle of proposed 3P3W soft switching UPQC is analysed in this section. The operation of both ZVS Series Active Filter and ZVS shunt active Filter is similar in operation. Hence, only Series active filter is explained here. When a MOSFET turns on, there are losses due to current and voltage overlap and the discharge of stored energy in its C_{oss} capacitor. In ZVS the C_{oss} is discharged its energy prior to turning on the MOSFET. ZVS operation eliminates only turn ON losses; switching losses during turn OFF, both due to overlap. For analysis following assumptions are made i) all components are considered as ideal, ii) the dc link between Series APF and Shunt APF is considered big so the voltage will be constant without any ripple, iii) all the soft switching capacitors are identical.

MODE 1: (Se1, Se2 Turn ON)

In this mode, the switches Se1 and Se2 in the series active filter are turned ON. When turning on, the switch voltage is first brought to zero before the gate voltage is applied, which results in a zero-loss transition.

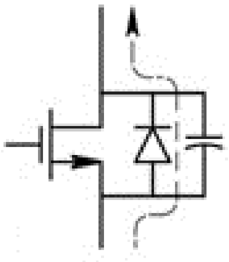

Fig 4: ZVS Turn ON

Figure 4 shows the turning ON the power semiconductor switch in soft switching mode. In mode 1 Switches Se1 and Se2 are turned ON while others are in off condition. The control signal for the switches is obtained from the Series Controller. The controlling technique used in this paper is d-q transformation technique. But any controlling technique like switching control method, direct deduction method, synchronous-q' reference base theory the soft switching converter does not need any changes. At the end of the Mode 1, Se1 and Se2 are turned OFF. And the next switching mode occurs. Fig 5 shows the turning OFF of the switch in ZVS mode.

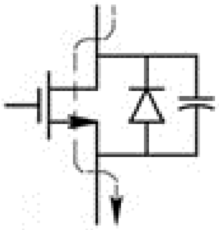

Fig 5: ZVS turn OFF

MODE 2: (Se3, Se4 Turn ON)

At the end of the mode, Se1 and Se2 are turned OFF. Turning off is a low loss transition where parallel capacitor is used as a lossless snubber. Then Se3 and Se4 are turned ON this is similar to mode1. Also, **Mode 3** is for Se5 and Se6. From this, all the switches work under soft switching technique. This cycle continues to mode 1 and so on.

III. SIMULATION RESULTS

The Matlab simulation is done for Voltage sag and Voltage swell. The simulation is done for a period of 0.25 secs. In Figure 6 input, output, converter waveform is shown for a period of 0 to 0.125 secs the input voltage is 440v then from a period of 0.125sec to 0.25 sec there is sag of about 0.5p.u. During this period the Soft switching UPQC operates and injects the required voltage to compensate the voltage sag. Hence, the load voltage is obtained without any sag.

In figure 7 input, output, converter waveform is shown for a period of 0 to 0.125 secs the input voltage is 440v then from a period of 0.125sec to 0.25 sec there is a swell of about 1.5p.u. During this period the Soft switching UPQC operates and absorbs the required voltage to compensate the voltage swell. Hence, the load voltage is obtained without any swell.

Harmonics are calculated for both conventional and soft switching UPQC and results are tabulated.

PARAMETERS:	**MITIGATED VOLATAGE %THD**	**MITIGATED CURRENT %THD**
WITHOUT UPQC	2.47	22.28
CONVENTIONAL UPQC	0.09	5.05
SOFT SWITCHING UPQC	**0.07**	**4.80**

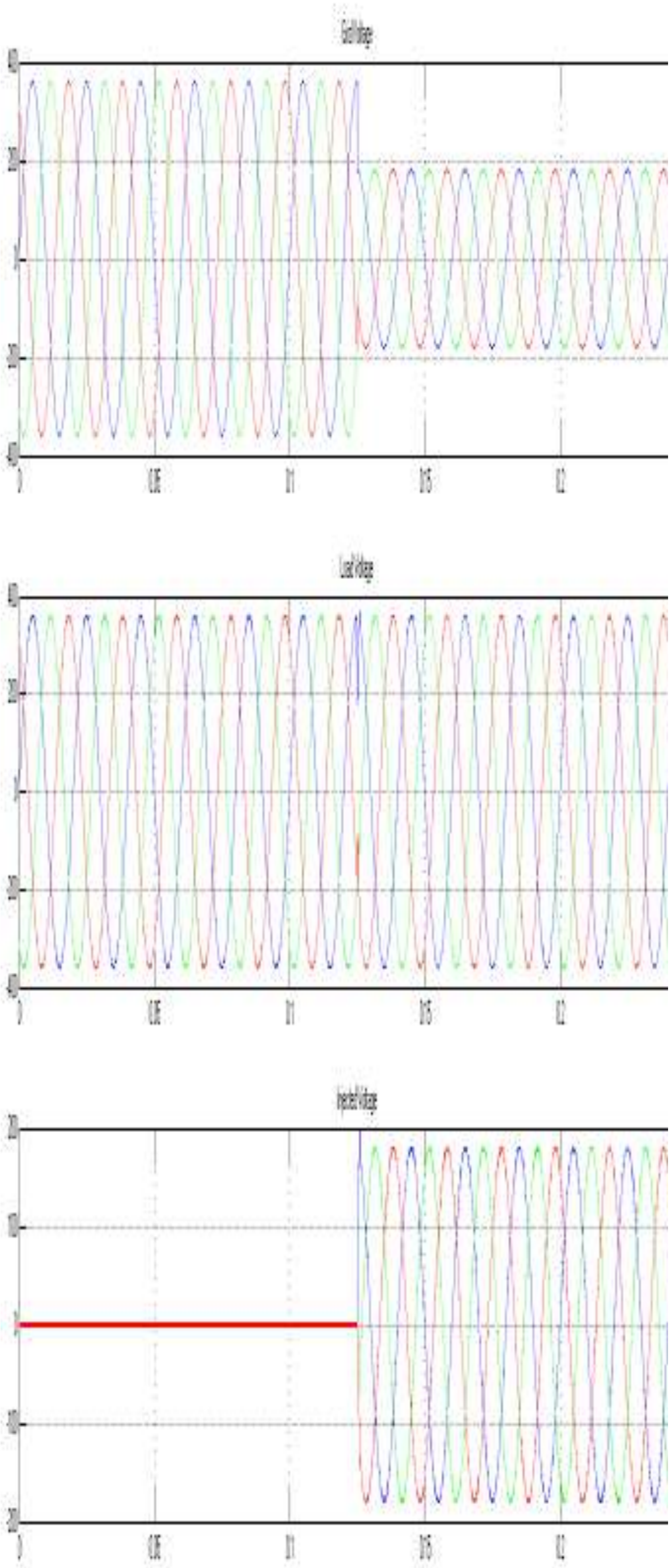

Fig 6: Input, Output, Converter Waveforms of UPQC during Voltage Sag

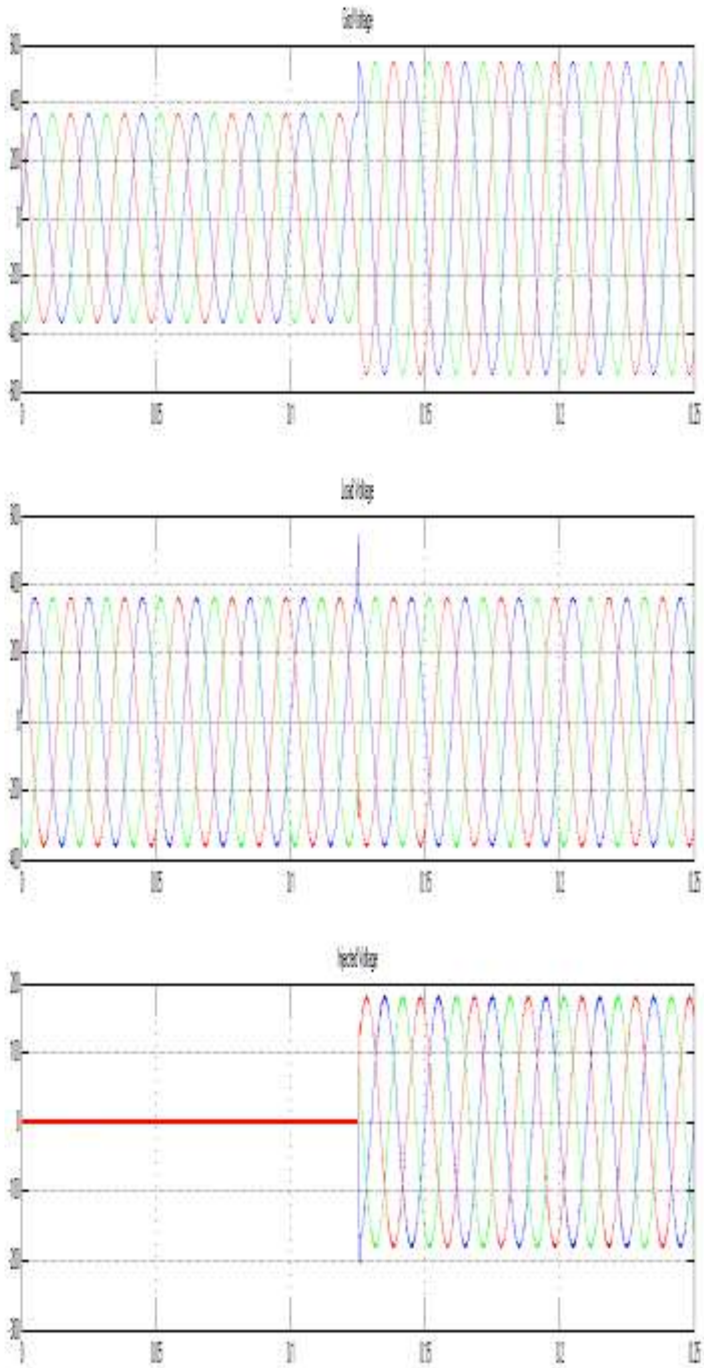

Fig 7: Input, Output, Converter Waveforms of UPQC during Voltage Swell

IV. CONCLUSION

The implementation of Soft Switching Unified Power Quality Conditioner (UPQC) connected to 3P3W distribution system has been presented. The simulation results show that the distorted and unbalanced supply voltages are mitigated and are free from distortion at the load side. Also, the compared results between

Conventional and Soft switching UPQC shows that the THD value of soft switching UPQC is less than that of Conventional UPQC. Clearly, the proposed UPQC is good at eliminating the current harmonics, compensating voltage distortions and improving system power factor. Moreover, in the
transient period, the source current remains a sinusoidal waveform in phase with source voltage and the load voltage still maintain 440V with stable and sinusoidal waveforms. It is evident that the proposed UPQC has good steady-state and transient performances.

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