Comparative Analysis of Voltage Source and Current Source Converter Based Unified Power Quality Conditioner for mitigating Power quality Problems

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ABSTRACT

Electric utilities and end users of electric power are becoming increasingly worried about meeting the growing energy demand. Renewable energy source (RES) form an indestructible part of electric power distribution. In this paper ,a unified power quality conditioner based on voltage source converter and current source converter are designed to mitigate power quality problems such as voltage sag, swell, unbalance, harmonics . The real power supply is given by the Photo Voltaic (PV) system for the compensation of Power quality problems. The reference current and voltage generation for shunt and series converter of UPQC is based on Phase Locked Loop and Synchronous reference frame theory. Simulations have been carried out in MATLAB Simulink platform. The simulation results for both CSC based UPQC and VSC based UPQC are compared and presented.

Keywords: UPQC-Unified Power Quality conditioner, VSC-Voltage Source Converter, CSC-Current Source Converter, PV-Photo Voltaic, PLL-Phase Locked Loop, SRF-Synchronous Reference Frame.

1. INTRODUCTION

The main concern about power distribution system is the quality of power which is greatly affected due to wide usage of non-linear loads. The usage of power electronic loads are increasing day by day, while considering industrial power electronic drives used for the automation of the industries in turn distorts the entire system. To compensate for distortion in the system, active filters were used. Nowadays custom power devices are generally used to mitigate not only the harmonics but also the voltage sag, swell and unbalance. There are three custom power devices such as Distribution Static Compensator (D STATCOM), Dynamic Voltage Restorer (DVR), Unified Power Quality Conditioner (UPQC) out of which UPQC which is the combination of Series and Shunt Active filters is commonly used since this is capable of compensating both voltage and current quality problems.

2. UNIFIED POWER QUALITY CONDITIONER

The Unified Power Quality Conditioner is commonly called as UPQC.

The design configuration is based on the connection of Series and Shunt inverters. In this, the design configuration is Right Series and Left shunt with the Current and voltage source inverters. The UPQC-VSC and UPQC-CSC [7] are designed and analysis of the results is to be done. Unified Power Quality Conditioner (UPQC) for non-linear and a voltage sensitive load has following facilities:

- It reduces the harmonics in the supply current, so that it can improves utility current quality for nonlinear loads.

- UPQC provides the VAR requirement of the load, so that the supply voltage and current are always in phase, therefore, no additional power factor correction equipment is required.
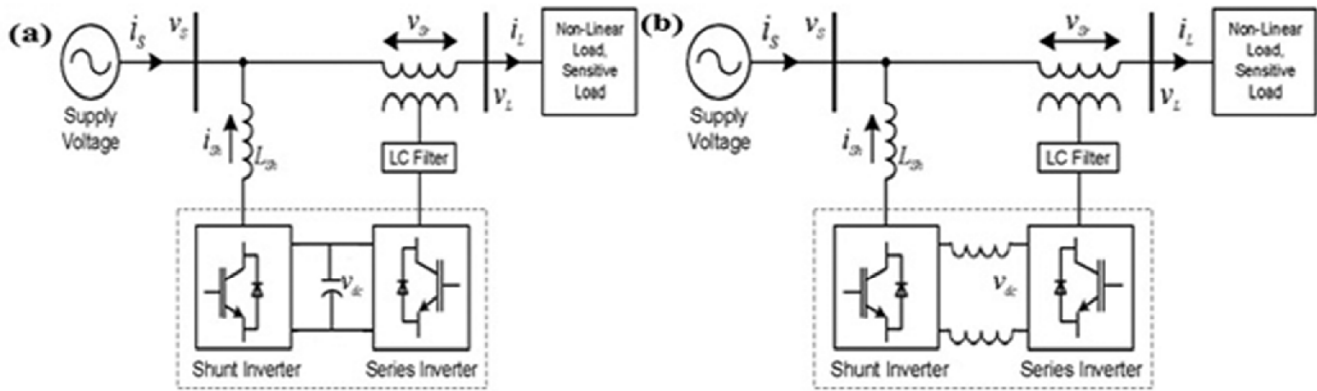
Figure 1: (a) Design configuration of UPQC-VSC and (b) UPQC-CSC

- UPQC [10]-[12] maintains load end voltage at the rated value even in the presence of supply voltage sag.

The design configuration of UPQC-VSC is shown in Fig. 1. (a) And UPQC-CSC is shown in Fig. 1. (b).

3. CONTROL STRATEGY

The control strategy for the Unified Power Quality Conditioner is based on the Synchronous Reference Frame (SRF) [13], [15] Theory. The supply voltage Vsabcis transformed as d-q-0 by using the Transformation matrix Tgiven by

$$\begin{bmatrix} V_{S0} \\ V_{SD} \\ V_{Sq} \end{bmatrix} = T \begin{bmatrix} V_{Sa} \\ V_{Sb} \\ V_{Sc} \end{bmatrix} \tag{1}$$

$$T = \sqrt{\frac{2}{3}} \begin{vmatrix} \dfrac{1}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} \\ \sin(wt) & \sin(wt - 2\pi/3) & \sin(wt + 2\pi/3) \\ \cos(wt) & \cos(wt - 2\pi/3) & \cos(wt + 2\pi/3) \end{vmatrix} \tag{2}$$

The inverse transformation matrix T^ (-1) is used for producing the reference load voltage by the average component of source voltage and ùt produced by PLL.

$$T^{-1} = \sqrt{\frac{2}{3}} \begin{vmatrix} \dfrac{1}{\sqrt{2}} & \sin(\omega t) & \cos(\omega t) \\ \dfrac{1}{\sqrt{2}} & \sin(\omega t - 2\pi/3) & \cos(\omega t - 2\pi/3) \\ \dfrac{1}{\sqrt{2}} & \sin(\omega t + 2\pi/3) & \cos(\omega t + 2\pi/3) \end{vmatrix} \tag{3}$$

The control strategy is for both the shunt and series converter along with the DC link control. The DC voltage for the compensation is supplied by the PV array. The control block diagram is shown in Fig. 3.

3.1. Series Controller

The Series converter has the function of compensating the Voltage Problems like Sag. The series controllers have the PLL which supplies the sine and cosine value to the abc to dq0 and dq0 to abc transformation. In series control the reference signal is generated by the use of abc to dq0 and dq0 to abc. The reference signal generated is compared with the PCC point voltage and using the hysteresis band Pulse signals is generated. The generated signals are given as the gate pulse to the converter. The simulation diagram for series controller is shown in Fig. 2.
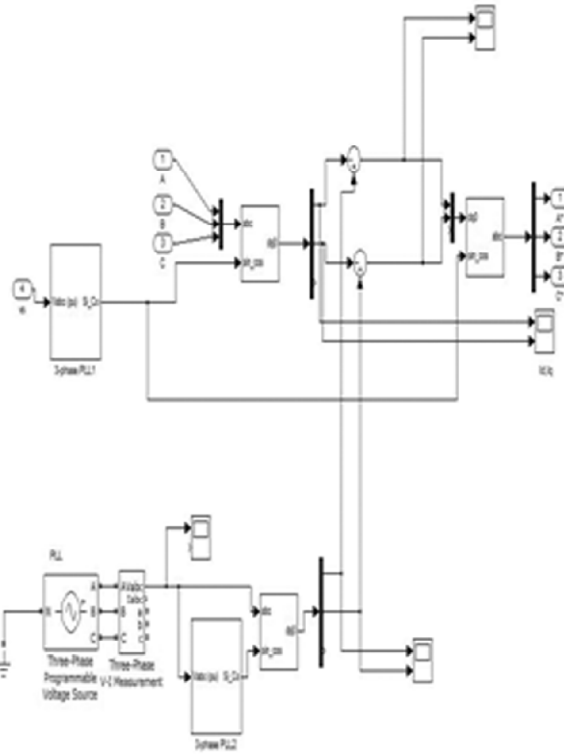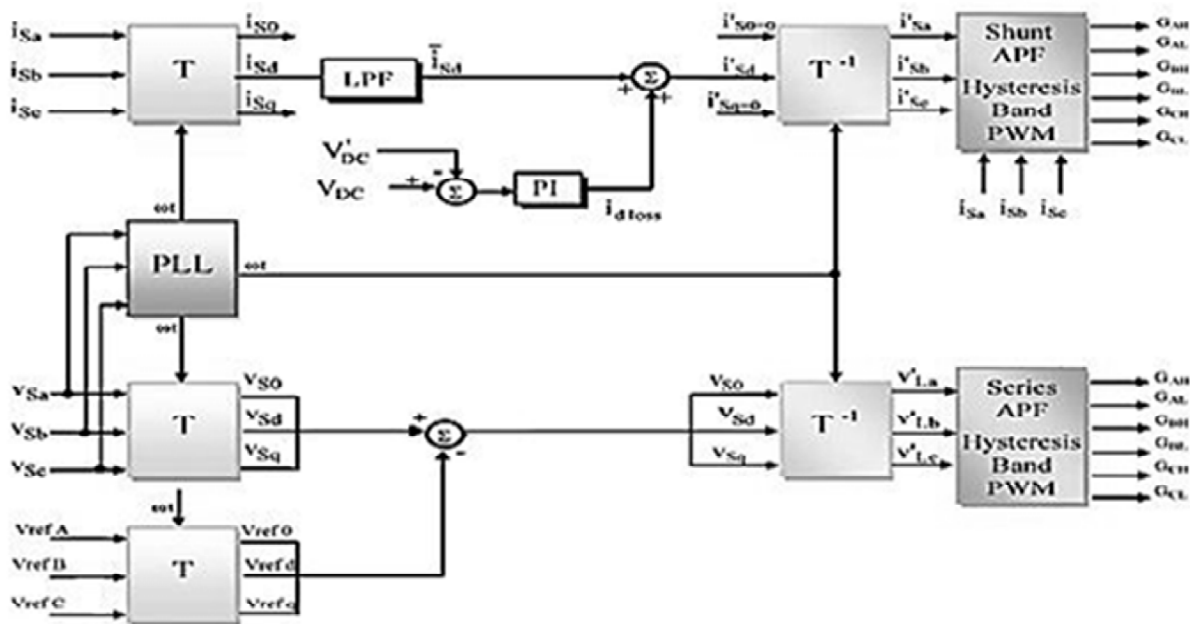

Figure 2: Simulation of Series Controller

Figure 3: Control Block Diagram

3.2. Shunt Controller

The shunt converter has the function of compensating the current problems like Harmonics. Along with the shunt controller, DC link controller. The abc to dq0 transform is inversed and converted to abc, that signal is given as the reference signal and the measured is given to the Hysteresis band PWM to produce the pulse signals for the operation of shunt converter. The simulation diagram for series controller is shown in Fig. 4.

3.3. DC Link Controller

The Direct Current link controller has the PI controller in which the constant voltage is given as the set point andthe measured voltage is given for the comparison to maintain the constant voltage. The PV array is attached with the DC link for injection. The DC link controller is shown in Fig. 5.
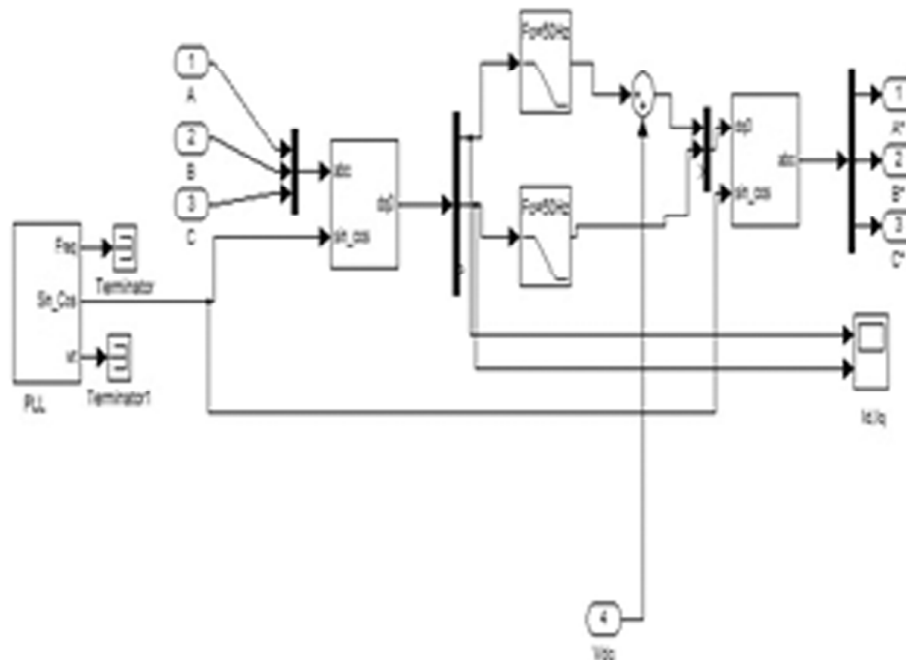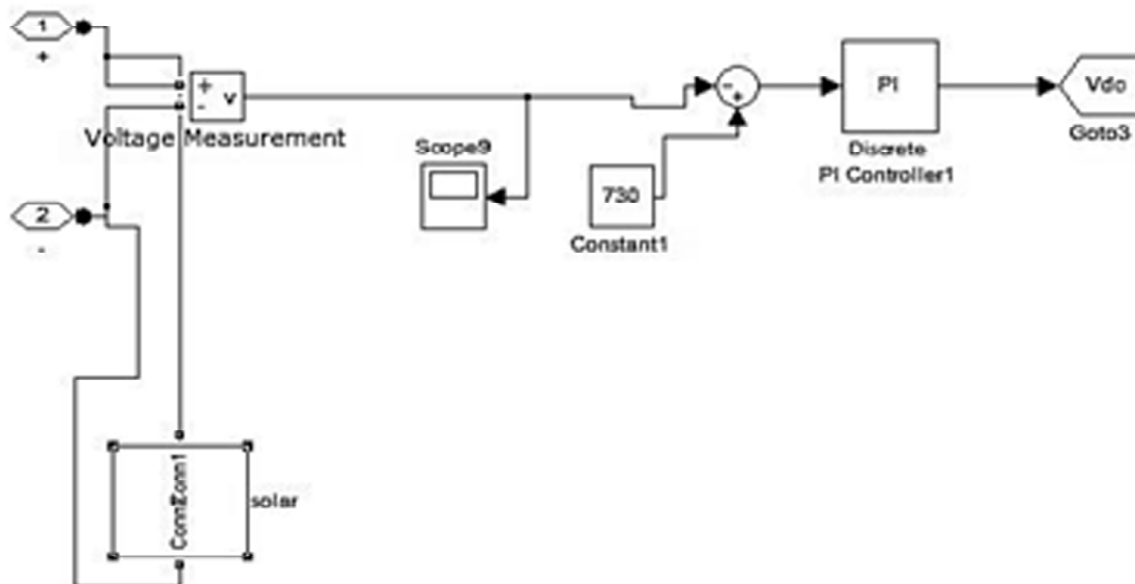

Figure 4: Simulation of Series Controller

Figure 5: DC Link controller

4. SIMULATION RESULTS

4.1. Simulation of UPQC-VSC

Simulation of UPQC-VSC is shown in Figure. 4. The simulation is designed in the MATLAB Simulink. The UPQC-VSC is controlled by the Synchronous Reference Frame (SRF) Theory and the pulse is generated by the hysteresis band controller. The shunt and series converter has the function of Compensating current and voltage problems respectively. The DC link has the capacitor as the link for shunt and series converter. The simulation output of the UPQC-VSC is shown in Figure 6. The sag is created in the PCC point is compensated by the series controller. The output shows in figure 7. That the PCCvoltage at sag, compensating voltage, voltage after compensating.

The series converter has the function of compensating the voltage problems, in this simulation the sag is createdat PCC and compensated by the Series converter. The compensating voltage is shown in figure 8.
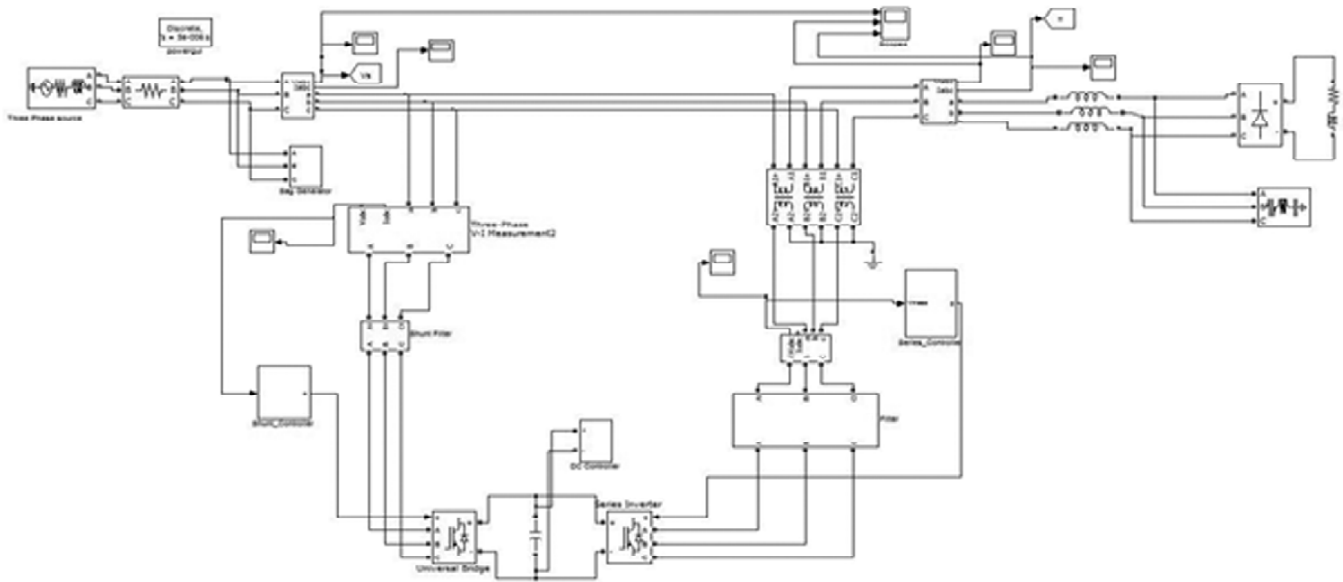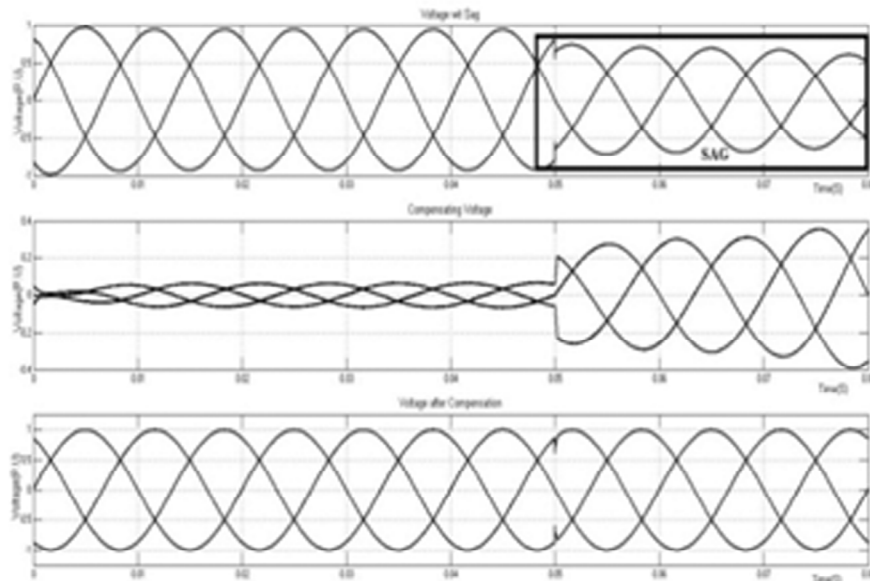

Figure 6: UPQC-VSC Simulation Diagram

Figure 7: PCC Voltage with sag, compensating voltage and
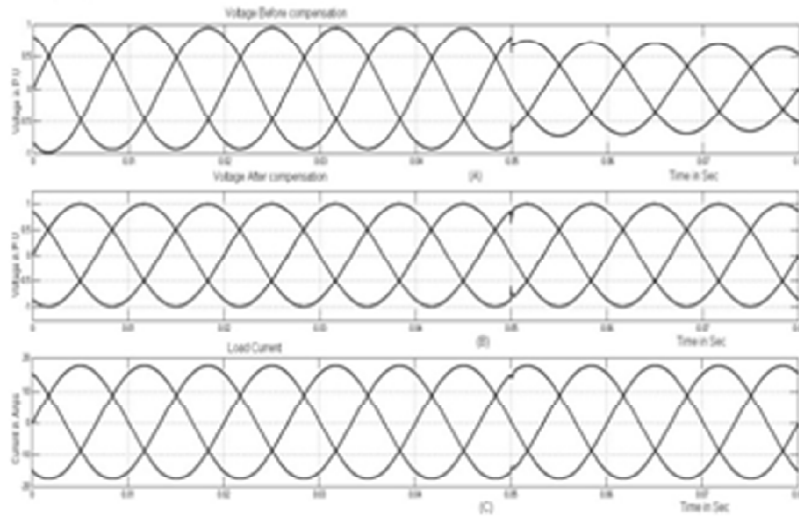**Voltage after compensating**

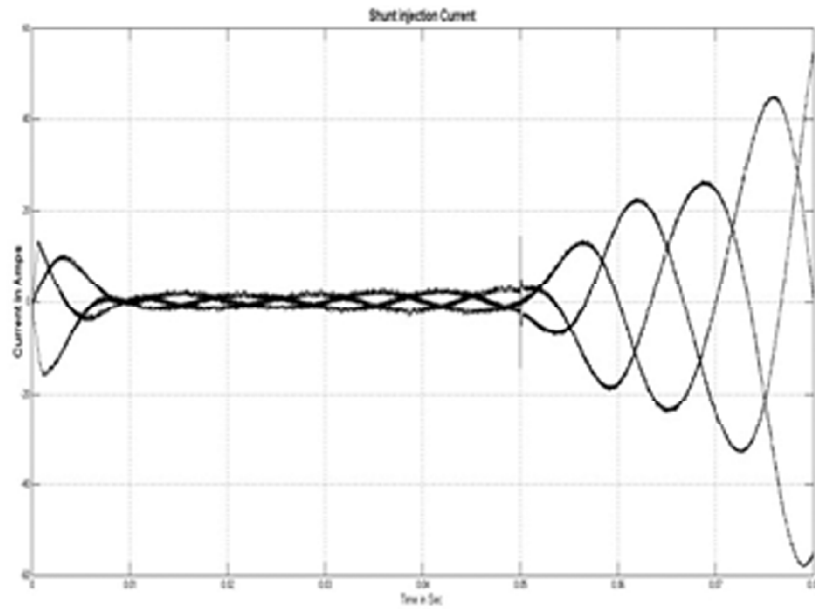**Figure 8: Output of UPQC-VSC**

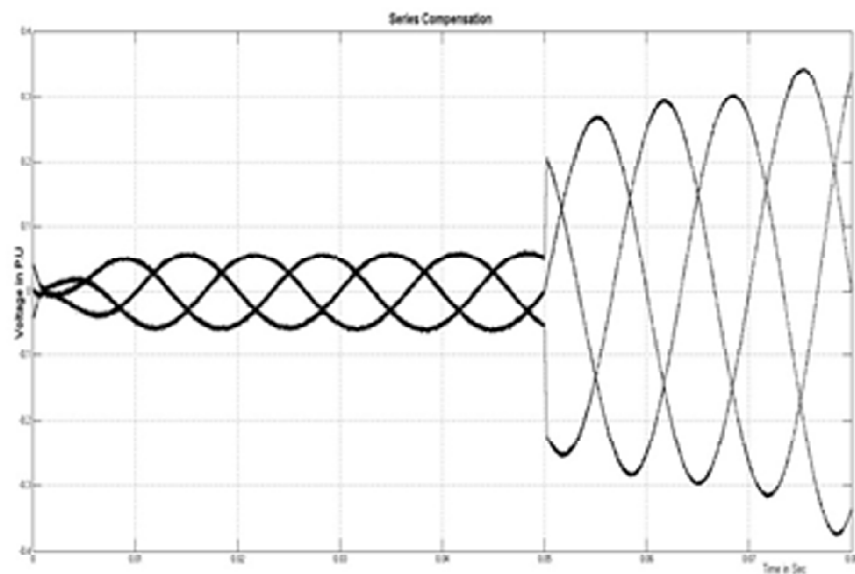**Figure 9: Shunt Compensation**
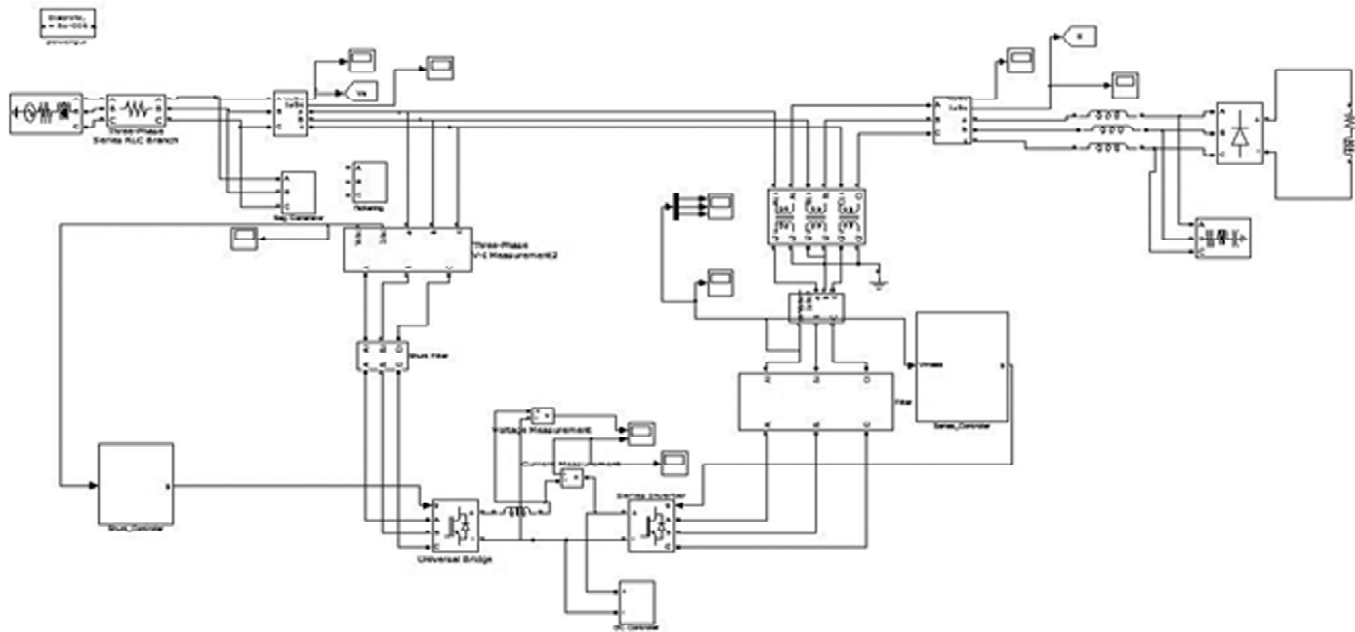
Figure 10: Series Compensation

Figure 11:

The shunt converter has the function of compensating the currentrelated problems like harmonics. The shunt compensation is shown in figure 9. The series compensations are shown in figure 10.

4.2. Simulation of UPQC-CSC

The UPQC-CSC has the DC link has the Reactor as the link for the series and shunt converter and controlled by the Synchronous Reference Frame (SRF) Theory and the pulse is generated by the hysteresis band
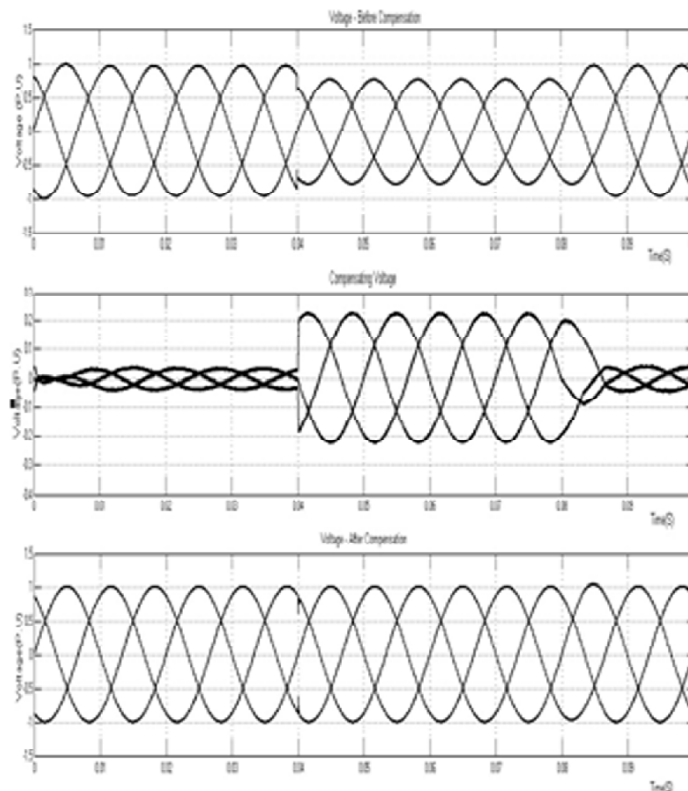

Figure 12: PCC Voltage with sag, compensating voltage and Voltage after compensating
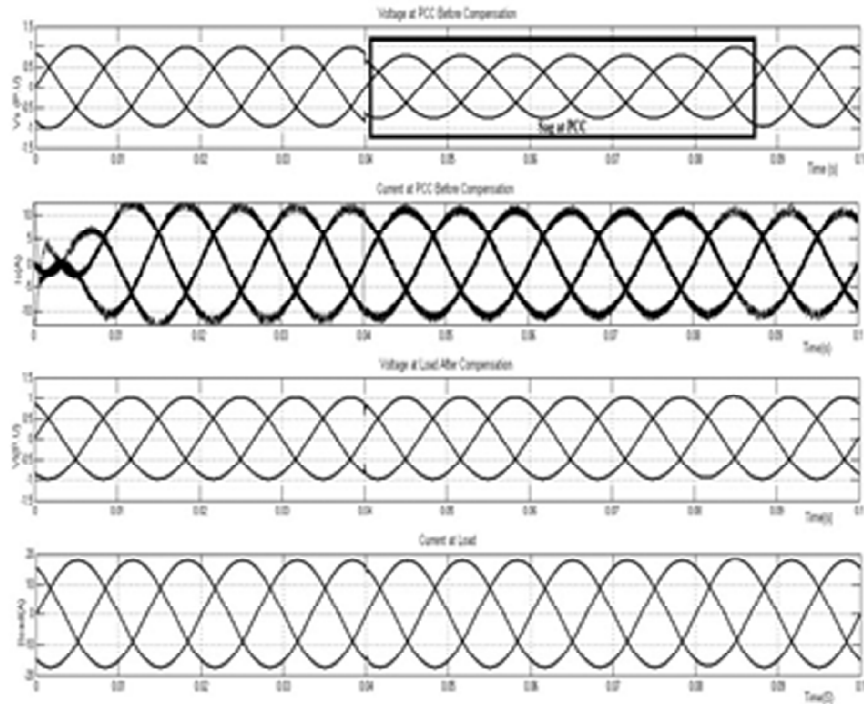
Figure 13: Output of UPQC-VSC
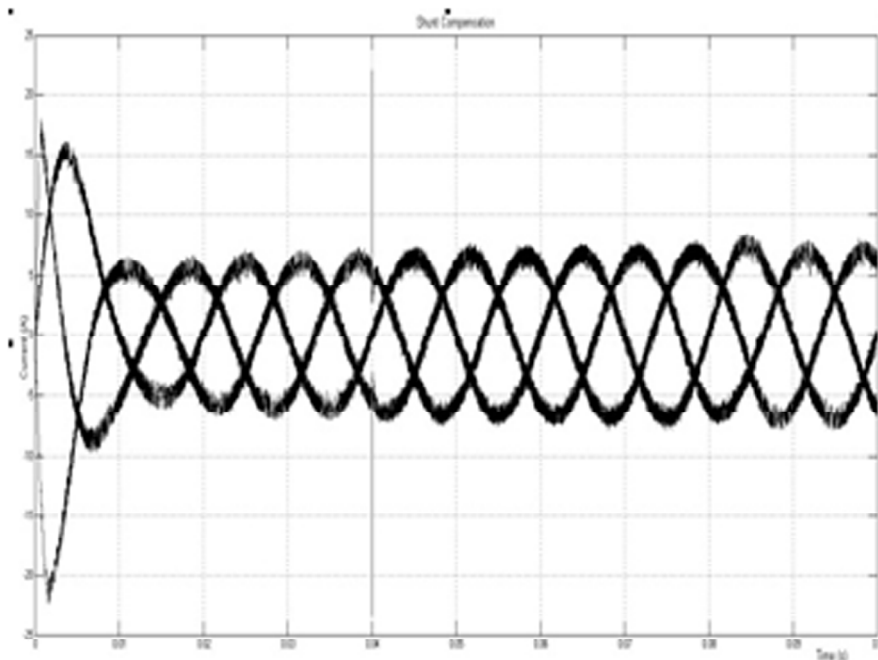
Figure 14: Shunt Compensation

controller. The shunt and series converter has the function of Compensating current and voltage problems respectively. The simulation of UPQC-CSC is shown in figure 11.

The output of UPQC-CSC is shown in the figure 12 which shows the voltage with sag, current with harmonics and compensated voltage and current. The shunt compensation is shown in the figure 14. The series compensation is shown in the figure 15.

The Total Harmonics Distortion (THD) for the Voltage Source Converter and Current Source Converter is shown in the table.1.The result shows that the THD of UPQC-Current Source Converter for the Source Voltage has the better efficiency than the UPQC-Voltage Source converter

Figure 15: Series Compensation
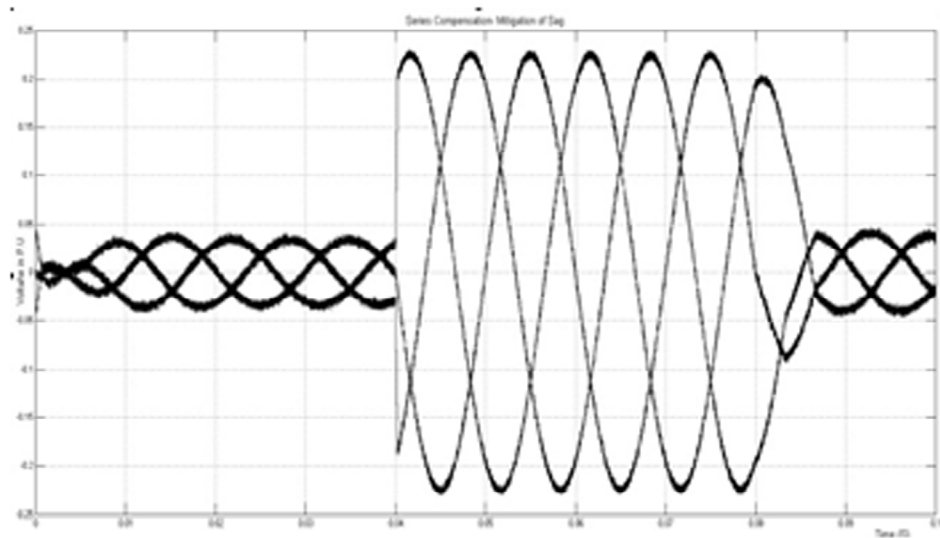
Table 1
Harmonics Order For VSC and CSC

HnOrder	Voltage Source Converter			Current Source Converter		
	Source Voltage (V_S)	*Load voltage* (V_L)	*Load current* (I_L)	*Source Voltage* (V_S)	*Load voltage* (V_L)	*Load current* (I_L)
H	0.95	0.99	19.74	0.97	0.99	17.57
H3	0.33	0.06	0.06	0.28	0.08	0.08
H5	0.11	0.05	0.04	0.09	0.05	0.06
H7	0.04	0.04	0.01	0.03	0.06	0.02
H9	0.04	0.03	0.03	0.03	0.04	0.04
H11	0.01	0.02	0.04	0.02	0.03	0.06
THD	1.02	0.37	0.14	0.89	0.45	0.17

System Parameters

Source Voltage	:	415V, 50Hz
Load Parameters		
Resistive Load	:	10KΩ
Inductive Load	:	2pH
RLC Load	:	10KW
Shunt Inverter side		
LC filter	:	3.5mH, 5Ω,10μF
Series Inverter Side		
LC filter	:	12μH, 5Ω, 10μF
DC Link Capacitor		
For UPQC-VSC	:	500mF, 700V
DC Link Reactor		
For UPQC-CSC	:	200mH
Solar Voltage	:	720V

5. CONCLUSION

In this project, Synchronous Reference Theory based control method is implemented to control the working of Unified Power Quality Conditioner based on Voltage Source Converter and Current Source Converter

topology. The highly developed graphic facilities available in MATLAB/SIMULINK were used to carry out extensive simulation studies on unified power quality conditioner. The simulation results show that the device is capable of compensating the current harmonics under unbalanced and nonlinear load conditions, simultaneously mitigating voltage sag and swell. The Proposed UPQC-VSC and UPQC-CSC results are compared. The UPQC-CSC design has superior performance in comparison with UPQC-VSC for mitigating the power quality problems.

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