POWER QUALITY IMPROVEMENT USING PV AND UPQC

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***Abstract*—The quality of electrical power plays vital role in the utility systems and industry. The quality of the power tends to have a direct economic impact on consumers and suppliers. Growing consumer demands lead to power quality issues. Many consumers may experience severe technical and economic impacts due to power quality problems such as voltage sag, swell, harmonics and voltage interruptions. In this paper the main focus is on UPQC, which is a combination of series and shunt active power filters. The series APF alleviates voltage based distortions, while shunt APF mitigates current based distortions. UPQC alleviates the voltage and current based distortions concurrently as well as independently. UPQC improves power quality by compensating both harmonics and load current which thereby makes source current and load voltage sinusoidal at the required voltage level. The modeling of series APF, shunt APF and the UPQC has been carried out using MATLAB/Simulink.**

Keywords—Power quality, Active power filter, Unified power quality conditioner, Harmonics.

I. INTRODUCTION

Power Quality (PQ) has become an important issue to maintain continues operation of sensitive equipment while interconnection of these equipment in industrial processes and networks is more severe. Importance of PQ is increased due to proliferation of using power electronics. Many equipment in use today is susceptible to damage or service interruptions during poor PQ events. Monitoring of PQ is necessary for those equipment that more sensitive to disturbances (IEEE Standard 1346–1998, 1998).

Nowadays, with the widespread use of non-linear and sensitive loads which are based on power electronic devices in distribution systems, power quality problems such as voltage and current harmonics, voltage flickers, voltage and current unbalances, etc. are increasing. Power system problems such as voltage sag/swell might cause malfunction in digital devices and other sensitive loads

Recent research on power quality improvement methods and devices has demonstrated that unified power quality conditioner (UPQC) is a comprehensive solution for all voltage and current problems; it was presented in for the first time and experimental result of its configuration was presented in 1998

UPQC consisted of a series and a shunt active power filter (APF), which were back to back connected through a common dc link capacitor.

The APF in the UPQC is connected in parallel with the load and is used to compensate for the load current harmonics, while the APF connected in series with the power supply is used to regulate the voltage at the load terminals.

The UPQC operates by injecting a compensating current in the system to cancel out the harmonics and regulate the voltage. It senses the voltage and current at the load terminals and uses a control algorithm to generate compensating currents.

UPQC is a very effective device for improving the power quality of the system, reducing power losses, and improving the efficiency of the system. It is commonly used in industrial and commercial applications where a stable and high-quality power supply is critical for the smooth operation of the equipment nowadays.[1] [2] [3] [10]

II. GENERAL CONFIGURATION OF UPQC AND CONTROL STRATEGY

Principally the structure of UPQC includes two active parallel and serial filters. Fig. 1 shows the arrangement of these filters in the network. Series active filter acts as a voltage source serial with the network and produces any form of wave given to it by the series controller using the PWM converters. On the other hand, the parallel active filter acts as a parallel current source with the network and is controlled using the parallel controllers. Considering that UPQC should be able to supply the active and reactive power, a fast energy storage, like capacitor, is used in DC side of power electronic converter of active filters.

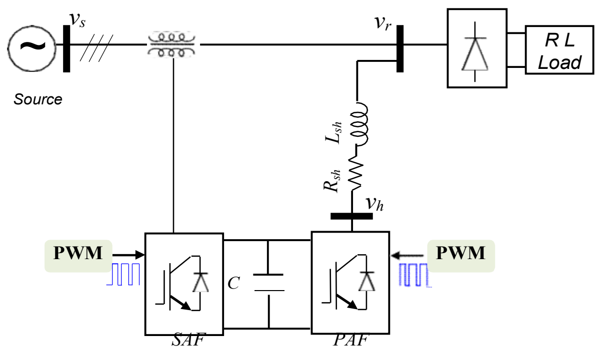


Fig.1. General structure of UPQC in the network.

A. Series Control

The series active power filter (APF) is useful for compensating the voltage because it determines the amount of voltage that has to be induced into the grid in order to make the voltage sinusoidal with the correct voltage magnitude and frequency. The supply voltage must be subtracted from the reference voltage (Vabc*), and after calculating the voltage error and comparing it to the error voltage generated in the lines, The inverter switching pattern is controlled by the hysteresis voltage controller, which also regulates the output voltage of the series APF. Fig. 2.1 depicts the basic schematic of fixed hysteresis band (HB) voltage control. When the sensed output signal deviates from the reference by more than a predetermined amount, the instantaneous value of the output voltage is compared with the reference voltage(Vc*), and the inverter is turned on to lessen the discrepancy. [8] [9] [10]

This indicates that switching happens each time the output voltage crosses the HB value. The Series APF's output voltage signal is provided by:

Vc=Vc* + HB in rising case.

Vc=Vc*- HB in decreasing case.

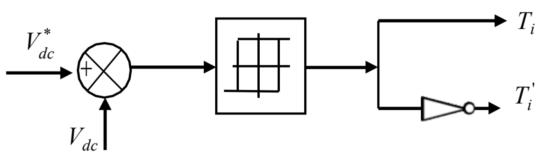


Fig.2 Simplified model for fixed hysteresis-band voltage control

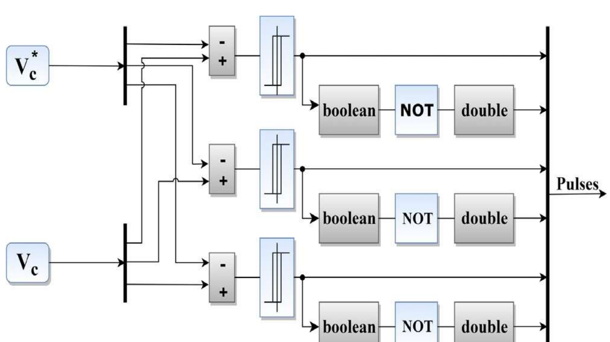


Fig.3 Model of the hysteresis voltage control in Simulink

B. Shunt Control

Active power filters must carefully consider their control technique (APF). The theory of Instantaneous Active and Reactive Power, also known as PQ theory, is utilized to identify harmonic current (shunt APF) and harmonic voltage (series APF), among other important time domain control approaches [5,6]. The key concept is to use Concordia transformation to divide the three-phase system (a-b-c) into two frames (α-β); this can be thought of as an estimation of triphasic measures on a motionless two-axis reference frame [7,10]. Calculations for the currents in the (αβ) frame are as follows: [2] [4]

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \quad (2)$$

The active, and reactive (instantaneous) power is:

$$p = v_\alpha i_\alpha + v_\beta i_\beta$$
$$q = v_\alpha i_\beta - v_\beta i_\alpha \quad (3)$$

In the three-phase system (a-b-c) equation (3) can be written as follows:

$$p = v_{sa} i_{la} + v_{sb} i_{lb} + v_{sc} i_{lc}$$
$$q = -\frac{1}{\sqrt{3}}\left[(v_{sa} - v_{sb}) i_{lc} + (v_{sb} - v_{sc}) i_{la} + (v_{sc} - v_{sa}) i_{lb}\right] \quad (4)$$

If we put:

$$\Delta = v_\alpha^2 + v_\beta^2 \quad (5)$$

From expression (3):

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} p \\ q \end{bmatrix} \quad (6)$$

We can decompose the powers p and q into two parts according to the following equations:

$p = \bar{p} + \tilde{p}$ And $q = \bar{q} + \tilde{q}$ (7)

With

$\bar{p}, \bar{q}$: Mean value (fundamental) value active and reactive power.

$\tilde{p}, \tilde{q}$: Alternating (harmonic) value of active and reactive power.

The filtering method used for extracting the alternative power is shown in Figure.2.

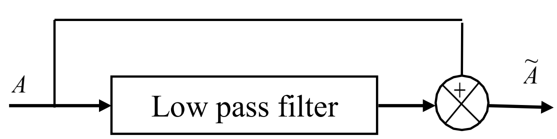


Fig.4 Principle of extraction the component alternative of p &q.

If replaced in (6), we find:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \bar{p} \\ 0 \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} 0 \\ \bar{q} \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (8)$$

Thus, the reference current will be calculated by the relationship:

$$\begin{bmatrix} i_{ref\alpha} \\ i_{ref\beta} \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} p \\ q \end{bmatrix} \quad (9)$$

Applying the inverse transformation, we can write:

$$\begin{bmatrix} i_{refa} \\ i_{refb} \\ i_{refc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} i_{ref\alpha} \\ i_{ref\beta} \end{bmatrix} \quad (10)$$

By the same principle, we find the reference voltages injected by the series active filter as follows:

$$\begin{bmatrix} v_{refa} \\ v_{refb} \\ v_{refc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} v_{ref\alpha} \\ v_{ref\beta} \end{bmatrix} \quad (11)$$

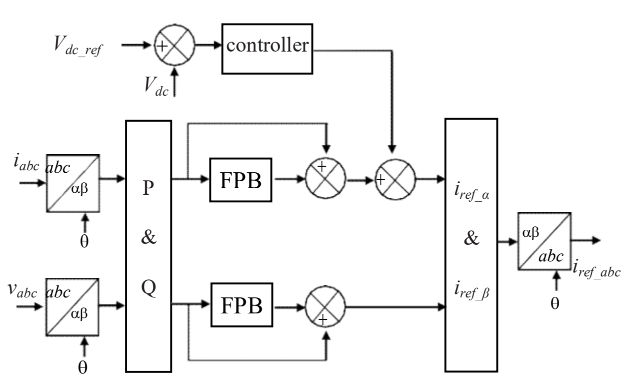


Fig.5.P-Q theory for shunt APF

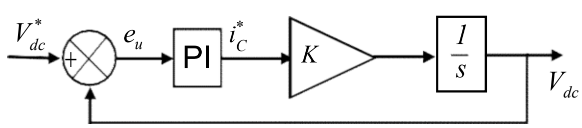


Fig.6 DC bus regulation

III. Simulation Results

TABLE I. ARAMETERS OF UPQC STUDIED

Parameter	***value***
Power Source	380v
Line impedance	Rs=0.01Ω Ls=0.1H
DC Voltage	850v
DC capacitor	500μF
Load impedance	R=0.001Ω L=1H
Line frequency	50Hz

Once we have decided on the perturbations to be applied to the networks, in order to test the response of our active filter, simulations under MATLAB/SIMULINK have been performed. These disturbances evolve as shown in the figure7

- From 0 s to 0.2 s normal operation.
- From 0.2 s to 0.4 s source voltage is applied to a harmonic voltage producing non-linear load.
- From 0.4 s to 0.6 s normal operation.
- From 0.6 s to 0.8 s 50% voltage drop.
- From 0.8 s to 1.1 s normal operation
- From 1.1 s to 1.3 s an overvoltage of 50 % is applied
- From 1.3 s to 1.6 s normal operation

TABLE II. VOLTAGE VARIATION

Time (s)	0s to 0.2s	0.2s to 0.4s	0.4s to 0.6s	0.6s to 0.8s	0.8s to 1.1s	1.1s to 1.3s	1.3s to1.6s
voltage	1pu	1pu Harmonic 5+7	1pu	0.5pu	1pu	1.5pu	1pu

A. Simulation results before filtering

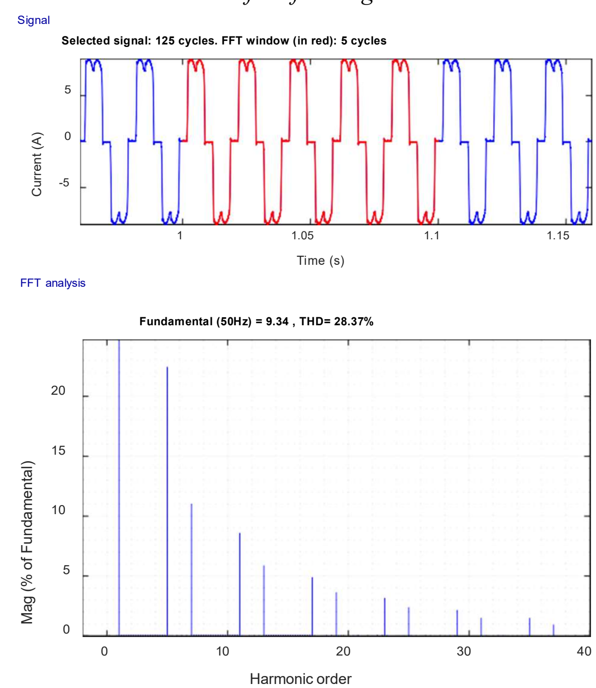


Fig.7 Source and load current and Harmonic Spectrum before filtering

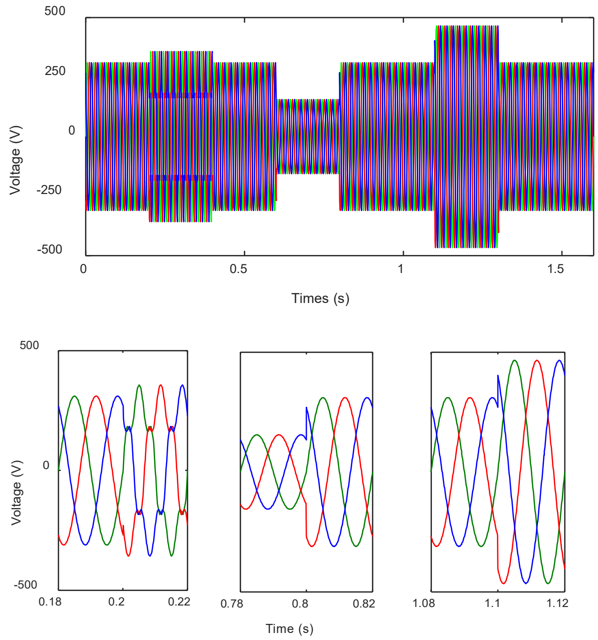


Fig.8 Source and load voltage befor filtering

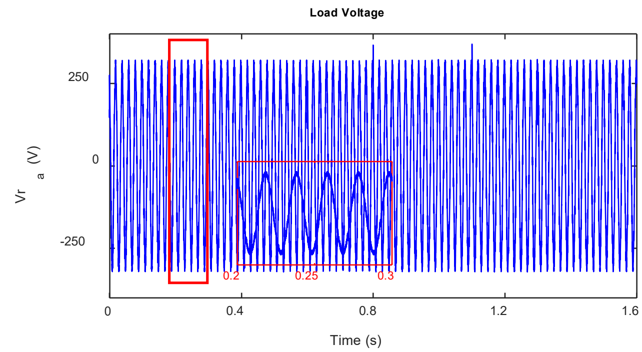
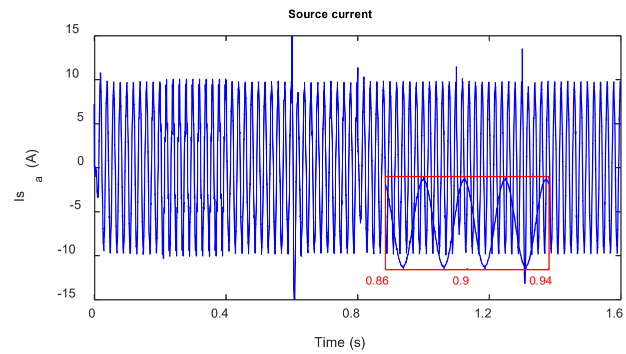
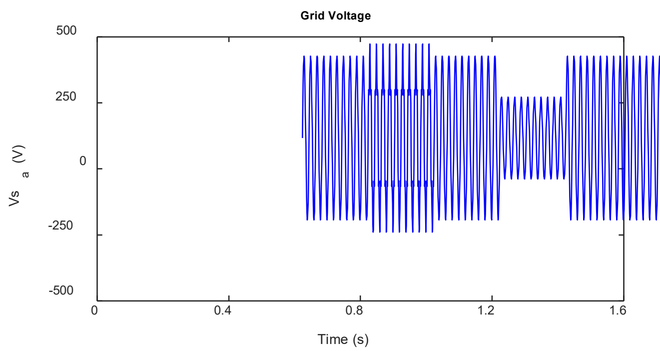
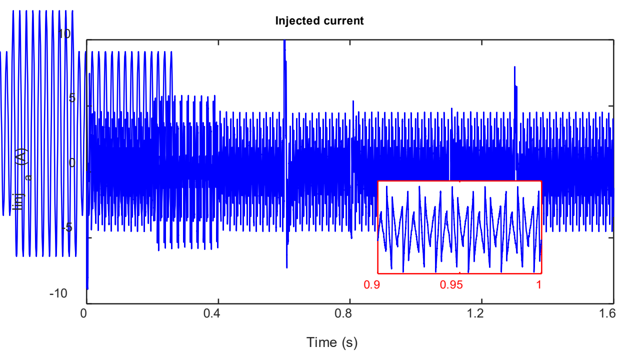


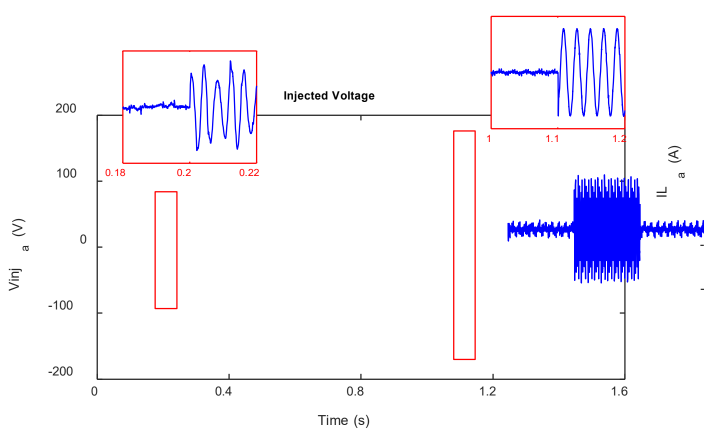
Fig.9 Source, Injection and Load voltage



B. *Simulation results after filtering*







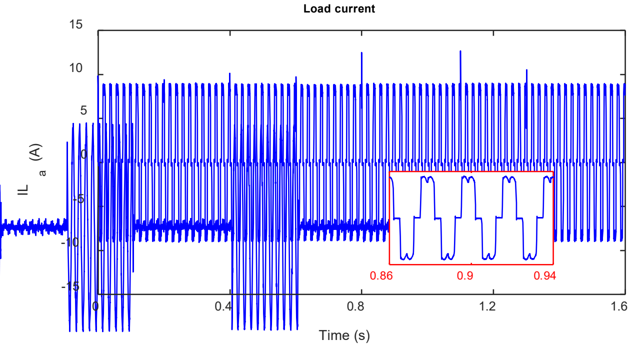


Fig.10 Source, Injection and Load current

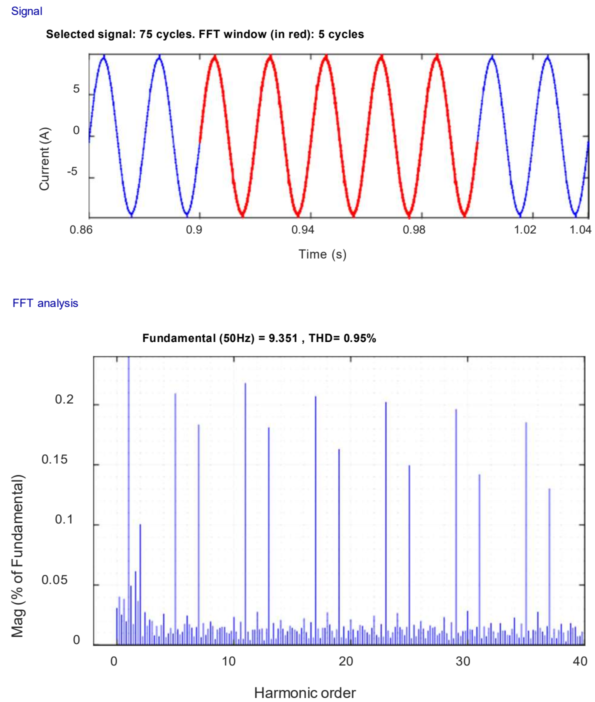


Fig.11 Source current and Harmonic spectum after filtering

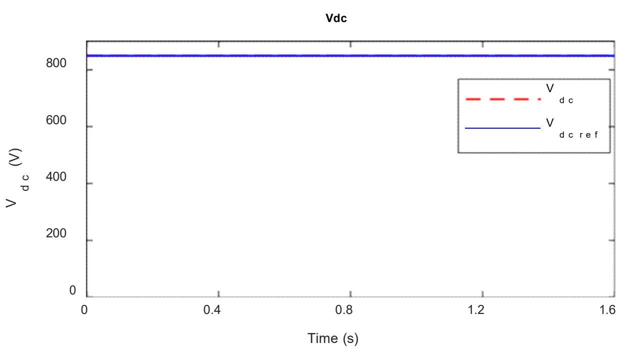


Fig.12 Vdc Voltage and its reference

IV. Discussion

The simulation results obtained before using UPQC

- Figures 7 and 8 show the waveform of load current and voltage, clearly depicting the deformation of their waveform.
- Figure 7 shows the harmonic spectrum of load current, noting a very high rate of total harmonic distortion at 28.37%.

The simulation results obtained after using UPQC

- Figure 9 Voltage sag, between 0.6 and 0.8 seconds, the network voltage drops to 50% of its maximum value. The UPQC quickly detects this sag state and injects the necessary output voltage to supply a steady, sinusoidal voltage to the LED load. This point must be made. In order to make up for the difference between the nominal voltage and the required voltage to be delivered, the series APF is responsible for quickly injecting a voltage in series with the supply voltage through the gate pulses of IGBTs.

Voltage swell from 1.1 to 1.3 seconds, the voltage in the network is increased to 150% of the normal value. It should be emphasized that UPQC detects this swelling condition immediately and absorbs the required amount of output voltage to support a stable, sinusoidal voltage at the load. In order to make up for the difference between the nominal voltage and the voltage needed to supply it, the APF series is in charge of quickly absorbing the voltage in series with the supply voltage through the IGBTs' gate pulses

- Figure 10 The shunt APF injects current harmonics through the capacitor and IGBT gate pulses to make up for the load's distorted current. The basic current must be forced to match the actual input current by the input current controller. The main part of the load current must be determined by the dc link voltage controller.
- After using our proposed device (UPQC), we notice a remarkable improvement in the waveform of the source current, which is becoming almost sinusoidal, as shown in Figure 11 where we noted lower THD values of 0.95% for the current, which is well within the norm.
- The series active power filter works by injecting a compensating voltage that cancels out the sag and swells problem components of the load voltage, resulting in a cleaner sinusoidal waveform.
- Figure 12 shows that the voltage at the terminals of the capacitor follows faithfully the reference voltage Vdc and it comes back to the regulation realized by the PI regulator used.

V. Conclusion

This article presents a Unified Power Quality Conditioner (UPQC), the system was designed and modeled successfully using the Matlab / Simulink. The Unified Power Quality Conditioner consists of combined of active power filter series and shunt for simultaneous compensation of harmonic currents and the voltage sag and swells.

The simulation results obtained show good performance of the UPQC for the compensation of harmonic disturbances; we observe a significant decrease of the THD of the current as well as the compensation of the reactive power voltage sag and swell. The performance of the proposed system is verified through simulation.

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