Power Quality Improvement Using UPQC for system with non linear loads

Sumeet Singh, Mukul Chankaya

***Abstract*— Power electronic devices has penetrated so deep in our daily lives that we cannot ignore them and these power electronics devices act as non linear loads for the power system. The non linear loads may have many applications in our lives but for the power sector they create problems by deteriorating the quality of power being supplied to the consumers. With the non linear loads the power supply suffer from harmonics and transients which create the malfunctioning of the devices and also give rise to the following problems such as insulation failures, noisy operation of the devices, interference with the communication lines etc. To tackle the problem of poor power quality FACTS devices play an important role. There are various facts devices categorized as series, shunt and series-shunt devices. In this paper we are using UPQC i.e. unified power quality conditioner which is a series-shunt FACTS device. The benefits of using the series-shunt device are that it compensates the voltage and current of the lines simultaneously and also compensates the demand of reactive power..**

***Index Terms*— APF – active power filter, P – active power, Q – reactive power, SRF- synchronous reference frame, PCC- Point of common coupling**

I. INTRODUCTION

Power quality is the parameter which defines whether the power being supplied is compatible with the device and the wiring of the premises [1]. The present era includes automation of devices all over the world, this automation needs electronics components to perform the operation. But along with the act of automation the electronic components acts as non linear loads. These non linear loads have severe impact on the power quality of the system. The non linear load creates distortions in the voltage profile and also injects harmonics in the system. With the above two problems the power supply gets affected and hence the power quality of the system gets distorted. The loads such as converters, inverters and SMPS (switch mode power supply) inject severe harmonics. So in order to compensate the harmonics we need custom power devices, such a FACTS device is UPQC (unified power quality conditioner). It is a series-shunt compensating device which eradicates both the problems of series and shunt compensation. The model given in this paper projects UPQC being installed at the point of common coupling (PCC). The UPQC control will be based on the synchronous reference frame theory, instantaneous reactive power theory, voltage vectors, phase locked loops and PI controllers. All of the above are used in such a manner to provide required gate pulses to the converter in the UPQC to provide compensation to the line. The UPQC will comprise of the two active power filters i.e. series and shunt APF (active power filters). These active power filters will be connected with a DC link which will be provided either by a capacitor or the battery. The series and shunt APF will be controlled by the series and shunt controllers respectively.

Sumeet Singh, school of electrical and electronics engineering, Lovely Professional university, Phagwara, India, 9417059038,

Mukul Chankaya, school of electrical and electronics engineering, Lovely Professional university, Phagwara, India

II. POWER QUALITY ISSUES

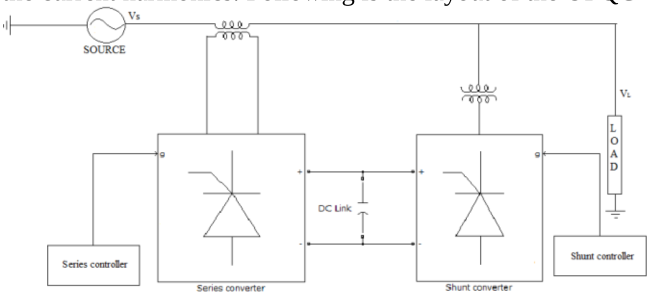
There are a number of power quality problems which cause distortion in system equilibrium, these problems are given in the following table :-

Problem	Cause	Effect
Surge and spikes in voltage	Abrupt removal of loads, lightning, switching of EHV&UHV lines	Equipment and insulation failure, loss of data from storage devices
Harmonics	Power electronics devices, SMPS, non linear loads	Interference with communication lines, noisy operation of devices, insulation failure, transformer heating
Transients	Switching of shunt capacitors, loads switching, lightening	Faulty operation of relays, overheating of drives, destroy the filaments of the lamps and lights get affected, electronic circuits gets burnt
Voltage variation	Heavy loads, unstable alternator operation, brown outs	Burning of devices, faulty operation of overvoltage operations, insulation failure
Interruptions and outage	Overloading of system and alternators, black outs	Power outage, system lock up, loss of valuable data, life in regions gets affected due to no power.
Electrical noise	Arc Welders, Switch mode power supplies, Fault clearing devices, Ground not dedicated	Fluctuation in waves , corruption of data, affects data acquisition systems

The FACTS devices could be very useful in solving these problems. There are three type of FACTS devices i.e. series, shunt and series-shunt devices. The series devices are used to compensate the voltage fluctuations, interruptions, sag and swells & shunt devices are used to compensate the reactive power demand and current. These devices inject the voltage and current respectively but the series-shunt devices have an upper hand as they inject both current and voltage simultaneously. These devices are UPFC, UPQC, IPFC and TPFC. In this paper we will pay stress on UPQC in solving these issues.[4]

III. UNIFIED POWER FLOW CONDITIONER (UPQC)

The UPQC is a custom power device which is capable of compensating the line by providing both series and shunt compensation. UPQC consists of series and shunt converters which provide voltage and reactive power compensation respectively. The shunt compensator also helps in regulating the DC voltage and suppresses
the current harmonics. Following is the layout of the UPQC



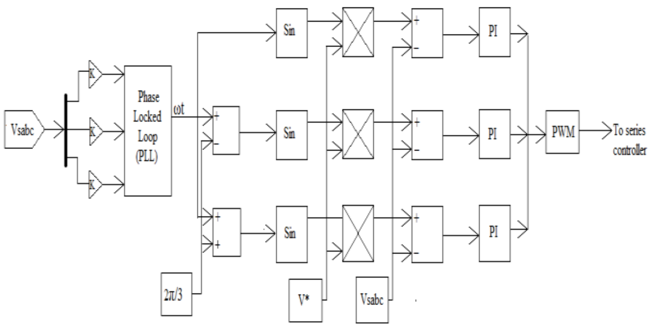
Block diagram of UPQC

UPQC have certain configuration of operation they are given as:-

- Right shunt UPQC
- Left shunt UPQC
- Interline UPQC[2]

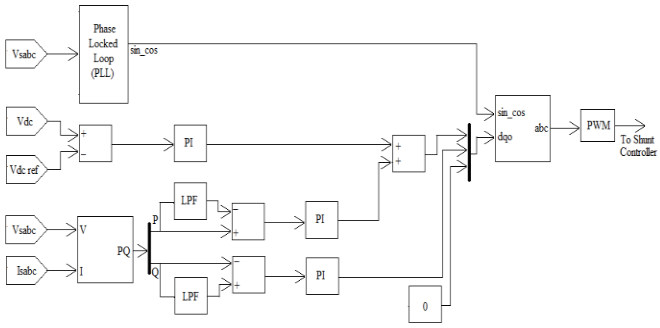
IV. CONTROL STRATEGY

A. Series controller



The series controller is fed from the source and the voltage of all the three phase is fed into the phase locked loop, and from phase locked loop the phase angle is calculated. Then the angles are created by adding and subtracting 2π/3 to the ωt. Then the angle is multiplied with the sin function to get sin ωt, sin(ωt-2π/3) and sin(ωt+2π/3). Further the sin functions are multiplied with the desired voltage magnitude and then these voltage vectors are the compared with the line voltage. Then the error signal is fed to the PI controllers and then to the PWM (pulse width modulator) and the signal is send to the gate of series controller.

B. Shunt controller



The shunt controller implements two theories i.e. instantaneous reactive power theory and synchronous reference frame theory. The source voltage is fed to the Phase locked loop (PLL) and the phase difference is calculated in order to synchronise the gate signals with the line phase. Then the DC from the Dc link is compared with DC reference and the error signal is given to the PI controller. Now current and voltage from the line is fed into the system and active(P) and reactive(Q) power are calculated and then the error signal is generated of these active and reactive powers by passing the signals from the low pass filters(LPF) then comparing with the original signal. Then the errors are conditioned in the PI controllers and then the error of the P signal and the Dc signal are added and are regarded as 'd' component and error from Q signal is regarded as 'q' component, then these 'd' and 'q' components along with constant '0' are given to the multiplexer and are made as 'dq0' signal. Then the this 'dq0' signal is given to the inverse parks transformation block and 'abc' components are produced by multiplying it with following expression

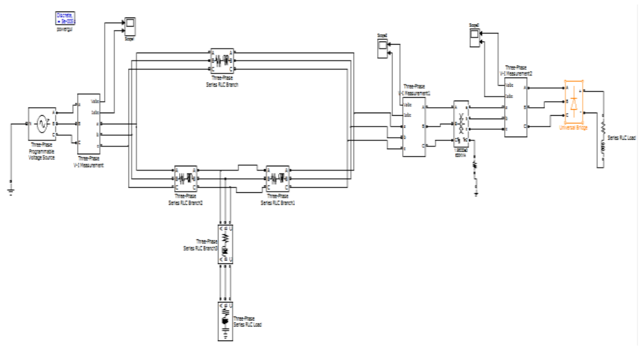
$$\sqrt{\frac{2}{3}}\begin{bmatrix}\cos\theta & -\sin\theta & \frac{1}{\sqrt{2}}\\ \cos\left(\theta-\frac{2\pi}{3}\right) & -\sin\left(\theta-\frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}}\\ \cos\left(\theta+\frac{2\pi}{3}\right) & -\sin\left(\theta+\frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}}\end{bmatrix}$$

then the signal is fed to the 'PWM' and further the gating pulses produced are given to the gate of the shunt converter.[3]

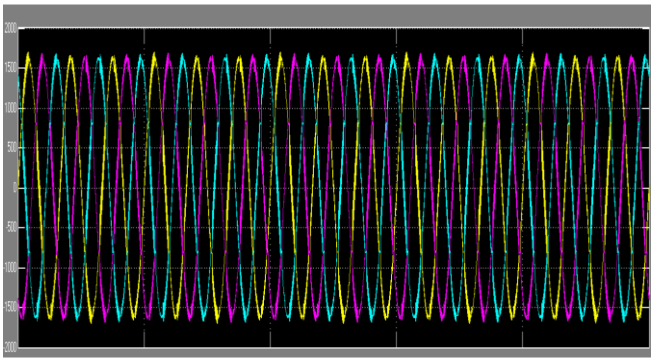
V. SIMULATION AND RESULTS

In this section comparison will be carried out between systems feeding non linear loads with and without UPQC.

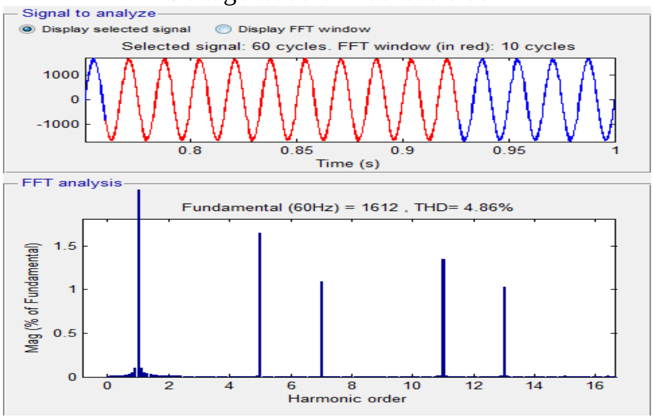
A. System without UPQC



- **Voltage at load side**



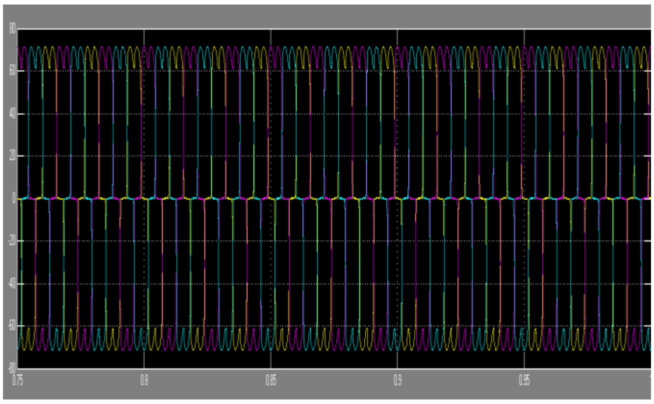
Voltage waveform at load side



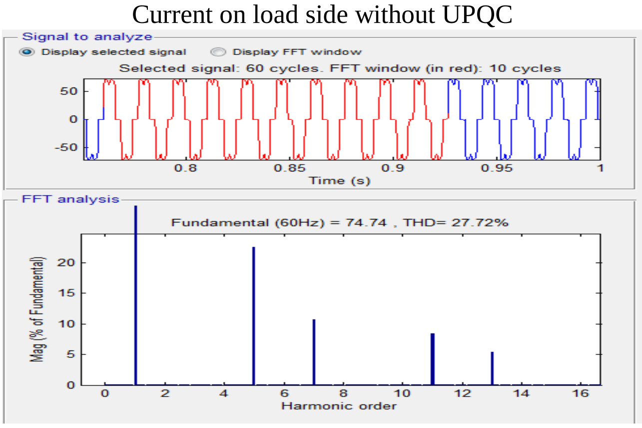
THD in voltage on load side

The waveform at the load side without compensation is quite distorted and the THd are 4.86%.

- **Current on load side**



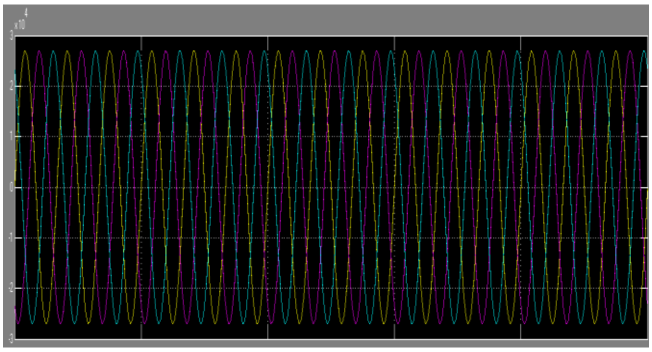
Current on load side without UPQC



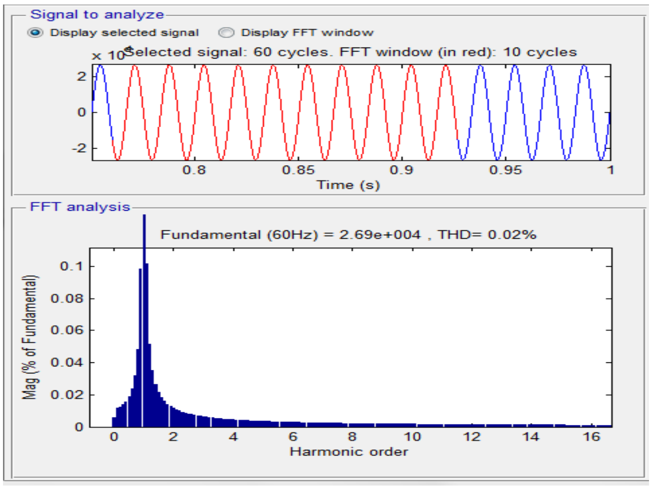
THD in current on load side

The waveform of current is also distorted and the THD in the current waveform is 27.72%.

- **Voltage at PCC**

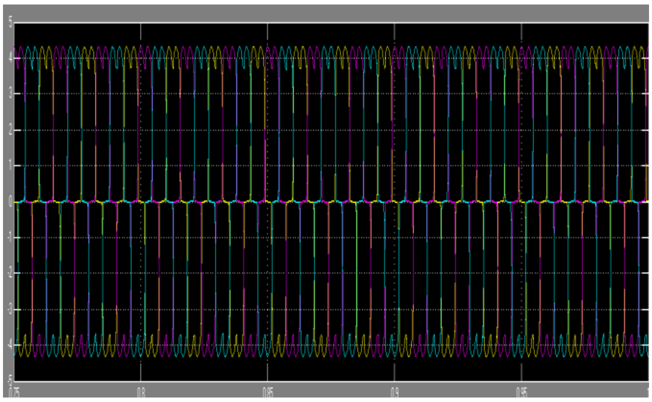


Voltage at PCC

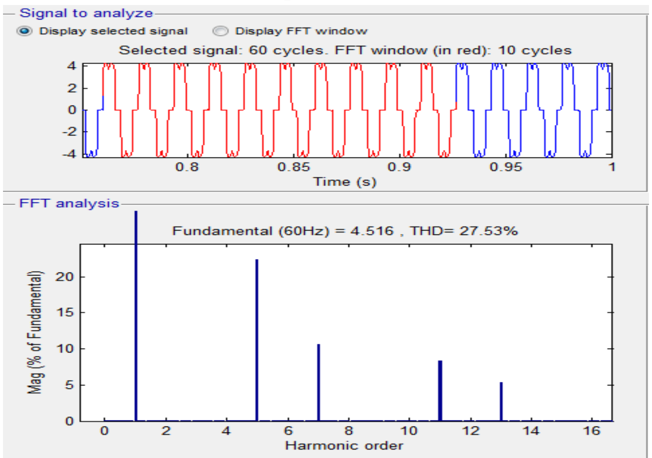


THD of voltage at PCC

- **Current at PCC**

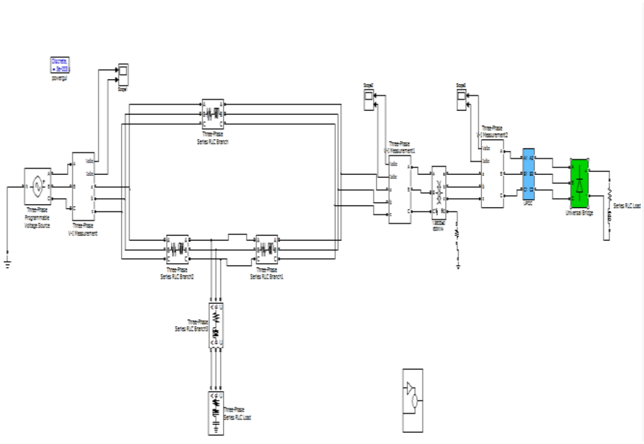


Current at pcc without UPQC



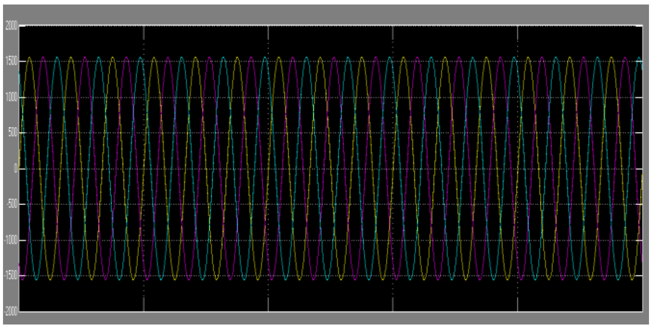
THD of voltage at PCC

a. System with UPQC

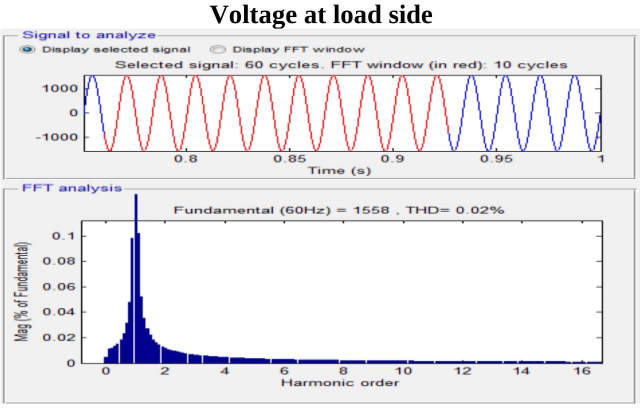


System with UPQC

- **Voltage at load side**

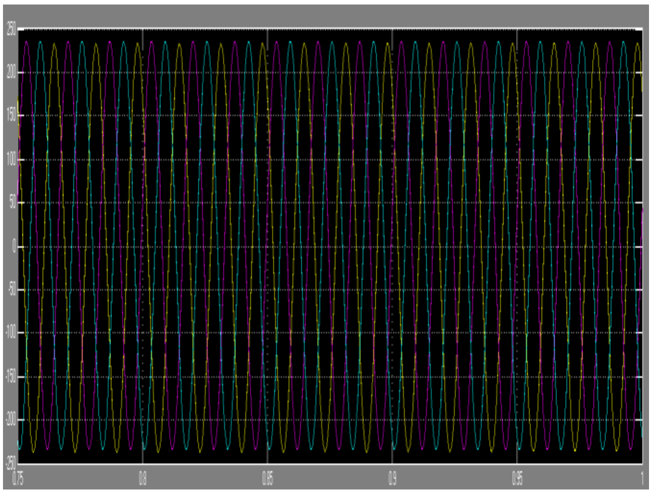


Voltage at load side

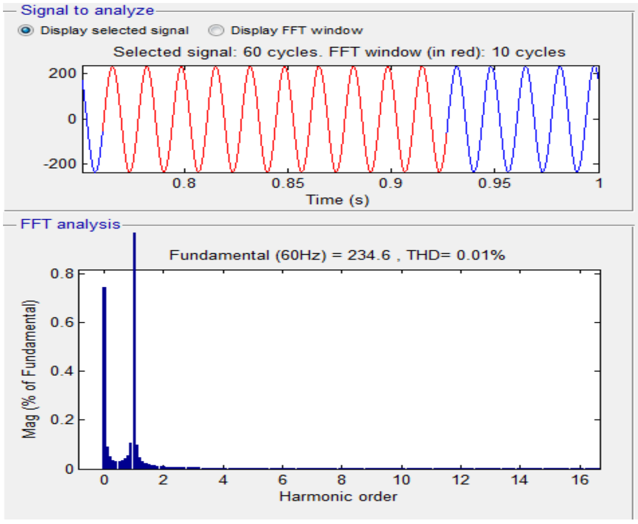


THD in voltage at load side

- **Current at load side**

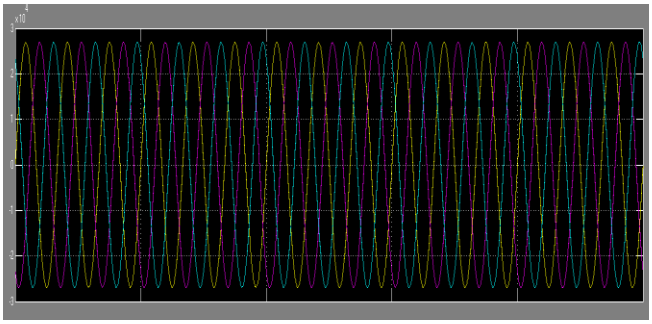


Ccurrent at load side



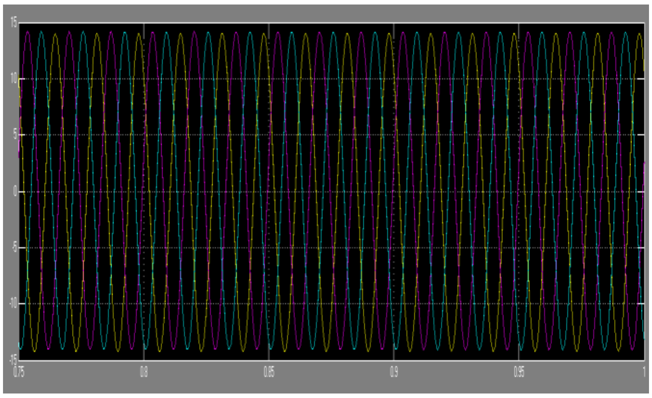
THD in current at load side

- **Voltage at PCC**

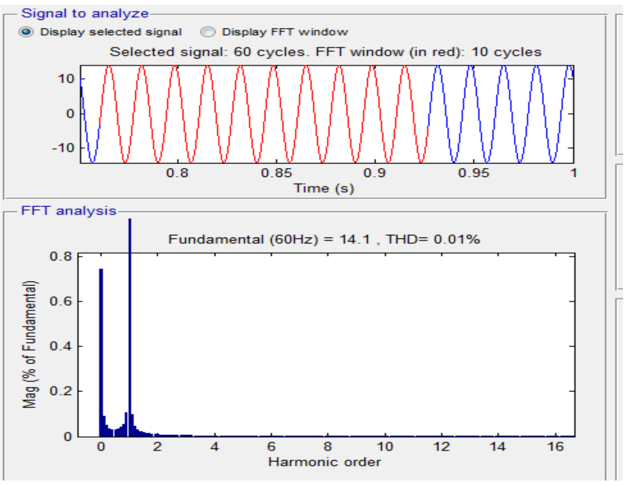


Voltage at PCC with UPQC

- **Current at PCC**



Current at PCC with compensation



THD in current at PCC

By using UPQC as compensating device the THD of voltage and current at load side has reduced from 4.86% and 27.76% to 0.2 and .01 respectively. At PCC the THD has of current has reduced from 27.8% to 0.01%, hence improving the power quality of the system..

VI. Conclusion

The problems of harmonics and distorted voltage have been resolved by the use of UPQC. The series and shunt APF work simultaneously to resolve the problem of voltage distortion and reactive power demand respectively. Hence UPQC is proved to be quite efficient in tackling the power quality problems.

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