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Unified Power Quality Conditioner in Power System

Jholapura.Deepali.R[1], Jhala.M.B[2]

PG Student (Power System), Dept. of EE, Government Engineering College, Bhuj, Gujarat, India [1]

Associate Professor& HOD, Dept. of EE, Government Engineering College, Bhuj, Gujarat, India[2]

ABSTRACT: The unified power quality conditioner (UPQC) is a power conditioning device. The UPQC with the combination of series active power and shunt active power can improve the power quality at the point of common coupling on power distribution systems under unbalanced and distorted load conditions. In this paper, synchronous-reference frame (SRF)-based control method to compensate power-quality (PQ) problems through a three-phase four-wire distribution system is proposed. For series active filter and shunt active filter SPWM controller used to produce insulated-gate bipolar transistor (IGBT) switching signals and to compensate all voltage-related problems, such as voltage harmonics, sag, swell, voltage unbalance, etc., at the PCC. The simulation results based on Matlab/Simulink are discussed in detail to support the SRF-based control method presented in this paper. The proposed approach is also validated through experimental study with the UPQC hardware prototype.

KEYWORDS: Active power filter (APF), phase locked loop (PLL), synchronous reference frame (SRF), sinusoidal pulse width modulation (SPWM) and unified power-quality conditioner (UPQC).

I.INTRODUCTION

In the present scenario of deregulated power market, satisfy power quality requirement to consumers has emerged as a figure of merit of distribution power utilities. Because of increased applications of power electronics based appliances, this is becoming tedious day by day to maintain constant voltage and uninterrupted power supply to different consumers non liner such as adjustable speed drives, computer power supplies, furnaces, power converters, and traction drives draws non-linear current and degrade electric power quality.so poor power quality issues arise at consumers ends, like overheating transformers, low power factor, low efficiency and so on[1],[9].Apart from this it is found that overall loads is scarcely found to be balanced. Many researchers worked on it and suggested passive filters to mitigate all voltage-current harmonics. but using conventional passive filters have some limitations like it gives only fixed compensations ,resonance with source impedance and difficulty in tuning time dependence of filter parameters have triggers the need of active and hybrid filters . These filters direct only few identified power quality problems of the present distribution networks. Relating power quality issues, the designers of power quality conditioner systems are required to follow the recommendations of some world-wide accepted standards like IEEE-519-1992 recommended practice and requirements for harmonics control in electric power systems [2-4]

The UPQC is one of the most powerful custom power devices, which can mitigate both voltage and current related problems simultaneously. The UPQC is a combination of back to back connected series and shunt APFs to a common dc link voltage. The series APF compensate all voltage harmonics and shunt APF cancels current-based distortions. And improve power factor by compensating reactive component of load current.In this paper, the improved synchronous-reference-frame with SPWM based control method for the UPQC system is optimized without using transformer voltage, load, and filter current measurement, so that the numbers of the current measurements are reduced and the system performance is improved.[11] In the proposed control method, load voltage, source voltage, and source current are measured, evaluated, and tested under unbalanced and distorted load conditions using Matlab /Simulink software. The proposed SRF-based method is also validated through experimental study. The UPQC configuration and the load under consideration are discussed in section II. The control algorithm discussed in section III. Results are discussed in section IV. Finally conclusion in section V.

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II. SYSTEM DISCRIPTION

The system under consideration is shown in fig-1. The UPQC is connected before the load to make the load voltage free from any distortions and at the same time, the reactive current drawn from source should be compensated in such a way that the currents at source side is, would be in phase with utility voltages. Provisions are made to realize voltage harmonics, voltage sag and swell in the source voltage by switching on/off the three phase rectifier load,R-L load and R-C load respectively. in order to create a voltage dip in source voltage an induction motor is connected suddenly on the load side . The UPQC, realized by using two VSI is shown in fig.2, one acting as a shunt APF while other as a series APF. Both the APFs share a common dc link in between them. Each inverter is realized by using six IGBT switches. The voltage at the source side before UPQC, the load voltage at load, the voltage injected by series APF and dc link voltage between two inverters are represented by v_s,v_L,v_{inj} and vdc respectively.whereas, the current on the source side,total current drawn by all the loads and the current injected by shunt APF are represented by i_s, i_l,and i_{sh} respectively. The values of the circuit parameters and load under consideration are given in appendix.[4-7]

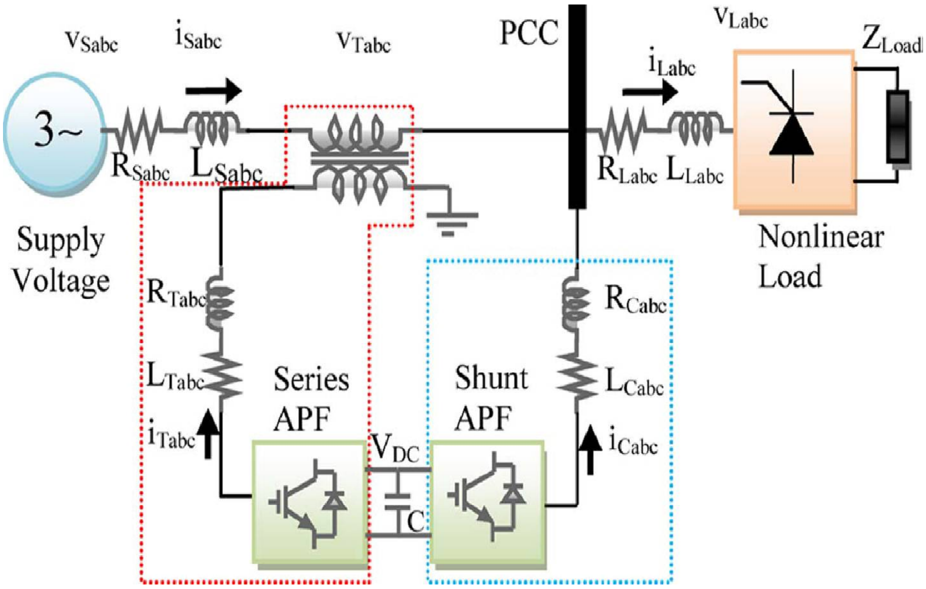

Fig.1 block diagram of UPQC

III. CONTROL STRATEGY

The proposed control strategy is aimed to generate reference signals for both shunt and series APFs of UPQC. In the following section an approach based on SRF theory is used to get reference signals for the series and shunt APFs. SRF-based control method is one of the most conventional and the most practical methods. The SRF method presents excellent characteristics but it requires decisive PLL techniques. This paper presents a new technique based on the SRF method using the modified PLL algorithm. The proposed SRF control method uses $a-b-c$ to $d-q-0$ transformation equations, filters, shown in Fig. 2. The sensing of only the source current to realize an SRF-based controller or another type of controller for shunt APF is not new, and this kind of controller can be found in literature. The proposed method is simple and easy to implement and offers reduced current measurement; therefore, it can be run efficiently in DSP Platforms. Hence, the proposed modified PLL algorithm efficiently improves the performance of the UPQC under unbalanced and distorted load conditions.[12]-[13].

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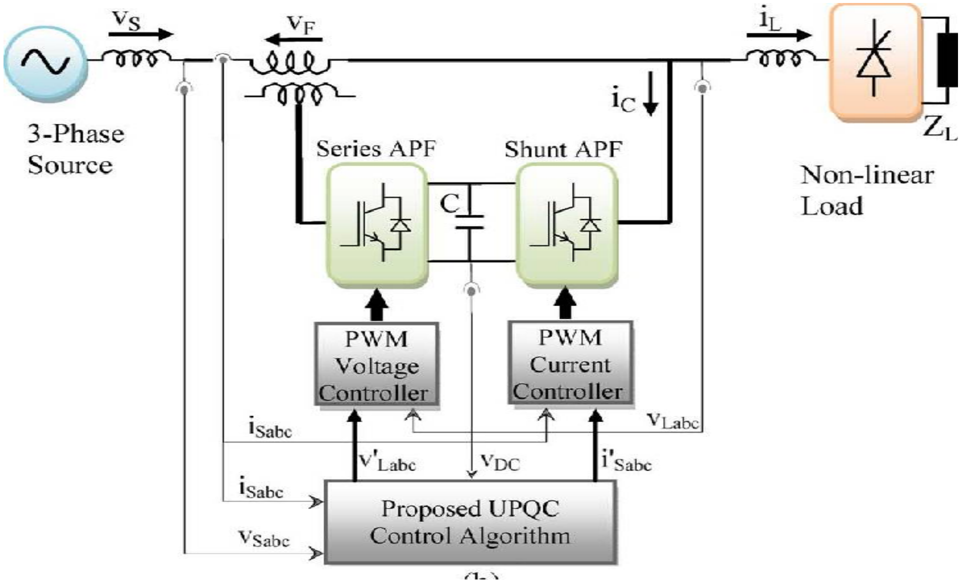

Fig.2 control block diagram of UPQC

A. Reference –Voltage Signal Generation for Series APF

The proposed SRF-based UPQC control algorithm can be used to solve the PQ problems related with source-voltage harmonics, unbalanced voltages, and voltage sag and swell at the same time for series APFs. In the proposed method, the series APF controller calculates the reference value to be injected by the STs, comparing the positive-sequence component of the source voltages with load-side line voltages. The series APF reference-voltage signal-generation algorithm is shown in Fig. 3. In (3), the supply voltages *v*Sabc are transformed $d{-}q{-}0$ by using the transformation matrix **T** given in (1). In addition, the modified PLL conversion is used for reference voltage calculation

$$T = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \sin(wt) & \sin(wt-\frac{2\pi}{3}) & \sin(wt+\frac{2\pi}{3}) \\ \cos(wt) & \cos(wt-\frac{2\pi}{3}) & \cos(wt+\frac{2\pi}{3}) \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\text{ (1)}$$

$$T^{-1} = \sqrt{\frac{2}{3}}\begin{bmatrix} \frac{1}{\sqrt{2}} & \sin(wt) & \cos(wt) \\ \frac{1}{\sqrt{2}} & \sin(wt-\frac{2\pi}{3}) & \cos(wt-\frac{2\Pi}{3}) \\ \frac{1}{\sqrt{2}} & \sin(wt+\frac{2\pi}{3}) & \cos(wt+\frac{2\Pi}{3}) \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\text{ (2)}$$

$$\begin{bmatrix} v_{S0} \\ v_{Sd} \\ v_{Sq} \end{bmatrix} = T\begin{bmatrix} v_{Sa} \\ v_{Sb} \\ v_{Sc} \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\text{(3)}$$

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The instantaneous source voltages (v_{Sd} and v_{Sq}) include both oscillating components (v_{Sd} and v_{Sq}) and average components (v_{Sd} and v_{Sq}) under unbalanced source voltage with harmonics. The oscillating components of v_{Sd} and v_{Sq} consist of the harmonics and negative-sequence components of the source voltages under distorted load conditions. An average component component includes the positive-sequence components of the voltages.The zero-sequence part (v_{S0}) of the source voltage occur when the source voltage is unbalanced. The source voltage in the d-axis (v_{Sd}) given in (4) consists of the average and oscillating Components

$vSd = \bar{v}Sd + \tilde{v}Sd$ .... (4)

The load reference voltages (v'Labc) are calculated as given in (5). The inverse transformation matrix $\mathbf{T}^{-1}$ given in (2) is used for producing the reference load voltages by the average component of source voltage and ωt produced in the modified PLL algorithm. The source-voltage positive-sequence average value (vSd) in the d-axis is calculated by LPF, as shown in Fig. 3. Zero and negative sequences of source voltage are set to zero in order to compensate load voltage harmonics, unbalance, and distortion, as shown in Fig. 3

$$\begin{bmatrix} v'La \\ v'Lb \\ v'Lc \end{bmatrix} = T^{-1} \begin{bmatrix} 0 \\ vSd \\ 0 \end{bmatrix} \quad \text{...........….. (5)}$$

The produced load reference voltages (v'_{La}, v'_{Lb}, and v'_{Lc}) and load voltages (v_{La}, v_{Lb}, and v_{Lc}) are compared in the Sinusoidal Pulse Width Modulation controller to produce insulated-gate bipolar transistor (IGBT) switching signals and to compensate all voltage-related problems, such as voltage harmonics, sag, swell, voltage unbalance, etc., at the PCC.

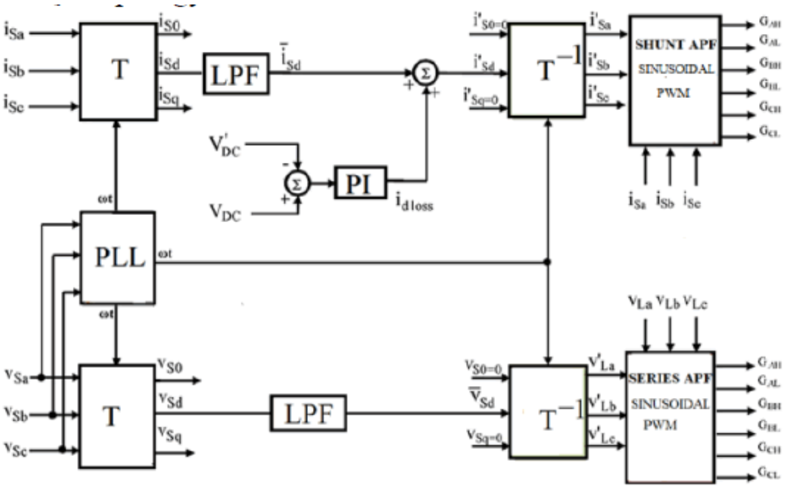

Fig 3: Proposed SRF based UPQC control block diagram

Control Block diagram for shunt and series APF

B. Reference-Source-Current Signal Generation for Shunt APF

The shunt APF described in this paper is used to compensate the current harmonics generated in the nonlinear load and the reactive power. The proposed SRF-based shunt APF reference source- current signal-generation algorithm uses only source voltages, source currents, and dc-link voltages. The source currents are transformed to $d{-}q{-}0$ coordinates, as given in (6) and (ωt) coming from the modified PLL. In 3P4W systems and nonlinear load conditions, the instantaneous source currents (iSd and iSq) include both oscillating components (_iSd and_iSq) and average components (*i*Sd and *i*Sq). The oscillating components consist of the harmonic and negative-sequence components of the source currents. The average components consist of the positive-sequence components of current and correspond to reactive currents. The negativesequence component of source current (*i*S0) appears when the load is unbalanced. The proposed SRF-based method employs the positive-sequence average component (*i*Sd) in the *d*-axis and the zero- and negative-sequence component (*i*S0 and *i*S0) in the 0- and *q*-axes of the source currents, in order to compensate harmonics and unbalances in the load

$$\begin{bmatrix} i_{S0} \\ i_{Sd} \\ i_{Sq} \end{bmatrix} = \mathrm{T} \begin{bmatrix} i_{Sa} \\ i_{Sb} \\ i_{Sc} \end{bmatrix} \qquad \text{.........} \ (6)$$

The active power is injected to the power system by the series APF in order to compensate the active power losses of the UPQC power circuit, which causes dc-link voltage reduction.Some active power, should be absorbed from the power system by the shunt APF for regulating dc-link voltage. For this purpose, the dc-link voltage is compared with its reference value (*v*_DC), and the required active current (*i*dloss) is obtained by a PI controller. The source current fundamental reference component is calculated by adding to the required active current and source current average component (*i*Sd), which is obtained by an LPF, as given in (7)

*i*Sd = *i*dloss +¯*i*Sd. .... (7)

In the proposed method, the zero- and negative-sequence components of the source current reference (*I'*s0 and *I'*Sq) in the 0- and *q*-axes are set to zero in order to compensate the harmonics, unbalance, distortion, and reactive power in the source current. The source current references are calculated as given in (8) to compensate the harmonics, neutral curre unbalance, and reactive power by regulating the dc-link voltage

The produced reference-source currents (i'sa, i'sb, and i'sc)and measured source currents (isa, isb, and isc) are compared by a Sinusoidal Pulse Width Modulation current controller for producing IGBT switching signals to compensate all current-related problems, such as the reactive power, current harmonic, neutral current, dc-link voltage regulation, and load-current unbalance. The proposed SRF-based UPQC control method block diagram is shown in Fig. 3

$$\begin{bmatrix} i'sa \\ i'_{Sb} \\ i'sc \end{bmatrix} = \mathrm{T}^{-1} \begin{bmatrix} 0 \\ i'sd \\ 0 \end{bmatrix} \qquad \text{.........} \ (8)$$

IV. SIMULATION RESULT

In this study, a new control algorithm for the UPQC is evaluated by using simulation results given in Matlab/Simulink software under non-ideal mains voltage and unbalanced load current conditions. In simulation studies, the results are specified before and after UPQC system are operated. The proposed control method has been examined under non-ideal mains voltage and unbalanced load current conditions. Before harmonic compensation, the THD of the supply voltage, load voltage, supply current, load current is 10.02%, 10.02%, 20.49%, 20.35% respectively. The obtained results show that the proposed control technique allows the 3.05%, 3.16%, 2.67%, 19.09% respectively mitigation of all harmonic components. As a result, the proposed method is very effective and successful in harmonic compensation under distorted load condition as shown in simulation results.

In the Fig 4a it shows graph between voltage and time. Supply voltage before UPQC and after UPQC. In the Fig 4b it shows graph between voltage and time. Load voltage before before UPQC and after UPQC....

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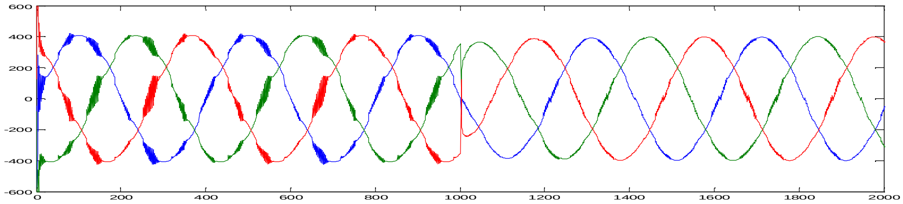

Fig. 4a. Supply Voltage

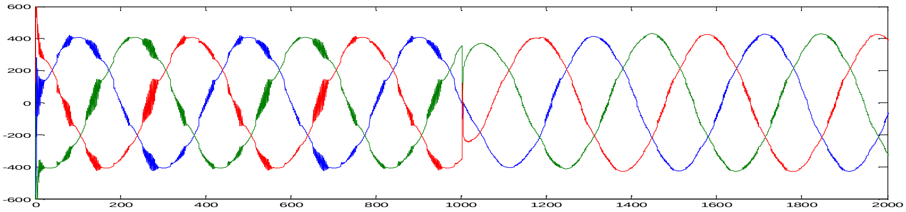

Fig. 4b Load Voltage

In the fig 5a it shows the graph of source current Vs time. Source current before UPQC and after UPQC. In the fig 5b its shows the graph of load current Vs time .load current before UPQC and after UPQC...

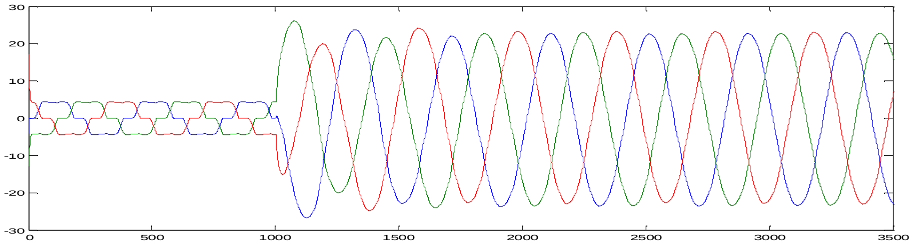

Fig. 5a Source Current

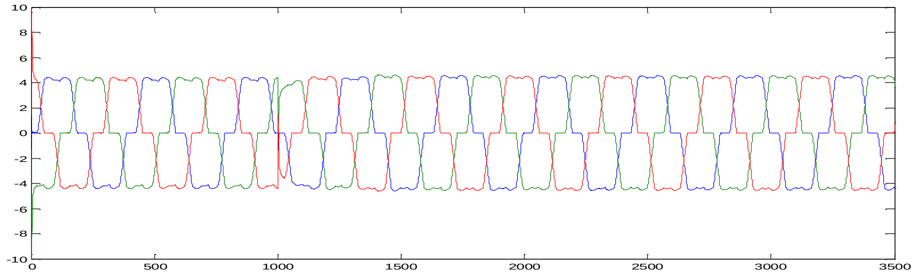

Fig. 5b Load Current

Fig 6a shows graph of injected transformer voltage to mitigate voltage distortion. Fig 6b shows compensated current to compensate current harmonics.Fig 6c dc link voltage which is constant due to shunt APF. Fig 6d shows compensated active and reactive power before UPQC and after UPQC

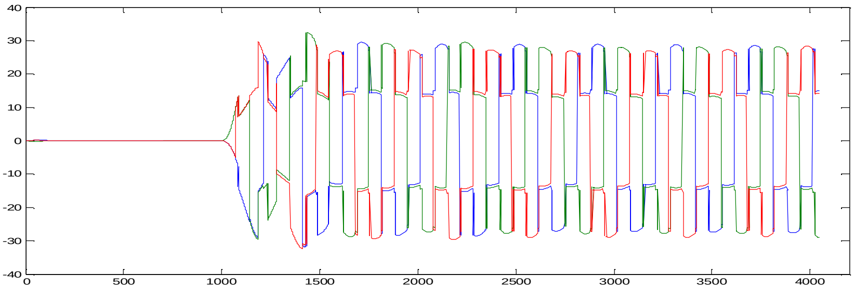

Fig. 6a Injected Transformer Voltages

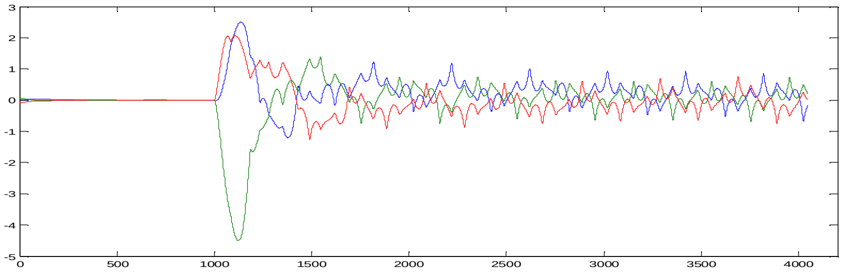

Fig. 6b Compensator Current

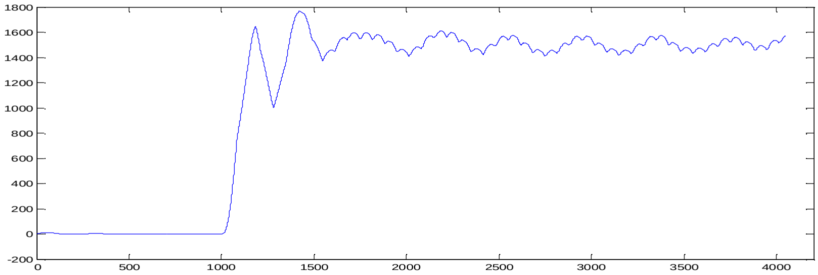

Fig. 6c DC Link Voltage

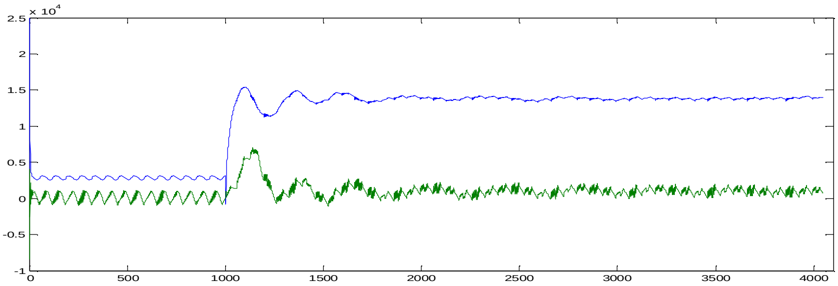

Fig. 6d Active Power & Reactive Power

V. CONCLUSION

This paper describes a new SRF with SPWM -based control strategy used in the UPQC, which mainly compensates the reactive power along with voltage and current harmonics under nonideal mains voltage and unbalanced load-current conditions. Proposed control scheme is more effective than other control stratagy. The proposed control strategy uses only loads and mains voltage measurements for the series APF, based on the SRF theory. The simulation results shows that, when under unbalanced and nonlinear load-current conditions, the aforementioned control algorithm eliminates the impact of distortion and unbalance of load current on the power line, making the power factor unity. Meanwhile, the series APF isolates the loads and source voltage in unbalanced and distorted load conditions, and the shunt APF compensates reactive power, neutral current, and harmonics and provides three-phase balanced and rated currents for the mains

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