Abstract-- This work is a comparative study of three regulators, two of these are already known, the PI and the IP the third is proposed the PIP. These controllers are used to regulate the voltage of the two inverters PAF and SAF of the UPQC using a new method of identifying of interference currents based on the fundamental components of the load currents. The results of this work have shown that the regulator PIP satisfactory results and thus maintain the voltage $V_c$ around its reference value. Also this new method, has detected the interference currents of the load.

Keywords-- UPQC; PIP controller; THD; fundamental components

I. INTRODUCTION

The Electric power must be supplied by the best quality that is to say supply of a three-phase sinusoidal voltage system balanced to all the various users. By cons the increased of the perturbations problems in the electrical networks, affects increasingly this power quality. Among the most predominant disturbances, the hollows voltage, harmonics, which are due to the proliferation of the non-linear loads in industrial and domestic equipment and the imbalance of the current and / or of the voltage caused generally by the non-symmetric single-phase loads. The various solutions of the remediation grids one more interesting than the other, have already been proposed in the literature. The UPQC (Unified Power Quality Conditioner) is a better solution for the decontamination of energy distribution networks. It not only compensates the harmonic currents and the imbalance created by a non-linear load, but also the harmonic interference and unbalanced voltage source through a combination series-parallel active, which results from the combination of two parallel active filters and series and thus improving power quality by offering other sensitive loads proper operation. And that it works with high efficiency, it is necessary that there are powerful commands.

Our work in this paper is a study of the UPQC with a comparison of two controllers PI and IP and third proposed PIP of the DC voltage of the two inverters. The control method of the shunt part of the UPQC is a new method that been named method of the fundamental components of the load current FC.

II. THE GENERAL STRUCTURE OF THE UPQC

The general structure of the UPQC consists of two parts: the parallel active filter and series active filter as shown in Fig.1. The active filter series (SAF) is connected in series with the electrical network via a low pass filter and a voltage transformer injection. SAF disturbances compensates for the voltage supply network so that the voltage across the load is remained unmoved. The parallel active filter (PAF) was connected in parallel with the nonlinear load through an inductor $L_f$ which has a good chosen value because it has over sizing that can cause the high a slow response of the current and the opposite can cause high frequency waves that affect the network distribution [3][6]. The goal of PAF is to eliminate harmonic currents drawn by the load and to offset the reactive power. The coupling capacitor C provides the voltage across the FAP and FAS, ideally once charged the DC bus coupling should not to decrease limited but due to losses of the inverter (the capacitor charge is to Travert PAF) [4]. The choice of the reference voltage depends of the percentage of voltage dips and offset the amount of reactive power injected.

![Fig.1. general structure of the UPQC][7][5]

III. FUNDAMENTAL COMPONENTS ALGORITHM FC

This proposed method of identifying the interference currents are calculated based on the reference of the fundamental components of the load current.
Indeed it was:

\[ I_{ch} = I_{cha} + I_{chr} + \sum I_{chh} \quad (1) \]

With:
\( I_{ch} \): the load current
\( I_{cha} \): active current load
\( I_{chr} \): the reactive current of the load
\( \sum I_{chh} \): harmonic currents active and reactive load

Since we want to compensate reactive power and harmonic currents it is necessary to maintain the current assets of the charge related to the active power given by the relation:

\[ p_{a} = 3U_{eff}.I_{eff} \cos \phi \quad (2) \]

With a power factor \( \cos \phi =1 \).

This relationship is true in the case where the voltage at the connection point is sinusoidal balanced.

In this case the source current is given by:

\[ I_{s} = I_{ch.a} \quad (3) \]

And reference currents are given by:

\[ I_{ref} = I_{ch} - I_{s} = I_{chr} + \sum I_{chh} - I_{reg} \quad (4) \]

\( I_{reg} \): the control current of the power obtained \( p_{av} \) to the regulator output of the DC voltage of the inverters.

The balanced sinusoidal voltages \( v_{a,b,c} \), which are divided by their amplitude \( U_{m} \), it remains that the parties sinusoidal without unity, we multiplied by the amplitude of the fundamental component \( I_{m} \) we obtain \( I_{cha} \).

\( I_{m} \) is defined by the decay of the charging current in Fourier series.

The overall scheme is shown in Figure 3:

The control scheme of a DC voltage corrector PI classic is illustrated by the following figure:

![Fig.3. Control loop of the DC voltage with PI](image)

We have the transfer function of the closed loop:

\[ \frac{V_{e}}{V_{ref}} = \frac{\omega_{c}^{2}(1 + \varphi p)}{p^{2} + 2\xi \omega_{c} p + \omega_{c}^{2}} \quad (5) \]

with:

\[ \omega_{c} = \sqrt{V_{ref} C_{f} \tau_{1}} \quad \text{and} \quad \xi = \frac{1}{2\sqrt{V_{ref} C_{f} \tau_{1}}} \]

To have a good damping coefficient of the closed-loop system, we chose \( \xi_{c} =0.7 \).

**B. The DC voltage regulator IP type**

Full IP proportional corrector is essentially different from the PI controller that it has no zero in the transfer function in a closed loop, so its output does not represent any discontinuity in the application of a desired type level [2].

The block diagram of the control voltage \( V_{c} \) including IP correction is illustrated by the following figure:

![Fig.4. Control loop of the DC voltage controller with the IP.](image)

The transfer function of the closed loop voltage is given by:

\[ \frac{V_{e}}{V_{ref}} = \frac{\omega_{c}^{2}}{p^{2} + 2\xi \omega_{c} p + \omega_{c}^{2}} \quad (6) \]

With:

\[ \omega_{c} = \frac{K_{i} K_{p}}{V_{ref} C_{f}} \quad \text{and} \quad \xi = \frac{1}{2\sqrt{K_{i} K_{p} V_{ref} C_{f}}} \]
The gains $K_i$ and $K_p$ correctors are expressed in terms of the parameters of the regulated voltage at these two formulas. Well to have a good damping coefficient of the closed-loop system, we chose $\xi_c=0.7$.

C. The DC voltage regulator PIP type

PIP controller and regulator controlled by a proportional IP P to improve the rise time of the voltage $V_c$ which influences the result of compensation. The block diagram of the control voltage $V_c$ including PIP correction is illustrated by the following figure:

![Block diagram of the control voltage Vc including PIP correction](image)

After a calculation with concentration, the transfer function of the closed-loop voltage is given by:

$$\frac{V_c}{V_{cref}} = \frac{\xi_c \omega_c p + \omega_c^2}{p^2 + 2\xi_c \omega_c p + \omega_c^2} \quad (7)$$

$$\omega_c = \frac{K_p}{V_{cref}C_f} \sqrt{\frac{K_i V_{cref} C_f}{K_p}} + 1$$

$$\xi_c = \frac{K_p}{K_i V_{cref} C_f + K_p}$$

For not to complicated the calculations we assumed the same value of $K_p$ proportional.

V. SIMULATION RESULTS AND DISCUSSION

The different parts of the UPQC are modeled and simulated in MATLAB SIMULINK, with the following characteristics:

- The value of DC voltage is $V_c = 850V$
- The nonlinear load is balanced: A AC / DC converter PD3 of diodes that supplies a load resistance $R = 3.333 \ \Omega$ and inductance $L = 60.10^{-3} \ \text{H}$.

We did the simulation in two cases of disturbance of the source voltage in order to assess the results and to compare the performance of three controllers PI, IP and PIP are submitted under the same operating conditions.

A. Case 1: balanced sinusoidal voltage source with a hollow.

![Simulation results (PI regulator)](image)

![Simulation results (IP regulator)](image)

![Simulation results (PI regulator)](image)
• Compensation results (PIP regulator)

![Load Voltage](image1)

![Source Current](image2)

Fig. 9. Voltages and currents after the compensation (Case 1)

• The DC voltage \( V_c \)

![Voltage Plots](image3)

Fig. 10. The DC Voltage \( V_c \) for the three controllers PI, IP and PIP (Case 1).

B. Case 2: The unbalanced sinusoidal voltage source.

• Compensation results (PI regulator)

![Load Voltage](image4)

![Source Voltage](image5)

Fig. 12. Voltages and currents after the compensation (Case 2)

• Compensation results (IP regulator)

![Load Voltage](image6)

![Source Current](image7)

Fig. 13. Voltages and currents after compensation (Case 2)

• Compensation results (PIP regulator)

![Load Voltage](image8)

![Source Current](image9)

Fig. 14. Voltages and currents before compensation (Case 1).


VI DISCUSSION OF RESULTS

According to the results obtained by the simulation of the UPQC following the two cases proposed with the three controllers PI, IP and PIP of the DC bus voltage $V_c$ we have seen that in the general case the UPQC which is controlled by the new method based of the fundamental components of the load current FC has given satisfactory results. And since we use the UPQC himself to reload the continues bus and if the compensator will function during a time which will depend on the severity of the hollow, imbalance or distortion, characteristics of the voltage $V_c$ and the compensation strategy chosen. The fall of this voltage provokes a profound discharge and its distortion due to malfunction of the static switches. Therefore our results we note that the controller IP and PIP was able to keep the value of $V_c$ at near its reference value. The PI gave slightly better results side waveform against the voltage $V_c$ presented falls more distortion in the two cases studied which is undesirable for practical standpoint. The rise time of $V_c$ in the transitional regime and the source current after compensation with the controller PIP are better compared to IP.

VII. CONCLUSIONS

In this paper we studied the UPQC with the shunt part is controlled by the new method of the fundamental components of the load current FC with a the performance comparison of the three controllers PI, IP and PIP. This study has shown that in the general case the UPQC gave the satisfactory results and could improve the quality of electrical energy. We compared the results yet, according to the three controllers PI, IP and PIP knowing that this comparison must take into account not only the best but also compensation or the performance of the storage element of the inverters. Indeed, since the compensator is used itself as a means of bus load, the compensation capacity depend on the value of the voltage $V_c$ (with a clear compromise between the depth and duration of the disturbance to compensate), more DC voltage drop lasts more deep discharge is interrupted and therefore compensation (for the relationship between the charge of a capacitor and the voltage at the terminals $Q = C.V_c$). For this reason we conclude that the UPQC with PIP gave the optimum results satisfactory (either for disturbance compensation, either for the good regulation of the voltage $V_c$) of the inverters of the two parties PAF and SAF and therefore the PIP is more convenient by report to the PI and the IP. Even the new control method has detected the interference currents, it is effective and practicable.

REFERENCES