High Performances of an Active Filter Compared to a Passive Filter: Improvement of the Electric Power Quality

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Abstract — The work presented in this paper focuses on the harmonic pollution of electrical networks, linked to disturbances generated by static converters. The solutions to eliminate these disturbances were presented; they are based on passive and active filtering methods. Some elements of definition and sizing of passive filters are mentioned. The active filter is then treated, with an approach based on the use the Instantaneous Active and Reactive Power (*p-q*) Method, in the purpose of controlling a Shunt Active Power Filter (Shunt APF). This latter offers to the filtering operation a great stability and robustness against various possible disturbances. However, the passive filter is less stable and loses its performance as soon as the network frequency varies, or once the pollutant load evolves. The temporal and frequency analysis of the obtained simulation results confirms the value of our considered approach.

Keyword- Shunt Active Power Filter (Shunt APF), Instantaneous Active and Reactive Power method (IARP), Two-level Inverter, Power Quality Improvement, Total Harmonic Distortion (THD).

I. INTRODUCTION

The use of static converters in conversion installations of electrical energy has significantly contributed to improve the performance and efficiency of these installations. International regulations defined lees to harmonics, that they must respected energy consumers. Then, the filtering of the harmonic components is one of the concerns of distributors and users of electrical power. However, the objective of our contribution resides essentially in the synthesis of two types of filters namely the Shunt Active Power Filter (APF) and the passive filter. The object of the first filter is to generate harmonic currents so as to compensate the disturbance responsible of the performance degradation of equipments and the electrical installations [1]-[2].

However the efficiency of this filter depends on the method of identification of harmonic currents in the temporary domain and the command used. Then the aim of the second is to demonstrate the effectiveness and importance of this type of filter in the filter operation.

However thereof cannot adapt to the evolution of the pollution load, as it can be the seat of a resonance causing important over voltages, ranging until the destruction of electrical equipment. For it the FAP filter comes as an alternative to passive filter with the aim eliminated its intrinsic problems like anti-resonances, and tripping caused to overloads of harmonic currents.

Simulation results clearly show the effectiveness and robustness of the approach to the APF, and consequently improving the performances of the energy system. While the passive filter is very limited in case of variation of the power frequency.

II. PASSIVE FILTER

Figure 1 shows the shape of the measured current that flows through a three-phase static converter. They absorb non-sinusoidal currents and generally consume reactive power [3] .In notes from the spectral analysis of the current; the latter is rich in harmonics, leading a polluted and poor electrical network in terms of quality of electric power.

The passive filter cleans the network, prevents them from harmonics currents spreading in the electrical network. It consists of placing in parallel with the network of very low value impedance around the frequency to be filtered and sufficiently large at the fundamental frequency of the network.

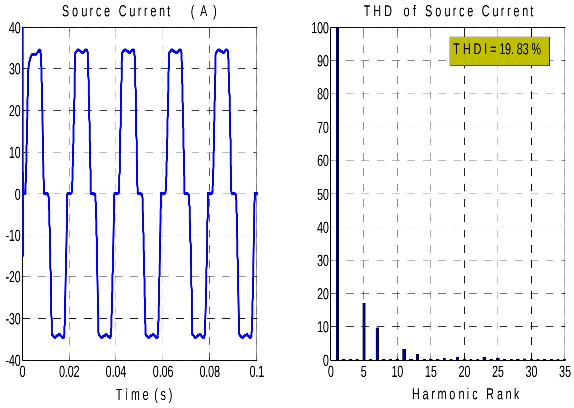

Fig. 1. Harmonics spectrum of the Source current

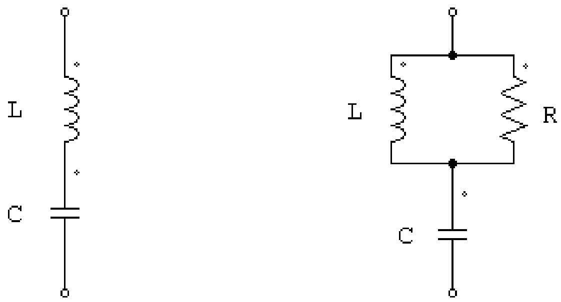

Fig. 2. Scheme of resonant and damped passive filter

Types of passive filter are chosen according to the sought harmonic attenuation [4] .Two types of passive filters are generally used, the resonant filter and damped filter as shown in Figure 2.

A. structure of passive filtering

The passive filtering device that allows the clean up the network is illustrated in Figure 3. The resonant filter is constituted of number of three-phase branches of LC dipoles by series, grouped in parallel, each branch being granted upon a harmonic filtered characteristic.

Whilst the damped filter consisting of number of branches [(R // L) + C] grouped three-phase in parallel, each branch being tuned to a band of harmonic to be filtered starting from the harmonic 11.

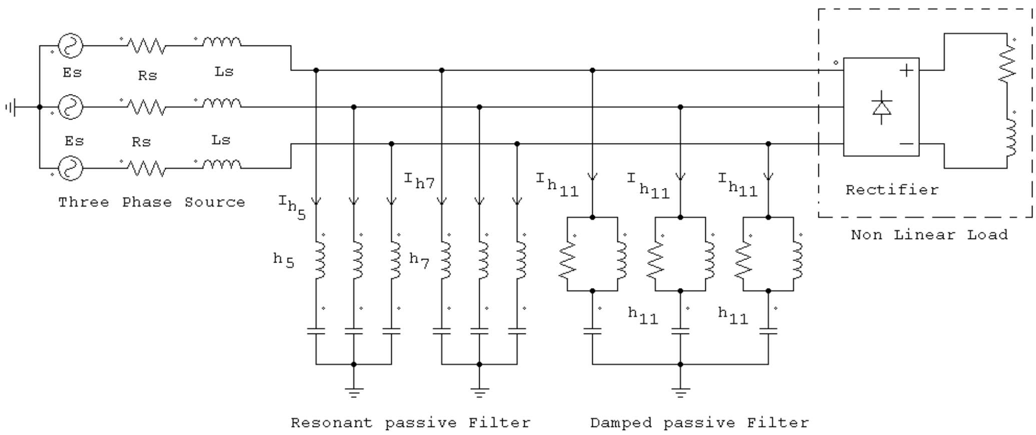

Fig. 3. Scheme of passive filter of the currents harmonics h_5, h_7

B. Parameters of the Simulation

TABLE I. PARAMETERS USED IN SIMULATION

Electrical Device	**Parameters**	
Electrical Network	$e_s(t) = 400*\sin \omega_s*t$; $\omega_s=100*\pi$; $f_s = 50Hz$; $E_s = 230$ V; $R_s = 1\Omega$; $L_s = 1$ mH	
Load	Bridge greâtz 6 diode, supplying a load : $R_L = 21$ mH ; $L_L = 10\ \Omega$	
Passive Filters	Resonant Filter	Harmonic 5 : L = 1.6 mH ; C = 255µ F Harmonic 7 : L = 0.96 mH ; C = 215µF
	Damped Filter	Harmonic 11: L = 0.19 mH ; C = 358 µF

C. Filter resonant to the network connection and simulation results

This filter is designed to eliminate current lower order harmonics H_5 and H_7. The rank of n_a agreement corresponds to multiple, whole or not, the nominal frequency of the network for which the impedance of the LC filter is minimal [5] as:

$$Z = \frac{1 + j(\frac{R}{L\omega_a})\frac{\omega}{\omega_a} - (\frac{\omega^2}{\omega_a^2})}{jC\omega} \qquad With \quad \omega_a = \frac{1}{\sqrt{LC}} \tag{1}$$

Two pulsations could be noticed during connecting a filter on the network impedance:

- Resonance of the filter: $\omega_a = 2\pi f_a = \frac{1}{\sqrt{LC}}$; $|Z(\omega_a)| = 0$
- Anti- Resonance filter: $\omega_{ar} = 2\pi f_{ar} = \frac{1}{\sqrt{(L_r+L)C}}$; $|Z(\omega_{ar})| = \infty$

With ω_a: Pulsation agreement

1) Elimination of harmonic h_5:

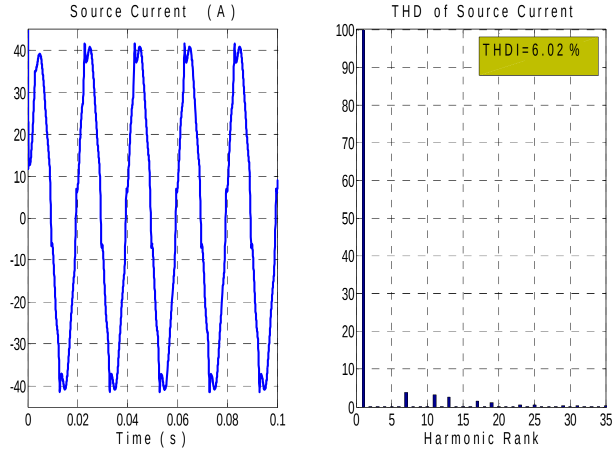

Fig. 4. Harmonics spectrum of the Source current after Elimination of h_5

2) Elimination of harmonic h_5 and h_7:

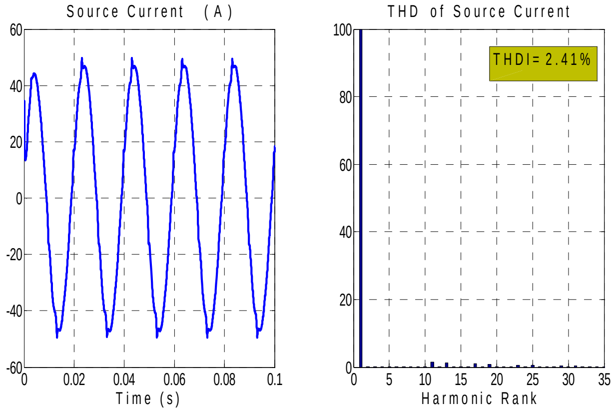

Fig. 5. Harmonics spectrum of the Source current after Elimination of h_5 and h_7

It is observed from Figures 4 and 5, that the resonant filter is very selective. It eliminates the harmonics of small frequency such as harmonics h_5 and h_7. However, the frequencies higher than those the rank of agreement such as h_{11}, h_{13}, h_{17} and h_{19} persist and slightly affect the current waveform despite the marked improvement in the value of THD I = 02.41%.

We note here over current at the time of resonance, which causes the time same overvoltage, ranging until the heating of the conductors lines and the destruction of equipment.

To mitigate an entire harmonic band (h_{11}, h_{13}, h_{19} and h_{17}), generally used a high pass filter (damped filter) of the second order. That is the subject of the following.

D. Damped filter to the network connection and simulation results

To mitigate an entire harmonic band such as h_{11}, h_{13}, h_{17} and h_{19}, generally used a high pass second order filter, called damped filter. The impedance of a damped filter is obtained by the following:

$$Z(\omega) = \frac{R + jL\omega + j^2 RLC\omega^2}{(R + jL\omega)\, jC\omega} \tag{2}$$

Knowing that $n_a = \dfrac{1}{\omega_1 \sqrt{LC}}$ Where n_a: Agreement Rank

ω_1: Pulsation of the fundamental

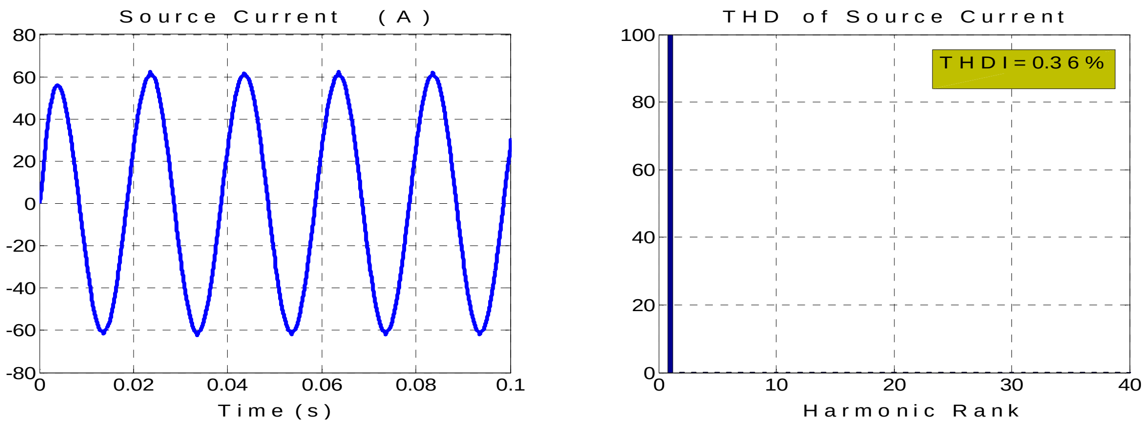

Fig. 6. Harmonics spectrum of the Source current after connection of resonant and damped passive filter

1) Filter to the network connection and simulation results: We can clearly noted from Figure 6 that the damped filter is intended to absorb the harmonics of high rank h_{11}, h_{13}, h_{17}. Spectral analysis current shows to cleanup of the network. Presented a THD 0.36% with an almost sinusoidal current form.

2) Damped filter connecting alone: Figure 7 shows that the influence of a damped filter is less important to the rank of agreement (h_5 and h_7) than the resonant filter. However, the damped filter is still effective at higher frequencies (h_{11}, h_{13}, h_{17} and h_{19}) those of the rank of agreement.

Reactive power results from the phase shift observed in Figure 8, between the fundamental voltage and current source. This power is generated by the filter is at the same time sent to the network (see figure 9), in between times t = 0.06sec and 0.12 sec, it is calculated as follows [5]

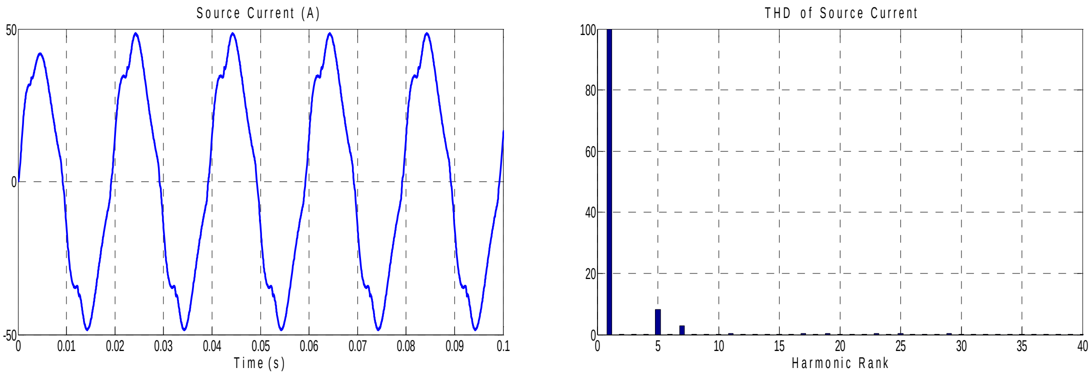

Fig. 7. Harmonics spectrum of the Source current after connection of only damped filter

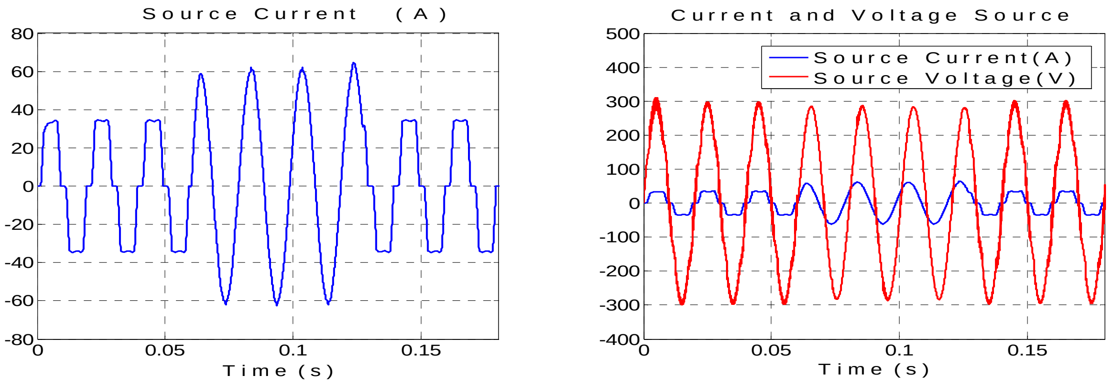

Fig. 8. Current and voltage source when connecting and disconnection filter resonant and damped passive filter

$$Q = \frac{C \omega_1 U^2}{1 - \frac{1}{n_a^2}} \qquad (3)$$

The implementation of a filter creates a rise in the voltage of the network, not negligible in some cases. This voltage variation is calculated as follows:

$$\frac{\Delta U}{U} = \frac{Q_s}{S_{cc}} \qquad (4)$$

With Q_s : Reactive power sent to the network (reactive power supplied by the filter less reactive power absorbed by other equipment)

S_{cc}: Network power short circuit.

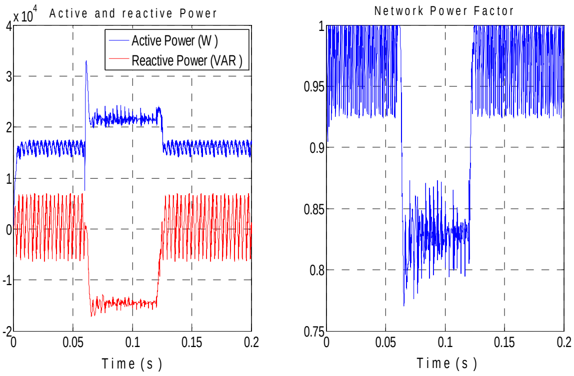

Fig. 9. Active and reactive power and Network power factor

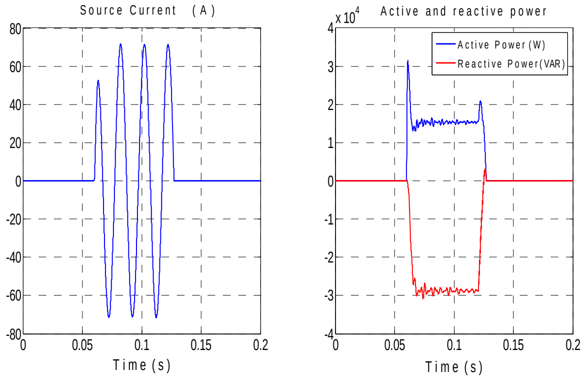

Fig. 10. Empty Network: Over current and reactive power returned to the network during connection of passive filter

The filtering operation is accompanied by a strong call current and active power (Fig .9) .This explains the phenomenon of resonance during the tuning frequencies. Reactive power returned by the filter that compensates absorbed by the load.

However, in the case of an empty network, reactive power created by the filter is reflected entirely on the network which can carry an important current, in the case of Figure 10. The power factor is very satisfactory according to the Figure 9.

E. Discussion

Note that filtering is most effective than the frequency agree with a resonant filter in return for an important anti-resonance. The damped filter provides a more apportioned but less effective at filtering the tuning frequency. The anti-resonance is less important than in the case of a resonant filter.

This last is therefore less subject to frequency variations and network impedance. The resonant filter requires a fixed frequency agreement, but if the network will be the seat of a variable frequency the filtering degrades, the current waveform deforms and the network will become very polluted, in terms of power quality (Figure 11).

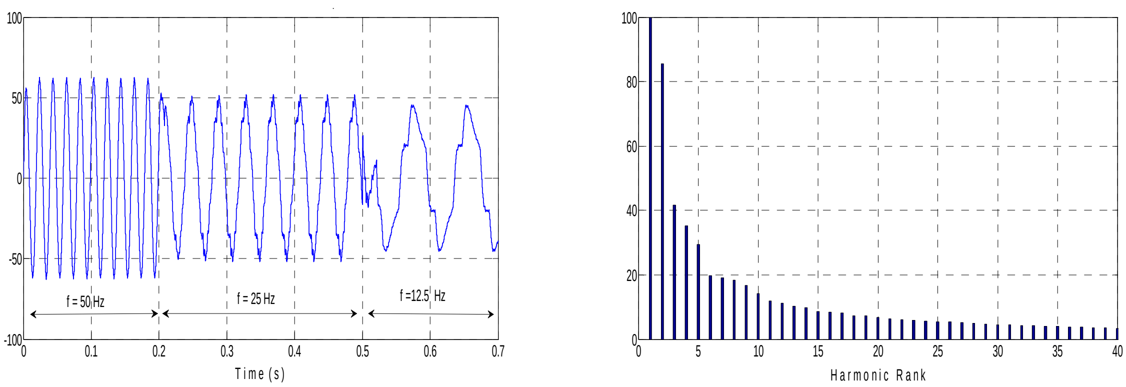

Fig. 11. Degradation of the harmonic spectrum of the current during the change in Power frequency

Passive filter highly efficient, and low cost. However its use is not an easy and its performance depends the network characteristics, on which it is connected, in addition, it could bring about a substantial parallel resonance, leads to significant over voltages ranging until the destruction of equipment.

In addition, passive filters cannot be adapted to the evolution of network and the pollution loads [6].

Searches were conducted with the objective of eliminating the intrinsic problems of passive filters.

The active filter has been developed with a view to avoiding problems due to the change in network frequency (see Figure 11), the anti-resonances, and triggering the filter caused by overloading of harmonic currents. The active filter is subject to the following the second part of this paper.

III. ACTIVE POWER FILTER

A. *Principle of Shunt Active Power Filter*

The Shunt Active Power Filter consists of generating the harmonics in phase opposition to those existing in the network. While the current absorbed by the pollutant load is non-sinusoidal, the current created by the active filter is such that the current absorbed by network is sinusoidal [7]-[8].

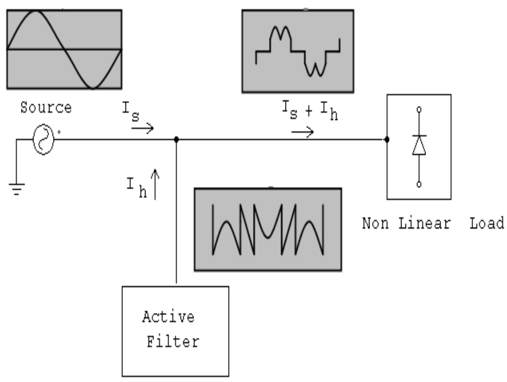

Fig. 12. Principle of Shunt Active Power Filter

B. *General structure of Shunt Active Power Filter*

Shunt Active Power Filter (FAP) is a voltage inverter of compensating harmonic currents, as shown in Figure 13. Connected in parallel to the pollutant load. It consists of two parts, power part and control part .

The power section is constituted by a voltage inverter based power switches, controllable at the opening and the closure in antiparallel with the diodes, an energy storage circuit, often capacitive, and an output filter L_f.

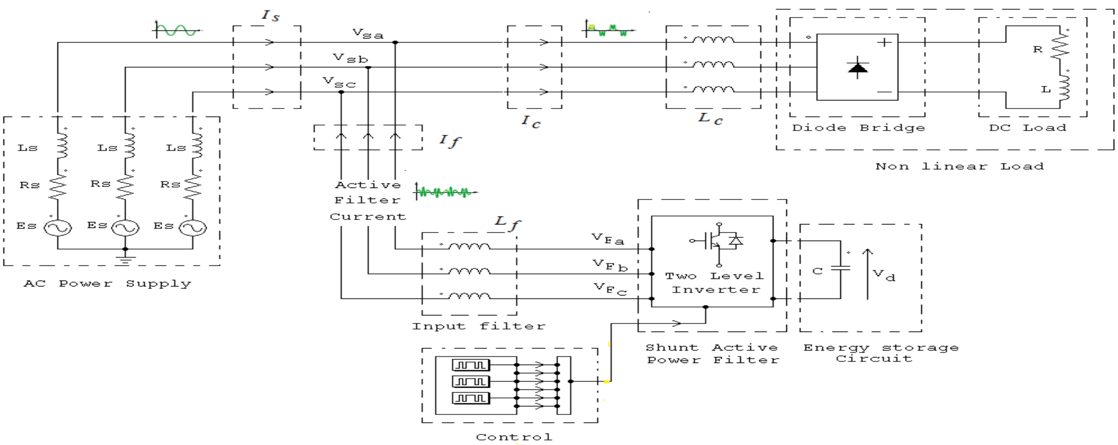

Fig. 13. General structure of Shunt Active Power Filter

As for the control part is based on the identification (p- q) method of the harmonic currents, the control of the DC voltage applied to energy storage elements, the regulation of the current injected onto the network from the voltage inverter. Regulation is assured from a PI controller.

The active filter generates the harmonic currents, the same amplitude as those of the network but in phase opposition with them. In this work the harmonic currents are identified by the Instantaneous Active and Reactive Power (*p*-*q*) Method [9]-[10].

C. Instantaneous Active and Reactive (p-q) Power Theory

This method is most commonly used, has the advantage of choosing the disturbance as to compensate with accuracy, speed and ease of implantation. The first step of this method to transforming the three phase (a, b, c) voltages / currents to two-phase α, β, using the Concordia Direct Transformation (CDT).

This method consists in converting the fundamental component to an equivalent DC component and harmonics AC components using low-pass filters (LPF) of the second order.

Note by $(v_\alpha \ v_\beta)$ and $(v_\alpha \ v_\beta)$ orthogonal components of the *(α, β)* respectively associated with voltages (v_s) the connection points of the active filter and current absorbed by the pollution load.The instantaneous real and imaginary power can be expressed by the following system (5):

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

The powers p and q can be broken down by system (6). Where $\overline{p}$, is of Part linked to continuous active fundamental component of the current and $\overline{q}$ continuous part linked to the reactive fundamental component of the current. Where as $\tilde{p}$ and $\tilde{q}$ fluctuating parts are linked to the sum of the harmonic components of the current and the voltage. A low pass second order filter is used to separate the fundamental component of interfering components.

$$\begin{cases} p = \overline{p} + \tilde{p} \\ q = \overline{q} + \tilde{q} \end{cases} \quad (5)$$

Two filters are needed, the first to isolate the portion of the instantaneous active power, the second to isolate the portion of the instantaneous reactive power. Both filters are dimensioned taking account of the frequency decomposition of the powers in the two-phase coordinate system.

The inverse powers of the equation (5) allows to establish the relationship (7) currents i_α ,i_β .

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha{}^2 + v^2{}_\beta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (7)$$

Replacing the powers *p* and *q* by their DC and AC parts, the following system (8) is obtained:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \overline{p} \\ 0 \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} 0 \\ \overline{q} \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad ,With \quad \Delta = v_\alpha{}^2 + v_\beta{}^2 \quad (8)$$

The calculation of harmonic currents in the two-phase reference (α, β) is finally given by the relation (9):

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha{}^2 + v^2{}_\beta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (9)$$

Through the Concordia Reverse Transformation (CRT), the AC components of the powers allow us to deduce the three-phase harmonics currents. These currents represent disturbances and reference currents (10), which will be injected in phase opposition on the electrical network for suppressing harmonics.

$$\begin{bmatrix} I_{ref\ 1} \\ I_{ref\ 2} \\ I_{ref\ 3} \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} \tilde{i}_\alpha \\ \tilde{i}_\beta \end{bmatrix} \quad (10)$$

Functional block of Fig. 14 explains and summarizes the reference currents calculation process by the method of Instantaneous active and reactive (p-q) power.

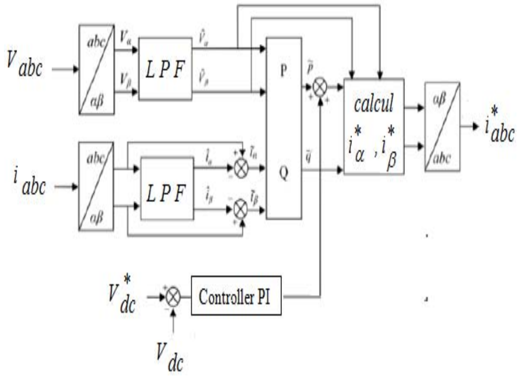

Fig. 14. Instantaneous active and reactive power algorithm

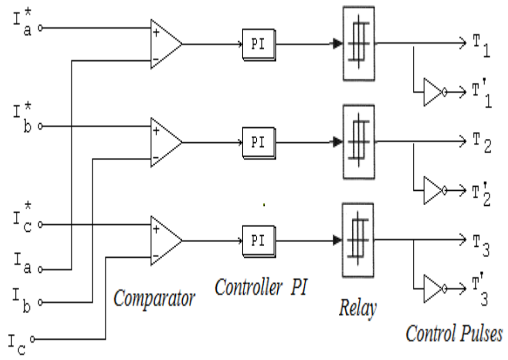

Fig. 15. Hysteresis band current control

D. Current of Hysteresis Control Pulses

The principle of current control by hysteresis is that used by the Fig.15. It mainly consists of maintaining each of the currents generated in a band enveloping reference currents.

Each violation of this band gives a switching command. The hysteresis control algorithm in harmonic current is summed up for a k arm of the inverter by the system (11).

Let ε_k be the difference between the reference current generated by the inverter and the actual current line identify temporally by the instantaneous power (p-q) method. Defined by:

$\varepsilon_k = I^*_h - I_h$ With k =1, 2, 3

B_k control orders of the switches are determined as follows:

$$\begin{cases} Si\ \varepsilon_k \geq \Delta i & then\ B_{k1} = 0 \\ Si\ \varepsilon_k \leq -\Delta i & then\ B_{k1} = 1 \end{cases} \tag{11}$$

If not control of the switches remains unchanged. Δi: is the width of the hysteresis band

E. Regulation of Continuous Voltage

The voltage across the capacitor must be maintained at a constant value. For this, we chosen a proportional-Integrator controller PI, mentioned below in order to maintain the voltage V_{DC} of the capacitor to its reference value V_{DC_ref} (V_{DC} *).

The value of the measured voltage V_{DC} is compared with its reference V_{DC} *. The error signal is then applied to the input of the PI controller. The relationship between the active power absorbed by the capacitor and the voltage across that - it is written. [11]

$$P_c = \frac{d}{dt}\left(\frac{1}{2}C.V^2_{dc}\right) \tag{12}$$

Either after the Laplace transforms

$$P_c(s) = \frac{1}{2}C.s.V^2_{dc}(s) \tag{13}$$

The following equation gives the general expression of the PI controller:

$$K(s) = \frac{K_p.s + K_i}{s} \tag{14}$$

With: K_p : Proportional gain of the regulator,
K_i : Integral gain of the regulator

Figure 16 shows the diagram of the control V_{DC}.

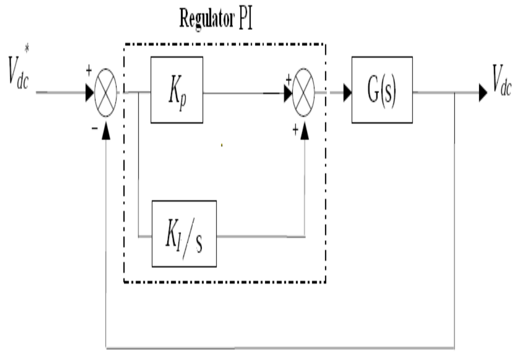

Fig. 16. Diagram of the V_{DC} control by a PI controller.

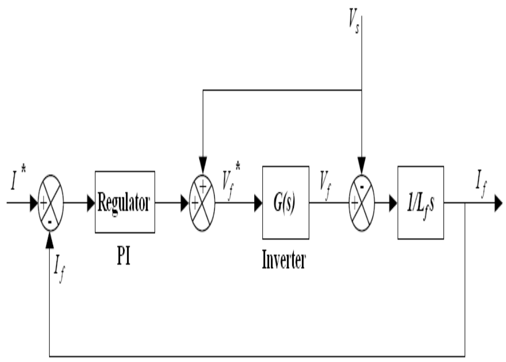

Fig. 17. Scheme for regulating current of A P F

The term G (s) is expressed as:

$$G(s) = \frac{2}{Cs} \tag{15}$$

The closed loop transfer function is then given by:

$$F(s) = \frac{\left(1 + \frac{K_p}{K_i}s\right)\frac{K_i}{C}}{s^2 + \frac{K_p}{C}s + \frac{K_i}{C}} \tag{16}$$

The general expression from a second-order transfer function is:

$$F(s) = \frac{\left(1 + \frac{K_p}{K_i}s\right).\omega_c^2}{s^2 + 2.\xi.\omega_c s + \omega_c^2} \tag{17}$$

After identification with equation (16) we obtain:

$$\begin{cases} K_i = \omega_c^{\ 2}.C \\ K_p = 2.\xi.\sqrt{K_i.C} \end{cases} \tag{18}$$

Knowing that the cutoff frequency is chosen: $\omega_c = 2\pi \times 18$ rad /s , well as the damping coefficient, $\xi_c = 0, 6$.

F. Regulation currents of Shunt Active Power Filter (A P F)

By neglecting the resistors of the output filter I_f the reference current (low frequency for harmonics that are far from the switching frequency) [12], we can write the following relation characterizing the current active filter I_f :

$$L_f \frac{d}{dt} i_f = v_f - v_s \tag{19}$$

We note Δi_f by the difference between the reference current and the current measured from the following equation:

$$\Delta i_f = i^* - i_f \tag{20}$$

Starting from equations (19) and (20), we obtain expression (21) below:

$$L_f \frac{d}{dt} \Delta i_f = \left(v_s + L_f \frac{d}{dt} i^* \right) - v_f \tag{21}$$

The first term of the right side of equation (21) can be defined as the reference voltage (Vf *), which gives us the following expression (22):

$$v_f^* = v_s + L_f \frac{d}{dt} i^* \tag{22}$$

The difference between V_f^* and V_f then produces an error on the current. According to the equation (22), the reference voltage is composed of two terms at different frequencies. The first represents the V_s voltage measured directly network

The second is equal to the voltage drop across the inductance $L\ f$, when it is traversed by a current equal to the reference. This term must be developed by a current regulator PI, as shown in Fig. 17. In this scheme of Figure 17, *G(s)* represents the inverter [13] that can be modeled by the following relationship (23):

$$\begin{cases} G(s) = K \dfrac{1}{1 + \tau s} \\ K = \dfrac{V_{dc}}{2 V_p} \end{cases} \tag{23}$$

With the V_{DC} voltage DC side of the inverter, the amplitude Vp of the triangular carrier and τ represents the delay caused by the calculation of harmonic currents.

G. Simulation and Interpretation

The simulation was performed to confirm the theoretical study in static mode and verifying dynamic performances of (A P F).To assess the effectiveness of our approach, based on the method of instantaneous power calculation, we performed robustness tests by changing the load value and the reference V_{DC}.

Parameters used in simulation are as follows in the table II.

TABLE II. PARAMETERS USED IN SIMULATION

Electrical Device	Parameters
Power Source	RMS voltage V = 220/380 V, frequency f = 50 Hz, R_s = 0.2Ω, L_s = 0.001 mH
Filer RL	L_f = 0.9 mH, R_f = 0.05 Ω, L_c = 0.1 mH , R_c = 0.02 Ω
Load	Three-phase rectifier bridge (PD3) IGBT initially powers a R-L load : (R = 45, L = 50mH), then added to each moment in parallel resistive load : (R_1 = 20 Ω, R_2 = 10 Ω then R_3 = 6 Ω)
Active Power Filter(A P F)	Based on an inverter, IGBT has two levels controlled by hysteresis , Storage capacity: C = 4.4mF, Capacitor initial voltage: 600 V, Reference voltage V_{DC_ref} = 850 V.
PI controller and hysteresis regulators	Sampling frequency of the PI controller: f_e = 100 kHz, Width of the hysteresis band: h_i = 0.001A , PI controller parameters: k_i = 200, k_p = 400, Output limits : [Upper : 10^5 , Lower : -10^5]

Figure 18 shows the current waveform before compensation. Clearly it is distorted and accordingly the harmonics others than the fundamental. Spectral analysis of such wave form is shown in Figure 18. This shows the presence of 6k ± 1 order harmonics and total distortion of 25.2%**.**

That exceeds from afar international norms [4].After compensation in the time of insertion of the active power filter (APF) in parallel with the network, noted from Figure 19, that the form of current is improved and it recovers the sin wave. The total distortion is 0.41%, so considerably better than before compensation.

Spectral analysis gives a fundamental line corresponding to the frequency of 50Hz, so it's clean in term of power quality.

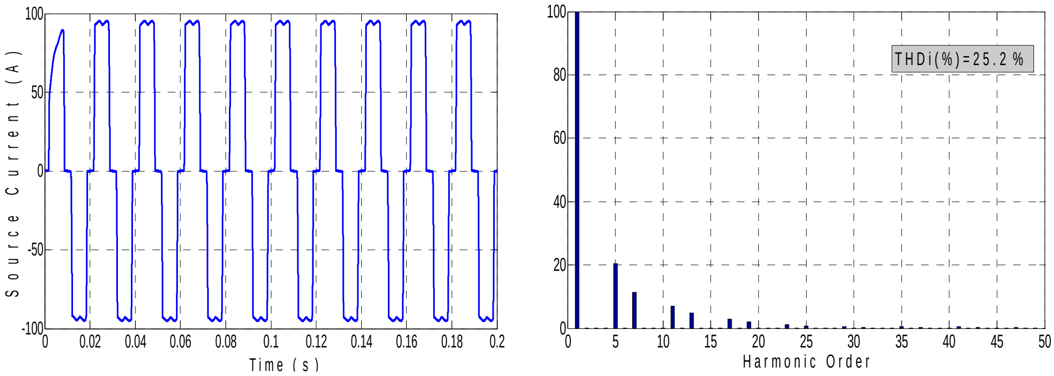

Fig. 18. Current source and his harmonic spectrum without Shunt APF

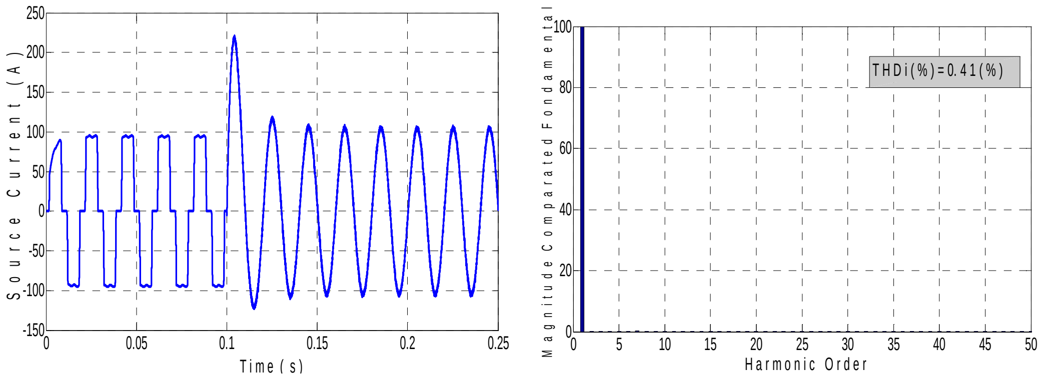

Fig. 19. Source Current Isa (A) before and after compensation and his harmonic spectrum with Shunt APF

Figures 20and 21, show the control of the direct voltage of FAP, before and after insertion of the PI controller. At time connecting the APF with the network, the DC bus voltage pass to 850 V, following the reference voltage $V_{DC\ -\ ref}$. The PI controller is manifested from 0.1s and keeps the stability of the voltage V_{DC} to the reference value.

At this time the filter injected harmonic currents in the network, as shown in Figures 22 for the first phase. Indeed a marked superposition between the identified and injected current, allows obtaining a purely sinusoidal source current corresponding to the power frequency 50 Hz (Fig. 23).

This last is in phase with the supply voltage. This induces a unity power factor (fig.24).

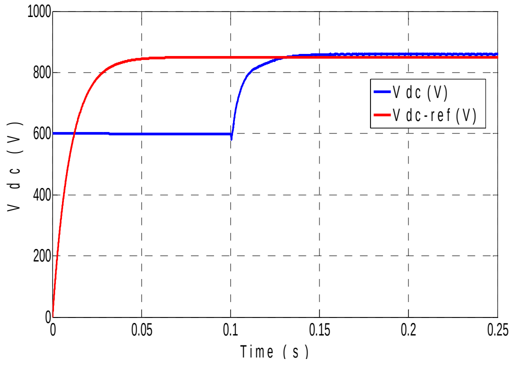

Fig. 20. D C side capacitor voltages V_{DC} (V)

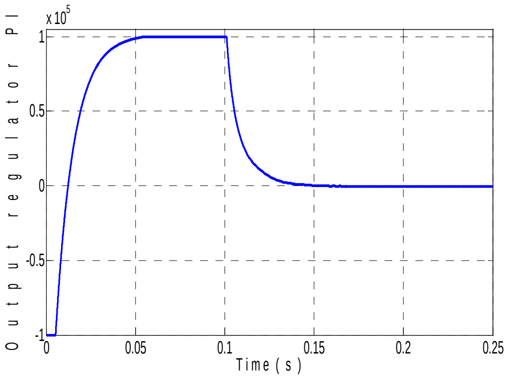

Fig.21. Response of the PI controller before and after compensation

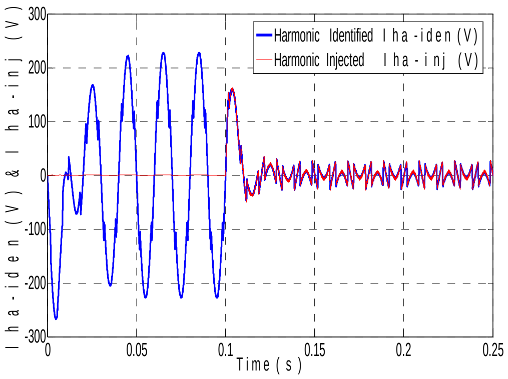

Fig. 22. The synchronization between the identified harmonic currents and Injected for the first Phase

It is found from Figures (fig.25, 26, 27, 28 and 29) than the PI Controller keeps the stability of the V_{DC} DC voltage. Requires V_{DC} follow correctly the 850V reference voltage despite the variations experienced by the load in the time interval [0.2s - 0.4s].

Indeed the amplitude of the current source and that of harmonic injected increases with the inrush current caused by the increased load.

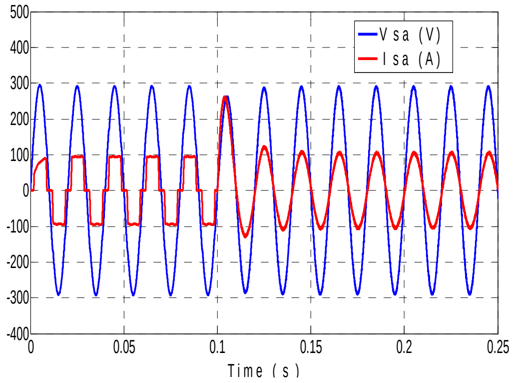

Fig.23. Source Current I_{sa} (A) and Source Voltage V_{sa} (V) before and after compensation

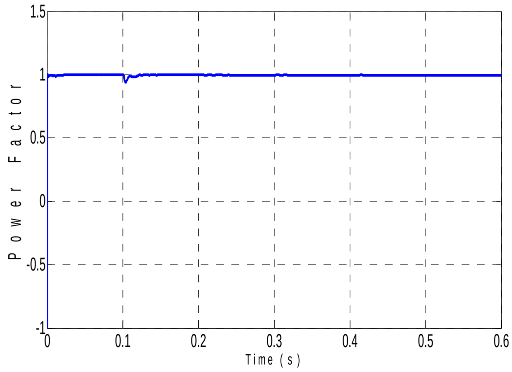

Fig. 24. Power Factor PF

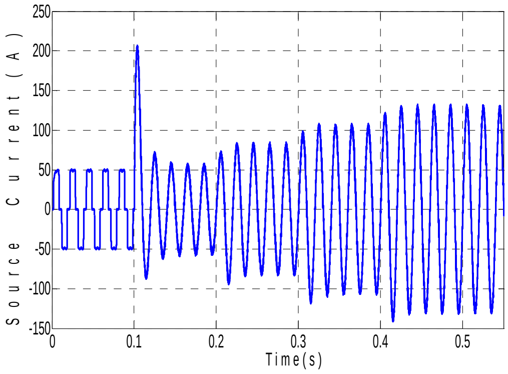

Fig. 25. Source Current Isa (A) with step change in Load (between t_1= 0.2 s - t_2= 0.4 s)

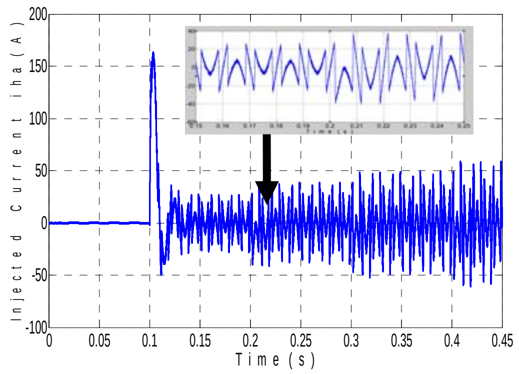

Fig.26. Injected Current I ha (A) with step change in Load (between $t_1 = 0.2$ s - $t_2 = 0.4$ s)

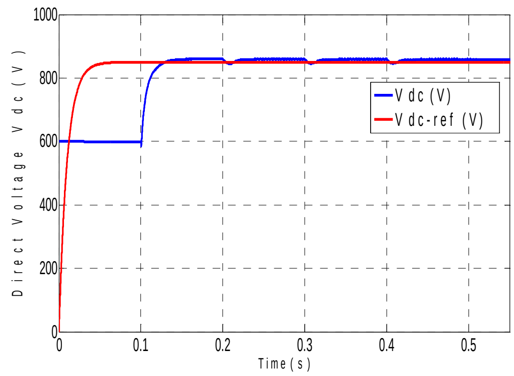

Fig.27. DC side capacitor voltage with step change in Load (between $t_1 = 0.2$ s - $t_2 = 0.4$ s)

Starting at time t = 0.1s (fig.30), the PI controller always maintaining synchronization between the current identify and the current injected even during change load. We deduce according to fig. 31, that the DC bus voltage always follows the reference for other values such as 600V, 800V, 1000V and 1200V.

The change of the reference does not affect the amplitude of the source current except to time of transitions $t_1 = 0.2$s, $t_2 = 0.35$s, $t_3 = 0.5$s (fig .32).

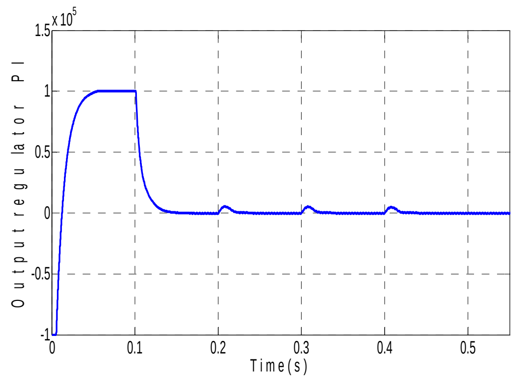

Fig.28. Response of the PI controller before and after compensation, during the load change

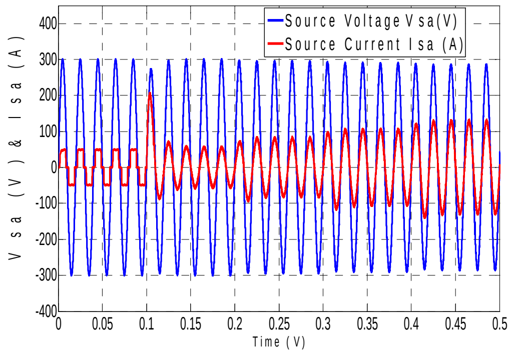

Fig. 29. Source Current and voltage before and after compensation
With step change in load (between t_1= 0.2 s - t_2= 0.4 s)

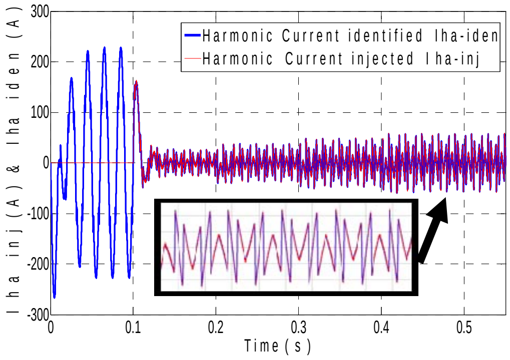

Fig. 30 The synchronization between the identified harmonic currents and
Injected during the variation of the load for the first Phase

Figures 33, 34 and 35 clearly illustrate the robustness of the APF, is confirmed again by the stability and efficiency that provides the PI controller, despite the disruptions created on one hand by the change of the load on the other hand by the passage of a constant value V_{DC} to another. Hence we find that the source current changes with the load but not with the DC bus voltage.

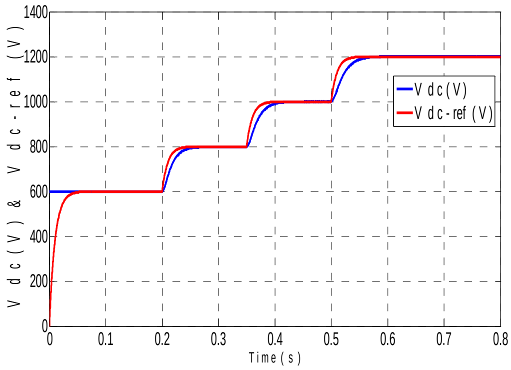

Fig. 31. V_{DC} follows the Reference $V_{DC\text{-}ref}$

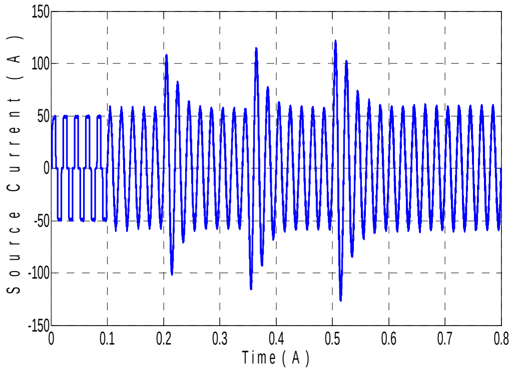

Fig. 32. Form the source current during the change V_{DC}

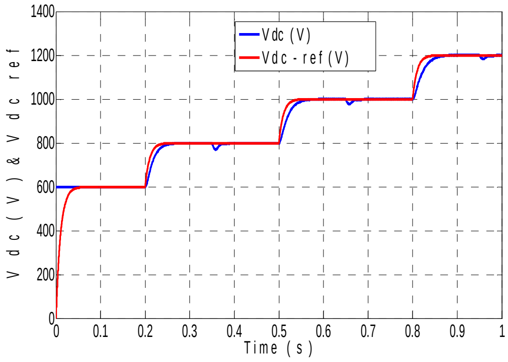

Fig. 33. V_{DC} follows the reference V_{DC-ref} with the variation load

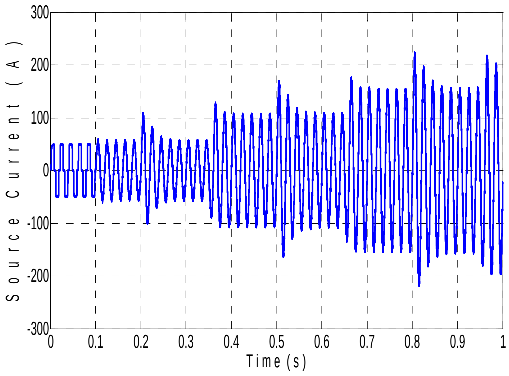

Fig.34. Current waveform during the variation V_{DC}
and the load ,between 0.2s - 0.95s

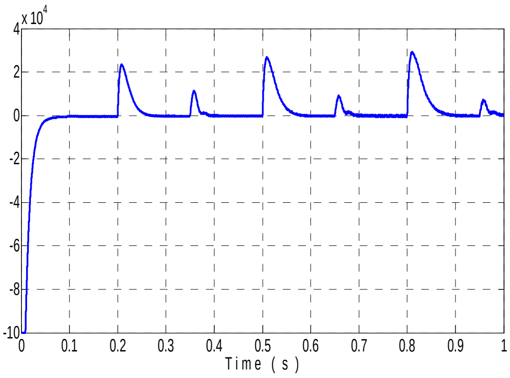

Fig. 35. Response of the PI controller before and after compensation, during the load change and Vdc

Before concluding the work developed in this paper, we want to make in the end, a comparative analysis [14] between the passive and active filter .The Table III below shows the performance of the two types of filtering.

TABLE III. PERFORMANCES BETWEEN PASSIVE AND ACTIVE FILTER

Characteristics	**Passive Filter**	**Active Power Filter**
Adaptation to the evolution of network and load	No	Yes, is automatic
Limit of compensation, rank harmonic	- The resonant filter compensates a harmonic order at a time. -The damped filter compensates in limit its pass band.	Compensates within the limits of its pass band that is determined by switching the frequency Maximum the semiconductor of its inverter.
Risk of resonance between filter and the network	Yes	No
Power compensation reactive	Yes	Yes, but at higher cost for passive filter.
Possible overload when harmonic current exceeds the dimensioning of the filter	Yes	No
Compensation in high power networks	Yes	Yes, but at very high cost

IV. Conclusion

The work presented in this paper deals with the harmonic pollution of electrical networks, that supply static converters considered non-linear loads. The reduction of the harmonics currents in an electrical network may be possible with the development of the active filter based on several new forced commutated components as GTO thyristors and IGBT.

The efficiency of this filter resides in the identification method of harmonic currents and the type of control. Indeed a significant superposition of the injected and identified currents has provided purely sinusoidal currents with unity power factor. Using the harmonic identification method by the principle of calculating the instantaneous active and reactive power provides to the

APF high efficiency and precision with ease of implantation. Knowing that we focused on the passive filtering at the beginning of this work and it was deduced that this type of filter also remains effective but limited because of the performance that depends on the network. In addition passive filters cannot be adapted to the evolution of network and the pollution loads.

However the APF remains the most solicit in the field of transport and distribution of energy, and this is because of its efficient performances deployed during the filtering operation, and that whatever the type of disturbance that the APF could face.

REFERENCES

[1] H. Rudnick, J. Dixon, L. Moran, “Active power filters as solution to power quality problems in distribution networks”, EPE Toulouse, 2003.

[2] H. Rudnick, J. Dixon and Luis Morán, “Delivering Pure and Clean Power”, IEEE Power & Energy Magazine, Vol. 1, Nº 5, September/October 2003, pp32-40.

[3] Moller. L, Technical problems with the connection of high power converters, EDF Review 2 (1985)

[4] J. Arrillaga & N.R. Watson, power system harmonics, University of Canterbury, Christchurch, New Zealand, John Wiley & Sons, 2003.

[5] C. Lott, O. Lapierre, H. and S. Saadat Pouliquen “Active filtering harmonic current and voltage of electrical networks Modé1isation, Numerical Simulation and Experimentation” J. Phys France III-7 december1997 pages 2433-2457

[6] D.Ould Abeslam, “Neuromimétriques Techniques for control in power systems: application to parallel active filter in low voltage electrical networks, ” PhD thesis, University of Haute Alsace, in December 2005.

[7] Saadate S., “G-T-O Thyristor high power fully controllable switch for electric traction / analysis and treatment induced disturbances in the power network by static converters AC / DC” Habilitation research, INP Lorraine, Nancy (12 Jan. 1995)

[8] Lott C., “Active filtering parallel current harmonics on industrial networks theoretical study and realization of a model GTO” I'INP PhD thesis of Lorraine, Nancy (1995).

[9] H. Akagi, Y. Kanazawa and A. Nabae, “Generalized theory of the instantaneous reactive power in three-phase circuits”, Proceeding 1983 International power electronics conference. Tokyo, Japan, pp. 1375-1386, 1983.

[10] H. Akagi, Y. Kanazawa and A. Nabae, “Instantaneous reactive power compensators comprising switching devices without energy storage components”, IEEE trans. on Ind. Appl. 20 (1984) pp, 625-630.

[11] Mohamed Muftah .Abdusalam, “Structures and control strategies of parallel hybrid active filters with experimental validations”, PhD thesis May 29, 2008, University Henri Poincaré, Nancy-I.

[12] Mohamad Alaa Eddin. Alali, “Contribution to the study of Compensators Active Low Voltage Electrical Network”, Doctoral thesis September 12, 2002, University Louis Pasteur - Strasbourg I.

[13] H. Akagi, “ Control strategy and site selection of a shunt active filter for damping of harmonic propagation in power distribution systems ”, IEEE Trans. on power delivery, vol. 12, No. 1, pp. 354-363, January1997.

[14] Steeve .Beaulieu, “Study and tune up of active harmonic filter to improve the quality of electrical power” Quebec University in Chicoutimi. Brief presented as partial requirement of the Master of Engineering. May 2007.