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Performances improvement of Shunt active power filter With voltage sensor failure

Aziz Boukadoum[1], Abla Bouguerne[2], Tahar Bahi[3]

[1, 2]Labget Laboratory, Department of Electrical Engineering, Echahid Cheikh Larbi Tebessi University, Algeria
3Laza laboratory, Department of Electrical Engineering, University of Annaba, Algeria

**Corresponding author: Email: azizboukadoum@yahoo.fr*

Abstract – *The recent development of fully controllable power semiconductors has led to the design of new structures of static converters called active power filters intended to compensate for harmonic disturbances. The purpose of this filter is to inject harmonic currents so that the source current and voltage are made sinusoidal. The active power filter is connected in parallel with the network. The effectiveness of this filter essentially lies in its control and command strategy to better respond to production and distribution constraints. It automatically adapts to the evolution of disturbances introduced by non-linear loads connected to the electrical network and their response is instantaneous. The objectives we have set are to improve the performance of this filter. The p-q theory has been developed to generate a reference current for the attenuation of harmonics. This method requires the information of three load currents and three source voltages. Therefore, the controller needs information from voltages and currents sensors. Therefore, the failure of one sensor will affect the overall performance of the power filter. Different cases have been studied to observe its effect on the sinusoidal shape of the source currents and the THD. As well, an algorithm for successful compensation of voltage sensor failure has been proposed. Simulation results are presented and discussed*

***Keywords**: Shunt active power filter, p-q theory, Voltage Sensor Failure, THD, Performances.*

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I. Introduction

The active power filters (APFs) was The evolution of power electronics due to the use of new structures of static converters has considerably encouraged the proliferation of the latter in the electrical network. These powers converters are considered non-linear loads because they absorb non-sinusoidal currents and sometimes consume reactive power. Based on this state of affairs, electrical energy recommendations and requirements imposed some harmonic limits [1]. In order to solve this problem, Firstly, different configuration are proposed of passive filters have been used to eliminate harmonics current and to compensate reactive power by increasing the power factor. But these filters have the disadvantages of large size. They are ineffective due to their inability to adapt to network parameters characteristic variation, problem of resonance, and deterioration of parameters [2].

been one of the effectiveness solutions to suppressing harmonic [3, 4], enhance power quality, and insure the better power distribution system. According to its procedure connection to the power system, there are two types of APFs) as series active power filter and shunt active power filter [5-9]. This paper present performance improvement of the shunt active under voltage sensor failure, the objectives are to improve the performance of power filter in term of harmonics compensation.

The p-q theory has been developed to generate a reference current for the attenuation of harmonics [11-12]. This method requires the three load currents and three source voltages measurement from voltages and currents sensors. Therefore, the failure of one sensor will affect the overall performance of the proposed system. Different cases have been studied to observe its effect on the sinusoidal waves of the source currents and the value of THD. A correction algorithm for compensation under voltage sensor failure has been proposed. Simulation results are presented and interpreted.

II. Methodology

II.1. Shunt active power filter

The shunt active power filter (SAPF) consists of a current controlled voltage-source inverter (VSI) which injects current at the PCC through the interface inductor. The operation of VSI is supported by a DC storage capacitor with proper DC voltage across it, which is schematically depicted in Figure 1.

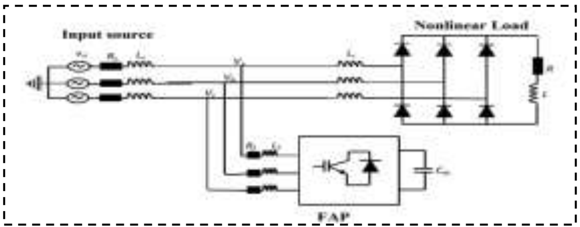


Figure 1. Shunt Active Power Filter

The shunt active filters are the effectiveness solution to the problem of harmonics pollution and their effects [8]. This type of filters is proved as an appropriate technique to suppress harmonic cased by nonlinear loads.

II.2. p-q theory

The p-q theory called the Instantaneous Reactive Power Algorithm is applied for extracting the reference compensating currents of the shunt power converter [11, 14]. For this purpose, the following development is necessary. Let;

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{2}$$

The instantaneous real and imaginary power can be expressed by the following system:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{3}$$

The instantaneous real and imaginary power can be decomposed into two ac and dc parts. The dc part resulted from the fundamental current and voltage and the ac part resulted from the harmonics:

$$p = \bar{p} + \tilde{p} \tag{4}$$

$$q = \bar{q} + \tilde{q} \tag{5}$$

Where,

$\bar{p}$, $\bar{q}$: dc average value of the instantaneous real and imaginary power respectively . It's corresponds to the resulted from the fundamental current and voltage from the power source to the load.

$\tilde{p}$, $\tilde{q}$: ac value of the instantaneous real and imaginary power respectively. It does not have average value, and is related to the harmonic currents and voltage from the power source to the load.

The references currents are calculated by the following expression:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} p \\ q \end{bmatrix} \tag{6}$$

With:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \bar{p} \\ 0 \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} 0 \\ \bar{q} \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \tag{7}$$

Here,

$$\Delta = v_\alpha^2 + v_\beta^2 \tag{8}$$

The reference current results based on the instantaneous real and imaginary power should be determined according to the flowing equation:

$$\begin{bmatrix} \tilde{i}_\alpha \\ \tilde{i}_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \tag{9}$$

Finally, we can calculate the reference harmonic current as:

$$\begin{bmatrix} i_{*a} \\ i_{*b} \\ i_{*c} \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} \tilde{i}_\alpha \\ \tilde{i}_\beta \end{bmatrix} \tag{10}$$

Hence, taking into account this development, the block diagram of p-q theory is shows by Figure 2.

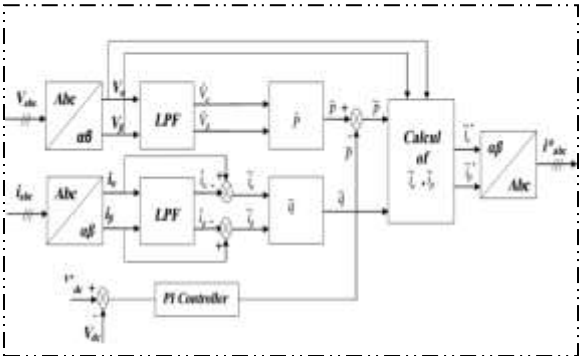


Figure 2. Block diagram of p-q theory

II.3. DC voltage control

The shunt active power filter is not an autonomous voltage source but a capacitor that charges and discharges. The voltage at the terminals of the latter is not constant, because of its sensitivity to the exchanges of active power between the polluting load and the network [15-18]. The losses in the power components also cause the voltage across the capacitor to vary, hence the need to regulate this voltage and maintain it at a constant level. For this, we have proposed a simple PI regulator, figure 3. The function of the PI regulator can be expressed as follows:

$$Kp + \frac{Ki}{s} = H(s) \tag{11}$$

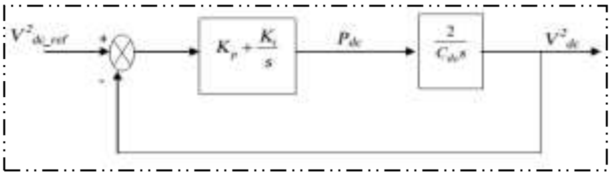


Figure 3. Block diagram of Vdc Control Using PI regulator

II.4. Open circuit voltage algorithm

Based on the assumption that the system is balanced [8], it calculates the signal of the default branch according to the principle of relations (12) and (13) and the algorithm of Figure 4.

$$v_{an} + v_{bn} + v_{cn} = 0 \tag{12}$$

And

$$v_{an} = -(v_{bn} + v_{cn}) \tag{13}$$

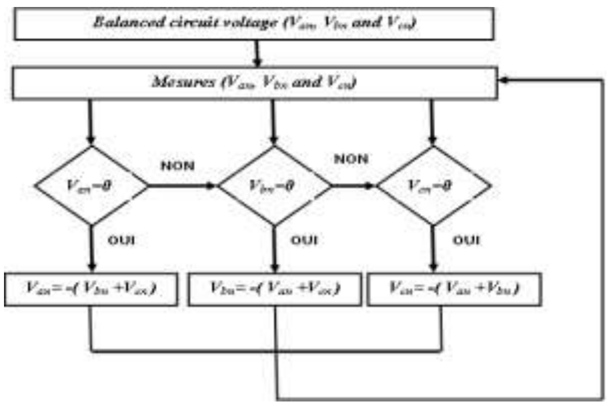


Figure 4. Open circuit voltage algorithm

II.5. Hysteresis control

The hysteresis control principle consists in maintaining each of the reference currents (iabc*) and the injected harmonic currents (iabc) within a band. The difference between the current and its reference is compared to a fixed band of width H called hysteresis band [19-24]. This method ensures the control of the switching frequency of the switches by action on the H. Each violation of this band leads to an order of switching of the switches. See Figure 5.

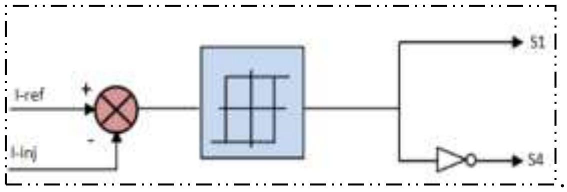


Figure 5 hysteresis control

III. Simulation results

The shunt active power filter was examined through simulations Matlab/Simulink. All spectrum analysis harmonic figures are below the levels imposed by international standards recommendation IEEE 519-1992, in terms of total distortion harmonic (THD). The parameters of the simulated system are shown in Table 1.

TABLE 1. PARAMETERS SYSTEM

Supply voltage	*220 V, 50Hz*
source impedance	*R=0.02Ω, L=0.1mH*
Load rectifier bridge	*R=5Ω, L=15mH*
DC bus voltage	*840 V*

The test realized for the validation of our approach consisted in simulating a behavior of the system under three operating conditions: at the beginning (0s-0.1s) the system works with the connection of the nonlinear load, in second stage, inserting the shunt active power filter from (0.1s-0.3s) and finally causing a sensor fault of measuring the voltage of the first phase (A).

Figure 6 shows the three voltages measured by the voltage sensors. Since the sensors were working correctly (0s-0.2s), we can see that the measured voltages are present for the harmonic identification algorithm. However, since the fault of the phase sensor (a) is simulated from 0.2, it is clear that the voltage of the first phase is not equal.

Figure 7 Shows the input current distorted due to the presence of the nonlinear load, when the SAPF is not connected (0s-0.1s) , when the SAPF is connected (0.1s-0.2s) and finally, when the sensor of phase (a) and in default without having an inserter of the fault algorithm.

Figure 8 presents exactly the condition that the case preceded for the two (2) first steps (0s-0.2s) with the exception that for the final phase, the default algorithm was introduced.

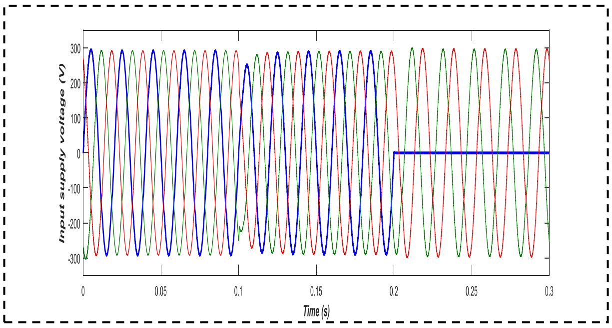


Figure 6. Tensions mesurées

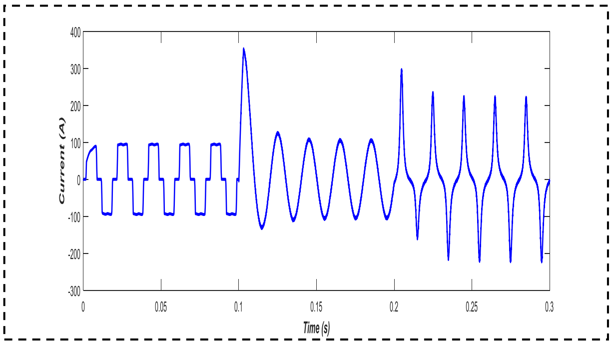


Figure 7. Courant sans sans algorithme de defaut

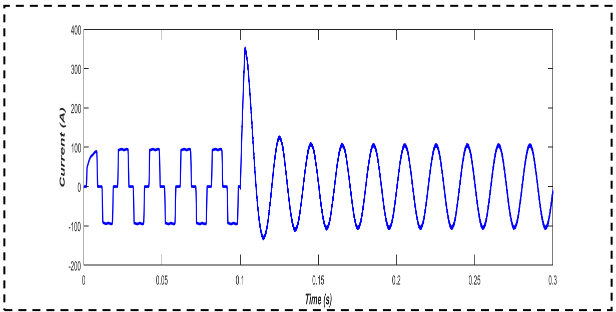
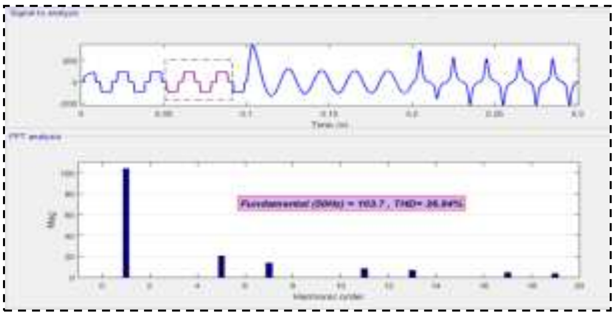


Figure 8. Courant sans avec algorithme de defaut



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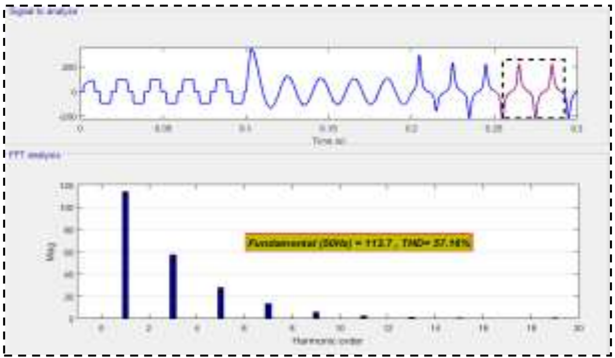

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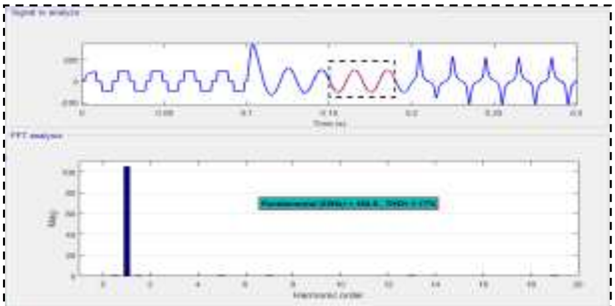

--c--

Figure 9. Spectrum Harmonics Analysis

For the operating conditions considered during these validation tests, the frequency analyzes for each step were carried out. Figure 9 presents the harmonic analyzes for:

In the figure 9(a), the input current distorted due to the presence of the nonlinear load; The THD is 26.52% that is far the limit of the harmonic standard IEEE 519-1992

In the figure 9(b), the input current distorted due to the presence of the nonlinear load when the SAPF is connected; The THD is 1.22%, it's respect the limit of the harmonic standard .

In the figure 9(c), the input current distorted due to the presence of the nonlinear load when the SAPF is connected; without algorithm faults. The THD is 57.16% that is far the limit of the harmonic standard IEEE 519-1992

Table 2 summarizes the results of the frequency analyzes and demonstrates the validity of the approach.

Table 2 Summary frequency analyzes

Time (s)	*0s -0.1s*	*0.1s -0.2s*	*0.2s -0.3s*
State	*Without filter*	*With filter*	*Failure sensor*
Without fault algorithm	*Fundamental (50Hz) = 103.7 , THD= 6.94%*	*Fundamental (50Hz) = 104.8 , THD= 1.17%*	*Fundamental (50Hz) = 113.7 , THD= 57.16%*
With fault algorithm	*Fundamental (50Hz) = 103.7 , THD= 6.94%*	*Fundamental (50Hz) = 104.8 , THD= 1.17%*	*Fundamental (50Hz) = 104.4 , THD= 1.37%*

IV. Conclusion

In this work, we considered the problem of voltage measurement sensor faults of a shunt active power filter. So, we presented a phase calculation algorithm based on the sum of the three voltages measured in balanced conditions. The effectiveness of the approach was illustrated by simulation results. Obtained results illustrate the effectiveness of the proposed control system in term of harmonic distortion. The currents are nearly sinusoidal, THD has been reduced clearly, and that is within the limit of the harmonic standard recommendation. As perspectives to this work, we propose the experimental realization of this flaw detector

Declaration

- The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.
- The authors declare that this article has not been published before and is not in the process of being published in any other journal.
- The authors confirmed that the paper was free of plagiarism.

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