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Fuzzy Direct Power Control of Voltage Source Rectifier (VSR)

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Abstract—**The main idea of direct power control Depend primarily on, direct control of active and reactive power without any internal control loop and any PWM modulator. The switching states at the rectifier are selected from the switching table where the instantaneous error between the estimation and the reference active and reactive power of choosing the states. Today, almost every intelligent machine has fuzzy logic technology inside it. It presents several advantages, especially its strength. This paper presents a direct power control with integration of FLC for more stability and reduction of harmonics current distortion.**

Key words—***PWM rectifier, DPC, Fuzzy logic control, harmonic pollution, PI controller***

I. INTRODUCTION

In recent decades, the multiplication of the use nonlinear loads during these last decades induces severe problems. The problem lies in the distortion of current and voltage waveforms. Several harmonic pollutions cancellation methods were proposed; the typical one was the connection along the AC side of shunt passive Filters. All the same, they are large and Expensive. Recently, active filtering and PWM Conversion is used in industrial plants [1].

Direct Power Control is a novel technology of control based on the instantaneous Active and reactive power control loops [2].

Noguchi proposes the DPC technical and it's similar to DTC technical for induction motors. In lieu of controlling torque and flux, we control the instantaneous active and reactive powers. For a unity power factor operation The Controlled reactive power Suppose it nil [3]. The Strength point of this technique, there are no internal current control loops and no PWM modulator block, And With that in DPC implementation requires the correct and the instant estimation of the active and reactive line power [2].

The beginning, introduced of the Fuzzy logic is Lofti A Zadeh in 1965in his paper "Fuzzy Sets". Then broke it with a group of scientists because some of the underlying mathematics had not hitherto been explored, this idea of the fuzzy sets and fuzzy logic were not taken well within academic universities. The applications of fuzzy logic were slow to germinate because of this, except in the Japan. In Japan, specific fuzzy logic was fully taken over and used in products simply because fuzzy logic worked, regardless of whether mathematicians agreed or disagreed. A revival the fuzzy logic in the US in the late 80s See to the success of many fuzzy logic products in Japan. Since that time, America has been playing Catch up with the Japan in the area of fuzzy logic [4]. In this paper, two different Ways of Direct Power Control for rectifier converter have been presented. The first way DPC uses typical PI controllers. The second way DPC introduces an FLC [5].

II. PWM RECTIFIER

A power circuit of the three-phase VSR is shown in Fig.1 [6]. L is the inductance between the grid and the PWM rectifier. Its main function is to filter harmonics and boost DC voltage; in this case, we consider AC current is sinusoidal. C is the capacitance, which stabilize DC voltage and store energy in the DC side [7].

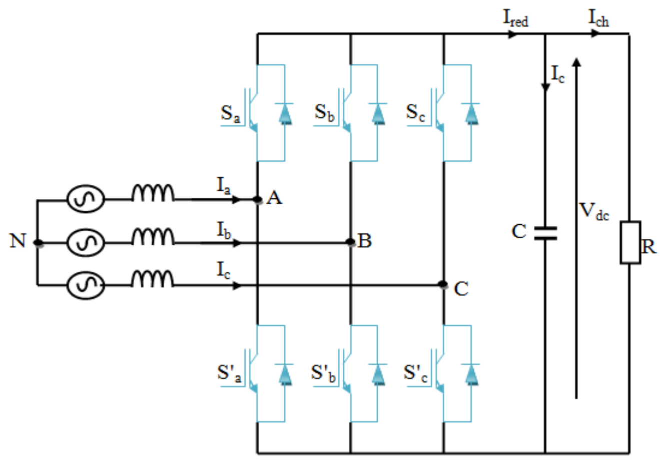

Fig. 1 Three-phase PWM Rectifier.

III. DIRECT POWER CONTROL

This technique depends primarily on the estimation of the instantaneous power p and q [8]. And is characterized by other

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techniques in the absence the internal current control loops and PWM modulator block, the switching table is the responsibility for selecting the rectifier switching states, it's based on the sector of voltage line and the instantaneous errors between the reference and estimated values of P and Q. Therefore, the most important thing of the direct power control application is to give the correct and fast estimated value of the active and reactive grid power [2] [8].

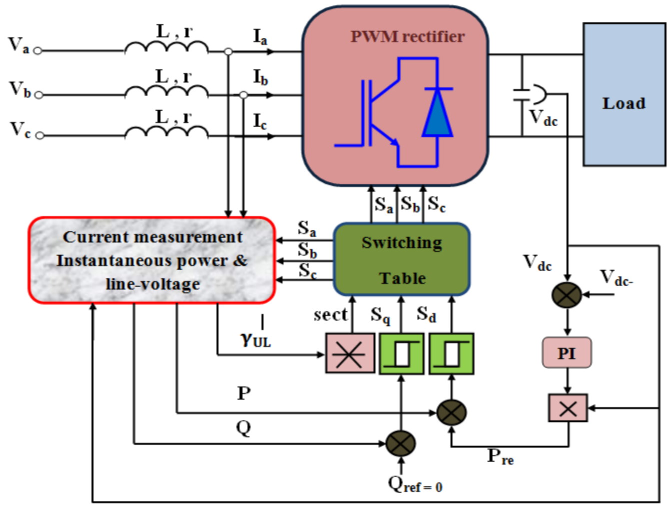

Fig. 2 Direct power control configuration.

A. Active and Reactive Power Estimator

The instantaneous active and the reactive power defines by:

$$p = \underline{v}_{(abc)} \cdot \underline{i}_{(abc)} = v_a i_a + v_b i_b + v_c i_c \quad (1)$$

$$q = \underline{v}_{(abc)} \wedge \underline{i}_{(abc)} = v'_a i'_a + v'_b i'_b + v'_c i'_c \quad (2)$$

The active and reactive powers values are estimated by the equations (3), (4). In this equation I_a; I_b; I_c are the ac-line, S_a; S_b; S_c are the switching state of the rectifier.
To compute p and q value from equations (1), (2), require knowing line inductance L [9].

$$\hat{p} = L(\frac{di_a}{dt} i_a + \frac{di_b}{dt} i_b + \frac{di_c}{dt} i_c) + v_{dc}(s_a i_a + s_b i_b + s_c i_c) \quad (3)$$

$$\hat{q} = \frac{1}{\sqrt{3}}[3L(\frac{di_a}{dt} i_c - \frac{di_c}{dt} i_a) + v_{dc}(s_a(i_b - i_c) + s_b(i_c - i_a) + s_c(i_a - i_b))] \quad (4)$$

B. Voltage estimator

The expressions of the P and Q can be Expression as follow

$$\hat{p} = \underline{v}_{(abc)} \cdot \underline{i}_{(abc)} = \underline{v}_\alpha \underline{i}_\alpha + \underline{v}_\beta \underline{i}_\beta \quad (5)$$

$$\hat{q} = \underline{v}_{(abc)} \wedge \underline{i}_{(abc)} = \underline{v}_\alpha \cdot \underline{i}_\beta - \underline{v}_\beta \cdot \underline{i}_\alpha \quad (6)$$

By measuring AC-line current and computing active and reactive power by equations (3), (4), the line voltage can be Extracted from the equation (7) [9] [10].

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

C. Detection of sector

The region of the estimated voltage vector is divided into twelve sectors [10].

$$(n-2)\frac{\pi}{6} \prec \mathrm{sect}_n \prec (n-1)\frac{\pi}{6} \cdots n = 1,2,\cdots,12 \quad (8)$$

IV. DC VOLTAGE REGULATION

A. PI regulator

In this proposed functional schema of the DPC, the fundamental input currents is delivered by outer proportional-integral (PI) controller of dc-bus voltage and multiplied the output by the dc voltage for given the reference value of the instantaneous active power, show Fig. 3 [1].

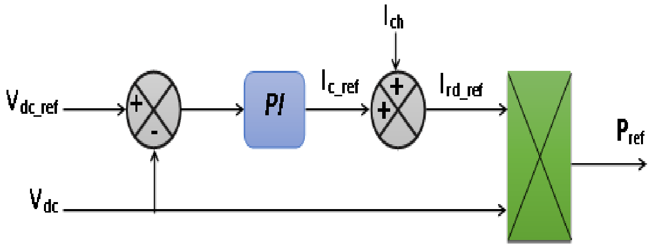

Fig. 3 DC voltage PI control.

B. Fuzzy Controller

Fig. 4 gives the main scheme of the presented FLC. The dc bus voltage V_{dc} is sensed and compared with a reference value V_{dcref} for obtain the error [3].

$$err(k) = v_{dcref}(k) - v_{dc}(k) \quad (9)$$

and its incremental variation

$$derr(k) = err(k) - err(k-1) \quad (10)$$

The k^{Th} sampling instant is used as inputs for fuzzy controller. So that we have in the output the instantaneous active Pref. The Vdc is controlled by regulating the active power using fuzzy controller [3]. To have a good result in the Vdc control. The inference system FLC Depends on IF-THEN rules. The example of fuzzy base rules is shown in Table I [2].

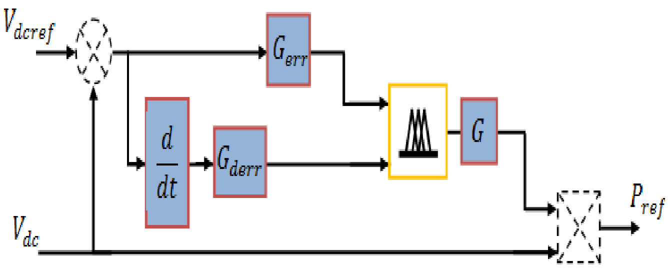

Fig. 4 DC voltage fuzzy control.

The Fuzzy logic Rules system, Determines a set of behaviors and transactions that relate to inputs for obtaining a good result in outputs. So, the fuzzy system approximates at the mathematical function of cause and his effect [11].

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Table I: Fuzzy Base Rule

err \ derr	N	Z	P
N	GN	N	N
Z	N	Z	P
P	Z	P	GP

V. SIMULATION

To study the operation of the fuzzy DPC system, the PWM rectifier with the whole control scheme has been simulated using MATLAB Simulink software.

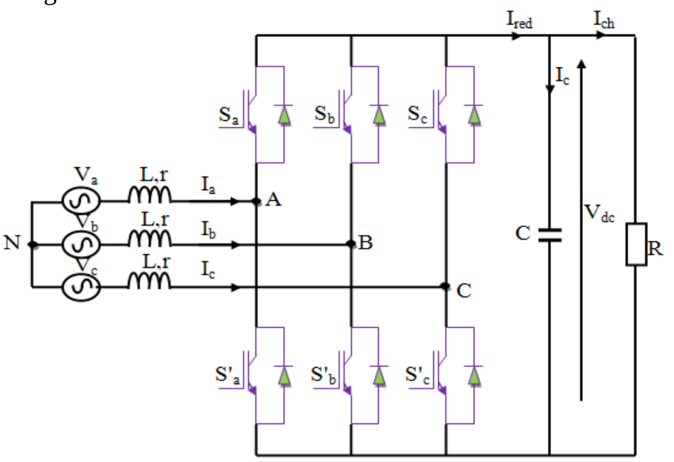

Fig. 5 Studied system

The main electrical parameters of the power circuit given in Table II:

Table 2. Fuzzy Base Rule

Resistance of reactors (R)	0.25[Ω]
Inductance of reactors (L)	10[mH]
DC-link capacitor	0.005[F]
Load resistance (RL)	100[Ω]
Phase voltage (V)	$220*\sqrt{2}$ [V]
Source voltage frequency	50[Hz]
DC-link voltage	600[V]

We can observe a comparison between the two kind of control conventional on left and fuzzy logic on right, Fig.6 and 7 shows the line current and voltage

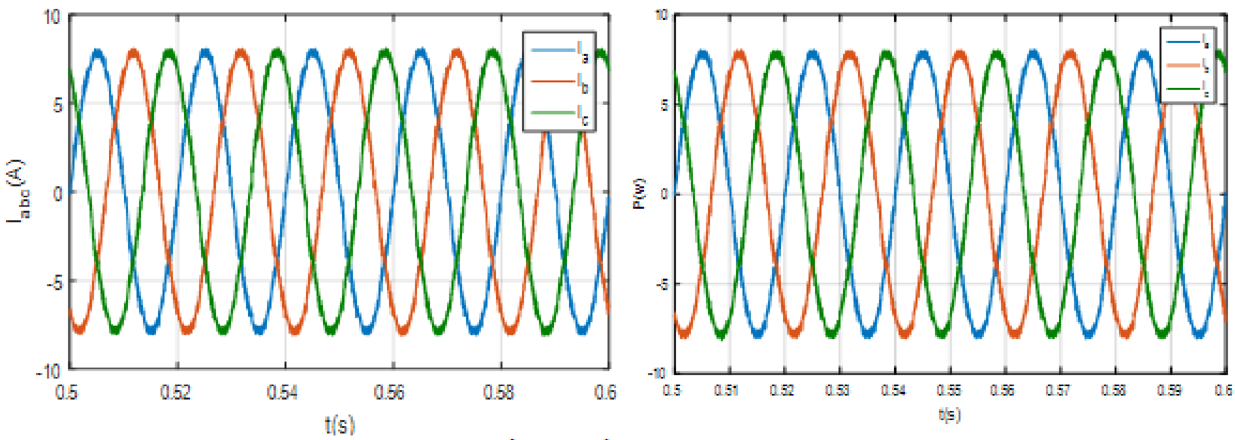

Fig. 6 Line current

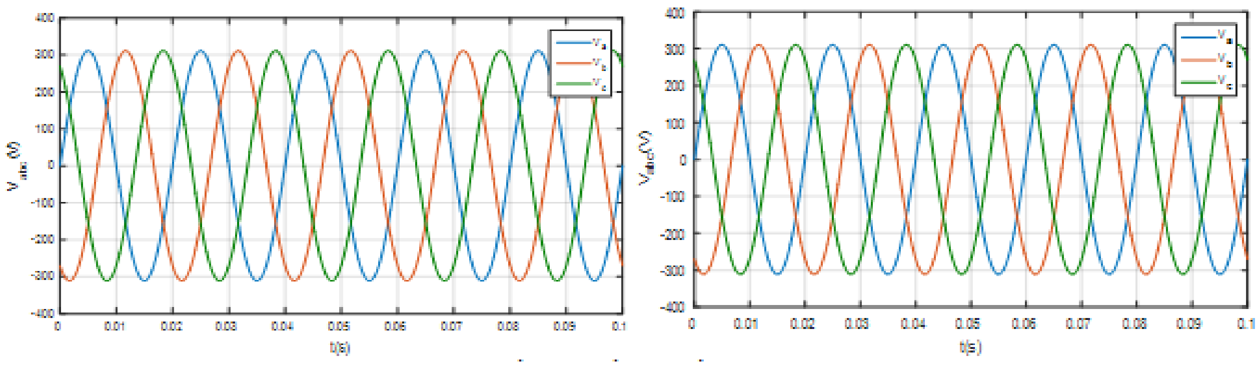

Fig. 7 Line voltage

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The control of DC link voltage is presented in fig. 8, fig. 9 we can observe the load current form.

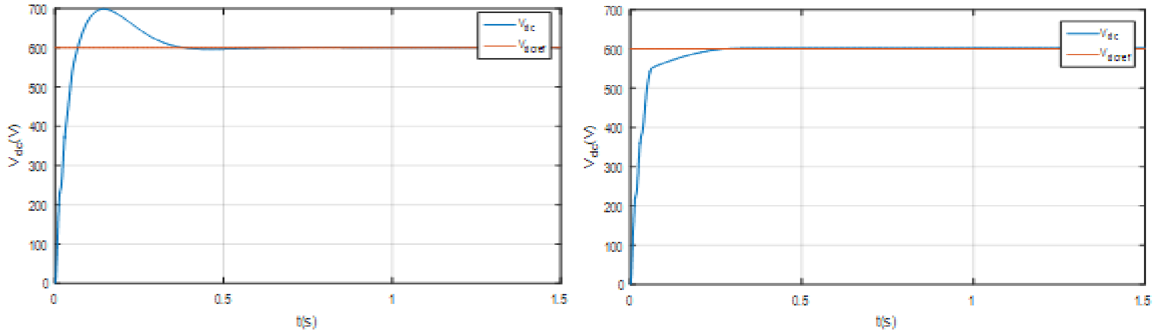

Fig. 8 Control of DC voltage

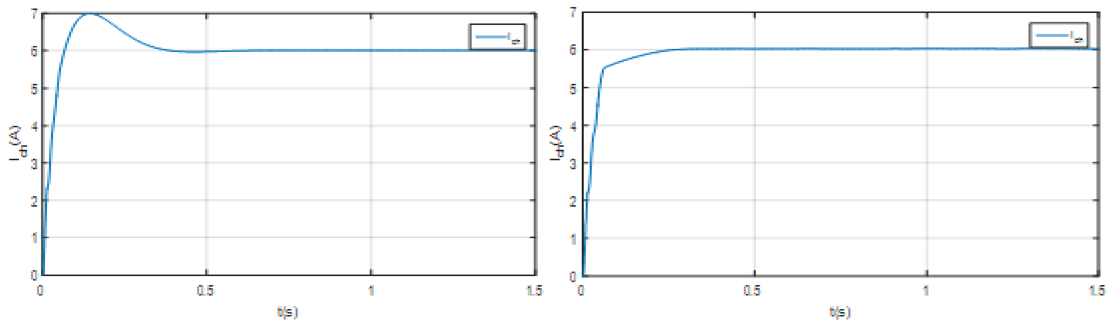

Fig. 9 Load current

In figs.10, 11 we present the estimated active and reactive power, and in, fig.12 Line current and voltage of the first phase.

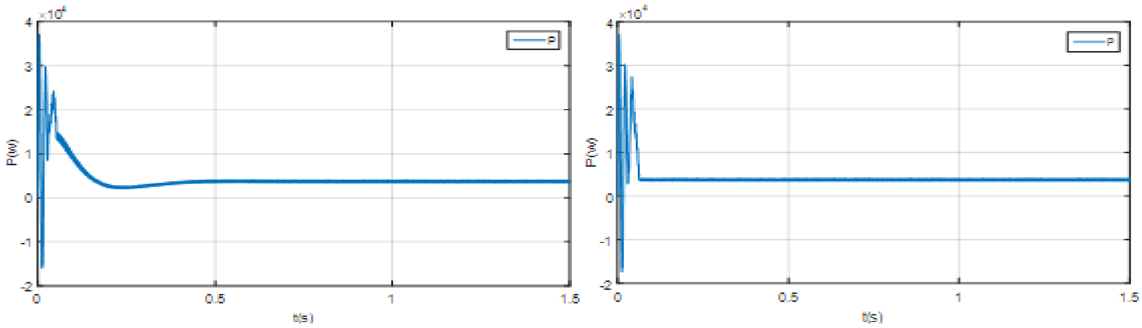

Fig. 10 Estimated active power

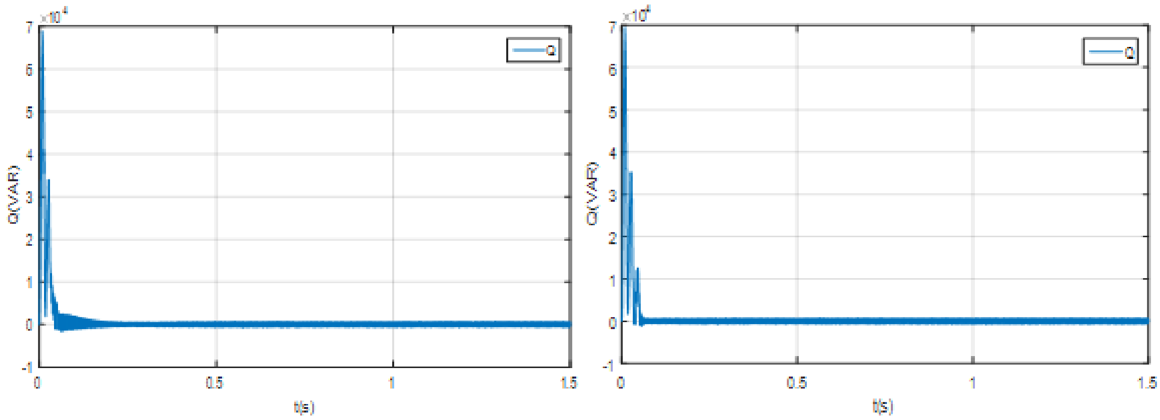

Fig. 11 Estimated reactive power

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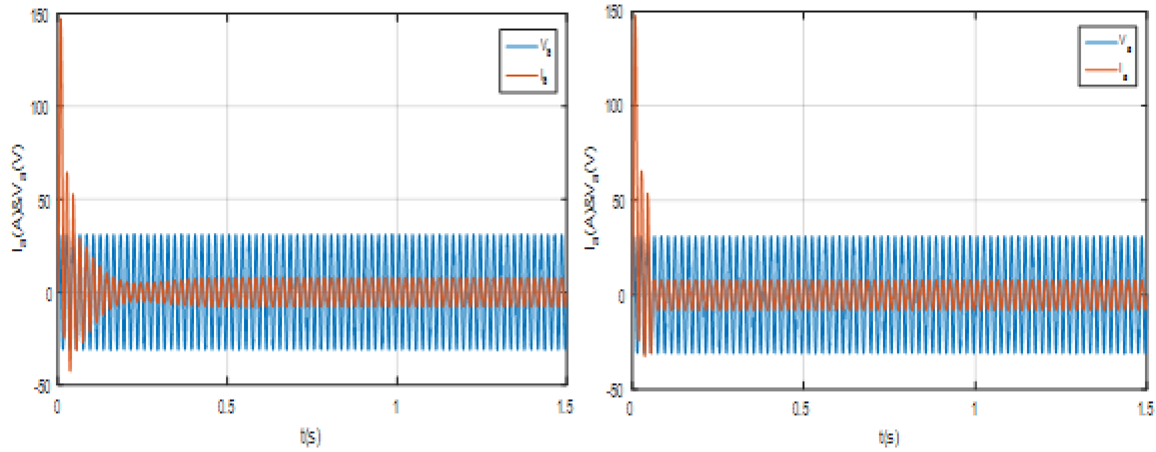

Fig. 12 Line current and voltage of the first phase

Alpha beta trajectory of networks voltage is presented in fig.13, and finally we obtain the spectral analysis of networks current.

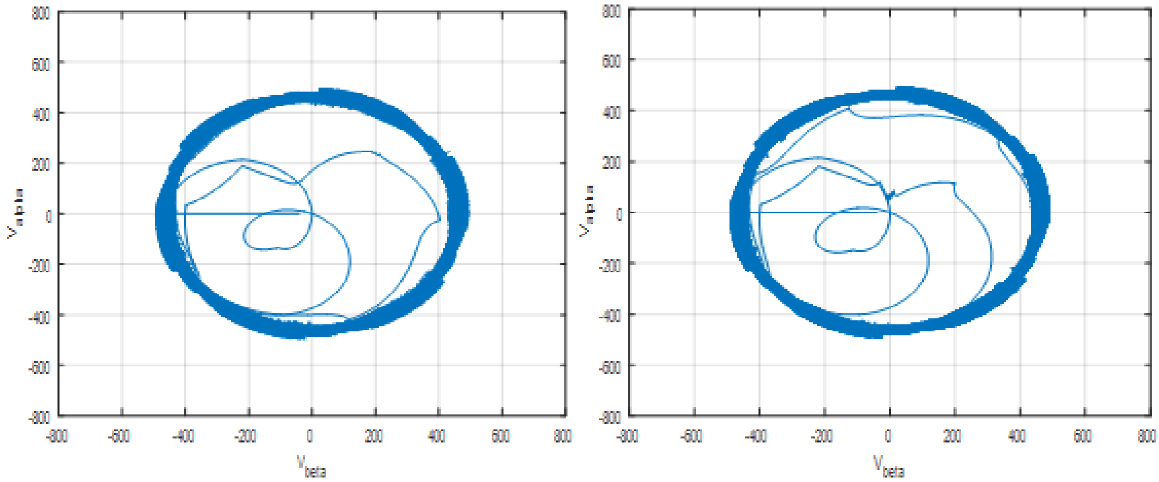

Fig. 13 Alpha beta trajectory of networks voltage

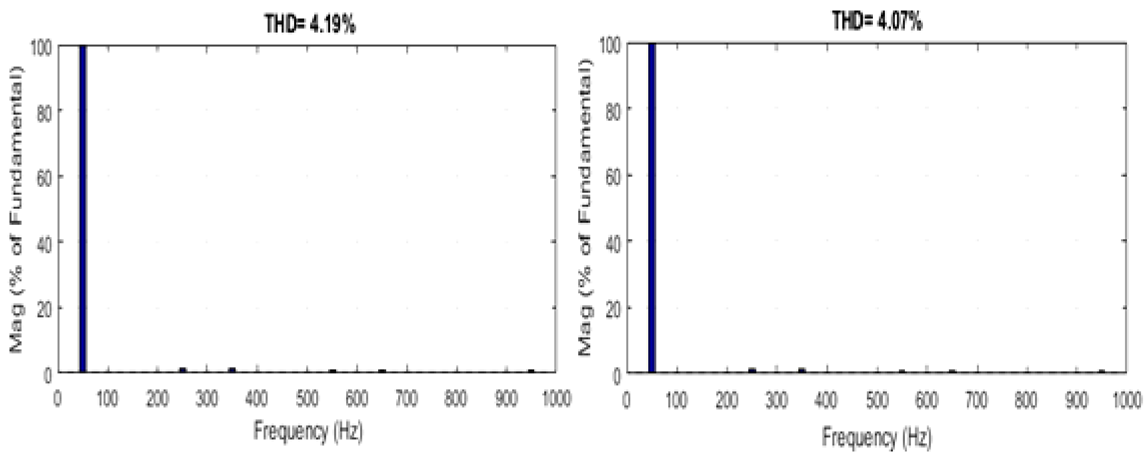

Fig. 14 THD of line current

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We can't notice much deference regarding the voltage and the current of networks, The control of DC link voltage with classical control present an overshoot of 100V, the uses of fuzzy controller eliminates this disadvantage with a reduced Response time, we not the same thing for load current, fuzzy logic have good performance in the case of power settings. In Fig.12, the voltage and the current are in phase, which is translated by a unit power factor.

Finally, the spectral analysis shows some improvement when using fuzzy logic; the two THD values are accepted in international standards that impose a THD less than 5%.

VI. Conclusion

This paper, proposed a new technique of control for a PWM AC-DC converter with a constant switching frequency. It concerns the use of the direct power control principle via an FLC system on the DC side. DPC technical allows reducing the number of sensors used. In order to obtain a stable exchange of the active power owe between the rectifier and the electrical network, a fuzzy logic regulator using for the DC voltage control. The results of Simulation showed that the direct power control technique with a fuzzy logic for dc voltage control improves the performance system. These improvements concern the performances of the system response on the DC side (overshoot and response time), as well as the power-factor and the THD of the line current [3]. However the conventional regulator has a simple shape, easy to make, and cheaper than the fuzzy regulator.

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