International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.13 pp.43-46

APF Based on FLC Applied on Wind Power Conversion Chain

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***Abstract*-- This work devoted to the study of the active power filter (APF) reliability on harmonic minimization of wind power conversion chain network in case the presence of nonlinear variable load, that, after modeling of each part and well choice of the rules bases and intervals for each selected fuzzy variable of the suitable fuzzy logic controller. To show the effectiveness of this kind of regulation on power quality improvement on wind power system, all system is simuled via MATLAB Simulink, Results are discussed and analyzed to represent the effectiveness of the proposed APF on power quality and harmonic reducing on wind conversion chain network.**

***Keywords*— APF, FLC, Harmonic, Wind.**

1. INTRODUCTION

The classical adjustment of the systems relies mainly on the sizing of the adjustment elements from the modeling of the overall system, but it turns out that this does not always easy to do this. It is here that the main advantage of fuzzy logic regulation resides, in fact this type of technique does not need to establish any model of the system [1-3]. A direct application to the APF capacitor voltage regulation with their simulation, by MATLAB, applied to wind power conversion chain network is presented in the case of a non-linear variable load conditions, after modeling, to show the effectiveness of this kind of regulators on electrical power quality and improve the reliability of the APF on wind power system harmonic reducing.

Where after wind chain modeling and PMSM output voltage regulation using PI controller we will present the mains knowledge of the proposed APF and the FLC controller, in the last we will present the simulation results under Matlab Simulink of each parts of the studied system described on the next step.

2. DESCRIPTION OF THE STUDIED SYSTEM

Our study presents the architecture "structure" of regulating the voltage delivered by a PMSM driven by a wind turbine via gear box controlled by a PI regulator [4], this after we present the model of each part of the conversion chain and the results of wind variation influence on the stability of PMSM output voltage amplitude, Wind profile is modeled as a fractional scalar evolves over time [5, 6]. PMSM supply a nonlinear load from the rectifier installed on the output of the conversion chain via a controlled power inverter. To see the influence of the FLC regulator on the quality of the filtering we have use a 3x3rules fuzzy regulator implanted in the control part of the APF [1,2,7], where the membership functions of the input and the output variables are shown in figure1.Simulation Bloc is presented by "fig 1".

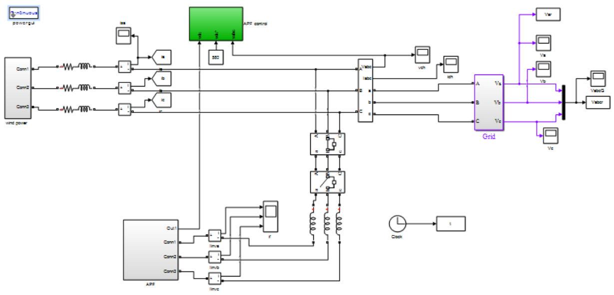

Fig. 1. Schemas Bloc of the proposed system.

3. MATHEMATIC MODELING & SIMULATION

fig.2 present an overall scheme which describe the various essential parts dedicated to the conversion of the wind power into electrical energy based on permanent magnet synchronous machine mechanically coupled with a wind turbine via a reduction gearbox, the latter is driven by a wind profile that will be modeled and simuled under Matlab Simulink Software.

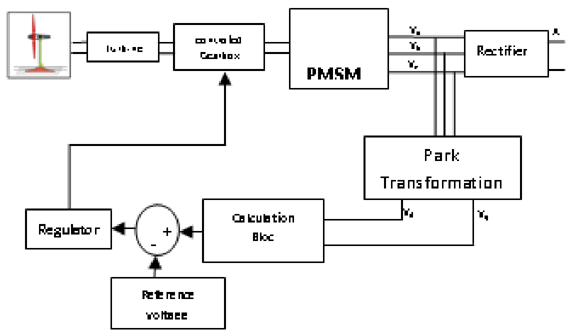

Fig. 2. wind power conversion chain PI closed loop regulator.

Where, Wind speed can be modeled as a fractional

ISSN 1737-9296

International Journal of Scientific Research & Engineering Technology (IJSET)
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scalar evolves over time as in "(1)"

$$v_v = f\left(t\right) \qquad (1)$$

Wind speed can be represented as a function of harmonics as in (2).

$$v_v(t) = A + \sum_{n=1}^{i} a_n \sin(b_n\, w_v t) \qquad (2)$$

Equation "(3)" represent an uncertain wind profile evolve around a known medial value

$$v_v = 9 + 0,2\sin(0,10477t) + 2\sin(0,2665t) + \sin(1,2930t) + 0,2\sin(3,6645t) \quad (3)$$

uncertain wind profile is presented on "fig.3"

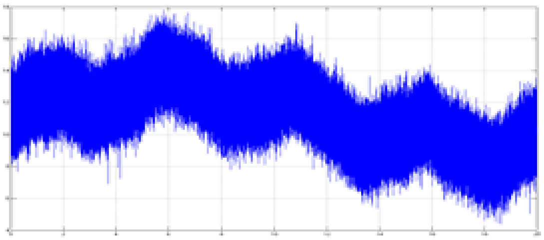

Fig. 3. Uncertain wind profile.

Where the PMSM voltage output befor PI regulation is shown on "fig. 4"

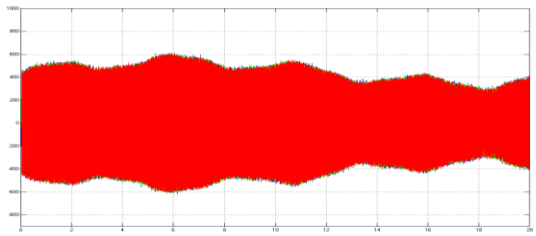

Fig. 4. PMSM output voltage (open loop).

After closed loop PI controller installation output voltage was stable as shown on "fig. 5"

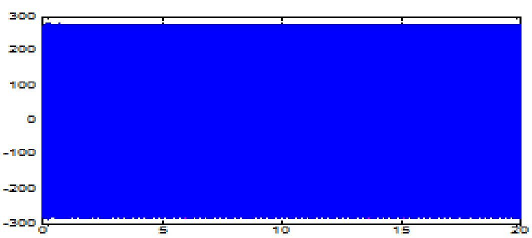

Fig. 5. PMSM output voltage (PI closed loop)..

After that we have a wind power converted to a stable tri-phases voltage by the PMSM and the PI controller loop; we will use the rectifier presented on "fig.6" modeled and implanted under Matlab Simulink to coupling the PMSM to the network via a power inverter

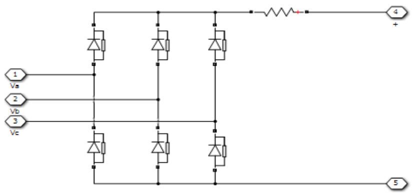

Fig. 6. Network coupling rectifier.

Presented by the simulation bloc "fig.7" after mathematic modeling on dq frame presented in (4), (5) below

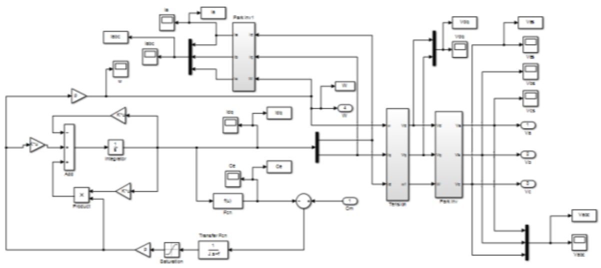

Fig. 7. PMSM simulation Bloc under Matlab.

$$v_d = R_s i_d + L\frac{d}{dt} i_d + w_r L_q i_q \qquad (4)$$

$$v_q = R_s i_q + L_q \frac{d}{dt} i_q + w_r (L_d i_d + \Phi_f) \qquad (5)$$

Where the simulation bloc of the studied network is shown in "fig.8"

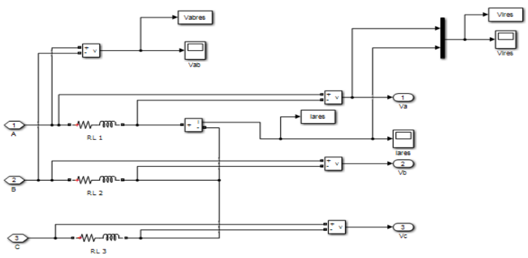

Fig.8. Network Simulation Bloc.

network load current shown on "fig.9" show clearly the presence of The 5,7 and 11 harmonic due to the presence of a nonlinear loads on the network

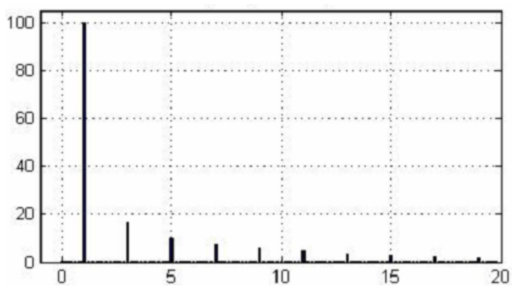

Fig. 9. Network Current Harmonic specter before filtering [4].

For the minimization of the undesired influence of harmonic on network we have propose to integrate an APF controlled by a PI

ISSN 1737-9296

International Journal of Scientific Research & Engineering Technology (IJSET)
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controller in the first time then by a more efficiency and modern controller the FLC [7], [9], [10] as shown on "fig.1"

The FLC based on the principle summarized on "fig.10"

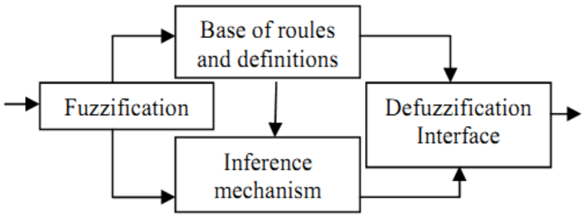

Fig. 10. Fuzzy Logic Controller general structure.

Where the chosen member sheep functions for error *e(t)*, error variation *de(t)* and control output *u(t)* are shown on "fig.11"

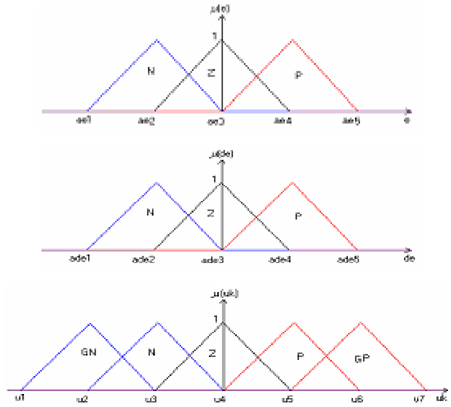

Fig. 11. FLC member sheep functions.

Simulation results shown that the installation of the APF on the network helps on harmonic minimization as improve the harmonic specter of "fig.12"

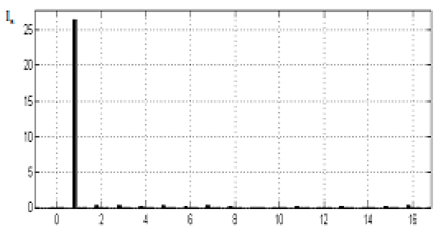

Fig. 12. Harmonic specter with APF use FLC

This let network current, shown on "fig.13", be more near to the sinusoidal wave and the THD value decrease.

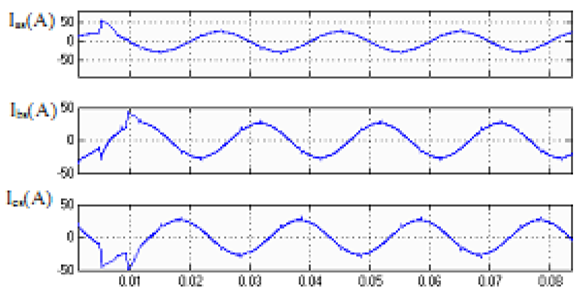

Fig. 13. Network Current after APF installation.

The APF current is shown on "fig.14" below

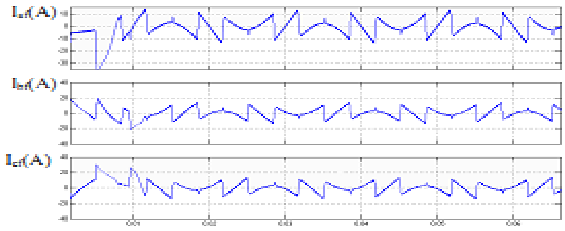

Fig. 14. APF injected Current.

So, APF installation on network has decrease the harmonic presence and this make the wind conversion chain more reliable and the regulation system working well as if the THD is more important.

The Dc voltage of APF capacitor is stabilized by de PI regulator first, as shown on "fig.15",

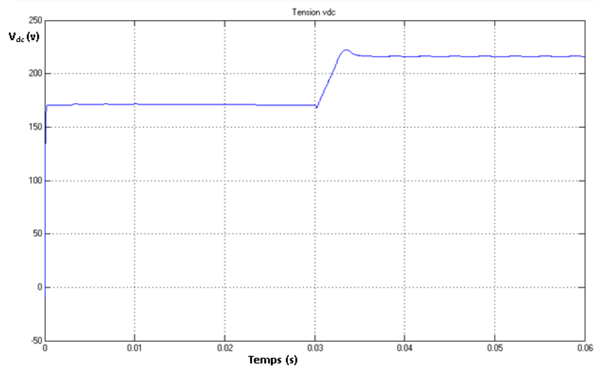

Fig. 15. APF Capacitor DC voltage regulation with PI.

then by FLC as shown on "fig.16

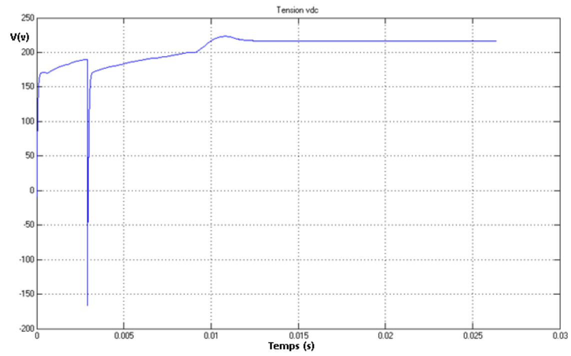

Fig. 16. APF Capacitor DC voltage regulation with FLC.

We can see clearly that response time and depassement in case of FLC regulator is less then that with PI controller.

CONCLUSION

Wind conversion chain model is represented in case of nonlinear load; output voltage has been regulated by PI controller then connected to the network via rectifier connected to an inverter supply nonlinear load. Harmonic generated by the nonlinear load has been decries by the use of an active power filter APF controlled by an fuzzy logic controller, connection of the APF on wind power conversion chain reduce the present harmonic due to nonlinear load supplied by the wind chain.

ISSN 1737-9296

In the last we hope applied more intelligent techniques to the studied system to have more suitable results in other works applied on laboratory.

ACKNOWLEDGMENT

Bay this work I would send acknowledge to LREEI laboratory director, Prf Nadji Bouchra, and to my thesis director, Prf Habi Idir.

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ISSN 1737-9296