Wind Power Conversion Chain Harmonic Compensation using APF Based on FLC

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ABSTRACT

The work deals study of the active power filter (APF) aplications on harmonic compensation of wind power conversion chain network in case of nonlinear load presence, this, 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 in wind power system and on APF function reliability on harmonic compensation compered to the use of PI controller, 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.

I. 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 [4,5,6,7] with their simulation, by MATLAB, applied to wind power conversion chain network [8,9] is represented in the case of a non-linear variable load conditions [6], 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.

II. Description of the Studied System

Our study represents 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 figure11.Simulation Bloc is presented by fig 1.

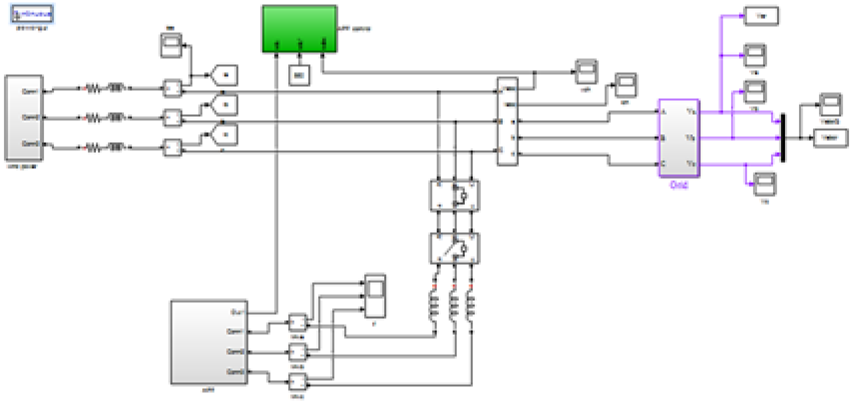


Figure. 1. Schemas Bloc of the proposed system.

Figure.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.

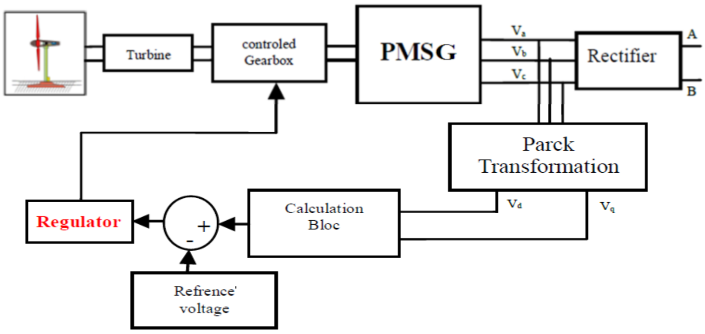


Figure. 2. wind power conversion chain PI closed loop regulator.

III. MATHEMATIC MODELING & SIMULATION

Wind speed can be modeled as a fractional scalar evolves over time as in “(1)”

$$v_v = f(t) \quad (1)$$

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

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

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

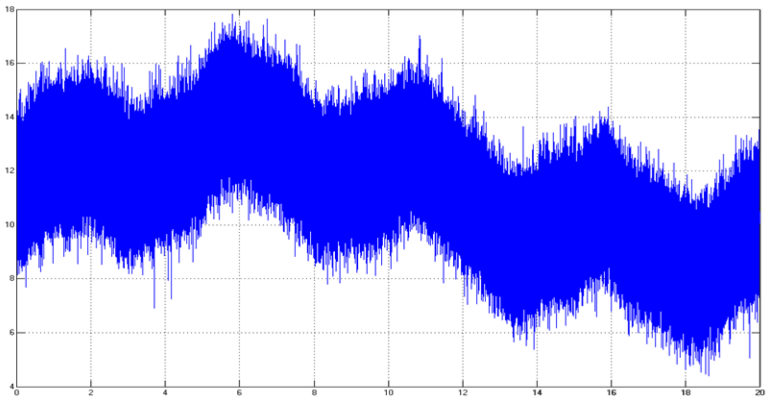


Figure.3. Uncertain wind profile.

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

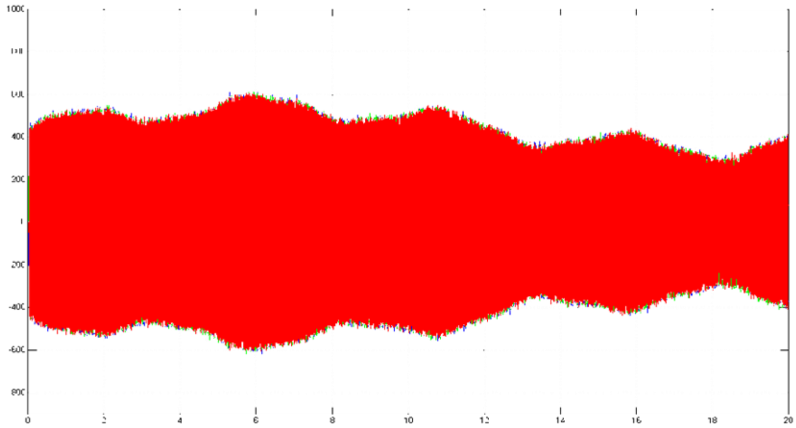


Figure. 4. PMSM output voltage (open loop).

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

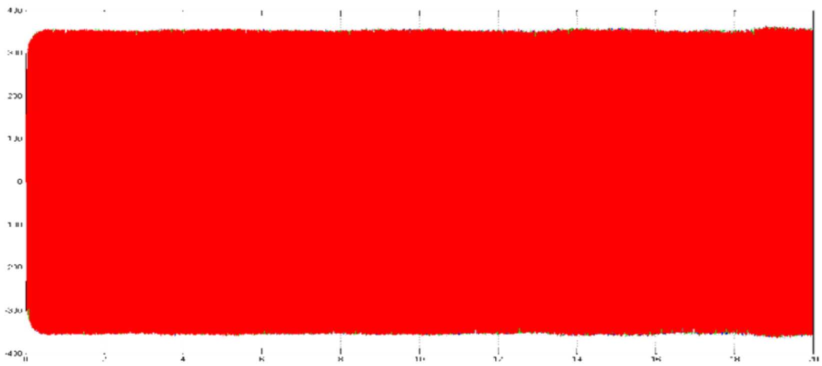


Figure. 5. PMSM output voltage (PI closed loop).

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

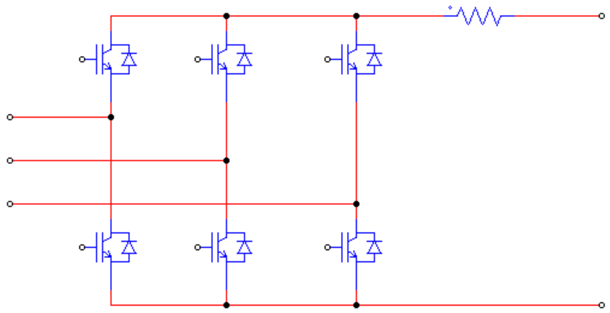


Figure. 6. Network coupling rectifier.

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

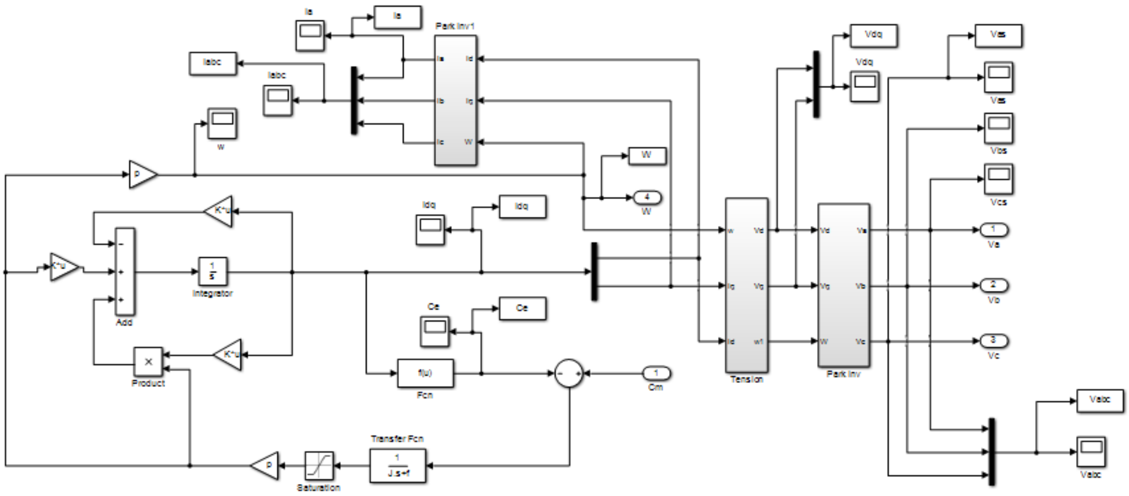


Figure. 7. PMSM simulation Bloc under Matlab.

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

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

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

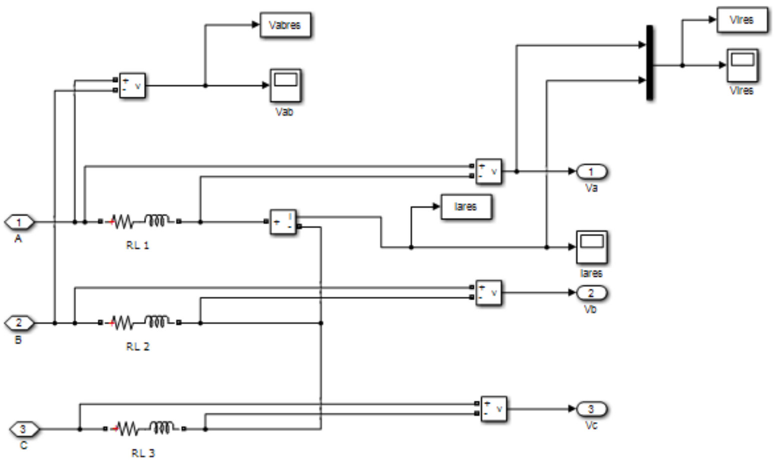
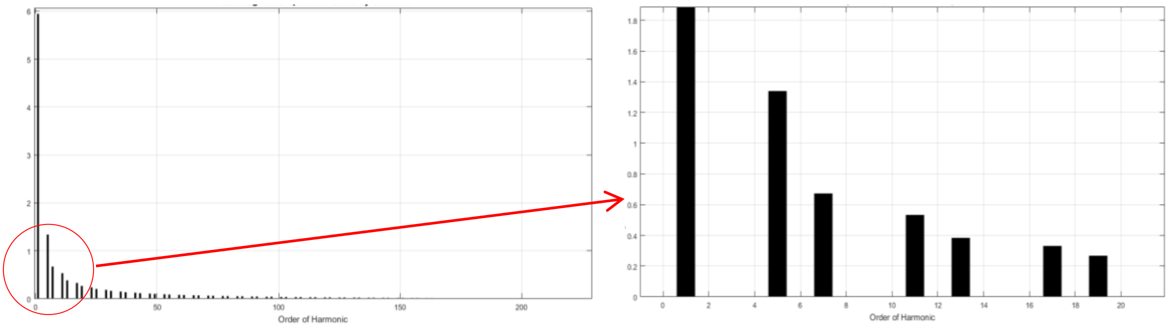


Figure.8. Network Simulation Bloc.

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



(a) (b)

Figure. 9. (a) Network Current Harmonic specter before filtering, (b) zoom.

For the minimization of the undesired influence of harmonic on network we have propose to integrate an APF controlled by a PI controller in the first time then by a more efficiency and modern controller the FLC [8], [10], [12-17] as shown on fig.1. The FLC based on the principle summarized on fig.10

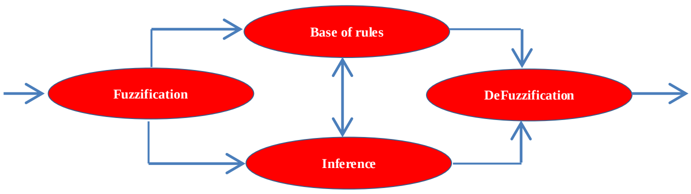


Figure. 10. Fuzzy Logic Controller general structure.

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

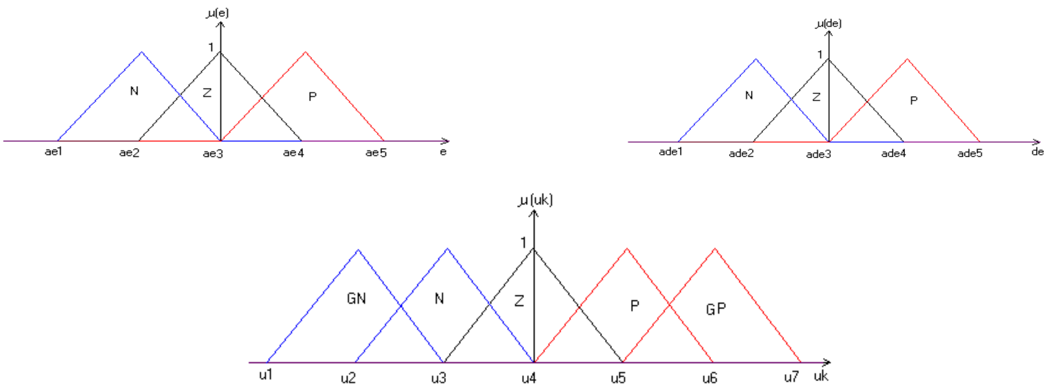


Figure. 11. FLC member sheep functions.

Wher the FLC intervals are: a=-0.002; b=0.002; for error(e), and c=-0.0005; d=0.0005; for error variation (de), and u1=-20; u2=-15; u3=-5; u0=0; u4=0.02; u5=29; u6=30; for command (U(t)).
The controller work based on rules table sumerazed on table I:

Table I: fuzzy logic controller rules

∆e/e	N	Z	P
N	GN	Z	Z
Z	N	Z	P
P	Z	Z	GP

The table.I is the result of the use of the logical rules if (e<0 & Δe(t)<0) ==> U is GN

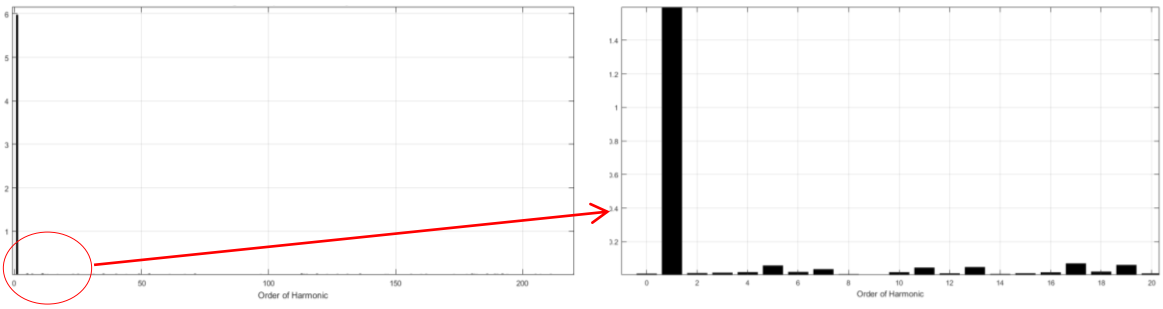
if (e>0 & Δe(t)>0) ==> U is GP

if (e<0 & Δe(t)>0) or (e=0 & Δe(t)=0) or (e=0 & Δe(t)>0) or (e=0 & Δe(t)<0) or (e>0 & Δe(t)<0) ====> U is Z.

if (e<0 & Δe(t)=0) ==> U is N.

if (e>0 & Δe(t)=0) ==> U is P.

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



(a) (b)

Figure. 12. (a) Harmonic specter with APF use FLC, (b) zoom

This let network current, shown on fig.13, be more near to the sinusoidal wave and the THD value [18,19] decrease from 30,4% to less then 3,7% value.

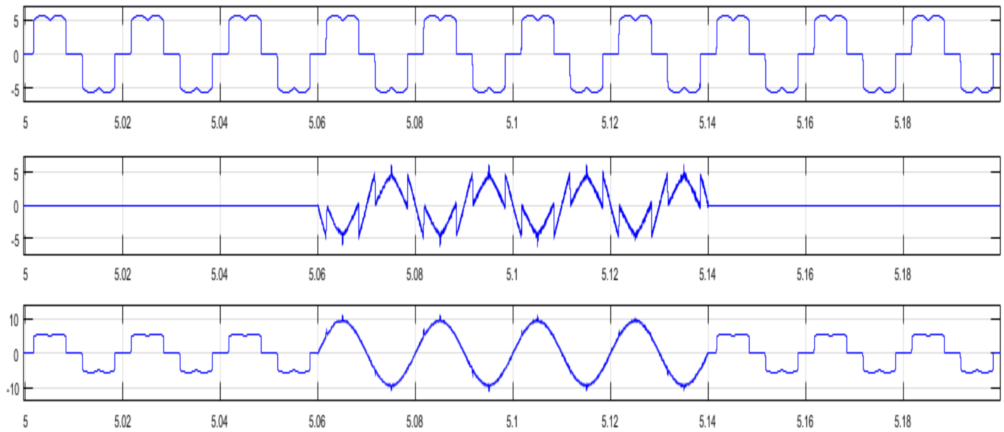


Figure. 13. Network, APF and Is current befor and after APF installation then disconnecting at t=5.14s.

The APF current is shown on fig.14 below with the load current and wind chain current after APF connecting.

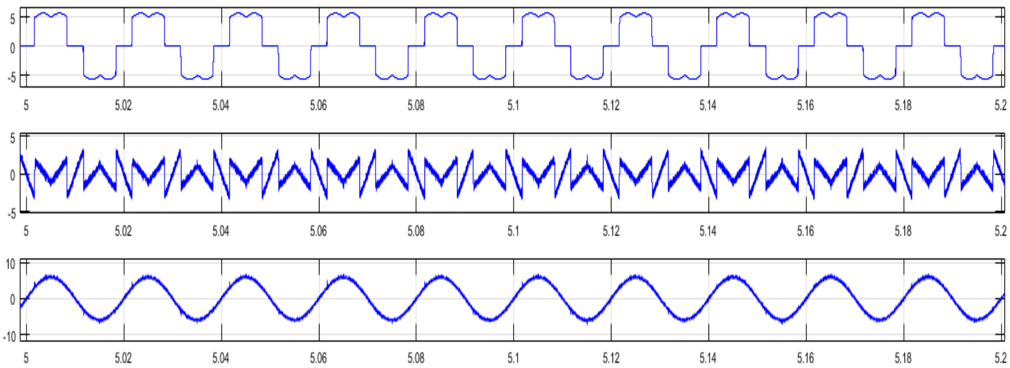


Figure. 14. Load, APF & supply delivred Current.

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, where the response time is near to 1.5 second.

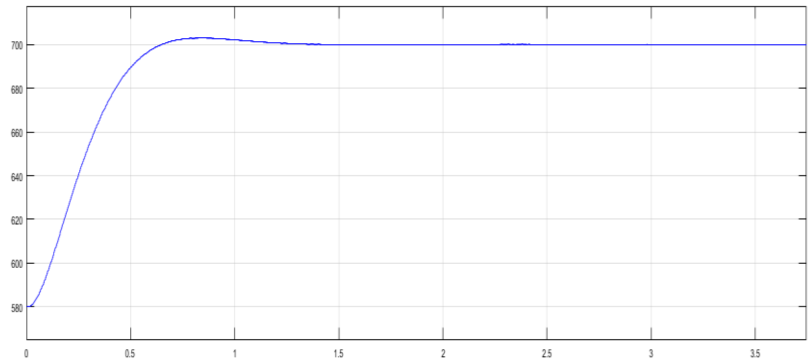


Figure. 15. APF Capacitor DC voltage regulation with PI.

then by FLC as shown on fig.16

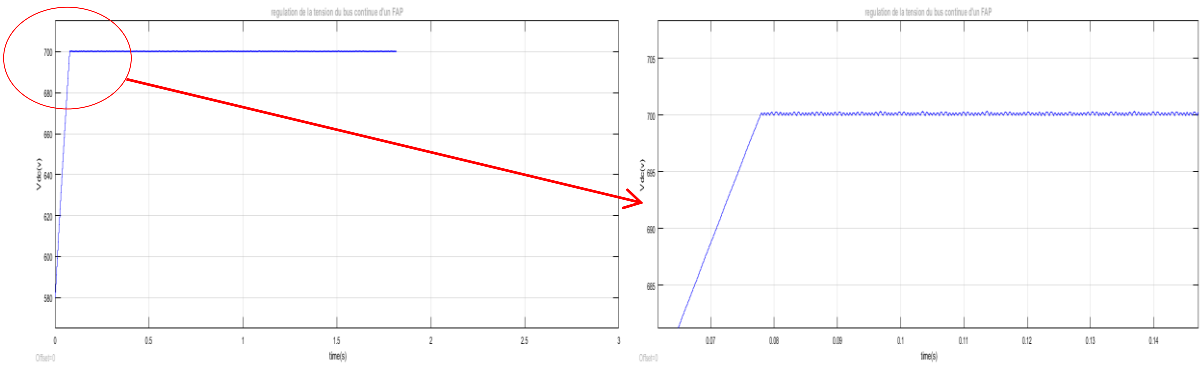


Figure. 16. APF Capacitor DC voltage regulation with FLC.

The response time and depassement in case of FLC (0.09s) regulator is less then that with PI (1.4s) controller. Wher the harmonics are reducing to less then (0.03A) max from (1.4A) befor the use of APF as shown in fig.17.

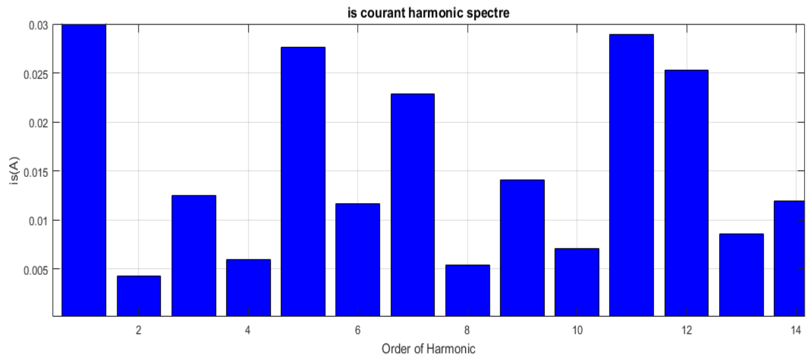


Figure. 17. Wind chain current Is harmonic spectre after APF connecting.

Also, the APF installation on the network has decrease the THD [18,19] of the network current from THD>30% to less then THD< 4%, fig.18 represent the THD value variation of delevred current by the wind power conversion chain befor and after connecting of the APF controlled by a FLC.

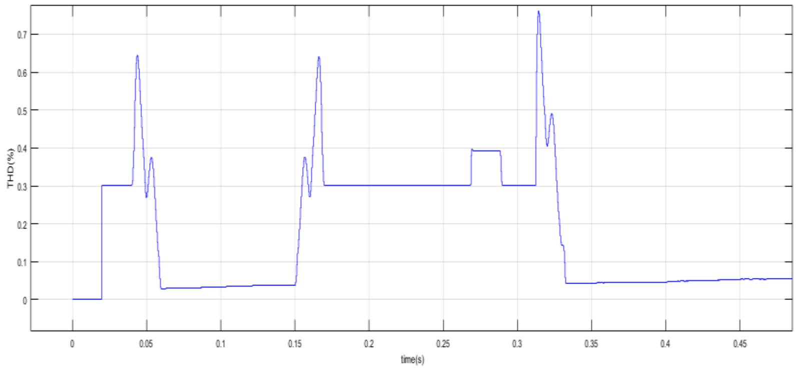


Figure 18. THD variation of wind chain befor and after APF connecting.

Simulation parameters are listed in Table.II below,

Table II. Simulation parameters

Variable	value	unit
R_{load}	270	Ω
L_{load}	6.10^{-3}	H
C_f	3650.10^{-6}	F

III. Conclusion

In this work, we have represented a wind conversion chain model oriented simulation, the output voltageof the wind conversion chain has been regulated by a PI controller then connected to the network via a rectifier connected to an inverter supply nonlinear loads. Nonlinear loads harmonic has been decrease by the use of a shunt three phase for wir APF, controlled by an FLC 3X3 rules. The APF installation on the network has decrease the THD of the network current from 30% to less then 4%.

Finaly we hope applied more intelligent techniques to the studied system with hybrid electrical power as solar or other renouweble energy to have more suitable results in other works applied in the laboratory.

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