# Power Quality Improvement by UPQC using Different Functions of Defuzzification

C. Benachaiba, *Member, IAENG*, B. Mazari, and M. Rahli

***Abstract*—Unified Power Quality Conditioner (UPQC) can compensate voltage and/or current disturbances such as: Sags, swell, unbalance voltage, harmonics and reactive power. UPQC consists of combined series active power filter that compensates voltage harmonics of the power supply, and shunt active power filter that compensates harmonic currents of a non-linear load. In this paper, we compare the effect of the different defuzzification functions of the FIS Properties Editor on the power quality improvement. The target controllers are located in the current loop of the shunt active filter. The simulation results in MATLAB/SIMULINK show that the defuzzification function affects the behavior of the FLC and consequently the compensation's characteristic.**

***Index Terms*—Shunt active filter, Series active filter, UPQC, power quality, Sags voltage, THD**

## I. Introduction

IDEAL power system is the power network which supplies a pure-resistive equivalent load. The proliferation of nonlinear loads results in the deterioration of the quality of both the voltage waveforms at the point of common coupling (PCC) and the current waveforms of the source side. Not only the electronic devices, but the power system itself, like the transformer, is the source of the harmonics. The power quality problem is now cared by the power customer which must be settled. Yet, due to the use of electric loads, it can be very complex. Active filters have been known as the best tool for harmonic mitigation as well as reactive power compensation. They have been developed since 1983, when one of the first prototypes based on instantaneous power theory was reported [1] [2].

Many configurations such as shunt, series, hybrid (a combination of shunt and series active filters), and unified power quality conditioner (UPQC, a combination of series and shunt active filters) have been introduced and improved [3]. The UPQC can compensate not only harmonic currents and unbalances of a non-linear load, but also voltage harmonics and unbalances of the power sup-ply. The latter improves the power quality offered for other harmonic sensitive loads.

There are also different custom power devices such as dynamic voltage restorer (DVR), which improves the quality of power supply, distribution static compensator (DSTATCOM), which compensates current unbalance and harmonics of non-linear loads, and combined SVC with DSTATCOM, which generates reactive power and compensates load current simultaneously [4]–[6].

C. Benachaiba is with Bechar University, Algeria (e-mail: chellali@ netscape.net).
B. Mazari is with USTOran, Algeria (e-mail: mazari_dz@yahoo.fr).
M. Rahli is with USTOran, Algeria (e-mail: rahlim@yahoo.fr).

## II. Unified Power Quality Conditioner

The basic circuit of the UPQC consists of two back to back connected IGBT based voltage source bi-directional converters with a common DC bus. One inverter is connected in series, while the other one is placed in shunt with the nonlinear load. The inverter connected in shunt with the load acts as a current source for injecting compensating current. While, the supply side inverter connected in series with the load acts as a voltage source feeding compensating voltage, through an insertion transformer. A diode bridge rectifier feeding *RL* load is considered as nonlinear load. The Fig. 1 shows the simulated system which contains a source voltage, a non linear load and UPQC based FLC.

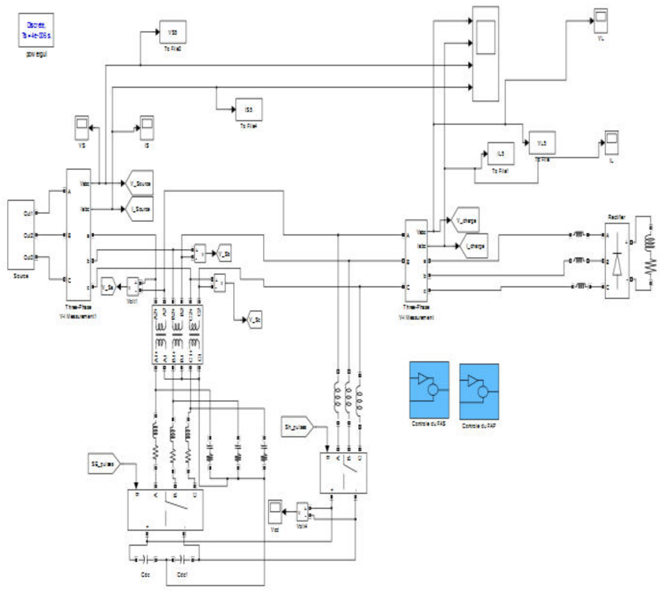

Fig. 1. Simulated system in matlab/simulink

### A. *Control of shunt active filter*

A fuzzy logic controller (FLC) converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database. In this work, the type of fuzzy inference engine used is Mamdani. As seen from Table 1, each interval of each variable is divided into seven membership functions: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB).

ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE 1
DECISION TABLE OF FLC

| Δu | | e | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | NB | NM | NS | Z | PS | PM | PB |
| Δe | PB | Z | PS | PM | PB | PB | PB | PB |
| | PM | NS | Z | PS | PM | PB | PB | PB |
| | PS | NM | NS | Z | PS | PM | PB | PB |
| | Z | NB | NM | NS | Z | PS | PM | PB |
| | NS | NB | NB | NM | NS | Z | PS | PM |
| | NM | NB | NB | NB | NM | NS | Z | PS |
| | NB | NB | NB | NB | NB | NM | NS | Z |

Fig. 2 shows the FLC's subsystem which has two inputs, the first one is the reference's harmonic currents and the second is the measured harmonic current. The PQ theory is adopted as control's algorithm.

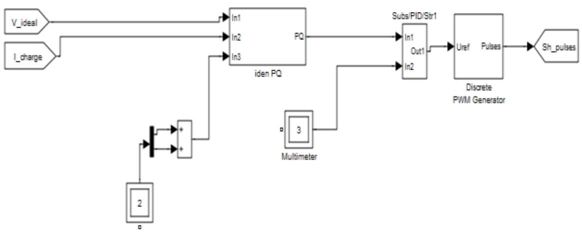


Fig. 2. Control of shunt active filter

Fig. 3 represents the implementation of the FLCs which are based on the error and the error's variation as inputs.

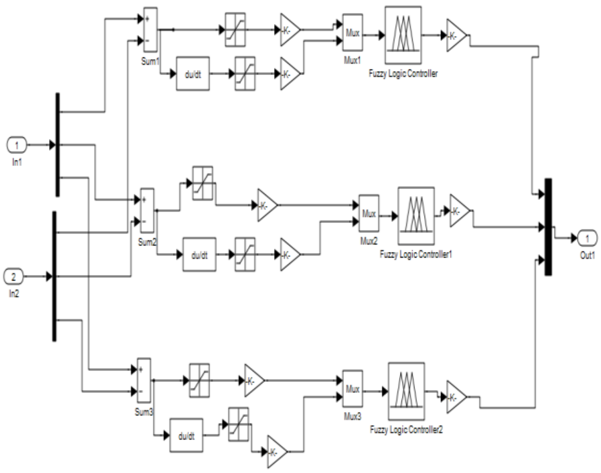


Fig.3. Fuzzy logic controller of Shunt active filter

The injected harmonic current for each phase is compared to its reference current. The error and error's variation are the input variables. The three FLC which control each phase are identical. The main objective of this work is to notice the behavior for these three FLC when we change the defuzzification function through the THD value of both voltage and current.

### *B. Description of FLC's parameters*

FIS Editor opens and displays a diagram of the fuzzy inference system with the names of each input and output variables.

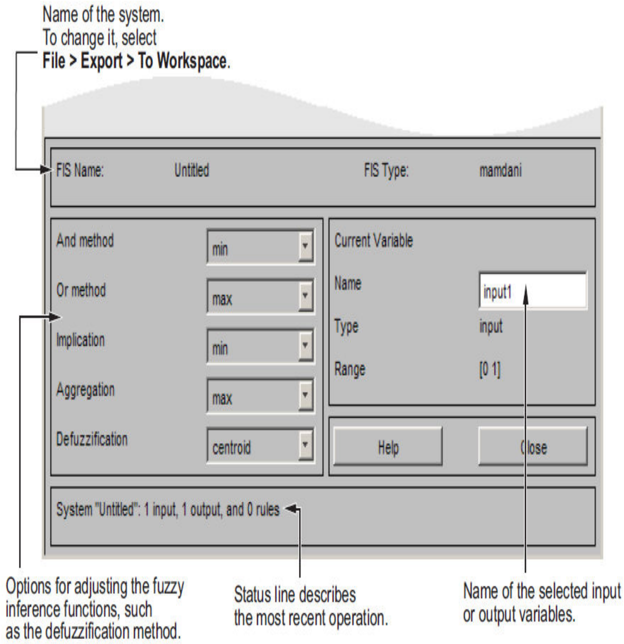


Fig. 4. FIS editor properties

Five pop-up menus are provided to change the functionality of the five basic steps in the fuzzy implication process:

• **And method**: Choose min, prod, or Custom, for a custom operation.

**Min:** It resolves the statement *A* AND *B*, where *A* and *B* are limited to the range (0,1), by using the function *min*(*A*,*B*).

**Prod:** It scales the output fuzzy set.

• **Or method**: Choose max, probor (probabilistic or), or Custom, for a custom operation.

**Max:** It resolves the statement *A OR B*, where *A* and *B* are limited to the range (0,1), by using the function max(*A*,*B*).

**Probor:** Probabilistic OR, y = probor(x) returns the probabilistic OR (also known as the algebraic sum) of the columns of x. if x has two rows such that x = [a; b], then y = a + b - ab. If x has only one row, then y = x.

• **Implication**: Choose min, prod, or Custom, for a custom operation.

• **Aggregation**: Choose max, sum, probor, or Custom, for a custom operation.

**Sum:** Simply the sum of each rule's output set.

• **Defuzzification**: For Mamdani-style inference, choose centroid, bisector, mom, som, lom, or Custom, for a custom operation.

**Centroid:** Centroid defuzzification returns the center of area under the curve. If you think of the area as a plate of equal density, the centroid is the point along the x axis about which this shape would balance.

**Bisector:** The bisector is the vertical line that will divide the region into two sub-regions of equal area. It is sometimes, but not always coincident with the centroid line.

**Mom:** middle of maximum (the average of the maximum value of the output set).

**Som:** Smallest of maximum (the smallest of the maximum value of the output set).

**Lom:** Largest of maximum (the largest of the maximum value of the output set).

## III. SIMULATION

The simulation has been done under sags disturbance of -50% between 0.2s and 0.3s.

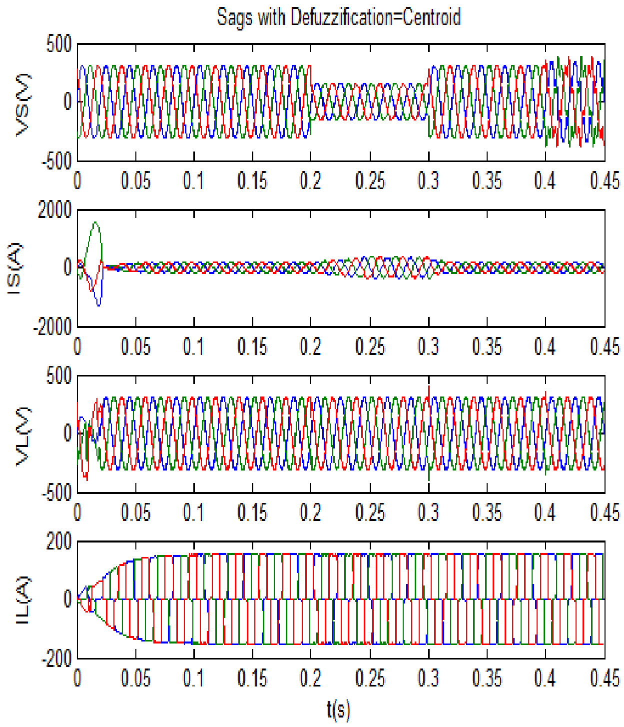


Fig. 5. Results with centroid defuzzification

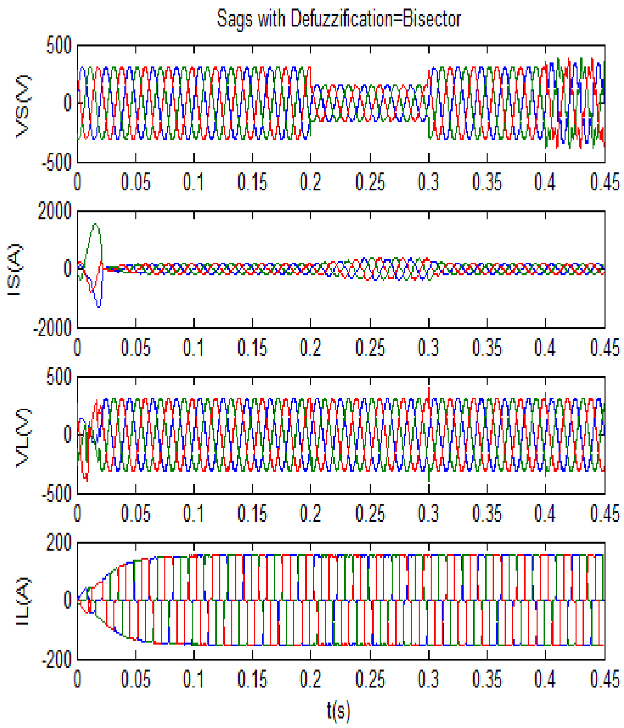


Fig. 6. Results with Bisector defuzzification

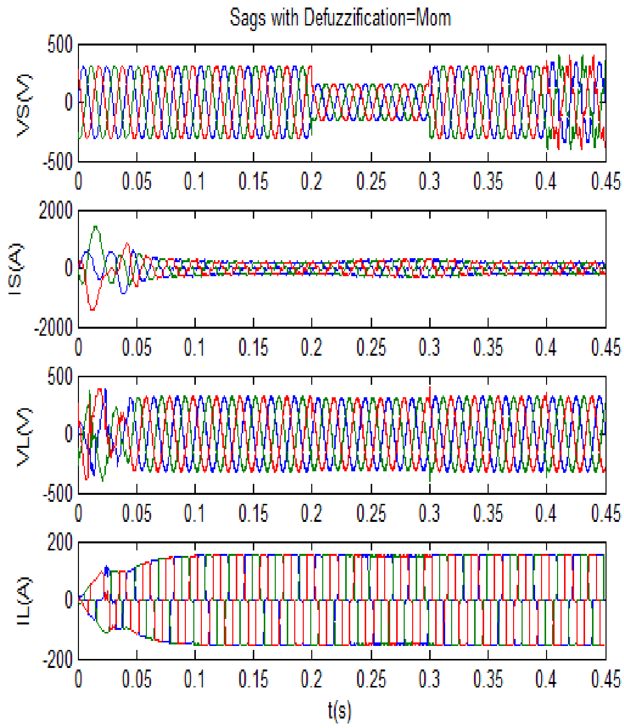


Fig. 7. Results with mom defuzzification

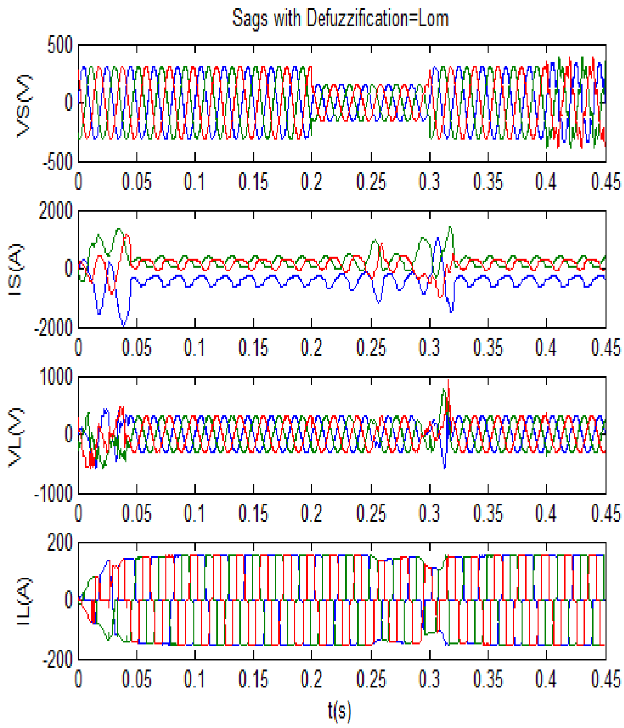


Fig. 8. Results with lom defuzzification

The defuzzification is a final operation of the fuzzy method which generates a crisp value. The choice of the defuzzification's function is very important. As we can see from the obtained results in Figures (from 5 to 9), the impact is significant according to the THD values (see Table 2). The defuzzification's functions Mom, Lom and Som are affected the supply current and their THD values are greater than the standard value according to the IEEE Std. 519-2014.

ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

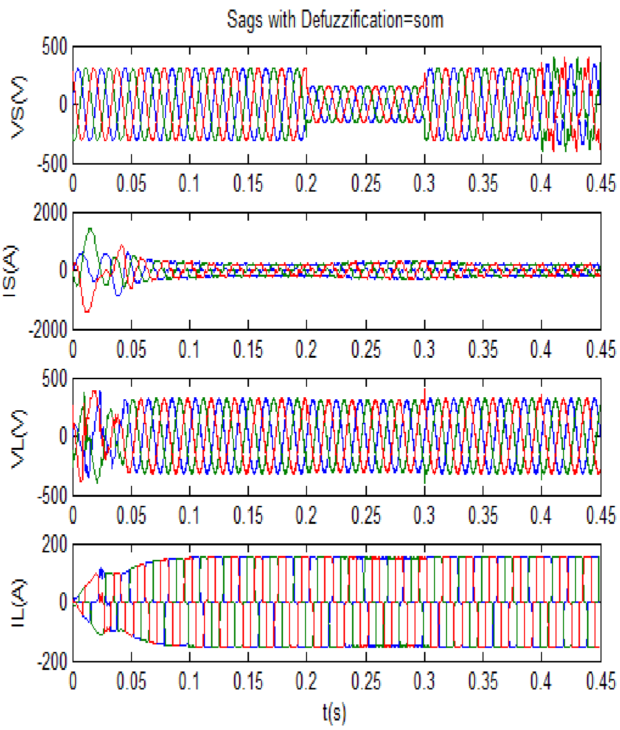


Fig. 9. Results with som defuzzification

The table 2 below gives the THD values for both voltage and current for different defuzzification's functions

TABLE 2
THD VALUES

| Defuz. | $V_{source}$ | $I_{source}$ | $V_{Load}$ | $I_{Load}$ |
|---|---|---|---|---|
| Centroid | 3.59% | 2.06% | 0.53% | 26.83% |
| Bisector | 3.59% | 2.06% | 0.53% | 26.83% |
| Mom | 3.66% | **25.56%** | 0.57% | 26.77% |
| Lom | 3.59% | **14.67%** | **5.73%** | 25.75% |
| Som | 3.66% | **25.56%** | 0.57% | 26.77% |

## IV. CONCLUSION

The fuzzy logic is an intelligent method which is more adapted for the non linear systems. The efficiency of the FLC depends strongly at each step of both the form and number of the membership functions, rules, and the weight which is always equal to unit in the majority of papers which, in contrast, could influence the results. The defuzzification is a final operation that determines the efficiency of the FLC, and its choice is very important. The centroid and the bisector have given better THD value than other defuzzifications' methods.

## REFERENCES

[1] B. Singh, K. Al-Haddad, and A. Chandra, "A review of active filters for power quality improvement," *IEEE Transactions on Industrial Electronics*, vol. 46, Issue: 5, pp.960–97, Oct. 1999.

[2] L.A. Moran, I Pastorini, J. Dixon, and R Wallace, "A fault protection scheme for series active power filters," *IEEE Transactions on Power Electronics*, vol. 14, Issue: 5, pp.928–938, Sept. 1999.

[3] Shu Hongchun, Liang Zuquan, Yu Jilai and Xu Liang, "A Novel Control Strategy for UPQC," *IEEE/PES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian,* pp. 1–4, *China*, 2005.

[4] C. Benachaiba, O. Abdelkhalek, S. Dib, M. Haidas, "Optimization of parameters of the unified power quality conditioner using genetic algorithm method," *Information Technology and Control*, vol.36, No.2, pp. 242–245, 2007.

[5] O. Abdelkhalek, C. Benachaiba, B. Gasbaoui, A. Nasri, "Using of Anfis and fis methods to improve the UPQC performance, " *International Journal of Engineering Science and Technology,* vol. 2(12), pp.6889-6901, 2010.

[6] C. Benachaiba, Ahmed M. A. Haidar, M. Habab, O. Abdelkhalek, "Smart Control of UPCQ within Micro grid Energy System," *ELSEVIER, Procedia Energy*, vol. 6, pp. 503–512, 2011.