INFLUENCE OF THE FLC'S PARAMETERS OF THE UPQC IN THE DISTRIBUTED GENERATION

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Abstract- The use of Distributed Generation (DG) has been increasing in recent years to fill the gap between both energy supply and demand. This paper presents the reaction of the Fuzzy Logic Controller (FLC) when its parameters change. It is located in the DC voltage control loop of the Unified Power Quality Conditioner (UPQC) which is used to improve the power quality of the distributed generation. The main contribution of this paper concerns the impact of the different parameters of the FLC which are generally used by default in the majority of the published papers. The obtained results show that the change of these parameters affects the compensation's characteristics of the UPQC.

Index Terms- Distributed Generation, Sags voltage, Series active filter, Shunt active filter, UPQC, Wind turbine.

I. INTRODUCTION

With the augmentation of electrical energy consumption in the world- due to the process of industrialization, the electrical power generation by classical methods needs increase to fill the gap between demand and supply by using new clean generation techniques, such as, wind, solar, and micro turbines. These alternative methods are called dispersed or Distributed Generation (DG) of electrical energy. Environmental policies or concerns are probably the major driving force of the demand for distributed generation in Europe. Environmental regulations force players in the electricity market to look for cleaner- energy and cost-efficient solutions. Many of the distributed generation technologies are recognized environmentally friendly [1].

The development of power electronic technology makes it possible to realize many kinds of Flexible Alternating Current Transmission Systems devices to obtain high quality electric energy and enhance the control over power system. As result of this innovation, the implementation of Active Power Line Conditioner like Unified Power Quality Conditioner (UPQC) in DG systems to improve the power quality is gaining greater importance. The Unified Power Quality Conditioner, UPQC, is a worthwhile equipment that provides power quality compensation since it is able to mitigate power quality issues of the utility current and of the load voltage, simultaneously. In this way, many studies have been focused on improving the UPQC effectiveness and robustness, as well as ensuring its viability in high power grids [2] [3].

The main contribution of this paper concerns the impact of the different parameters of the FLC which are generally used by default in the majority of the published papers. The obtained results show that the change of these parameters affects the characteristics of compensation which are represented by the THD value.

II. DESCRIPTION OF THE SIMULATED SYSTEM

The simulation in (Fig.1) concerns a distributed generation system which contains a FACTS device called UPQC based Fuzzy Logic Controller, two passive filters which are tuned on the harmonics of rank 5 and 7 and both loads linear and non linear. The wind speed is maintained to 10 m/s. The generator is an asynchronous model. The wind energy is transformed into mechanical energy by wind turbine whose rotation is transmitted to the generator by a mechanical drive train [4].

The equations below present the modeling of the wind turbine:

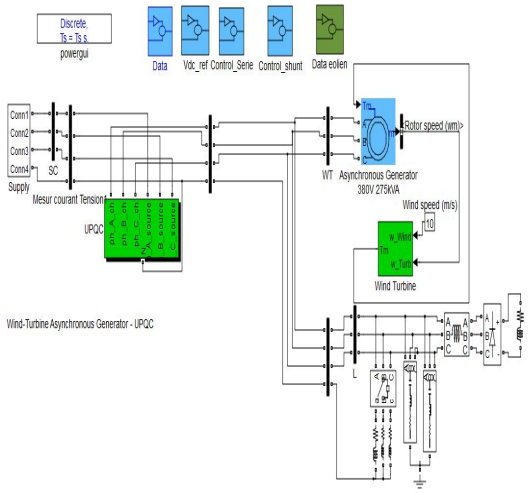


Fig. 1 The simulated system

$$P_t = \frac{1}{2}\rho\pi r^2 V^3 C_p(\lambda,\beta) \quad (1)$$

$$C_p(\lambda,\beta) = \frac{1}{2}(\Gamma - 0.022\beta^2 - 5.6)e^{-0.17\Gamma} \quad (2)$$

$$\lambda = \frac{w.r}{V} \quad (3)$$

$$\Gamma = \frac{r.(3600)}{\lambda.(1609)} \quad (4)$$

where, P_t [W] is the extracted power from the wind, ρ is the air density [kg/m3], r is the turbine radius [m], V is the wind speed [m/s], β is blade pitch angle [deg], w is the rotational speed [rad/s], Cp is the turbine power coefficient which represents the power conversion efficiency and is a function of the ratio of the rotor tip-speed to the wind speed, λ is the tip speed ratio of the rotor blade tip speed to wind speed.

The torque coefficient and the turbine torque are expressed as follows [5-6]:

$$C_t = \frac{C_p.(\lambda)}{\lambda} \quad (5)$$

$$T_M = \frac{1}{2}\rho C_t(\lambda)\pi r^3 V^2 \quad (6)$$

III. UNIFIED POWER QUALITY CONDITIONER

UPQC is the integration of series and shunt active filters, connected back-to-back on the DC side, sharing a common DC capacitor. The series active filter of the UPQC mitigates the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt active filter is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance. It injects currents in the ac system so that the source currents become balanced sinusoidal and in phase with the source voltages. A basic functional block diagram of a UPQC controller is shown in Fig. 2 [7].

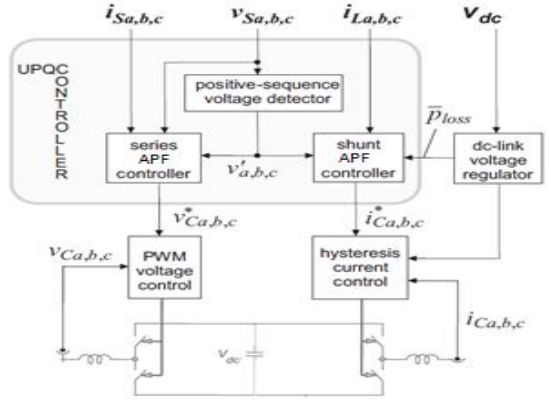


Fig. 2 Functional block diagram of a UPQC controller

A. UPQC control strategy

The control strategy can be separated to shunt strategy, series control strategy and DC capacitor control.

1. Shunt control Strategy

The shunt active filter (SHAF) is provided by the current and the reactive power (if the system needs) compensation. It acts as a controlled current generator that compensated the load current to force the source currents drained from the network to be sinusoidal, balanced and in phase with the positive-sequence system voltages.

2. Series Control Strategy

The series active filter (SAF) is provided by the voltage compensation. It generates the compensation voltage that synthesized by the converter and inserted in series with the supply voltage, to force the voltage at PCC to become sinusoidal and balanced.

3. DC Voltage controller

In compensation process, the DC side voltage will be changed because UPQC compensates the active power and the losses of switches, etc. If the DC voltage is not the same as the rating value, the output voltage of the series active filter will not equal to the compensation value. The compensation will not be correct. It is the same with the shunt active filter. The DC voltage regulator is used to generate a control signal to keep the voltage constant. It forces the shunt active filter to draw additional active current from the network. 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. Firstly, the error e (t) and the variation error Δe (t) have been placed of the angular velocity to be the input variables of the FLC. Then the output variable of the FLC is presented by the control voltage u (t). In this work, the type of fuzzy inference engine used is Mamdani type. The linguistic variables are defined as (NB, NM, NS, Z, PS, PM, PB) which mean Negative Big, Negative Medium, Negative Small, Zero, Positive Small, Positive Medium and Positive Big respectively. The fuzzy inference mechanism used in this work is given by Equation (7).

$$\mu_B(u(t)) = \max_i^m\left[\mu_{A1j}(e(t)), \mu_{A2j}(\Delta e(t)), \mu_{Bj}(u(t))\right]$$

Fuzzy output u(t) can be calculated by the centre of gravity defuzzification as:

$$u(t) = \frac{\sum_i^m \mu_B(\mu_i(t))\mu_i}{\sum_i^m \mu_B(\mu_i(t))} \quad (8)$$

Decision table (Table I) shows 49 rules of the two inputs (e and Δe) and one output (Δu). The example of the first rule is: If e is NB (Negative Big) and Δe is PB (Positive Big) then Δu is Z (Zero). The output is obtained by applying a particular rule according to the input values.

Table I
Decision table

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	NM	NM	NS	Z	PS
	NB	NB	NB	NB	NB	NM	NS	Z

IV. DESCRIPTION OF THE FLCS' PARAMETERS

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

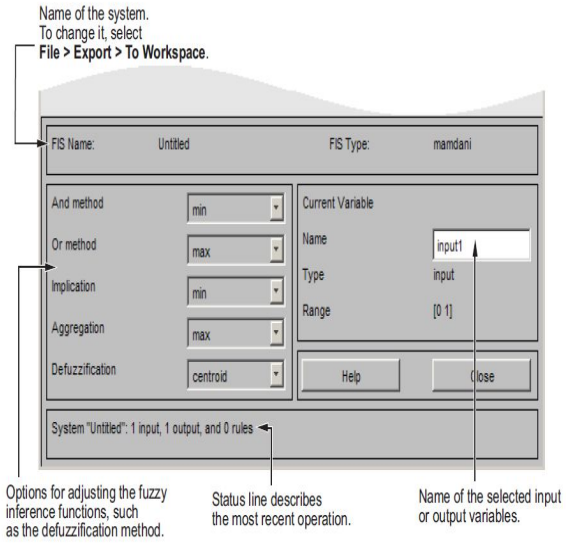


Fig. 3 FIS properties

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 (middle of maximum), som (smallest of maximum), lom (largest of maximum), 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).

V. SIMULATION AND DISCUSSION

FLC controller which has been chosen for evaluating the impact of its parameters is inserted in the DC voltage loop.

A. Parameters of the FLC with the unit weight

This first simulation is considered as a reference and the chosen parameters are below:

And method=min, Or method=max, Implication=min, Aggregation=max, Defuzzification=centroid, Connection=and, Weight=1

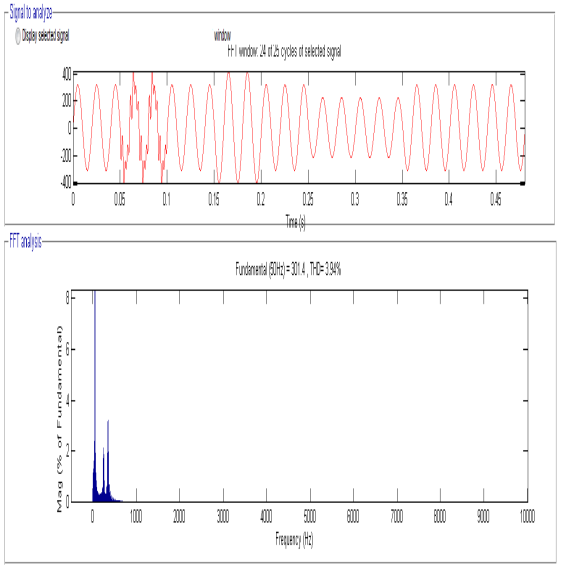


Fig. 4 Source voltage of the phase (a) and its specter

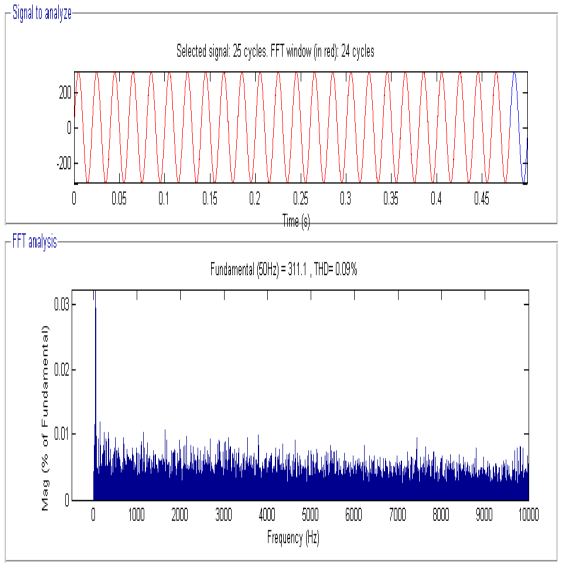


Fig. 5 Load voltage of the phase (a) and its specter

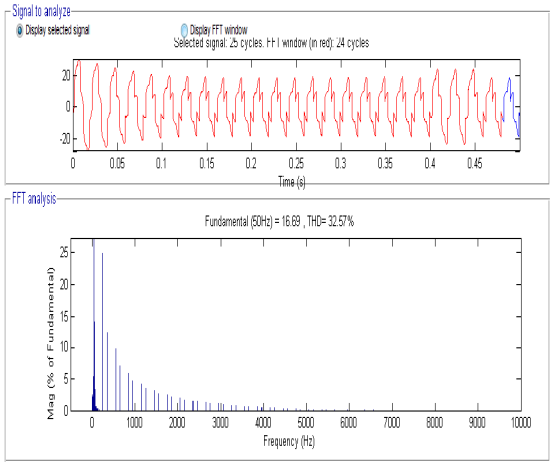


Fig. 6 Load current of the phase (a) and its specter

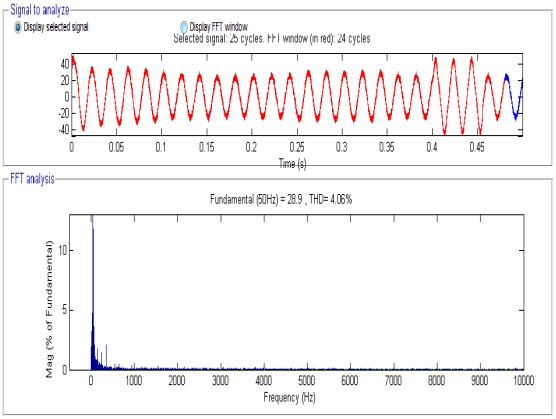


Fig. 7 Source current of the phase (a) and its specter

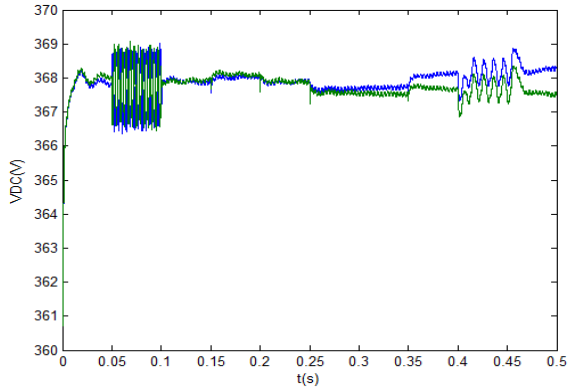


Fig. 8 DC voltage of UPQC

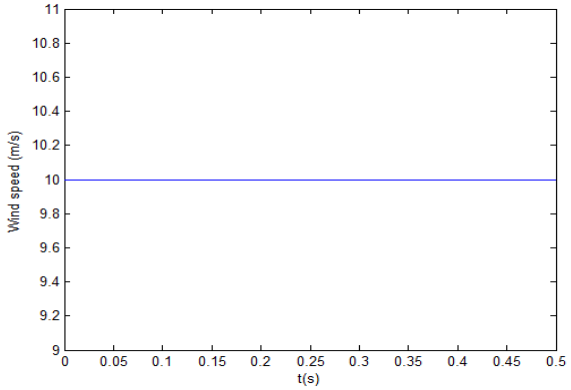


Fig. 9 Wind speed

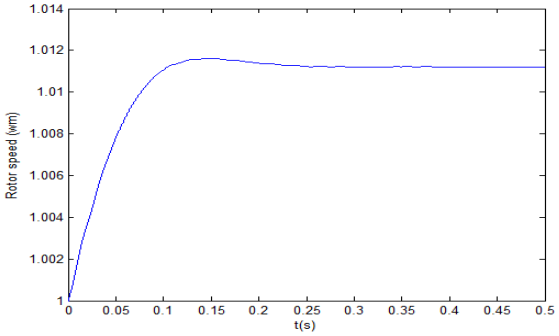


Fig. 9 Rotor speed

The source voltage (Fig. 4) has a THD value of 3.94% and contains three disturbances. The first one is caused by the harmonics 5 and 7 between 0.05 s and 0.1 s, the second represents a swell of 50% of the nominal voltage between 0.15 s and 0.2 s, and the last one is sags voltage of 50% between 0.3 s and 0.35 s. After compensation (Fig. 4), the load voltage is kept at nominal value with a THD value equal to 0.09%. The THD value of the non linear load (Fig. 6) is equal to 32.57%. The source current (Fig. 7) has become sinusoidal with a THD value of 4.06%. Each part of the split capacitor follows its reference voltage (Fig. 8). The impact of the voltage harmonics of the supply voltage is noticeable on the DC voltage between 0.05 s and 0.1 s but without significant impact on the load voltage. The wind speed (Fig. 9) is maintained constant at 10 m/s and the rotor speed too (Fig. 10), due to the control circuit.

B. Parameters of the FLC with the variable weight

And method=min, Or method=max, Implication=min Aggregation=max, Defuzzification=centroid, Connection=and, Weight= variable from 0.1to 1

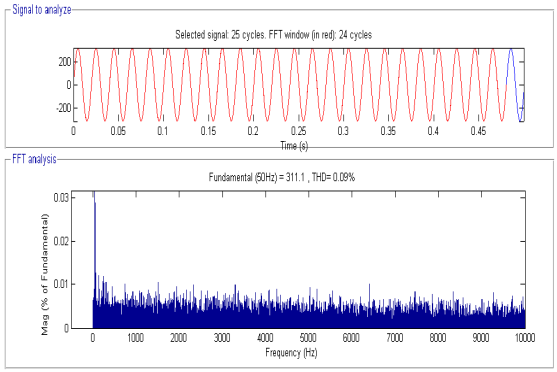


Fig. 11 Load voltage of the phase (a) and its specter

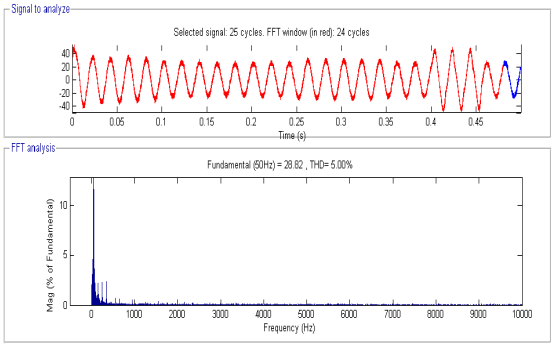


Fig. 12 Source current of the phase (a) and its specter

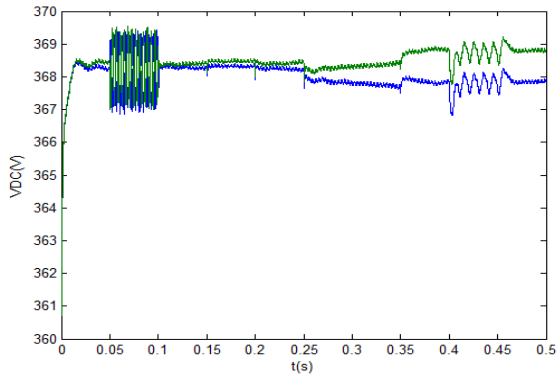


Fig. 13 DC voltage of UPQC

In this case, we have changed the weight value for evaluating its impact during the inference. Generally, the user of the membership fuzzy editor (mfedit) of MATLAB/SIMULINK uses the default value which is equal to 1. The supply and the load are kept at the same conditions as the first simulation. The load voltage (Fig. 11) remains without change with the same value of the THD. Otherwise, we have noticed that the THD value of the source current (Fig. 12) has endured a small change and is equal to 5%. Also, the DC voltage response (Fig. 13) shows a small divergence at the end but without significant influence on the THD value.

C. Parameters of the FLC with new functions

And method=prob, Or method=probor, Implication=min

Aggregation=probor, Defuzzification=som

Connection=and, Weight=1

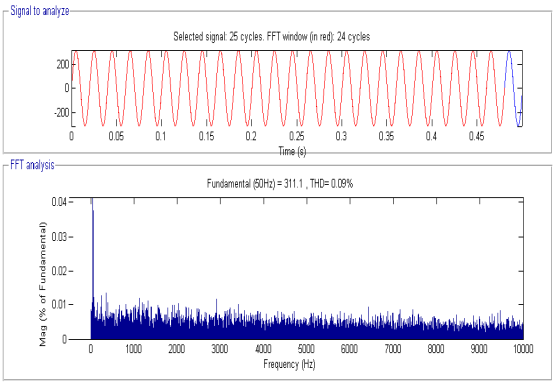


Fig. 13 Load voltage of the phase (a) and its specter

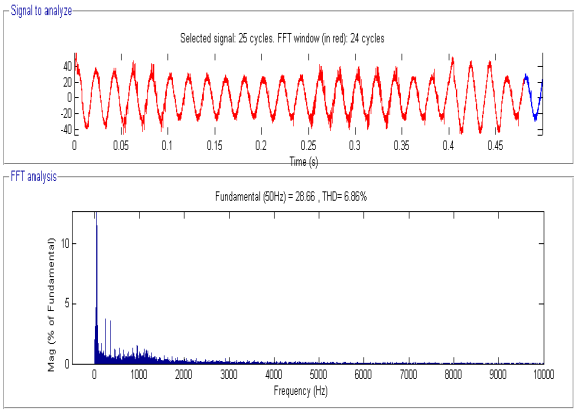


Fig. 15 Load voltage of the phase (a) and its specter

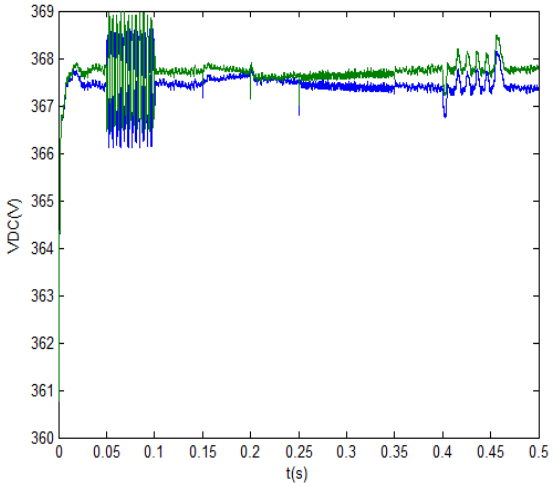


Fig. 16 DC voltage of UPQC

For this last simulation, we have changed the FLC's FIS properties of the DC voltage loop. All characteristics (Figs 14-16) are remained unchanged. The THD value of the source current has endured a small increase.

CONCLUSION

The FLC has become a solution when the classical controller does not satisfy the performance's criteria. Especially, when the non linearity of the model is more important but, the most users of this kind of control use the default parameters of the FIS proprieties. In this paper, we have presented the different functions which are contained in the membership fuzzy editor and also, we have used them for evaluating their impact on the behavior of the FLC which is inserted in the DC voltage loop of the UPQC. The obtained results show that the best choice of these parameters could be a way to improve the system's response such as the variation of the membership function's number or the different functions of the defuzzification. The obtained results in different cases have shown a small change of the behavior of the FLC.

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