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FUZZY CONTROLLER FOR A SHUNT ACTIVE POWER FILTER

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Abstract: The paper proposes an analysis for a fuzzy controller of a single-phase shunt active power filter, used to improve the power transfer in an electrical distribution system. With an inputs minimum number, the active component of the polluting loads current is determined by fuzzy techniques. Also, the active power filter can be used to feed a DC load. The results of a Matlab simulation show: improving power factor, stability in steady-state regime and proper response in two transient regimes.

Keyword: active power factor correction, fuzzy control

1. INTRODUCTION

Conventionally passive LC filters were used to reduce harmonics and capacitors were employed to improve the power factor of AC loads. The increasing problems of the harmonic pollution have attracted the attention on power electronic converters used to improve the quality in the electrical distribution network. Such equipment is known as active filters.

Series active powers filters, connected before the load in series with the mains, are used to eliminate voltage harmonics, to balance and to regulate the voltage of the load terminals. Shunt active power filters, mainly used in parallel at the load's terminals, inject a compensating current, to chancel harmonics and reactive components of the non-linear loads current.

A shunt active power filter comprises a current controlled voltage source inverter. Controller of this filter contains a circuit used to calculate the active component of the load currents and a current modulator to regulate the injected current in the electrical network.

Different controller strategies for active power filters, widely investigated, present the disadvantages that are difficult to implement in large scale, the control is complicated and the cost is high. Fuzzy techniques were employed in the control of the inverters, however, for the regulation of load currents.

This paper proposes to investigate fuzzy techniques for the determination of the active component of the load currents. As it can be seen from the next line, the main advantages of this solution are the simplicity, the possibility to use active filter as a rectifier with active power factor correction and the eliminating of the sensors for the load currents. A Matlab simulation is realized to verify the behavior of the active power filter with fuzzy logic controller. For the mathematical description of the power circuit is used the state variable method.

2. ACTIVE POWER FILTER WITH FUZZY CONTROLLER

Fig. 1 presents analyzed block scheme that comprises a non-linear (polluting) load and a shunt active power filter. The filter has a power circuit (a current controlled voltage source inverter) and a controller. On the DC side of the filter can be connected a DC consumer. Only the voltage across the DC capacitor and the current absorbed from generator have to be measured.

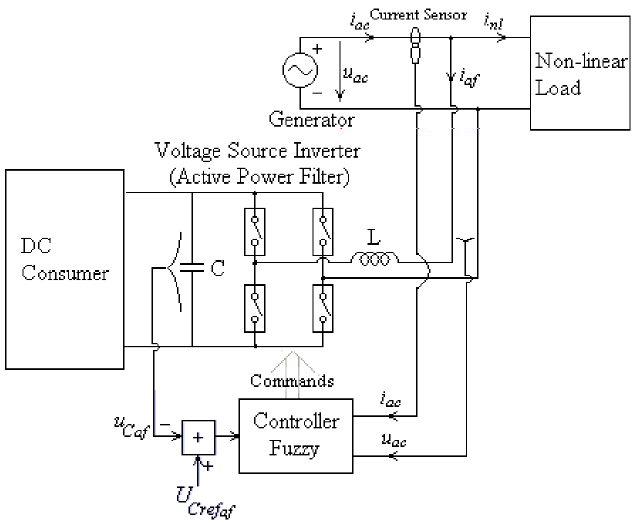


Fig. 1. Shunt active power filter with fuzzy controller

If the current of the non-linear load is i_{nl}, the injected current of the active filter is i_{af} and the current absorbed from generator is i_{ac}, then

$$i_{ac} = i_{af} + i_{nl} .$$

Active power filter should have in view that

$$u_{ac} = R \cdot i_{ac} ,$$

where u_{ac} is the voltage of the generator and R is the resistance that represents the power consumers.

We remark that both absorbed currents by non-linear load and injected currents by active filter are not measured. Every harmonic polluting load can be connected in parallel with active filter, on the same side of the current sensor. Without losing its characteristics, the filter behaves like a rectifier with active power correction. Only the current absorbed from generator is measured by a sensor and controlled to follow a sinusoidal reference.

Control strategy is based on the matter that DC voltage across the filter's capacitor is controlled by adjusting the amplitude of the AC current absorbed from generator. When the voltage across the capacitor is decreasing, the accumulated energy on this is decreasing, and then the active filter should absorb energy into capacitor for a short time, so that it has to take a supplementary active component from generator. When the voltage across the capacitor is increasing, the accumulated energy on this is increasing and then the active filter should cede energy form capacitor for a short time, so that it has to inject a supplementary active component into electrical network. All this time, active filter is controlled in current, so that absorbed current from generator is sinusoidal.

Active power filter absorbs or cedes in electrical network an active component needful to maintain constant voltage across the DC condenser. Also, an active component is necessary to supply the consumer on the DC side of the active filter.

We conclude that fuzzy controller calculates the amplitude of the active component of the current absorbed from generator.

3. FUZZY CONTROLLER FOR CALCULUS OF ACTIVE COMPONENT

Fuzzy control block [1], fig. 2, generates the sinusoidal reference amplitude for the generator's current. The amplitude is controlled adjusting the error between the DC voltage of the active filter, u_{Caf}, and a preestablished reference voltage, u_{Crefaf}. The reference current absorbed from electrical network is synchronized with the generator's voltage.

The voltage error is low-pass filtered and applied to a Sample&Hold circuit, resulting the error signal *e(k)*. One can be considered that the inputs of the fuzzy controller, discrete values, are the error of the DC condenser voltage *e(k)* and its incremental variation

$d(k) = e(k) - e(k-1)$,

which are amplified (by GD and GE, respectively) to assure the variation into the allowed domain of the fuzzy controller [-1;1].

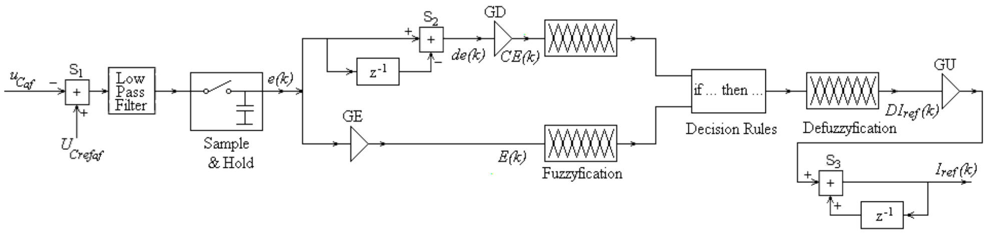


Fig. 2. Fuzzy control block for determination of active component

The output of the fuzzy controller is the incremental variation of the reference current amplitude, $DI_{ref}(k)$. Also, this value is amplified (by GU). The amplitude of the reference current results

$I_{ref}(k) = GU \cdot DI_{ref}(k) + I_{ref}(k-1)$.

The fuzzy controller used in applications with power factor correction was few investigated. There is a lot of room for research and results.

The main characteristics of the fuzzy controller used in next analysis are [1,2]:

- seven fuzzy sets for each of the two inputs;
- seven fuzzy set for the output;
- triangular membership function;
- fuzzyfication using continuous universe of discourse;
- AND operation using "min" operator;
- OR operation using "max" operator;
- defuzzyfication using the "centroid" method.

The seven triangular membership functions used for fuzzyfication-defazzyfication are represented in fig. 3. These correspond to fuzzy sets: negative big (NB), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM) and positive big (PB).

The rules of the fuzzy controller has the form

if (E is MF1) AND (DE is MF2) THEN (DI_{ref} is MF3),

where MF1, MF2 and MF3 could be one of the fuzzy set presented before.

The used rules are exposed in table I.

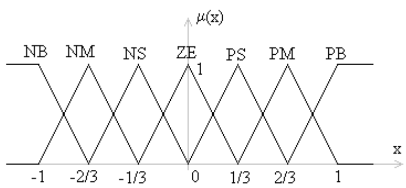


Fig. 3. Membership functions of the fuzzy controller

Table I. The rules of the fuzzy controller

Inputs	E							
	Output	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
	NB	NB	NB	NB	NM	NM	PS	PM
	NM	NB	NB	NM	NS	NM	PM	PB
	NS	NB	NB	NM	NS	NS	PM	PB
CE	**ZE**	NB	NM	NS	ZE	PS	PM	PB
	PS	NB	NM	PS	PS	PM	PB	PB
	PM	NB	NM	PM	PS	PM	PB	PB
	PB	NM	NS	PM	PM	PB	PB	PB

4. MATLAB SIMULATION

Fig. 3 presents the circuit used for Matlab simulation. The non-linear load (polluting consumer) is a full-bridge rectifier with LC filter. The power circuit of the shunt active power filter is a current-controlled voltage source inverter. A resistor, R_{saf}, represents the DC consumer on the DC side of the active filter.

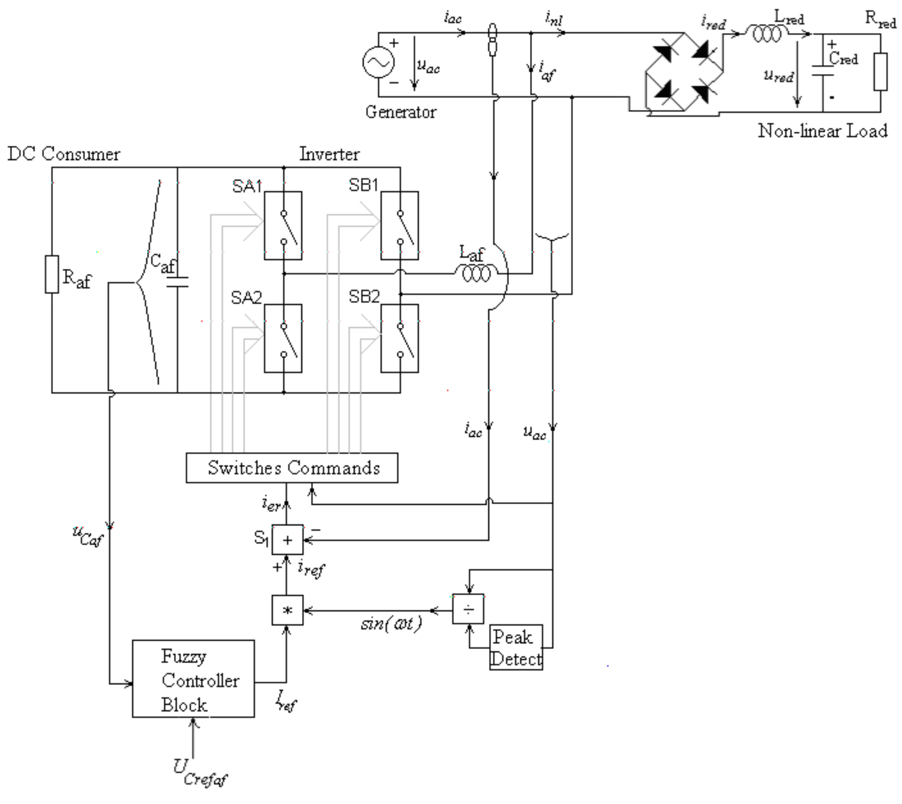


Fig. 3. The circuit used for simulation

The amplitude of the reference current is determined by fuzzy block, presented before. A sinusoidal frame, extracted from feeding voltage multiplies this amplitude. The error current is obtained subtracting from the reference current the current absorbed from generator. The error current is applied to a hysteresis modulator to obtain the switching signals.

The voltage across DC capacitor, u_{Caf}, is sampled with the frequency of the main generator.

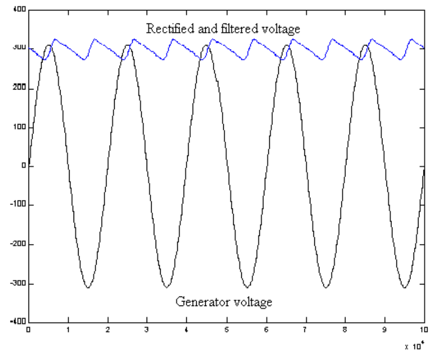
The other values used for simulation are: $u_{ac}(t) = 310 \cdot \sin(2\pi \cdot 50 \cdot t)$, $N_{itper}=20000$ (number of iterations into a period), $I_{er}^{+} = -I_{er}^{-} = 1A$ (thresholds of the hysteresis comparator),

$U_{Cref}=400V$, $R_{red}=40\Omega$, $L_{red}=1mH$, $C_{red}=1000\mu F$, $L_{fa}=0.1mH$, $R_{Lfa}=0.1\Omega$ (series resistance of the inductance L_{af}), $C_{af}=1000\mu F$, $R_{Caf}=0.1\Omega$ (series resistance of the capacitor C_{af}), $R_{sfa}=1Meg\Omega$, GE=GD=0,333, GU=3.

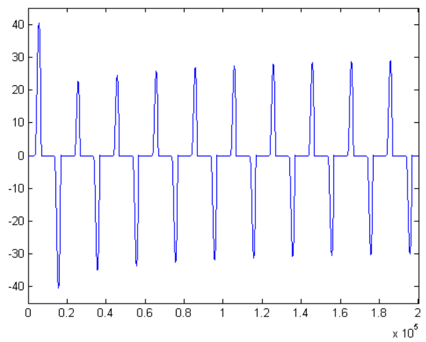
The power circuits of the shunt active power filter and the rectifier were simulated on the basis of the state variable method [3,4].

Fig. 4 presents simulation results for steady-state regime. The active filter increases the power factor from 0,67 (rectifier terminals) to 0,99 (generator terminals).

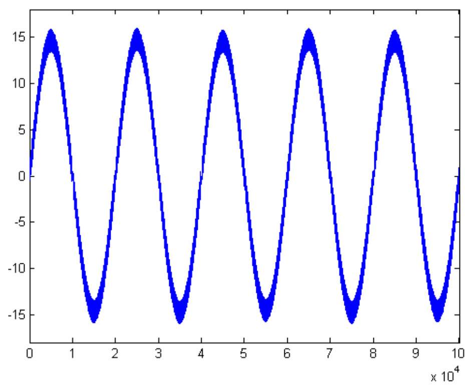
Fig. 5 and fig.6 presents simulation results in transient regimes.



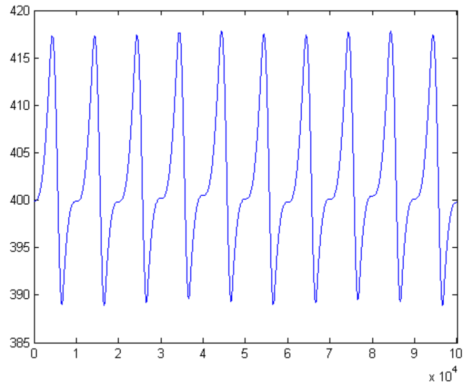
a) Generator voltage and rectified voltage



b) Current absorbed by rectifier

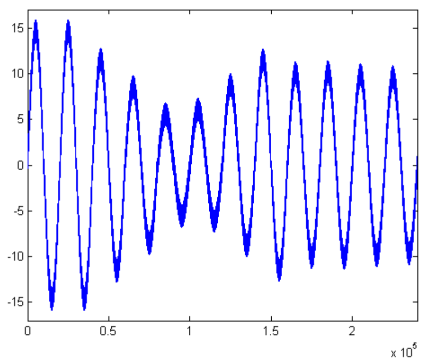


c) Generator current (filtered)

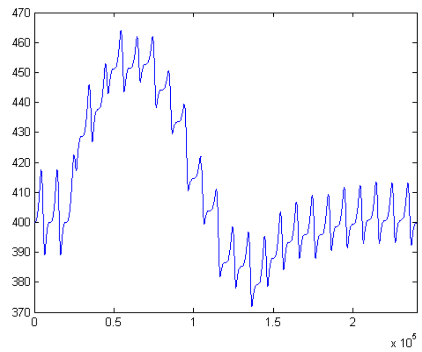


d) DC condenser voltage of active filter

Fig. 4. Simulation results in steady-state regime

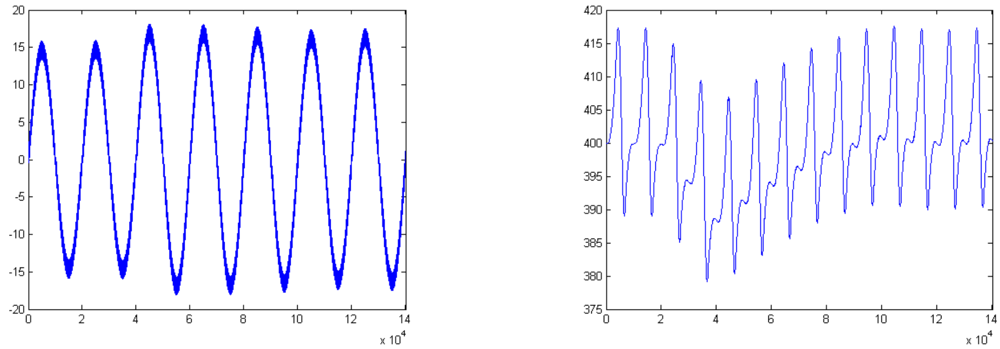


a) Current generator (filtered)



b) DC condenser voltage of active filter

Fig. 5. Simulation results for transient regime, when rectifier's load becomes 60Ω at moment ωt=2π (iteration=2x10[4])



a) Current generator (filtered) b) DC condenser voltage of active filter

Fig. 5. Simulation results for transient regime, when DC load of active filter becomes 650Ω, at moment $\omega t=2\pi$ (iteration=$2x10^4$)

5. CONCLUSIONS

This paper introduces the fuzzy techniques for the controller circuit of a shunt active power filter, in order to calculate the active component of the polluting loads current.

One can mention among the advantages of the fuzzy controller for a shunt active power filter: the simplicity, the possibility to use the active filter as a rectifier with active power factor correction and the eliminating of sensors of the load current.

The results of Matlab simulation show improving power factor, stability in steady-state regime and proper response in two transient regimes: polluting consumer of electrical network and DC side consumer of active filter changes instantaneously its active power.

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