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Research Paper

Fuzzy Based Control of Shunt Active Filter for Harmonic Compensation for Application in Three Phase Four Wire Power System

Engineering

KEYWORDS : fuzzy control, power quality, harmonics, shunt active filters

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ABSTRACT

Non-linear loads, especially power electronic loads, create harmonic currents and voltages in the power systems. For many years, various active power filters (APF) have been developed to suppress the harmonics, as well as compensate for reactive power, so that the utility grid will supply sinusoidal voltage and current with unity power factor. Conventionally, a shunt APF is controlled in such a way as to inject harmonic and reactive compensation currents based on calculated reference currents. The injected currents are meant to "cancel" the harmonic and reactive currents drawn by the non-linear loads. In this paper the fuzzy control scheme for harmonic compensation using shunt active filter is presented and analyzed.

1. Introduction:

Among the various options available to improve power quality, the use of active power filters is widely accepted and implemented as a more flexible and dynamic means of power conditioning [1-2]. These shunt active power filters and series active power filters are basically pulse width modulated (PWM) current source inverters (CSI) and voltage source inverters (VSI), respectively. The drawbacks of the conventional passive filters such as huge size, problems associated with resonance, dependency on source impedance and fixed compensation. The hybrid filters combine passive and reactive filters reducing the effective cost.

The active power filter is expected to generate the appropriate compensating voltage/current signals that cancel the harmonic and reactive power components in the voltage/currents from the mains. The reference compensation signals are generated by making use of a control algorithm. The Instantaneous PQ theory by Akagi [3] and the synchronous detection method [4] are two of the most widely used control algorithms for three-phase shunt active power filters. There have been several published papers on various time-domain based shunt active filtering algorithms [5, 6]. In [7], a modification of Instantaneous Reactive Power Theory (IRPT) in conjunction with Discrete Fourier Transform (DFT) has been proposed to extract the reference compensation currents.

In all the above mentioned algorithms, the computation steps and the circuits involved remain complex. In this context, the authors had proposed a new, simple, three-phase, shunt active power filter algorithm [8]. In this paper, the proposed algorithm which is known as IcosΦ algorithm is compared with the Time-Domain Current Detection (TDCD) algorithm [9], Synchronous Reference Frame Theory (SRF) [10] especially for an AC voltage controller feeding an induction motor while the motor is being started. The simulation results have been presented for both the algorithms to compare the effectiveness and simplicity of one over the other.

2. Shunt Active Filter

Fig.1 presents the electrical scheme of a shunt active filter for a three-phase power system with neutral wire, which is able to compensate for both current harmonics and power factor. Furthermore, it allows load balancing, eliminating the current in the neutral wire. The power stage is, basically, a voltage-source inverter controlled in a way that it acts like a current-source [11]. From the measured values of the phase voltages (va, vb, vc) and load currents (ia, ib, ic), the controller calculates the reference currents (ica*, icb*, icc*, icn*) used by the inverter to produce the compensation currents (ica, icb, icc, icn). This solution requires 6 current sensors and 4 voltage sensors, and the inverter has 4 legs. For balanced loads (three-phase motors, three-phase adjustable speed drives, three-phase controlled or non-controlled rectifiers, etc) there is no need to compensate for the current in neutral wire. These allow the use of a simpler inverter (with only three legs) and only 4 current sensors. It also eases the controller calculations.

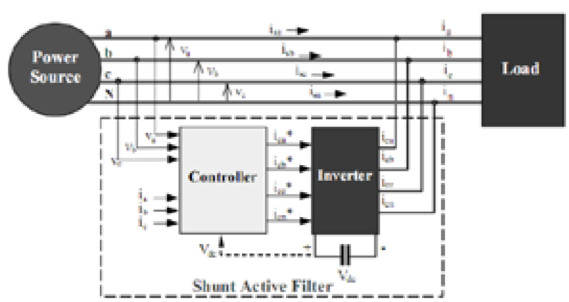

Fig.1 Shunt active filter in a three-phase four wire power system

3. Fuzzy Logic controller

As shown in Fig.2 the fuzzy control algorithm is implemented to control the load phase voltage based on processing of the voltage error e(t) and its variation Δe (t) in order to improve the dynamic of SAF.

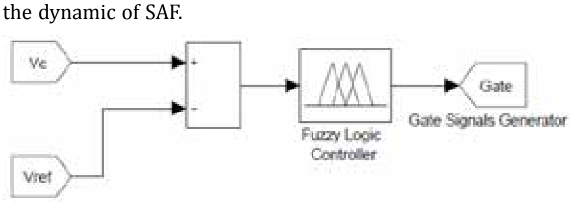

Fig.2. Fuzzy controller structure block diagram

The main advantages of fuzzy control are its linguistic description, independence of mathematical model, robustness, and its universal approximation [12]. As shown in Fig.3 the fuzzy logic controller is consisting of four stages: fuzzification, knowledge base, inference mechanism and defuzzification.

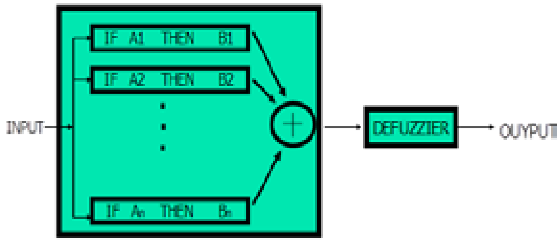

Fig.3 the basic scheme of fuzzy logic controller

The knowledge base is composed of a data base and rule base and is designed to obtain good dynamic response under uncertainty in process parameters and external disturbances. As shown in Fig.4 the data base consisting of input and output membership functions provides information for the appropriate fuzzificztion operations, the inference mechanism and defuzzification. The inference mechanism uses a collection of linguistic rules to convert the input conditions into a fuzzified output. Finally, defuzzification is used to convert the fuzzy outputs into control signals.

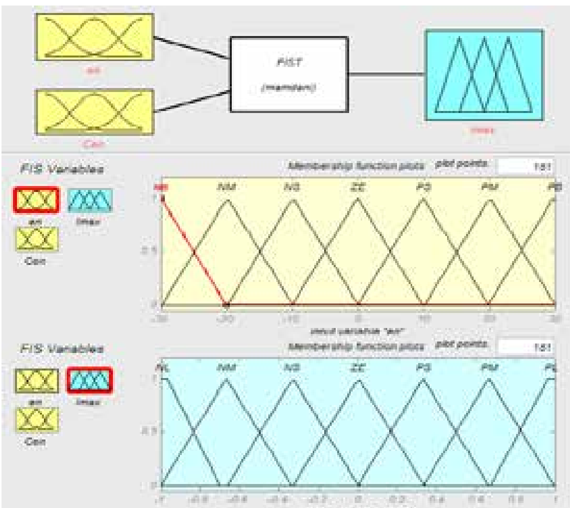

Fig.4 the GUI interface of fuzzy logic controller setting in MATLAB

In designing of a fuzzy control system, the formulation of its rule set plays a key role in improvement of the system performance. These rules are listed in Table 1.

Table 1.Fuzzy rule set used in fuzzy controller of series active filter

e(n)	Ce(n)					
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

As shown in Fig.5 the setting of fuzzy rules in MATLAB environment software is presented.

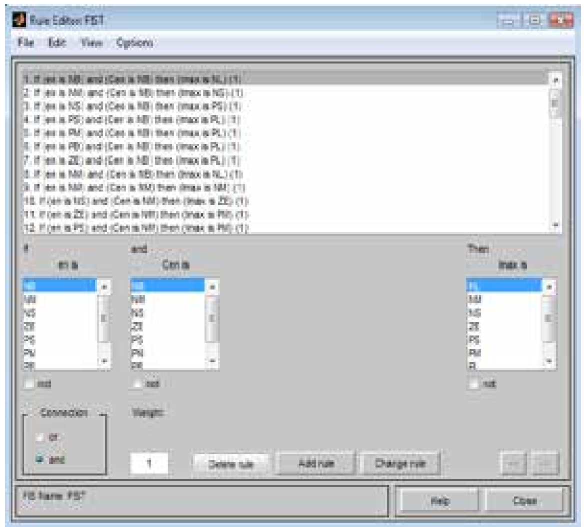

Fig.5.Setting of fuzzy rules in MATLAB

The desired switching signals for the filter inverter circuit are determined according to the error in the filter current using fuzzy logic controller.

The parameters for the fuzzy logic current controller used in this paper are as follow [13].

- The design uses centrifugal defuzzification method.
- There are two inputs; error and its derivative and one output, which is the command signal to the PWM of the filer inverter.
- The two input uses Gaussian membership functions while the output use triangle membership function.

Fig.6 shows the degree of membership for the error and its derivative and the command signal respectively.

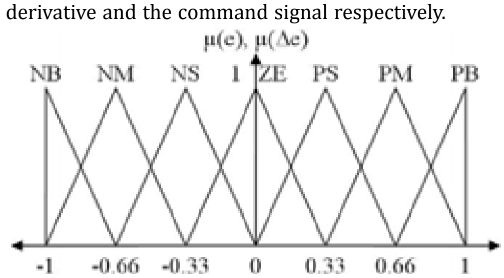

Fig.6 Membership functions for (e) and (Δe)

4. Simulation and Results

In this section the influence of shunt active power filter on harmonic compensation is analyzed Figure 7 presents the load currents which is harmonic distorted in each phase. The active filter compensation currents and the source currents for the three phases and neutral wire are shown in Figures 8 and 9. It can be seen that, by action of the shunt active filter, the power supply phase currents become balanced, sinusoidal

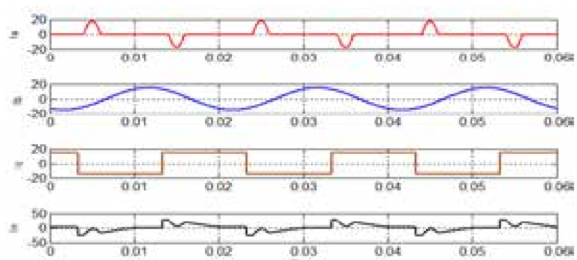

Fig.7. Load currents waveforms

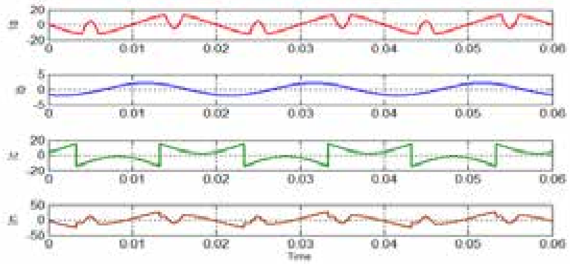

Fig.8.Active filter compensation currents waveforms

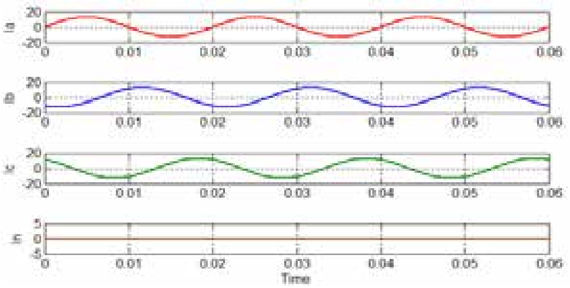

Fig.9. Source currents waveforms

It is interesting to observe that the load neutral wire current is even larger than the phase currents at load (the vertical scale of the neutral wire load current waveform is larger than the one of the load phase currents), but this current vanishes in the source, because of the active filter compensation action.

Figure 10 presents the waveform of the instantaneous three-phase power at load. It's mean value corresponds to the conventional three-phase active power, consumed by the loads of phases a, b and c.

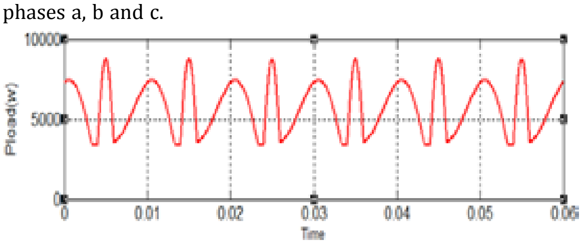

Fig.10. Instantaneous power at load

The indices of harmonics have been calculated using developed simulation model as shown in Figure 11.

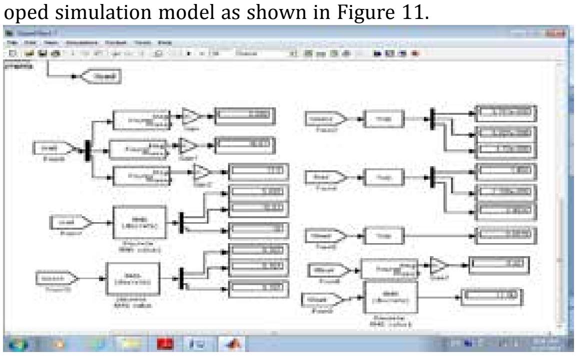

Fig.11. Harmonics indices evaluation in Matlab/Simulink developed model

Tables 2 and 3 present the values of the fundamental component of current (I1rms), the rms value of harmonic distorted current (Irms) in each phase and natural wire, displacement power factor (DPF), power factor (PF), and current total harmonic distortion (THD), respectively for the load and power supply. The values of THD are showed for the phase and neutral currents. The values of DPF and PF are presented to each of the phases.

Table 2 - I1rms, Irms, DPF, THD and PF values at load

Phase	I1rms(A)	Irms (A)	DPF	THD (%)	PF
Phase a	3.45	5.76	1.00	149.8	0.58
Phase b	11.43	11.43	0.75	0.00	0.75
Phase c	13.70	15	1.00	52.4	0.97
Neutral	9.22	11.16	--	48.6	-

Table 3 - I1rms, Irms, DPF, THD and PF values at power supply

Phase	I1rms(A)	Irms (A)	DPF	THD (%)	PF
Phase a	3.21	3.21	1.00	0.00	1.00
Phase b	11.43	11.43	1.00	0.00	1.00
Phase c	13.5	13.5	1.00	0.00	1.00

Comparing these two tables it is confirmed that the shunt active filter can compensate the power factor and the harmonic currents, turning then respectively into one and zero at power supply.

5. Conclusion:

This research deals with the power quality improvement of power electrical system. The harmonic compensation with attention of the growth of non linear load in system seems to be necessary. In this research the harmonic compensation in three phase four wire power system using active filter is addressed. This paper deals with fuzzy based control of shunt active filter in harmonic compensation. The proposed approach is simulated under MATLAB/SIMULINK and the results are presented also. The simulation results shows that the load neutral wire current is even larger than the phase currents at load (the vertical scale of the neutral wire load current waveform is larger than the one of the load phase currents), but this current vanishes in the source, because of the active filter compensation action.

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