Fuzzy Controller based Hybrid Active Power Filter for Energy Saving

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ABSTRACT
In this paper three leg Voltage source converter (VSC) based Hybrid Active Power filter (HAPF) is proposed for existing problems of harmonics, reactive power compensation, high total harmonic distortion (THD) and Power factor improvement for three phase non linear loads. In the system, a hybrid active power filters which is the combination of active filter and passive filter. The reference current has been generated by comparing load current, source current using fuzzy controller and pulses for switching VSC has been obtained by reference current generation. The main purpose is to get high quality power. The MATLAB was the simulation tool, used in the study, development, and performance evaluation of the Hybrid Active Power filter.

Keywords
Hybrid active power filter, Fuzzy controller, Non linear load, three phase supply

1. INTRODUCTION
Increasing demand of electric and electronic instruments including non-linear loads (e.g. computers, power electronic inverters and induction furnace) necessitates investigations about stability maintenance, continuous energy serving and power quality considering economic concerns. Non-linear loads result in voltage and current harmonics in distribution network.

Harmonic is defined as “a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency”. Harmonics provides main problems in network like power losses and excess heat. Thus, harmonic limitation seems to be vital. This nonlinear current having a high amount of harmonics distorts ac voltage at the point of Common coupling and therefore affects the other neighboring loads connected to the same system. Excessive reactive power demand increases feeder losses and reduces the active power flow capability of distortion system, whereas unbalancing affects the operation of transformers and generators. Nowadays, active power filters (APF) play effective role in distortion recognition and elimination. The use of the active power filter (APF) to mitigate harmonic problems has drawn much attention since the 1970s [1], [2]. APFs seem to be a feasible solution for eliminating harmonic currents and voltages. They are usually in parallel to harmonic loads and, therefore, are called shunt APFs. In recent years, there has been a trend to develop the shunt APF that can be used under non sinusoidal supply voltages, where the voltages at the PCC of the APF are harmonics-contaminated and caused by connecting nonlinear loads in the APF application environment. The control of SAF depends on two major factors: the first is extraction of reference currents, and second is the method of generation of pulse width-modulation (PWM) signals using these extracted reference currents.

They recognize current distortions by sampling the line current and compensate distorted current components to maintain sinusoidal source current. In most recommended grids, the reference signal can be extracted by sampling and analyzing the input voltages and load currents for harmonics. The parallel passive filters were implemented since 1920, to compensate harmonics caused by nonlinear loads and passive filter is often used at the point of common coupling conventionally. Passive filter will reduce only the selected harmonics and compensate reactive power. However it has many disadvantages such as mistuning, resonance, instability, etc however, they are limited by high cost, low-power capacity, and are difficult to use in high-voltage grids. Another solution for the harmonic problem is to adopt a hybrid active power filter (HAPF) [4].The HAPF is the combination of active and passive power filters. The aim in the HAPF design is to complement or enhance the performance of the active power filter or passive power filter by adding passive or active components to its structure. HAPF is categorized in parallel hybrid active power filters (PHAPFs) and series hybrid active power filters(SHAPFs) based on the used active filter type. A series of PHAPFs was proposed after the 1990s [8]–[10]. Cheng etal. proposed a new hybrid active power filter to achieve the power-rating reduction of the active filter [10]. But the active power filter still bears the fundamental voltage in this design. In this paper, a novel HAPF with injection circuit was proposed. The novel topology has great promise in reducing harmonics with a relatively low capacity APF. Hybrid active filter which is the combination of small rated active power filter and passive filter. The active connected in parallel and eliminates the harmonics in the line caused by nonlinear load and also improves the performance of passive filter. The passive filter will compensate the reactive power, some selected harmonics. In industrial and domestic sectors employing solid state control thus requiring the attention to the problem of harmonic pollution .This paper is aimed to propose three phase hybrid active filter with simple control scheme to mitigate harmonics to a considerable limit and compensate reactive power. The advantages of fuzzy logic controllers over the conventional PI controller are that they do not need an accurate mathematical model; they can work with imprecise inputs, can handle nonlinearity, and may be more robust than the conventional PI controller. This paper, therefore, presents an auto tuned active power filter using Mamdani fuzzy-controller to control the harmonics under variable load conditions apart from balanced and unbalanced load conditions.

2. HYBRID ACTIVE POWER FILTER

In a modern electrical distribution system, there has been a sudden increase of nonlinear loads, such as power supplies, rectifier equipment, domestic appliances, and adjustable speed drives (ASD), etc.As the number of these loads increased, harmonics currents generated by these loads may become very significant. These harmonics can lead to a variety of different power system problems including the distorted voltage waveforms, equipment overheating, malfunction in system protection, excessive neutral currents, light flicker, in accurate power flow metering etc. They also reduce efficiency by drawing reactive current component from the distribution network [8]. In order to overcome these problems, hybrid active power filters (HAPFs) have been developed. The voltage-source inverter (VSI)-based shunt hybrid active power filter has been used in recent years and recognized as a viable solution the control scheme, in which the required compensating currents are determined by sensing line currents only, which is simple and easy to implement.

2.1 Basic compensation principle

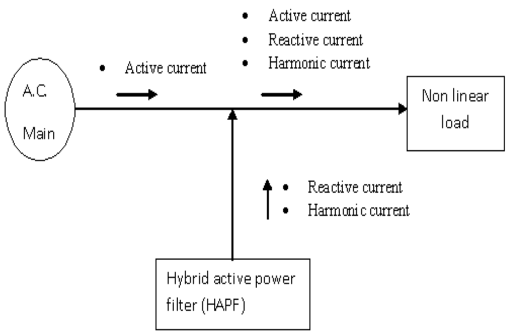

Fig 1: Connection of shunt hybrid active filter with nonlinear load

A current controlled voltage source inverter with necessary passive components is used as an HAPF as shown in fig 1. Passive filter is used along with active filter to reduce the harmonics and to improve its filtering performance. Pulse signal from controller is given as an input to activate the active filter. An opposite harmonics from active filter is injected to line at the Point of Common Coupling (PCC) by means of inductance and it will cancel the distorted harmonics produced and reactive power gets compensated. Now we get the undistorted output and its performance is increased and THD get reduced. In order to clarify the compensation principle of HAPF, a single-phase equivalent circuit is shown in Fig 2, where APF is considered a controlled current source I_{af}, and the nonlinear load is considered to be a harmonic current source I_f. U_s and L_s are $_{the}$ supply voltage and equivalent inductor of the grid C_f, and C_1, L_1 ,C_p and L_p are the injection capacitor, fundamental resonance capacitor, fundamental resonance inductor, and the PPF capacitor and inductor, respectively.

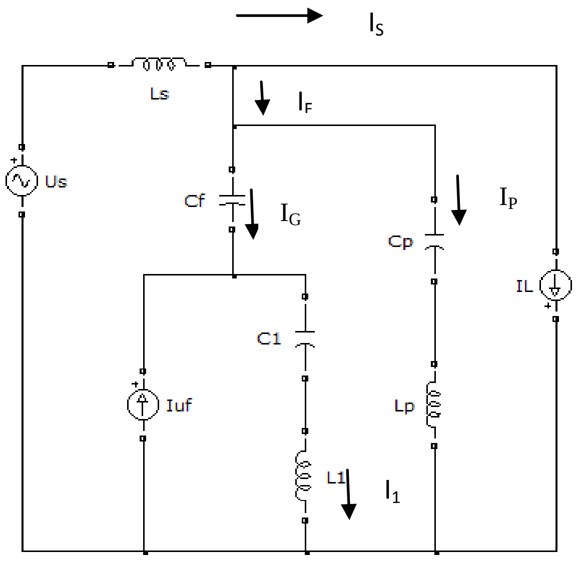

Fig 2: single phase compensation principle

2.2 Reference current calculation

The following equations describe the procedure used for reference compensation

$$I_{load} = I_{loadfund} + I_{harmonics} \quad (5)$$

$$I_{loadfund} = \left|I_{loadfund}\right| \sin\omega t \quad (6)$$

The load current is a periodic function and according to Fourier series

$$I_{LOAD} = +\frac{a_0}{2}\sum_{n=1}^{\infty}(a_n\cos(n\omega t) + b_n\sin(n\omega t))$$

where,

$$a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi} \text{Iload}(t)dt$$

$$a_n = \frac{1}{\pi}\int_{-\pi}^{\pi} \text{Iload}(t)\cos(nt)\,dt$$

$$b_n = \frac{1}{\pi}\int_{-\pi}^{\pi} \text{Iload}(t)\sin(nt)\,dt \quad (7)$$

$$I_{loadfund} = \sqrt{(a_n^2 + b_n^2)} \quad (8)$$

$$I_S^* = I_{loadfund} + I_{dc} \quad (9)$$

The reference compensating current is

$$I_S^* = I_{loadfund} + I_{dc}\sin\omega t \quad (10)$$

$$I_f^* = I_S^* - I_{l\ load} \quad (11)$$

$$I_F^* = I_{dc}\sin\omega t - I_{harmonics} \quad (12)$$

2.3 Principle of operation

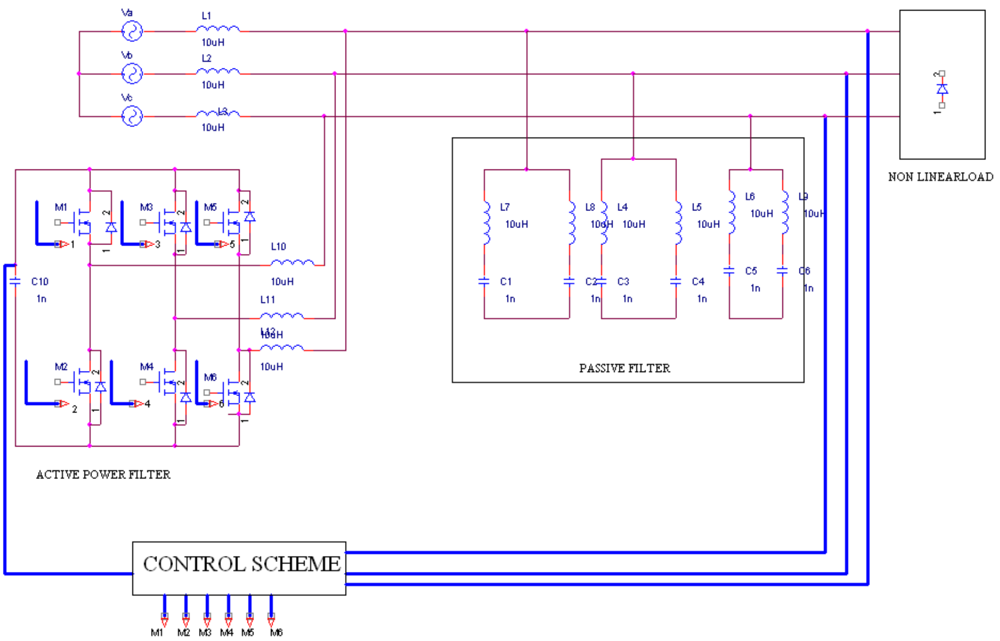

Fig 3: Proposed circuit diagram

Three phase supply is given as an input to the non linear load as shown in Figure 2.3. The non linear load will produce some distortion in output waveform. Due to this input also get affected and more losses, more power consumption and equipment get damaged. Passive filter is used along with active filter to reduce the harmonics and to improve its filtering performance. Reference current taken from the output side is compared with the input current and is given as an input to the Fuzzy controller. In Fuzzy controller the following step such as fuzzification, inference mechanism and defuzzification process takes place. Pulse signal from controller is given as an input to activate the shunt active filter. An opposite harmonics from active filter is injected to line at the Point of Common Coupling (PCC) by means of inductance and it will cancel the distorted harmonics produced and reactive power is compensated. Now we get the undistorted output and its performance is increased.

3. FUZZY CONTROLLER

The first step in creating a fuzzy model of a system is to "fuzzify" the inputs. This basically means applying fuzzy membership functions to the input assigning group memberships and membership values to input data. The second step is to use Zadeh's fuzzy set logic combined with knowledge about the system to make a set of inferences and associations between and among members in various groups. The last step is to "defuzzify" these inferences and associations and reach a decision or create some output for the system. This basic methodology, while very simply presented and conceptually discussed, can get very complex mathematically and logically. It is used in many different ways in many different arenas. Most of its applications to date have little or nothing to do with psychology: creation of machine intelligence and expert systems, complex machine control systems, robotics, computer processor design, man-machine interfacing, weather system modeling and endless uses in consumer products.

3.1 Operation of fuzzy controller

A Fuzzy Logic Controller (FLC) is composed of a knowledge base, that includes the information given by the expert in the form of linguistic control rules, a fuzzification interface, which has the effect of transforming crisp data into fuzzy sets, an Inference System, that uses them together with the knowledge base to make inference by means of a reasoning method, and a defuzzification interface, that translates the fuzzy control action thus obtained to a real control action using a defuzzification method

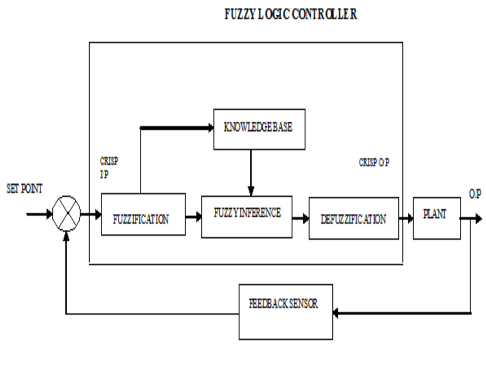

Fig 4: Fuzzy controller circuit diagram

Table 1. Fuzzy Control Rule Table

Δe	E						
	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	N	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

The fuzzy logic controller diagram is shown in Fig 3. The rule table for the fuzzy logic controller is indicated in Table I.The membership function is a graphical representation of the magnitude of participation of each input and membership diagram is shown in fig 5. It associates a weighting with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system.

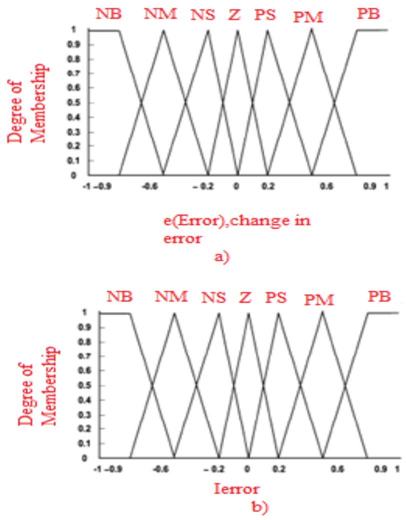

Fig 5: Membership functions for a) input variable e, input variable Δe, and b) output variable Ierror.

4. SIMULATION RESULT

The three phase nonlinear load with hybrid active power filter was simulated using MATLAB/SIMULINK.The non linear load connected to the three phase supply will produce distortion in voltage and current and THD value will be high. To eliminate the harmonics and to decrease thd fuzzy based HAPF was proposed. The source current waveform, source voltage waveform and output current waveform with fuzzy controller is shown in Fig 6, Fig 6.1, Fig 6.2. The voltage harmonics THD waveform of hybrid filter with fuzzy controller is shown in Figure 6.3.The current harmonics THD waveform of hybrid filter with fuzzy controller are shown in Figure 6.4.

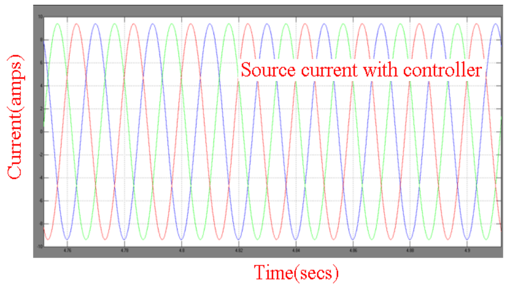

Fig 6: source current after compensation

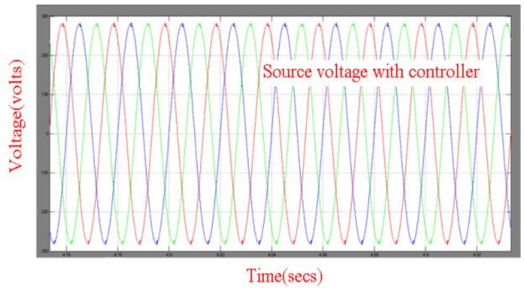

Fig 6.1: source voltage after compensation

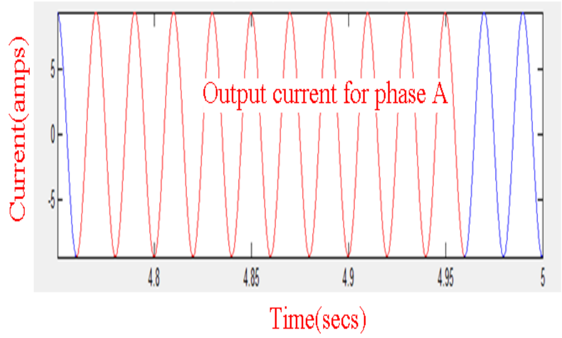

Fig 6.2: output current after compensation

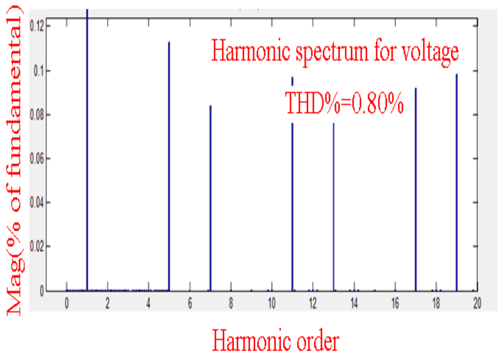

Fig 6.3: Voltage harmonics THD waveform

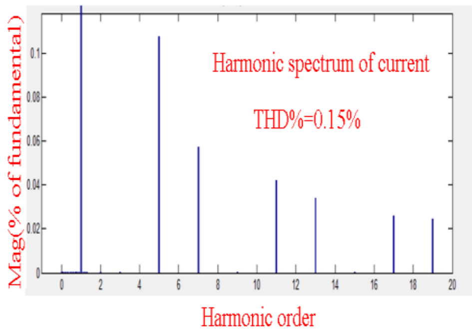

Fig 6.4: Current harmonics THD waveform

The comparison of hybrid filter before and after compensation, with and without controller was indicated in table 2

Table 2. Comparison between their THD values

Harmonics	THD value Without controller	THD value With controller
Current harmonics	26.45	0.15
Voltage harmonics	7.56	0.80

5.CONCLUSION

This paper describes about the Fuzzy logic based Hybrid Filter (HF) for non linear loads. The Fuzzy controller used for complex load and it reduce equation. The three leg VSC based hybrid filter is used along with fuzzy control in order to reduce THD below5% (IEE 519-1993), eliminate harmonics and reactive power compensation. For high power industrial power quality applications HAPF with non linear load active power based Fuzzy logic controller is efficient and economical. Using low cost (shunt connected active filter and passive filters) hybrid active power filter provides better performance in term of reduction in THD.

6. REFERENCES

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