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Review of Fuzzy Control Based APF for Power Quality Improvement

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ABSTRACT: A good power quality is an important factor for the reliable operation of electrical loads. The nonlinear loads such as compact fluorescent lamps, light-emitting diode lamps, switching mode power suppliers, induction motors give rise to serious challenges in power quality for power systems. Due to the non- linear load connected in the power system harmonics will presented, which effects power quality of the at the distribution level. Conventional PI, PD and PID controllers and fuzzy logic controllers are used to improve power quality. Fuzzy logic controllers (FLC's) have the advantages over the conventional controllers: they are cheaper to develop, fast, robust, they cover a wider range of operating conditions, and they are more readily customizable in natural language terms. Fuzzy logic controller is conjunction with the PLL synchronizing circuit as the controller for shunt APF facilitates improving power quality. For power quality improvement separate converter with shunt APF is used. The APF is controlled by d-q theory with hysteresis controller is used to generate gate pulses to inverter switches. The FLC ensures that the dc-side capacitor voltage is nearly constant with small ripple besides extracting fundamental reference currents. The PLL synchronizing circuit assists the active filter to function even under distorted voltage or current conditions. The shunt APF system is implemented with voltage source inverter and is connected in parallel at PCC for filtering the current harmonics and compensating the reactive power in traction system. The APF controlled by Fuzzy controller is modelled using MATLAB\Simulink. Another application of fuzzy logic controller are defence, underwater target recognition, automatic target recognition of thermal infrared images, naval decision support aids, control of a hypervelocity interceptor, satellite altitude *control*; flow and mixture regulation in aircraft de-icing vehicles automotive etc.

KEYWORDS: APF (Active Power Filter), Hysteresis Current Controller (HCC), PCC (Point of common coupling), Fuzzy logic controller.

I. INTRODUCTION

A good power quality is an important factor for the reliable operation of electrical loads.AC power supply feeds different kind of linear and nonlinear loads in traction applications. The non-linear loads produce harmonics and reactive power related problems in the utility systems. The harmonic and reactive power cause poor power factor and distort the supply voltage at the customer service point, increased power losses in customer equipment, power transformers and power lines, flicker, shorter life of organic insulation [1].

Conventionally passive filters are used to compensate the lagging power factor of the reactive load and suppress the harmonic problems, but these passive filters are having some drawbacks; such as resonance, large in size, weight, and are limited too few harmonics. Recently, Active Power Filters (APF) is developed for compensating harmonics and reactive power simultaneously. There are two main categories of APF exist: shunt filters and series filters. The active power filter topology can be connected in series for voltage harmonic compensation and in parallel for current harmonic compensation. Most of the applications need current harmonic compensation, so the shunt active filter is popular than series active filter. The shunt active power filter has the ability to keep the mains current balanced and sinusoidal after compensation regardless of whether the load is non-linear [1].

The feasibility of fuzzy logic controller along with PLL synchronization controller based shunt active power filter for the harmonics and reactive power mitigation due to the non-linear loads. The fundamental component of the reference current is extracted from load current using fuzzy logic controller methods and dc-side capacitor voltage of the inverter is continuously maintained constant. The voltage source inverter switching signals are generated from hysteresis band

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current control techniques. The proposed concept for shunt APF system is validated through extensive simulation with nonlinear load. [2]

II. LITRATURE SURVEY

Harmonics

Harmonic is multiple of the fundamental frequency and it can be voltage and current in an electric power system due to non-linear electric loads. Examples of nonlinear loads include transistors, electrical motors, and the non-ideal transformer. Non-linear loads create disturbances in the fundamental harmonic, which produce all types of harmonics. Harmonic frequencies in the power system are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors.

Current Harmonics

In a normal alternating current power system, the current varies sinusoidally at a specific frequency, usually 50 Hz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage.

Current harmonics are caused by non-linear loads. When a non-linear load, such as a rectifier is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. The current waveform as described through Fourier series analysis, it is possible to deconstruct it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency.

Total Harmonic Distortion

Total harmonic distortion (THD) is a common measurement of the level of harmonic distortion present in power systems. THD can be related to either current harmonics or voltage harmonics, and it is defined as the ratio of total harmonics to the value at fundamental frequency times 100%.

$$\mathrm{THD_V} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1} * 100\% = \frac{\sqrt{\sum_{k=2}^{n} V_k^2}}{V_1} * 100\%$$

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}}{I_1} * 100\% = \frac{\sqrt{\sum_{k=2}^{n} I_k^2}}{I_1} * 100\%$$

EXISTING CONTROL STRATEGIES

PI-Controller

Fig. 1 shows the block diagram of the proposed PI control scheme for the active power filter. The DC side capacitor voltage is sensed and compared with a reference voltage. This error

e =Vdc, ref−Vdcat

the *nth* sampling instant used as input for PI controller. The error signal is passed through Butterworth design based Low Pass Filter (LPF). The LPF filter has cut off frequency at 50 Hz that can suppress the higher order components and allows only fundamental components. The PI controller is estimate the magnitude of peak reference current Imax and control the dc-side capacitor voltage of voltage source inverter. Its transfer function is represented as

$$H(s) = K_P + \frac{K_I}{s} \qquad \text{........ (1)}$$

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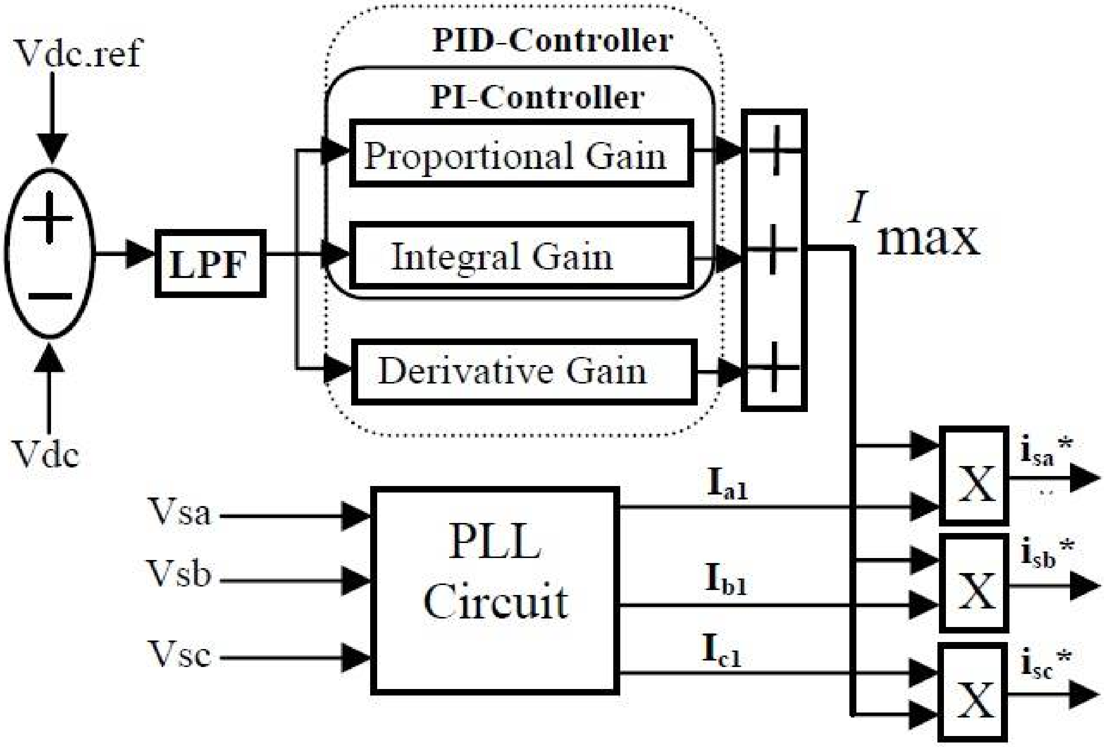

Fig. 1 Blok Diagram of the PLL with PI and PID controller

Where, [*KP*=0.7] is the proportional constant that determines the dynamic response of the Dc side voltage control and [*KI* =23] is the integration constant that determines it's settling time. The proportional integral controller is eliminating steady state error in the DC-side voltage.

PID Controller

Fig. 1 shows the block diagram of the proposed Proportional Integrator Derivative (PID) control scheme of an active power filter. The error

e = Vdc, ref−Vdcat

The *nth* sampling instant issued as input for PID controller. The error signal is passed through LPF; that can suppress the higher order components and pass only the fundamental component.

The PID controller is a linear combination of the P, I and D controller. Its transfer function can be represented as

$$H(s) = K_P + \frac{K_I}{s} + K_D(s) \quad \text{……..(2)}$$

Where, KP is the proportional constant that determines the dynamic response of the Dc-side voltage control, KI is the integration constant that determines it's settling time and KD is the derivative of the error representing the trends. The controller is tuned with proper gain parameters [KP =0.7, KI =23, KD =0.01] for estimating the magnitude of peak reference current Imax and control the dc-side capacitor voltage of inverter. The peak reference current multiplied with PLL output determines the desired reference current.

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III. SYSTEM SETUP

Comparison Between PI, PID And Fuzzy Logic Controller

PARAMETERS	PI CONTROLLER	PID CONTROLLER	FUZZY LOGIC CONTROLLER
Definition	The proportional integral controller produces an output which is the combination of outputs of the proportional and integral controllers.	The proportional integral derivative controller produces an output, which is the combination of the outputs of proportional, integral and derivative controllers.	Fuzzy controller converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model.
Input variables	PI controller uses numerical variables.	PID controller uses numerical variables.	Fuzzy logic uses Linguistic variables
Function	The proportional integral controller is used to decrease the steady state error without affecting the stability of the system.	The proportional Integral derivative controller is used to improve the stability of the system and to decrease steady state error.	Fuzzy controller improves the stability of the system and decrease steady state error than PID controller.
DC voltage Settling time	More	Less than PI controller	Very less
Stability	It tends to make the system unstable because it responds slowly towards the produced error.	It tends to make the system stable because it eliminates steady state error more faster than PI controller.	Fuzzy controller make system stable.
Performance in non linear system	Variable	Variable	Stable
Total harmonic distortion (THD)	More	Less than PI controller	Very less

Why Should We Use Fuzzy Controllers?

- It is very robust
- It can be easily modified
- It can use multiple inputs and outputs sources
- Much simpler than its predecessors (linear algebraic equations)
- It is very quick and cheaper to implement.

Architecture of Fuzzy Logic Controller

The architecture of the fuzzy logic controller shown in Fig. 2 includes four components: Fuzzifier, Rule Base, Fuzzy Inference Engine (decision making unit), and Defuzzifier.

Fuzzifier:

Fuzzy logic uses linguistic variables instead of numerical variables. In a control system, error between reference signal and output signal can be assigned as Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive small (PS), Positive Medium (PM), Positive Big (PB). The triangular membership function is used for fuzzifications. The process of fuzzification convert numerical variable (real number) to a linguistic variable (fuzzy number) so that it can be matched with the premises of the fuzzy rules defined in the application specific rule base.

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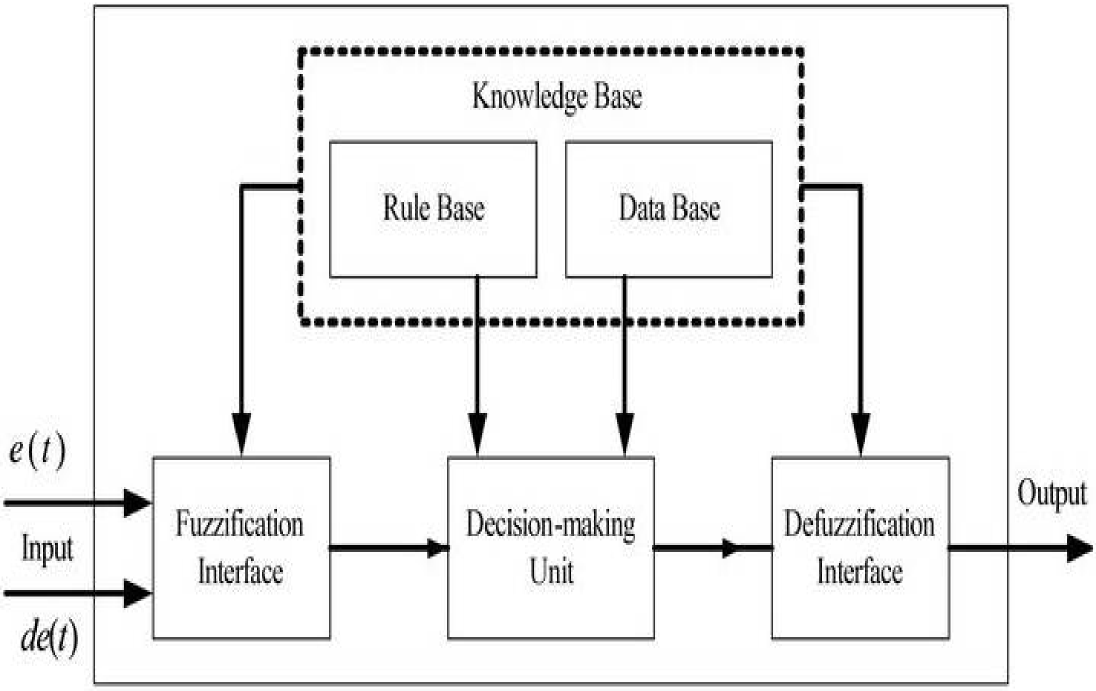

Fig. 2 Architecture of Fuzzy Logic Controller

Rule Base:
The rule base contains a set of fuzzy if-then rules which defines the actions of the controller in terms of linguistic variables and membership functions of linguistic terms. The Rule base stores the linguistic control rules required by rule evaluator (decision making logic).The output of the fuzzy controller is estimating the magnitude of peak reference current. This peak reference current comprises active power demand of the non-linear load and losses in the distribution system. The peak reference current is multiplied with PLL output for determining the desired reference current.

Database:
The Database stores the definition of the triangular membership function required by fuzzifier and defuzzifier.

Fuzzy Inference Engine:
The fuzzy inference engine applies the inference mechanism to the set of rules in the fuzzy rule base to produce a fuzzy output set. This involves matching the input fuzzy set with the premises of the rules, activation of the rules to deduce the conclusion of each rule that is fired, and combination of all activated conclusions using fuzzy set union to generate fuzzy set output.

Defuzzifier:
The rules of fuzzy logic controller generate required output in a linguistic variable (Fuzzy Number), according to real world requirements; linguistic variables have to be transformed to crisp output (Real number). This selection of strategy is a compromise between accuracy and computational intensity.

How Fuzzy Logic Controller works?
Fuzzy logic control is deduced from fuzzy set theory in 1965; where transition is between membership and non-membership function. Therefore, limitation or boundaries of fuzzy sets can be undefined and ambiguous; FLC's are an excellent choice when precise mathematical formula calculations are impossible. Fig. 2 shows block diagram of the

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fuzzy logic control scheme. In order to implement the control algorithm of a shunt active power filter in a closed loop, the dc capacitor voltage VDC is sensed and then compared with the desired reference value V_{DC},ref. The error signal:

$$e = V_{DC,ref} - V_{DC}$$

is passed through LPF with a cut off frequency that pass only the fundamental component. The error signal e(n) and integration of error signal is termed as ce(n) are used as inputs for fuzzy processing. The output of the fuzzy logic controller limits the magnitude of peak reference current Imax. This current takes care of the active power demand of the non-linear load and losses in the distribution system. The switching signals for the PWM inverter are generated by comparing the actual source currents isa, isb , isc with the reference current (isa*,isb*,isc *) using the hysteresis current control method.

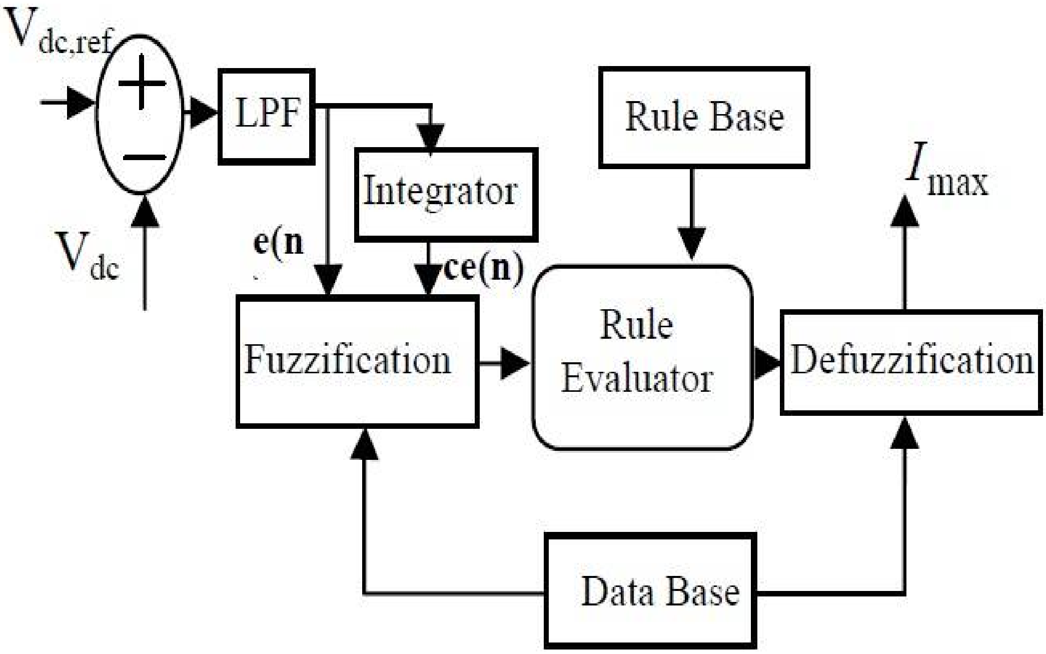

Fig 3 Fuzzy Logic Controller

Hysteresis Current Controller (HCC)

HCC is utilized independently for each phase and directly generates the switching signals for three phase voltage source inverter. An error signal e(t) is the difference between the desired current $I_{ref}(t)$ and the actual current I_{actual} (t). If the error current exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned OFF and the lower switch is turned ON. As a result, the current start to decay that is shown in Fig. 3. If the error current crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned OFF and the upper switch is turned ON.As a result, the current gets back into the hysteresis band [3].

The switching performance as follows:

$$S = \begin{cases} 0 & if\ i_{actual}(t) > i_{ref}(t) + h \\ 1 & if\ i_{actual}(t) < i_{ref}(t) - h \end{cases} \quad ....(3)$$

Here the hysteresis band limit h=0.5. The interface inductor between inverter and PCC suppresses the harmonics caused by the switching operation of the inverter.

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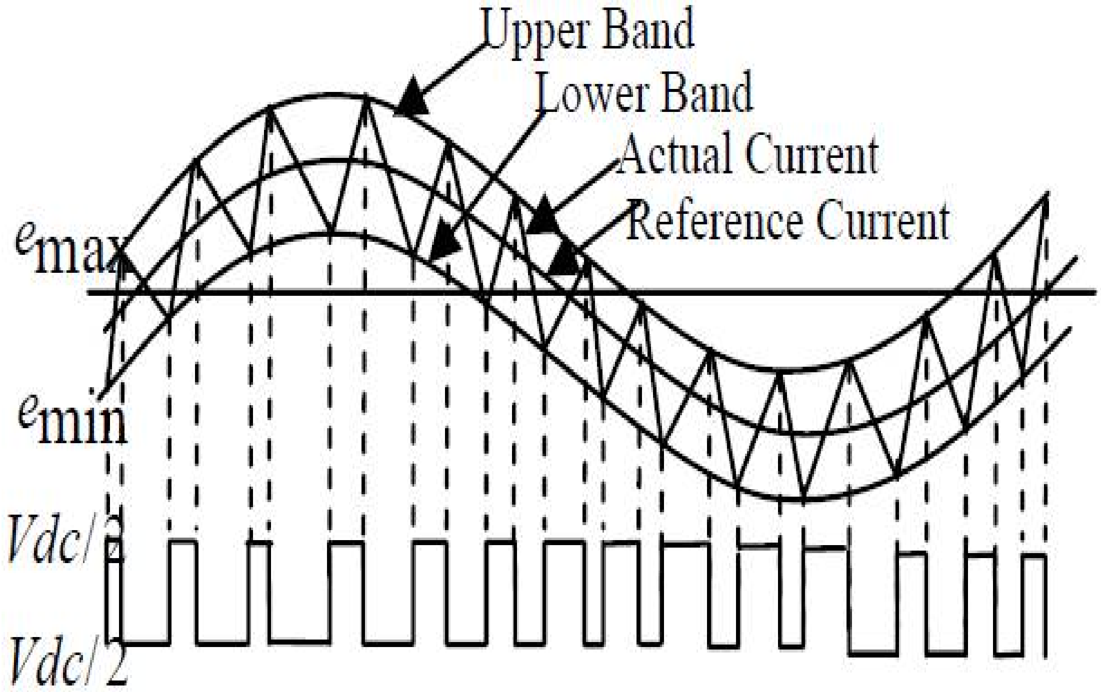

Fig. 4 Diagram of hysteresis current control

Fuzzy Control Of Active Power Filter (APF)

The identified Load frequency control and interconnection problems can be effectively reduced by controlling AGC. Fuzzy logic is wide employed in controlling technique. The word "fuzzy" maintain fact that the logic concerned that can't be expressed as "true" or "false" however rather as "partially true". Though various approaches like genetic algorithms and ANN will perform even as well as formal logic in several cases, formal logic has the advantage that the answer to the matter is forged in terms that human operators will perceive, so their expertise is employed in the controller of prognosticative current control. The linguistic variables area unit outlined as (NB, NM, NS, Z, PS,PM, PB) that means negative big, negative medium, negative sall, zero, positive small, positive medium and positive big.

E CE	NB	NM	NS	Z	PS	PM	PB
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

Table. 1 The Membership Functions For FLC

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IV. CIRCUIT DIAGRAM OF SYSTEM

A three-phase inverter for traction system requiring power quality features, such as harmonic and reactive power compensation by using fuzzy logic controller. The proposed active power filter with fuzzy control and the effectiveness of the associated harmonic and reactive power compensation are simulated using Matlab/Simulink.

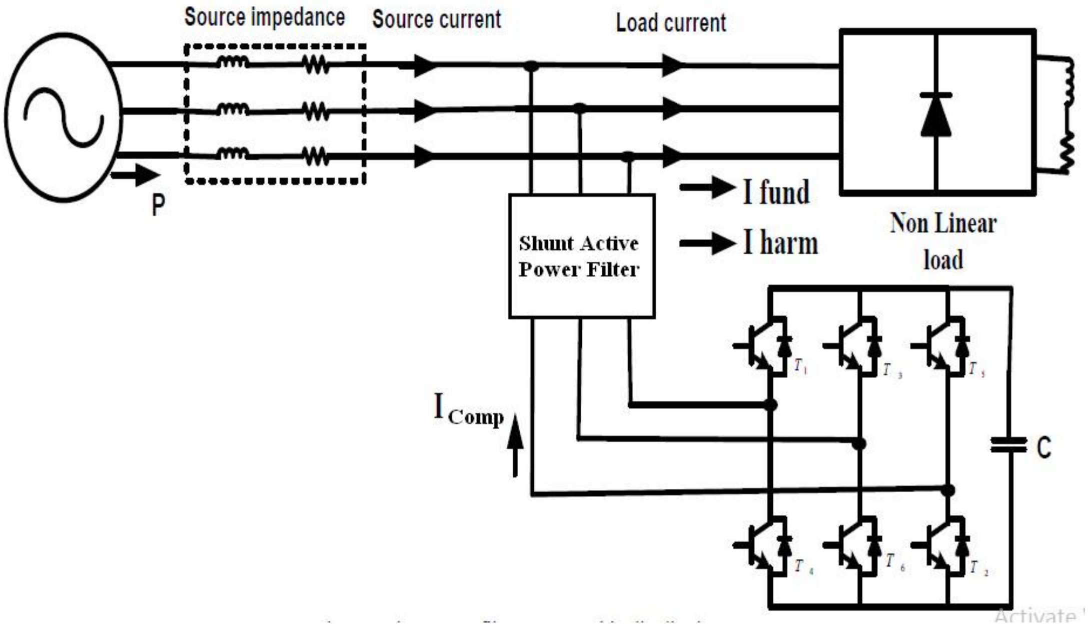

Fig. 5 Active Power Filter With Fuzzy Logic Controller in Traction System

Fig. 5 shows active power filter with fuzzy logic controller in 25KV traction system. Active power filter generates compensating currents and induces these generated compensated currents in to the system thus mitigating harmonics in the system. Unwanted neutral currents might flow caused due to non-linear loads with uncompensated and unbalanced systems. In this case, a three phase APF can deliver compensation. Active power filters are of different types. Series compensator, shunt compensator or combination of both series and shunt compensator called UPQC. Here in this paper shunt active power filter was considered to mitigate the harmonic pollution in the system containing induction motor as non linear load. A typical arrangement of inverter as shunt active power filter was connected is showed in fig. 5. This is a converter based APF with VSI configuration. VSI configured APF is low cost, simple, expandable to multi-level and consists of a self supporting DC Voltage. This shunt active power filter can effectively mitigate harmonics. The APF shunted at PCC in distribution system and also at PCC we have AC source is connected with source impedance. This three phase ac source is supplies a active power to load and load is connected with nonlinear load which has load reactive power demand is high on source and harmonics will generated. To eliminate problems will be produced by load by using APF is shunted with system [1].

V. CONCLUSION

Fuzzy Logic Controller (FLC) to become one of intelligent controller over conventional controllers because its behaviour is easily understood by a human expert, as knowledge is expressed by means of linguistic rule. Due to the non- linear load connected in the distribution system harmonics will presented, which effects power quality of the at the distribution level. Fuzzy logic controller will perform the function of active power filtering to improve power quality. The shunt APF system is implemented with voltage source inverter and is connected at PCC for filtering the current harmonics and compensating the reactive power.

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BIOGRAPHY

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