Implementation of Fuzzy Logic Controller Based Active Power Filter to Improve Power Quality of 25KV Traction System

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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, 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 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 25KV traction system details are taken from POH, ELW, Bhusawal. The APF controlled by Fuzzy controller is modelled using MATLAB\Simulink.

Keywords- Active Power Filter (APF), Electric Locomotive Workshop (ELW), Hysteresis Current Controller (HCC), Point of common coupling (PCC), Periodically Overlying House (POH).

I. INTRODUCTION

Now a day's electricity demand increases, poor quality is increases and becoming difficult to mitigate. The system needs to be protected against different power quality problems. Harmonics is one of the power quality issues that influence to a great extent transformer overheating, rotary machine vibration, voltage quality degradation, destruction of electric power components, and malfunctioning of medical facilities. The nonlinear loads generate current harmonics that can be asymmetric and can cause voltage drops on the supply network impedance resulting in unbalanced conditions. These effects can be worse in the case where the loads change randomly. With the great progress of power electronics, active filters have been focused in a large number of published works. The behaviour of the active filters under unbalanced conditions has been already studied and analysed. Control schemes applied to the control of active power filter under unbalanced three-phase systems have also been introduced. These strategies have been used mostly by considering fixed harmonic compensation for balanced or unbalanced loads. Besides the problems of harmonic distortion, there exist also low power factor and unbalanced load currents at the point of common coupling (PCC) due to the power delivered by the nonlinear loads. Control algorithms for compensating all these power quality problems simultaneously have also been introduced. Conventional solutions like passive filters for reducing the current harmonic pollution are ineffective. The standard regulations and recommendations regarding the power flow of electrical energy, such as IEC 61000-3-2 and IEEE519 have become restricted and this has stimulated the use of active power compensation. Active power filters are usually employed to solve the power quality problems [1]. Active power compensation is normally achieved with the help of switching power converters connected to the network as an active filter. An important component of a shunt active power filters (SAPF) is the current controller, which has the task of making the controlled current tracking its respective reference. In conventional control strategies applied for SAPF, these current controllers are employed for controlling output filter currents. These currents are composed of a fundamental component for compensating reactive power and harmonic components. Normally, the standard solution is to use linear proportional-integral (PI) current controllers.However,the use of these controllers has resulted in steady-state errors and their bandwidth limitation turns into a low quality of compensation. Apart from the conventional SAPF control schemes, this paper deals with fuzzy control strategy for SAPF for compensation of harmonic distortion, reactive power. The proposed active power filter with fuzzy control and the effectiveness of the associated control scheme compensation, power quality improvement is simulated using MATLAB/SIMULINK.

II. PRINCIPLE OF APF

The active power filter consists of a Voltage Source Inverter (VSI) supported by a DC storage capacitor [2]. The VSI is connected to Point of Common Coupling (PCC) through a coupling transformer in shunt to the distribution network. The VSI converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the APF output voltages allows effective control of active and reactive power exchanges between the APF and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power [3].

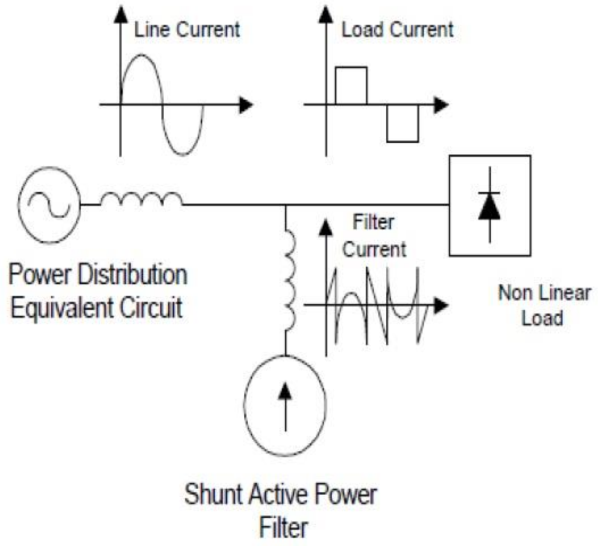

Fig.1: Schematic Diagram of Active Power Filter

The VSI connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Elimination of current harmonics.
2. Compensation of reactive power.

III. FUZZY LOGIC CONTROLLER

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. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behaviour [4]. FLC's are an excellent choice when precise mathematical formula calculations are impossible. The block diagram of Fuzzy Logic Controller consists following component.

Fuzzification: 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).

Rule Elevator: Conventional controllers like PI and PID have control gains which are numerical values. Fuzzy logic controller useslinguistic variables instead of the numerical values. The basic fuzzy logic controller operation uses the following fuzzy set rules to control the system.

AND -Intersection: $\mu A\cap B=\min[\mu A(X),\mu B(x)]$
OR -Union: $\mu A\cup B=\max[\mu A(X),\mu B(x)]$
NOT -Complement: $\mu A=1-\mu A(x)$

AND		
A	B	Min(A,B)
0	0	0
0	1	0
1	0	0
1	1	1

OR		
A	B	Max(A,B)
0	0	0
0	1	1
1	0	1
1	1	1

NOT	
A	1-A
0	1
1	0

Table 1 Truth table for operation of Fuzzy Logic Controller

Defuzzification: 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.

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

Rule Base: The rule base stores the linguistic control rules required by rule evaluator (decision making logic) [5].

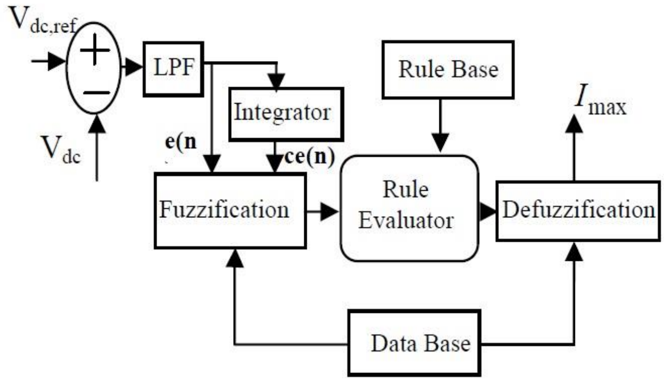

Fig. 2 Block Diagram of the Fuzzy Logic Control Scheme

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 VDC, ref. The error signal e =VDC,ref−VDC is passed through LPF with a cut off frequency of 50 Hz; 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 peak reference current is multiplied with PLL output for determining the desired reference current. The switching signals for the inverter are generated by comparing the actual source current isa, isb, isc with the reference current (isa*,isb*,isc*) using the HCC method.

A. D-Q Control Strategy for APF:

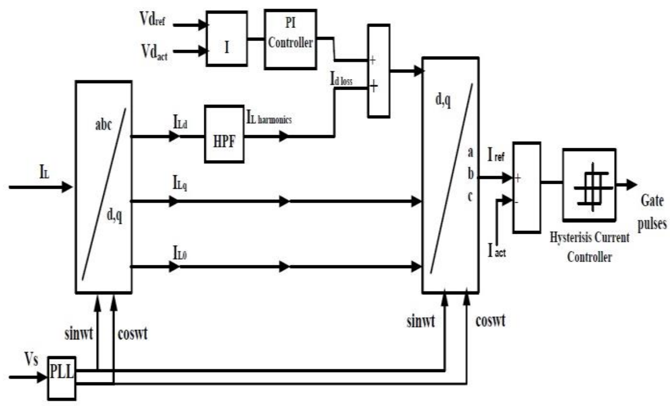

Fig.3: D-Q Control Strategy for APF

In this paper we use DQ theory control strategy with the APF is showed in fig.3. This controller with internal PI controller generates the reference currents and after comparing the original feedback signal with the reference currents, produces error signal. The controller controls the switches of the VSI accordingly and thus the currents will be injected in to the system through VSI converter [3]. These are called compensating currents or negative currents that compensate the harmonics at the source point. Active power filter should be capable of nullify the variations in component of instantaneous power and also the reactive power of fundamental frequency. A simple control strategy called active and reactive power (DQ) theory can control the APF by defining instantaneous active power and reactive power. The definitions apply in either the αβ0- or dq0-domains and for balanced sinusoidal three-phase systems would yield constant values. There are various representations of the equations such as complex power or a two-dimensional cross product. The total set-up of system with APF along with its control circuit was shown in figure.3.

Those dq0 values passed through HPF then go to inverse transformation means dq0 converted into abc parameters. PI controller is used for comparing dc voltage reference and actual then added with direct axis component of controller. The inverse transformation value is actual current is compared with reference current then connected to hysteresis controller; it generates gate pulses to switches used in inverter.

B. Fuzzy control of Active power filters (APF):

Fuzzy logic is a controlling technique. The word "fuzzy" maintain fact that the logic 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. The linguistic variables area unit outlined as (NB, NM, NS, Z, PS,PM, PB) that means negative big, negative medium, negative small, zero, positive small, positive medium and positive big.

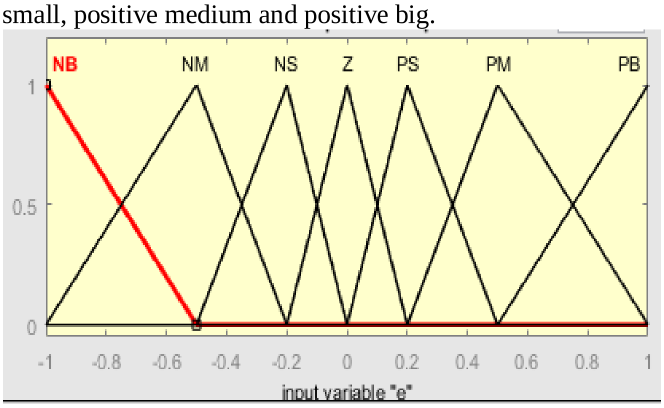

Fig.4: Triangular Membership Function

The membership functions area unit as below:

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. 2 The Membership Functions for FLC

IV. MATLAB MODELLING AND SIMULATION RESULT

A. Simulation model of project:

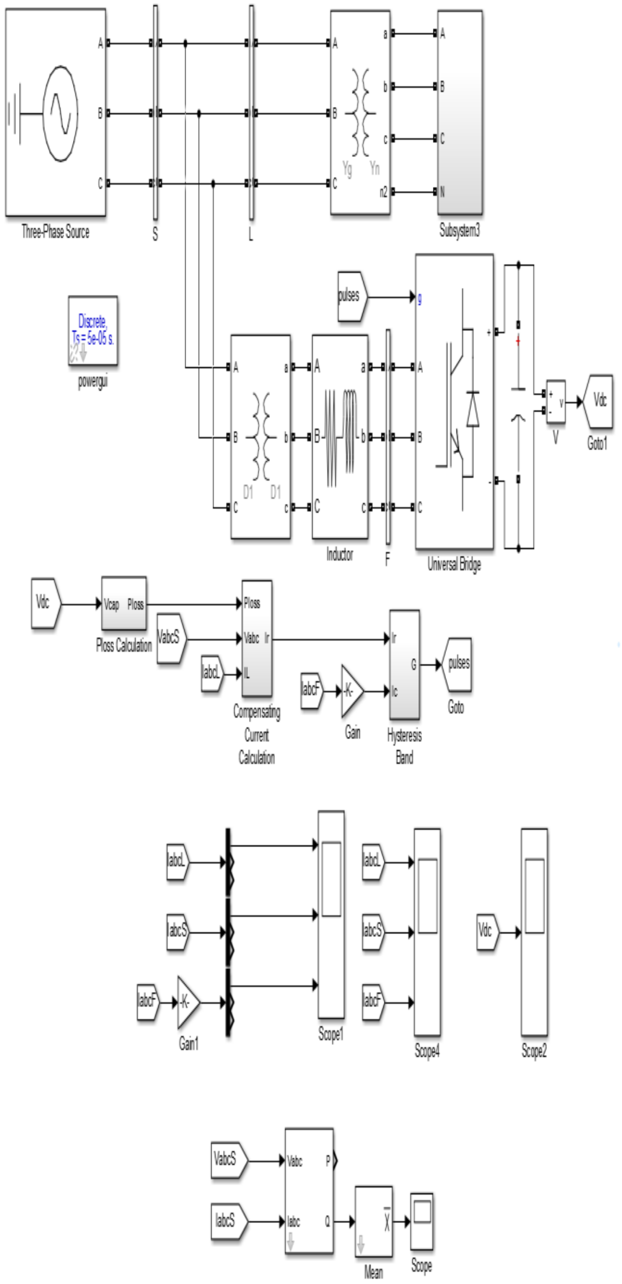

Fig.5: Simulink Model of APF with PI & Fuzzy Logic Controllers.

Figure 5 shows the simulink model of APF with conventional PI & Fuzzy Logic Controllers.

1. Simulation Results:

Case I: APF with Conventional PI Controller:

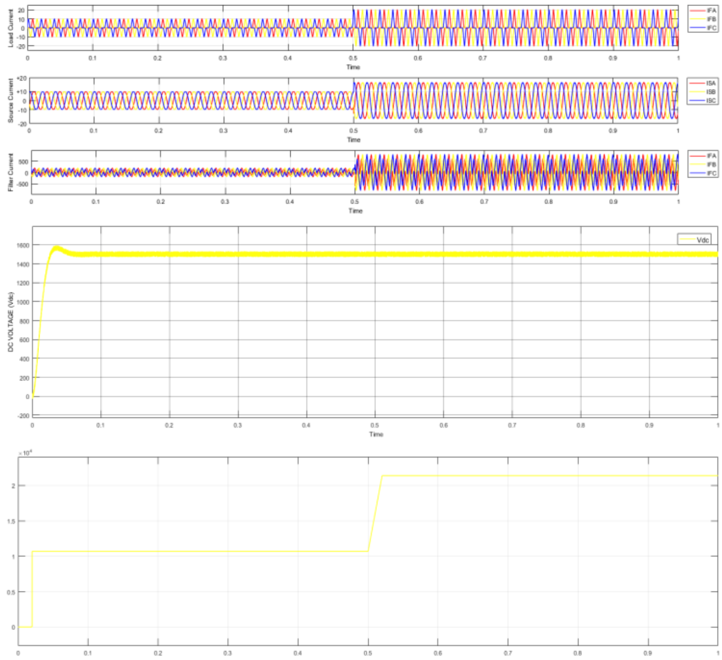

Fig.6: Simulation results for APF with PI Controller (a) Load current (b) Source Voltage (c) Compensator Current (d) DC Link Voltage (f) Reactive Power Compensation

Case II: APF with Fuzzy Logic Controller:

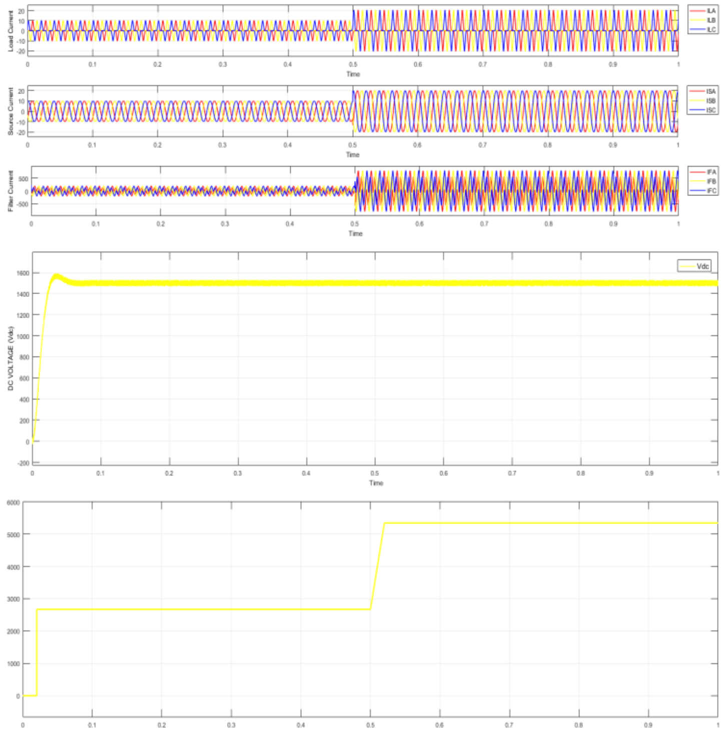

Fig.7: Simulation results for APF with Fuzzy Logic Controller (a) Load current (b) Source Voltage (c) Compensator Current (d) DC Link Voltage (f) Reactive Power Compensation

Here compensation is turned on at 0.5 seconds, before we get some harmonics coming from non-linear load, then distorts our parameters and get sinusoidal when compensator is on.

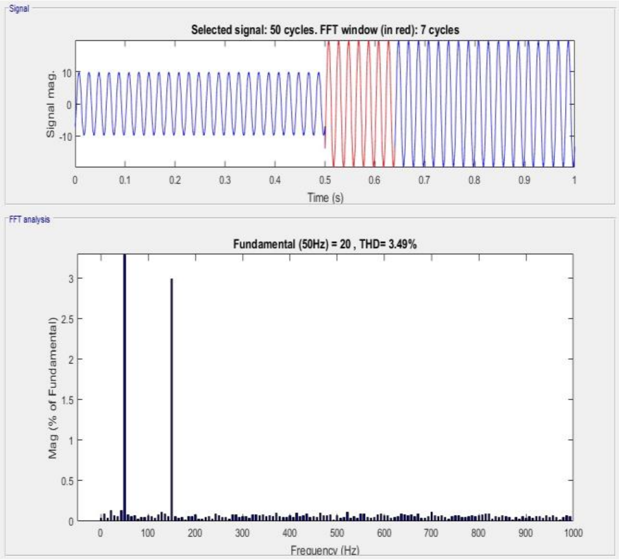

Fig.8: THD of Source Current with PI Controller

Figure 8 shows the % THD of source current with PI Controller in Traction System. The THD is 3.49%.

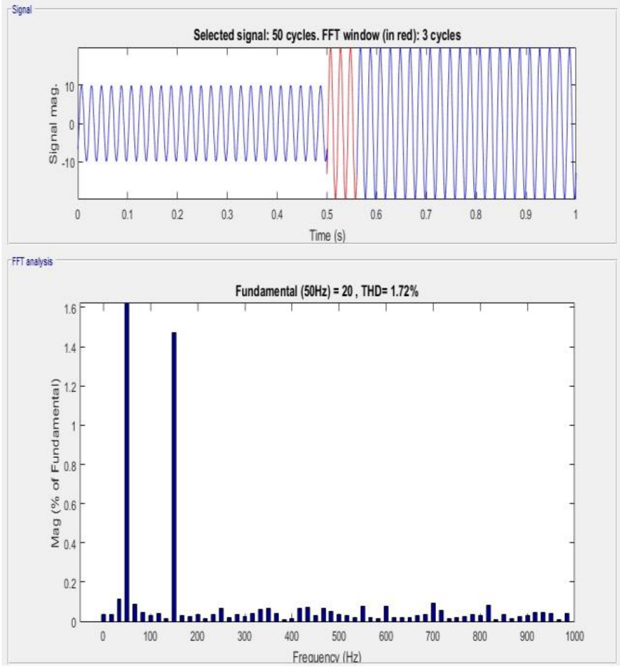

Fig.9: THD of Source Current with Fuzzy Controller

Figure 9 shows the % THD of source current with Fuzzy Controller in Traction System. The THD is 1.72%.

Parameter	With PI Controller	With Fuzzy Controller
%THD	3.49%	1.72%

Table. 3 %THD of the System

V. CONCLUSION

This proposed model is implemented using MATLAB/Simulink software and the obtained resultant waveforms were evaluated and the effectiveness of the system stability and performance of power system have been established. Improved dynamic current harmonics and a reactive power compensation scheme to improve power quality oftraction system. Advantages of the proposed scheme are related to its simplicity, modelling, and implementation. This paper has presented a control of APF using conventional PI controller & fuzzy logic controller to improve the quality of power at PCC for 25kv traction system. By using PI controller we get THD value is 3.49% and using Fuzzy Logic Controller THD value is 1.72%. The THD of source current with PI and Fuzzy Controller is presented and compared to PI, Fuzzy have less % THD in system.

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VII. REFERENCES

[1]. Mr. Kranthi Kumar, Fuzzy control based APF with DG integration for power quality improvement in distribution system, *International conference on Signal Processing, Communication, Power and Embedded System, 2016*.

[2]. Linash P. Kunjumuhammed, Mahesh K. Mishra, Comparison of Single Phase Shunt Active Power Filter Algorithms, IEEE Trans, 2006.

[3]. G. SatyaNarayana, Ch. Narendra Kumar, Ch. Rambabu, A comparative analysis of PI controller and fuzzy logic controller for hybrid active power filter using dual instantaneous power theory, *International Journal of Engineering Research & Development, Vol-4, Issue-6, p.p. 29-39, Oct-2012*.

[4]. Lavudya Shankar, Fuzzy logic controller based APF with advanced power quality, *International journal of scientific engineering and technology research,August 2015*.

[5]. Karuppanan, PLL with PI, PID and fuzzy logic controllers based shunt active power line conditioners,*International Conference on Power Electronics, Drives and Energy Systems,2010*.

[6]. Ravish Khanna,Performance and investigation of hybrid filters for power quality improvement,*The 5th International Power Engineering and Optimization Conference, June 2011*.

[7]. Prahlada, Improving efficiency of active power filter for renewable power generation systems by using predictive control method and fuzzy logic control method, *International Research Journal of Engineering and Technology, Sep -2017*.

[8]. Pichai Jintakosonwit, Implementation and performance of cooperative control of shunt active filters for harmonic

damping throughout a power distribution system, IEEE transactions on industry applications, vol. 39, no. 2April 2003.
[9]. Kavya Mittal, AnkitaKosti, Hybrid active power filter for power quality improvement, *International Journal of Emerging Technology And Advanced Engineering Volume 4, Issue 5, May 2014.*
[10]. B. Mohan Reddy, G. Balasundaram, Improvement of power quality using hybrid active power filter in three- phase three wire system applied to induction drive, *Journal Of Advanced Research In Electrical, Electronics And Instrumentation Engineering, Vol. 3, Issue 11, November 2014.*
[11]. M. Aredes, J. Hafner, and K. Heumann, Three-phase four-wire shunt active filter control strategies, IEEE Trans. Power Electron., vol. 12, no. 2, pp. 311–318, Mar 1997.
[12]. N. Prabhakar and M. Mishra, Dynamic hysteresis current control to minimize switching for three-phase four-leg VSI topology to compensate nonlinear load, IEEE Trans. Power Electron., vol. 25, no. 8, pp. 1935–1942, Aug. 2010.
[13]. R. de Araujo Ribeiro, C. de Azevedo, and R. de Sousa, A robust adaptive control strategy of active power filters for power-factor correction, harmonic compensation, and balancing of nonlinear loads, IEEE Trans. Power Electron., vol. 27, no. 2, pp. 718–730, Feb. 2012.
[14]. P. Correa, J. Rodriguez, I. Lizama, and D. Andler, A predictive control scheme for current-source rectifiers, IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1813–1815, May 2009.

BIOGRAPHY

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