Power Quality Improvement using Fuzzy Logic Controller based Hybrid Active Power Filter

K. Ananthi, S. Manoharan

Abstract: The performance of Hybrid Active Power Filter (HAPF)for power quality improvement is presented in this paper. Power quality issues are usually caused by nonlinear loads available in the network. HAPF will be a better solution for improving power quality issues. It reduces harmonics, improves power factor and compensates reactive power in the network. Performance benefits of both active filters and passive filters are passive filters are incorporated in HAPF. These filer shave an economical advantage over active filters. Here, the reference current is generated using Synchronous Reference Frame theory (SRF). Fuzzy Logic Controllers (FLC) are used to reduce Total Harmonic Distortion of the source current. The efficiency of Fuzzy Logic Controller based HAPF is evaluated by the simulation implemented in MATLAB/Simulink software.

Keywords: Total harmonic distortion, Hybrid Active Power filter (HAPF), Fuzzy logic controller

I. INTRODUCTION

Due to increased use of power electronics devices which act as a non linear load, the system power quality is affected. Harmonics are created by non linear loads which draws the current in abrupt short instead of sinusoidal nature. Harmonic is a sinusoidal component of a periodic wave or quantity it is having a frequency which is an integral multiple of fundamental frequency. The best solution to reduce harmonics is filters. It is mandatory to control the filters that are connected to the system so that it can create the desired response characteristics [1].Filters are categorized as Active and Passive filters. In passive Filter, bank of tuned LC filters is connected in parallel with the load solve harmonic pollution problems. Passive filters are designed only for a particular frequency so they are unable to compensate random harmonic variation and it will have more resonance at point of common coupling. It may create adverse effects when capacitors are available for power factor corrections. The elements required for the passive filters design are bulkier in size. The other type of filters, active power filters can be further classified into Shunt Active Power Filter (SAPF)and series active power filters [2,3]. Nowadays, shunt active filters are broadly used in commercial applications. The controllers designed for these filters will determine the required compensating reference current and it will generate corresponding gating signal.

SAPF has the capability to compensate harmonic current of selected nonlinear loads and will continuously the track changes in their harmonic content. As HAPF are the combination of passive filters and active filters, it improves resonance characteristics along with reduction in filter rating. In HAPF, passive filter which is connected parallelly with load will help to suppress the harmonic current generated by the load and in this configuration active filter which is connected with the source in series performs as a harmonic isolator between the load and the source. Hence a hybrid filter eliminates the limitaionsof active and passive filters occurred when they are used independently [4-6]. Fig. 1 and 2 depicts the schematic representation of Shunt APF and HAPF.

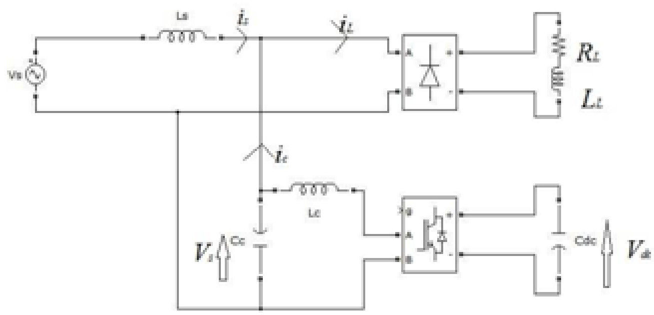

Fig. 1 Shunt active power filter

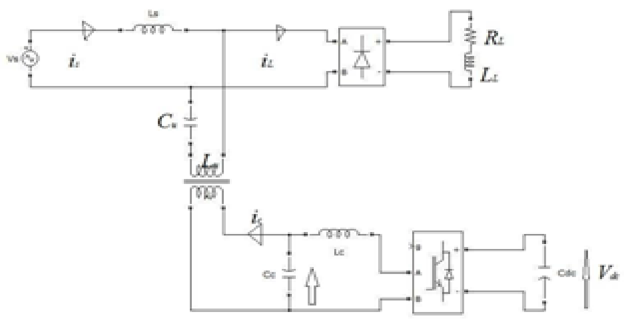

Fig. 2 Hybrid Active Power Filter

II. CONTROL STRATEGY

The control strategy implemented is based on “D-Q theory” to mitigate harmonics. Generally, electric power at sinusoidal and balanced voltage is desirable in power generation. This can be accomplished when load current at Point of Common Coupling is in co-linear with supply voltage. But, it is difficult to accomplish because of the presence of nonlinear loads in the system. In order to

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achieve this, reference current needs to be calculated based on that gating signal will be generated. Here to calculate reference current SRF theory is used and Fuzzy logic controller (FLC) is implemented to generate gating signal.The FLC has two important functions, to extract reference current from distorted current and to generate switching signals [7-10].Harmonic components can be extracted by using various control strategies. One popular method is by using PI controller. It is simple to implement but the performance of PI controller is not appreciableif the parameters are varying and there are disturbances. Another constraint of this controller is that the gains for tuning this controller are selected randomly. To overcome these limitations, Fuzzy Logic Controllers are introduced [13-14]. The FLC are widely applied in power electronic applications as they can easily handle nonlinearities. It is simple to design and accurate mathematical modeling of the system is not required.

Reference source current calculation

Synchronous Reference Frame Theory(SRF)

Synchronous Reference Frame theory is also known as I_d–I_q method or d-q method. This is widely applied in 3Φ system and it is one of the best and most preferred techniques for calculating reference current. The Synchronous Reference Frame theory extracts harmonic content and reactive component of the distorted current accurately and quickly. One of the significant features of this techniques is to obtain reference current directly from the nonlinear load current without considering the supply voltage. Reference current generated will not be affected by unbalanced supply voltage or any distortion [12].Fig.3 shows the block diagram of SRF theory. From the diagram it is clear that sensed voltages and current are given as input. The input signal is processed by the phase locked loop (PLL)and it generates sine and cosine signal. Current signal is transformed to d-q frame and these transformed signals are filtered and transformed back to a-b-c frame which is fed to controller to generate required switching signal. During implementation of this method, delays should be considered else this is may cause the controller to be unstable which results the whole system to become unstable. In synchronous reference frame theory, Clark's and Park's transformation is used to change the harmonic frequency, and to eliminate this frequency LPF is used. To generate the reference currents reverse Park's and Clark's transformation is used. PLL block is used to generate the angle θ which is used in reference current generation. This transformation done in two step.

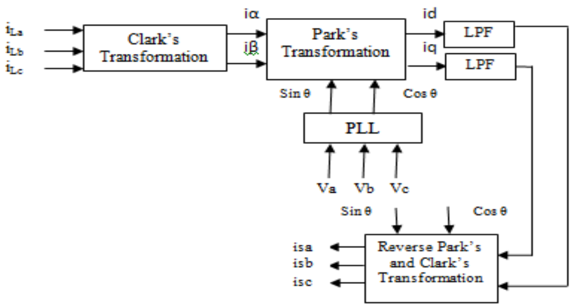

Fig. 3 Block diagram of Synchronous Reference Frame Theory

The First step of transformation is from abc frame to α-β-0 frame which is also known α-β transformation or Clark's transformation and is given by

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & -1/2 & 1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} iLa \\ iLb \\ iLc \end{bmatrix}$$

The next step is to transform from α-β-0 to d–q–0 frame which is also known as Park's transformation or d-q transformation and is given by

$$\begin{bmatrix} id \\ iq \end{bmatrix} = \begin{bmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{bmatrix}\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix}$$

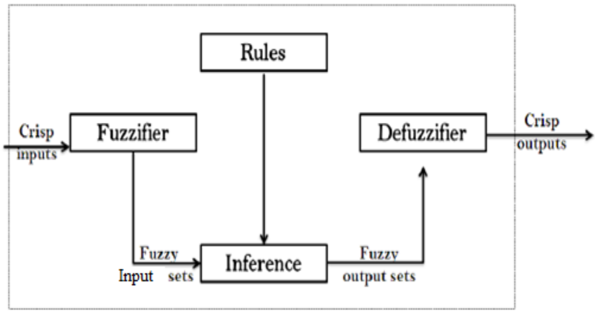

Fig. 4 Block diagram of Fuzzy Logic Controller

III. FUZZY LOGIC CONTROLLER

Fuzzy logic-based controllers are used to improve power quality efficiently and produce good performance results. Fuzzy logic controllers are most chosen controllers as they do not require precise mathematical modelling of the system. Here, controller based on fuzzy logic is applied. This controller is implemented for compensating line current drawn by the non-linear loads and Fuzzy logic controlleris more efficient than PI controller to compensate harmonics and to regulate DC bus voltage.[11]

The FLC is characterized as Seven fuzzy sets for each input and output. For simplicity, membership function opted here is triangular function. Fuzzy logic controller model is shown in Fig 4.[15]

Fuzzification

In a control system, reference signal and output signal are compared to calculate error. This is assigned as Positive Big(PB), Positive Medium(PM), Positive Small(PS), Zero(Z),Negative Small(NS),Negative Medium(NM) Negative Big(NB). The triangular membership function is opted for fuzzification. Fuzzification is performed to convert crisp inputs which is numerical variable to fuzzy input sets which is linguistic variable. Triangular membership function is selected for conversion.

Defuzzification

Based on the rules given to the FLC, by fuzzification FLC generates output in a linguistic variable as fuzzy numbers. But for real world applications, linguistic variables are unable to use directly. It is needed to convert to crisp output as real number. Defuzzification involves in the process of converting fuzzy output sets into crisp outputs. It involves in producing quantifiable outputs required by real world systems.

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Rules

The rule evaluator requires linguistic control rules based on which decision making is done and are stored in rule base table. The elements of the rule base table are determined based on transient state and steady state which requires coarse control and fine control respectively. Usually coarse control involves coarse input/output variables when there is large errors and fine control needs fine input/output variables if the errors are small. The rule base table obtained are shown in Table-I. MATLAB simulation of FLC in Simulink is shown in Fig.5

Table. 1 Rule base Representation

ΔE / E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	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

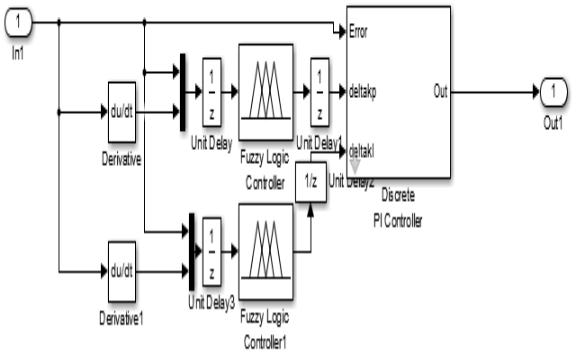

Fig. 5 Fuzzy logic Controller model in MATLAB

IV. PERFORMANCE EVALUATION

The proposed Fuzzy logic controller based HAPF is implemented in the MATLAB/Simulink software to evaluate performance measures. The MATLAB simulation of HAPF for improving power quality is shown in Fig. 8. The system parameters required for simulation are given in Table-II

Table. 2 System Parameters

S.No.	System Parameters	Value
1.	Source Voltage	230V
2.	DC bus voltage	500V
3.	Source Frequency	50Hz
4.	DC link inductance	1.5mH
5.	DC bus capacitor	2200µF
6.	Load inductance	20mH
7.	Load resistance	10Ω

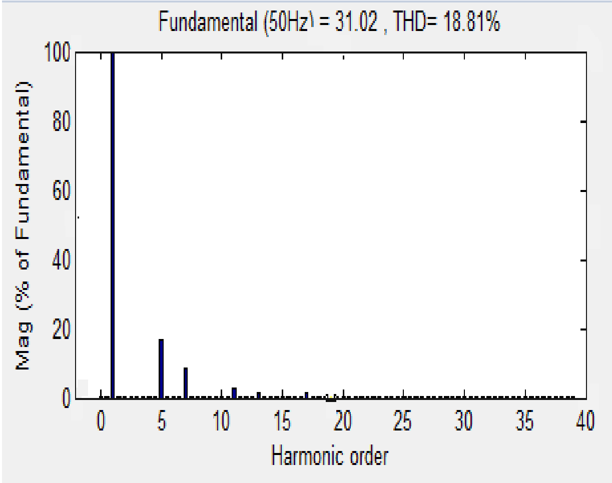

Fig. 6 Harmonic spectrum of source current without filters

The above system is implemented without applying filter. It is highly affected by the non-linear loads present in power system and produce Total Harmonic Distortion (THD). Without filter, the source current is profoundly distorted with a THD of 18.81% and it is as shown in Fig.6. It is more than the permissible limit given by IEEE-519-1992 standard.

Shunt APF is connected to the system in order to compensate harmonics and reactive power drawn by the non-linear loads. By connecting it, the THD in source current is significantly decreased from 18.81% to 3.85%.

The harmonic spectrum with Shunt APFis depicted in Fig.7.

Asshunt APF using Hysteresis Current Control method is functioning at a narrow hysteresis band of ± 0.01, it will create increased switching frequency. In this technique switching power losses are more and it has less conversion efficiency.

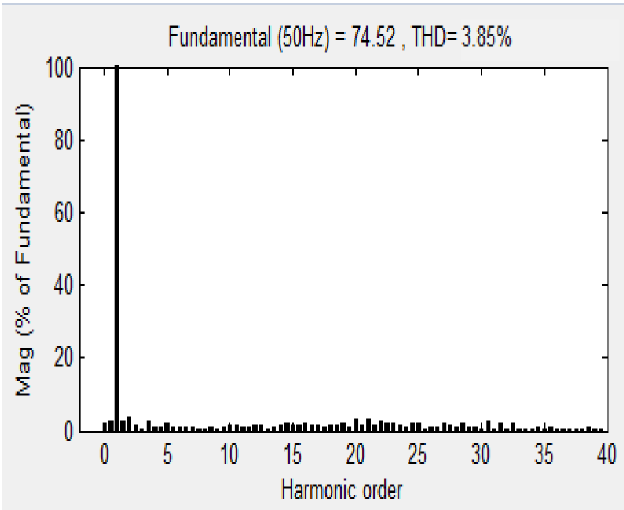

Fig. 7 Harmonic spectrum of source current with shunt Active Power filters

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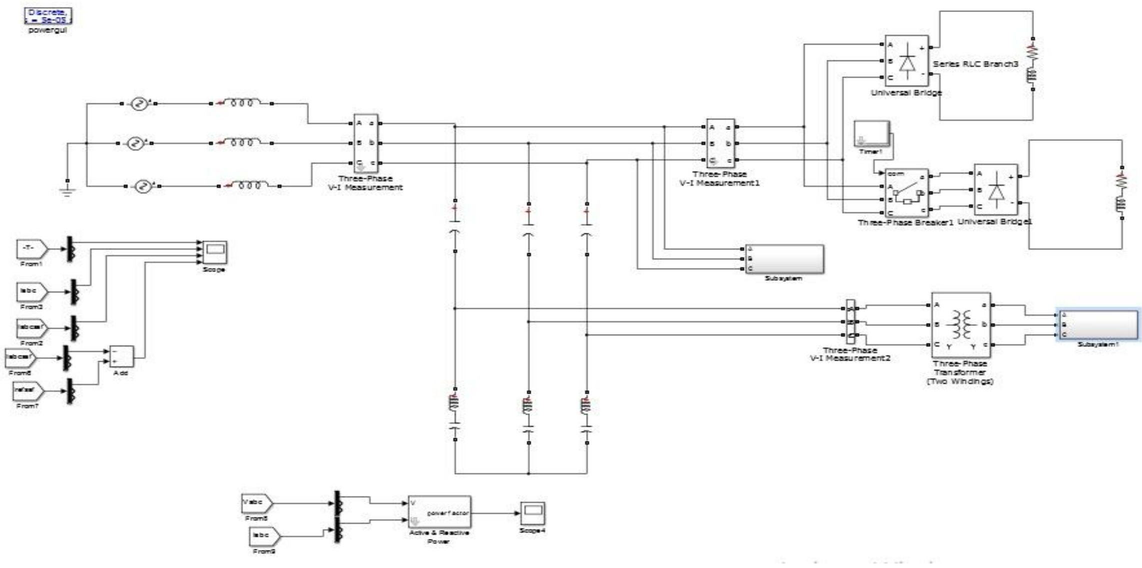

Fig. 8 MATLAB Simulation of Hybrid Active Power Filter

HAPF is a combination of shunt APF and passive filter is implemented for reducing harmonics and also for reactive power compensation. The operation of HAPF gives nearly sinusoidal source current. The THD is significantly decreased to 2.18% for HAPF from3.85% in case of Shunt APF. It is given in Fig.9. Thus, harmonic free source current is achieved by hybrid filters at lower switching frequency.

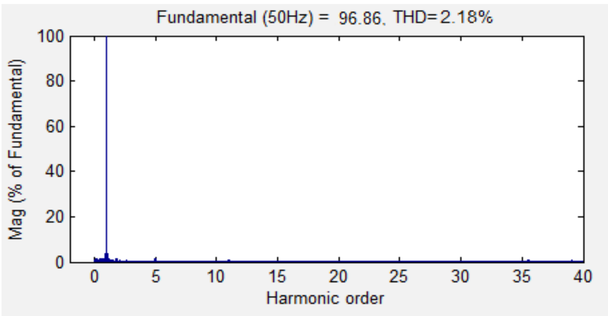

Fig. 9 Harmonic spectrum of source current with HAPF

V. CONCLUSION

The performance of HAPF with FLC for power quality improvement is given in this paper.FLC based HAPF results in better controller execution with almost sinusoidal source current. Thus, proposed FLC performance is highly satisfactory to reduce Total Harmonics Distortion and it improves the power quality. Hybrid filters play an important role to reduce resonances. It also provides a cost-effective, improved reliability, higher efficiency and significant harmonics reduction when compared to active filters and other existing possibilities for power quality improvement. The proposed method requires reduced size of filters and this will be also a suitable solution to mitigate harmonics.

REFERENCES

1. Archana K ; M. S. Sumukha ; Thousif. M, “Power Quality Improvement using Shunt Active Filter”, International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), 2017
2. Aissa O, Moulahoum S, Colak I, Babes B, Kabache N, “Analysis and experimental evaluation of shunt active power filter for power quality improvement based on predictive direct power control” Environ Sci Pollut Res Int. , Sep, 2018
3. Xiao Z., Deng X., Yuan R., Guo P., “Shunt active power filter with enhanced dynamic performance using novel control strategy”, let Power Electronics, 7(12):3169-3181. 2014.
4. Zhengyou Ma, “The Design of Hybrid Active Power Filter based on Harmonics Detection and Its Simulation Research”, Chemical Engineering Transactions, VOL. 51, 2016
5. V Muneer , Avik Bhattacharya, “Shunt Hybrid Active Filter By Using Cascaded H Bridge Multilevel Inverter”, 14th IEEE India Council International Conference (INDICON), 2017.
6. A. Cleary-Balderas ,et. al., “Hybrid active power filter based on the IRP theory for harmonic current mitigation”, IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC), 2016
7. Abdeldjabbar M. K, Tayeb Allaoui , Mouloud Denai, George Pissanidis , “Grid power quality enhancement using fuzzy control-based shunt active filtering”, SAI Intelligent Systems Conference (IntelliSys), 2015
8. J. Rodriguez, J. Pontt, C. Silva, P. Correa, P. Lezana, P. Cortes,U. Ammann, “Predictive current control of a voltage source inverter,” IEEE Trans. Ind. Electron. , vol. 54, no. 1, pp. 495–503, Feb. 2007.
9. Shyamaladevi.E, Vijayakumar.G, “Fuzzy Controller based Hybrid Active Power Filter for Energy Saving”, International Journal of Computer Applications, 2012
10. R Balasubramanian, R Sankaran, S Palani, “Simulation and performance evaluation of shunt hybrid power filter using fuzzy logic based non-linear control for power quality improvement”, Indian Academy of Sciences, Vol. 42, issue 9, pg. no. 1443 – 1452, 2017
11. Karuppanan P and Kamala Kanta Mahapatra, “PLL with PI, PID and Fuzzy Logic Controllers based Shunt Active Power Line Conditioners” Proceedings of IEEE International Conference-PEDES at IIT-Delhi, Dec. 21-23, 2010.
12. Najiya C K1, Krishnakumari T2,Sijo George3, “ Shunt Active Power Filter based on SRF theory and Hysteresis Band Current Controller under different Load conditions”, IOSR Journal of Electrical and Electronics Engineering, pp 20 -26, 2017.
13. Azuki Abdul Salam , Nik Azran ab Hadi, “Fuzzy logic controller for shunt Active Power Filter”, 4th International Conference on Engineering Technology and Technopreneuship (ICE2T), 2014
14. SomlalJarupula, Venu Gopala R M, Ramesh Matta, “Power Quality Improvement in Distribution Systems Using Fuzzy Based Hybrid Active Power Filter”, International Journal of Advanced Scientific Research and Technology Vol 3, Issue 2, 2012
15. Amit Kumar, Dr. Abdul Hamid Bhat, “Fuzzy Logic Controlled Hybrid Filter For Power Quality Improvement”, International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016

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