PI Controller SVPWM Based Shunt Active Power Filter For Hybrid/Mixed Load

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Abstract- **Electricity is the major & predominant source of energy in today's perspective. With the advent of technology & increase in buying capacity of household's, the usage of Heavy Electric Load's such as Air Conditioner, Hooters, Washing Machines have seen a drastic rise. Also, unlike industrial loads are much heavier, they run in a fixed pattern & generally load is balanced across all three phases & are seldom non-linear. Also, proliferation of electronic equipment has increased the Non-Linear load such as SMPS, which have rectifier component in line, & introduction of Inverter Technology for Ac's & Washing Machines, despite saving energy, has created severe concern of harmonic / high frequency noise introduction in Power System. The proposed system intends to implement a Shunt Active Power Filter using PI (Proportional Integral) Technique that can cater to power system harmonic & noise introduced by Non-Linear Load, Unbalanced Load & Mixed Load.**

Keywords- Shunt Active Power Filter, PI Control, Simulink, Harmonic Compensation.

1. INTRODUCTION

Electricity is one of the most significant endowments that science provides for humankind. It has likewise become a piece of current life, and people can't imagine a world without it. Electricity has numerous utilizations in our everyday lives. It is utilized in working fans, lighting related rooms and household machines, such as air-conditioner, electric ovens, etc. The entirety of this gives people sense of comfort. In the factory, large machines work with the assistance of power. Many necessities, for example, food, paper and materials are power products. Modern modes of transport have undergone revolutionary changes. Traveling battery related vehicles and electric trains is a brisk way [1]. Power likewise offers radio, entertainment, TV & movie means, which is the most well-known type of electric amusement. Modern devices such as robots & PCs have likewise been produced for power. Power additionally assumes a key part in the medical and surgical fields - for example, X-rays and electrocardiograms [2]. The utilization of power is expanding. The electric power network to the villages, and the transmission power of the electronic components used. The powers of the reckoning of an exemplar display your valor, wide area he wishes to. The system can be divided into a grid power generator provide power, power transmission and power transmission system from the center to the center of the load, the power transmission and distribution system in the country at home and industry [1, 3]. The industry, hospitals, homes and commercial buildings are also smaller power systems. Most of these are three-sighted and power supply systems of time - this is the standard in today's world of big-scale power transmission and distribution. The edit or by air, rail electrical systems, automobiles and ocean liners can be found reason cannot always rely on a three-dedicated power supply and the power of the time [4].

An electronic filter is a signal handling filter as a circuit comprising of discrete (lumped) electronic parts [5]. These channels eliminate frequency recurrence parts from the applied sign, improve the desired frequency components, or both. The electronic filter can be:

- Passive or dynamic
- Digital or Analog
- Qualcomm, low pass, band pass, band stop (band stop; score) or all pass.
- Finite impulse response (FIR type) or Infinite impulse response (IIR type)
- Linear or nonlinear
- Discrete time (testing) or consistent time

The most well-known sort of electronic filter is a straight filter, despite to different parts of its plan. For more information on its design and analysis, see articles on the straight filters [5, 6].

1) Passive Filters

The passive implementation of the direct filter depends on a combination of resistor (R), inductor (L) & capacitor (C). These sorts are all things considered alluded to as passive filters since they don't depend on outside electric supplies or potentially they don't contain dynamic segments, for example, transistors [6].

The inductor passes the low frequency signal and blocks the high frequency signal, on the other hand the capacitor is transmitted the reverse direction. The sign goes through the inductor or a filter where the capacitor gives a ground way to attenuate the low recurrence signal not exactly the high recurrence signal and is therefore a low pass channel. On the off chance that the signal goes through the capacitor, or if the inductor has a ground way, the filter attenuates the high frequency signal less than the low recurrence signal and is subsequently a high pass channel. The resistors themselves have no recurrence selection characteristics, however to determine the frequency of the circuit response and to decide the time constant of the circuit resistors are included to the inductor and capacitor. [7-9].

The inductor and capacitor are the receptive components of the filters. The quantity of components decides the request for the filters. For this situation, the LC tuning circuit for the band stop or band pass filter is viewed as a solitary part despite the fact that it comprises of two segments [10].

Sometimes the inductor consists of a solitary ring or sheet of metal and the capacitor consists of nearby portions of metal at high frequencies (above around 100 megahertz) [11]. These capacitive or inductive metal sheets are called stubs.

Active Filter

An active filter is a simple circuit that implements an electronic filter, normally an intensifier that uses active components. The amplifiers integrated for the channel configuration can be utilized to improve the cost, execution and consistency of the filter. The amplifier prevented the heap impedance of subsequent stages from influencing the attributes of the filter. Active filters can have complex shafts and zeros without the use of massive or costly inductors. The form of the reaction, quality factor and tuning recurrence must be estimated by modest variable resistors. In many dynamic channel circuits, one boundary can be balanced with different parameters unaffected [12].

2. LITERATURE SURVEY

In the past few years, the shunt active power filter SAPF has received much attention with many control techniques and identification algorithms for compensating the current harmonic pollution. The quality of current harmonics compensation depends heavily on the performance of the chosen algorithm of identification. This paper compares several current generation algorithms for 3-phase hysteresis inverters used as SAPF.

This paper proposes another three-stage equal dynamic force channel control strategy that can be used in three or four-wire frameworks. It depends on a momentary representation of equal dynamic force. The rule of this control strategy is to adjust the instantaneous segment of the source and the load representing the DC part of the dynamic power, including loss compensation and zero sequence power [13].

Recently, the consonant reverberation or harmonic spread amongst the shunt capacitors and line inductance introduced for power factors adjustment has increased voltage and current sounds in mechanical power plants and utilities of force dissemination frameworks. In this paper describes an equal dynamic force channel for attenuating consonant spread brought about by arrangement/equal reverberation among line inductors in dispersion lines and capacitors for power factor adjustment [14].

This paper represents a similar investigation of consolidated arrangement dynamic and parallel passive force filters utilizing quick dynamic and responsive power (p-q) & momentary dynamic and receptive current segment (id-iq) techniques. The p-q technique has been projected as a control strategy for consolidated filters and provides palatable execution, while the id-iq strategy has been shown to provide better execution to resemble dynamic power filters in symphonious compensation [15].

This article portrays the use of a tuned power harmonic filter (PHF) in a three stages of parallel dynamic power filter for consonant minimization of nonlinear burden generation. This is done to show the execution of the improved symphonious power filter to the shunt dynamic force filter, which can decrease absolute consonant distortion without making new framework resonances [16].

With the multiplication of non-straight loads as power electronics, the disservices of harmonics are increasing, which affects the nature of the power grid. Active power channel is another symphonious suppression technique. Compared with passive filter, passive filter is a kind of power electronic device. In this paper, the symphonious current dependent on the momentary receptive power hypothesis of three-stage circuit is studied, and the three-stage three-wire parallel dynamic power filter is simulated [17].

A decentralized control system is proposed to arrange various equal dynamic force filters to improve the force nature of the regular coupling point regarding power factor amendment and symphonious cancellation. Under the proposed control system, each AP utilizes a privately estimated current signal to determine the measure of intensity quality improvement job that is restricted to the rated power [18].

S. U. Bhople et el. presents an arrangement dynamic filter and a parallel dynamic filter to limit the power quality effects represents in the grid converter, instead of uninvolved filters. Network converters produce noteworthy harmonic and non-standard recurrence segments in the load. The proposed framework successfully makes up for drooping and development issues in a network converter [19].

Shunt active power filters have proven to be useful devices for eliminating harmonic currents are compensating for linear/non-linear load reactive power. This paper proposed another strategy for finding the reference compensation current for a three-stage parallel active power filter (APF) under unbalanced source voltage or steady-state distortion, or both [20].

The harmonic frequency is the integral of the periodic multi-wave and the central electrical cable frequency. Harmonics are multiples of the fundamental frequency, and complete consonant twisting is the commitment of all harmonic recurrence flows to the major. Harmonics are a by-product of current hardware.

3. METHODOLOGY

The space vector transform of a time domain signal (eg, flux, current, voltage, etc.) is known as the Clarke transform and it is derive from a normal three-phase coordinate system (ABC) to a static two-phase reference frame [21, 22].

Two-phase and three-phase fixed locus frame reflect the voltage phasor in the image to very much right [23]. In the normal reference frame, the three stationary axes Ua, Ub and Uc are 120° spaced out from each other for the voltage distributions. A Cartesian coordinate axis is furthermore depicted, here, Uα is the horizontal axis line up with phase Ua, and the vertical axis rotated 90° is denoted by U_β. The unit size of Uα and U_β are same [24-27].

To convert into two-phase voltages that vary with time along axes α and β, the three-phase voltages that vary with time axes a, b, and c is passed through the subsequent transformation matrix:

$$T_{\alpha\beta 0} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

To take the quantities back from two-phase to three-phase the inverse transformation can also be obtained:

$$T_{\alpha\beta 0}^{-1} = \begin{bmatrix} 1 & 0 & 1 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & 1 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & 1 \end{bmatrix}$$

The Park transform is a space vector transformation of three-phase time-domain signals, starting a stationary phase coordinate system (ABC) to a rotating coordinate system (dq0) also known as the Park transform.

To find the time-domain voltages in the natural frame (i.e. ua, ub and uc), the transformation matrix is as follows:

$$\begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}$$

Where, δ_A (initial phase shift of the voltage), $\theta = \omega t + \delta_A$ (angle between the rotating and fixed coordinate system at each time t).

To obtain the natural Ua, Ub, and Uc from dq0 frame, this inverse transformation matrix is used:

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 1 \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix}\begin{bmatrix} u_d \\ u_q \\ u_o \end{bmatrix}$$

It is interesting to note that the zero sequence component in the symmetrical components transform and 0-component in the Clarke's Transform is similar. E.g., the zero sequence component for both symmetrical components transforms and the dq0 for voltages Ua, Ub and Uc, is: $\frac{1}{3}\ (Ua + Ub\ + Uc)$.

At last, this article offers some of the perceptions for the effectiveness of the dq0 transform in electrical engineering.

3.1 Main Simulink Diagram (fig.1)

First, we generate the power through power generation station that passes through V-I Measurement block. There is a passive filter to observe noise and harmonics of power system, and also a contactor to on/off the switch having nonlinear load. By passive filter line another contactor is linked having unbalanced load and current supply through inductive coupling after that universal bridge to identify the current and bulk capacitor, dc voltage measurement to measure the voltage. PI Controller to control the power and current.

3.2 PQ & I compensation Calculation

In fig.2 we see that there is VCT Clarke V, AND ICT Clarke. A PQ calculation to calculate power and current flow. There is also a alpha beta current device and a scope 1 to measure the load. A compensation current device is also mount there.

4. RESULT

Table 1 Switching of Load of Contactor at various Time Interval

S. No	Time Range	Non-Linear Load	Unbalanced Load	PI SVPWM Active Power Filter
1.	0 - 0.1 sec	OFF	OFF	OFF
2.	0.1 – 0.2 sec	ON	OFF	OFF
3.	0.2 – 0.3 sec	OFF	ON	OFF
4.	0.3 – 0.4 sec	ON	ON	OFF
5.	0.4 – 0.5 sec	OFF	OFF	ON
6.	0.5 – 0.6 sec	ON	OFF	ON
7.	0.6 – 0.7 sec	OFF	ON	ON
8.	0.7 – 0.8 sec	ON	ON	ON

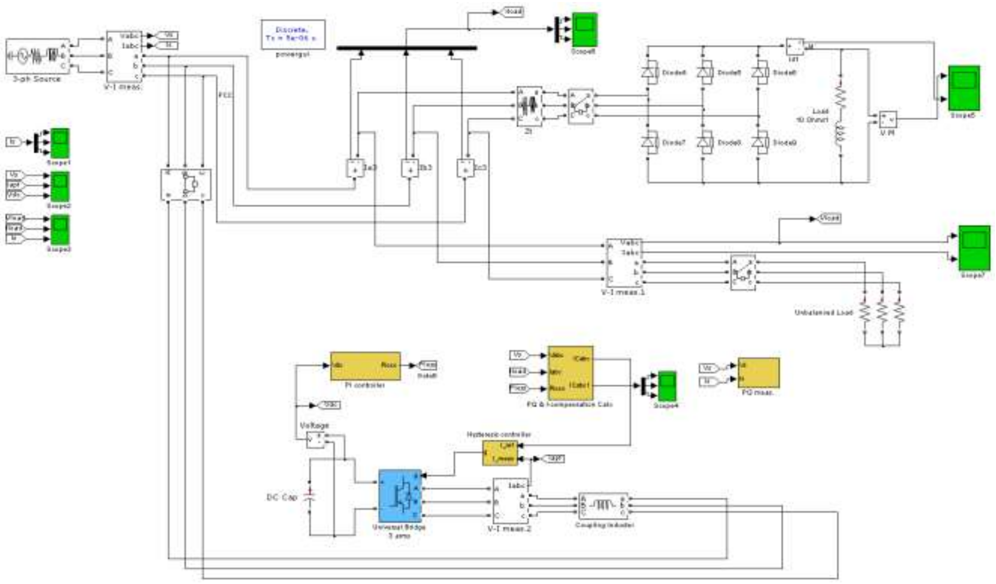

Fig.1: Main Simulink Diagram

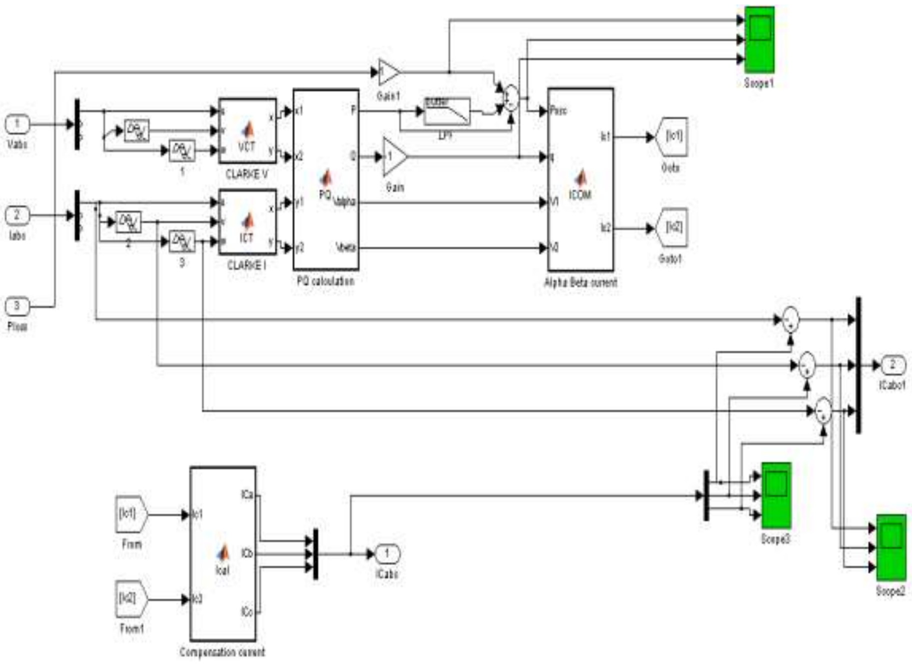

Fig.2 PQ & I Compensation calculation

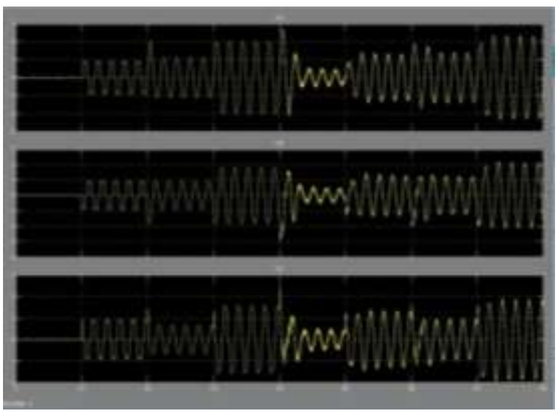

Fig.3 Scope 1- IS

Switching of different loads of contactor at various time intervals has been shown in table 1. Different combinations of loads have been taken into account wiz. Non-Linear Load, Unbalanced Load, Unequal combinations of Non-Linear as well as Unbalanced Load, referred to as mixed load as hybrid load in this work. Referring to this table various results have been calculated mentioned below.

In fig.3 we see that the sine wave graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, 0 to 0.01 sec there is no load, then wave is straight line, between 0.1 to 0.04 under nonlinear condition, under unbalanced load condition, under mixed load condition sine wave is disturbed. After connecting active power filter wave format is sequentially.

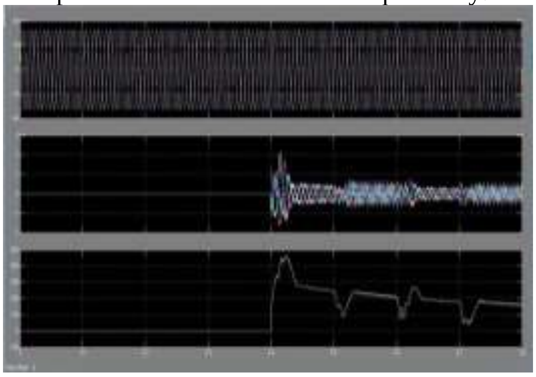

Fig.4 Scope 2 - Vs Iapf Vdc

In fig.4 we see that graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, between 0.1 to 0.04 no load, under nonlinear condition, under unbalanced load condition, under mixed load condition graph is straight line. After connecting active power filter graph is start.

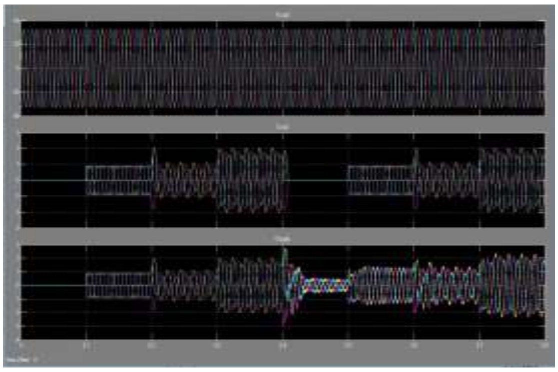

Fig.5 Scope 3 - V load, I load, IS

In fig.5 we see that graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, between 0.1 to 0.04no load, under nonlinear condition, under unbalanced load condition, under mixed load condition graph is disturbed. After connecting active power filter graph is start.

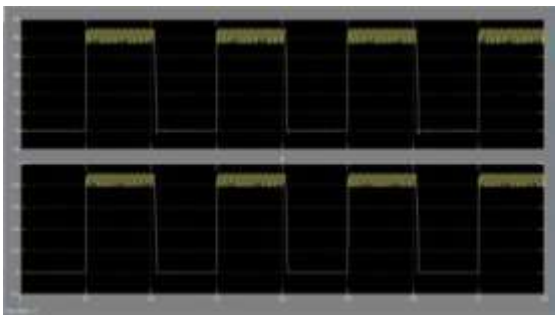

Fig.6 Nonlinear load, V&I

In fig.6 we see that graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, between 0.1 to 0.04 under no load, under nonlinear condition, under unbalanced load condition, under mixed load condition graph is disturbed line. After connecting active power filter graph is start sequentially.

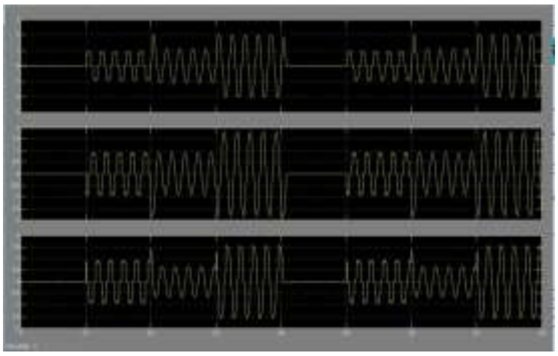

Fig.7 Scope 6 - I load

In fig.7 we see that the sine wave graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, 0 to 0.01 sec there is no load then wave is straight line, between 0.1 to 0.04 under nonlinear condition, under unbalanced load condition, under mixed load condition sine wave is disturbed. After connecting active power filter wave format is same.

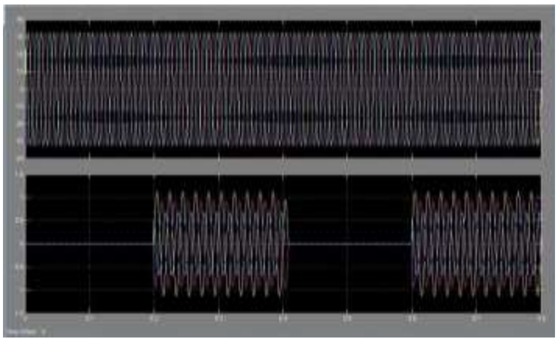

Fig.8 Scope7- Unbalanced load, V&I

In fig.8 we see that the sine wave graph variation between 0 to 0.8 sec. Of no-load condition, nonlinear load, unbalanced load and mixed load condition. We see that before connecting active power filter, between 0.1 to 0.04under nonlinear condition, under unbalanced load condition, under mixed load condition wave is disturbed. After connecting active power filter wave format is sequentially.

5. CONCLUSION

The author has presented a versatile Shunt Active Power Filter which eliminates Power System Noise

& Provide Harmonic Compensation, to improve over all power qualities. The proposed system has been designed in such as a way, that it can cater to noise / harmonics generated by Non-Linear Load, Un Balanced Load, Un equal combinations of Non-Linear as well as Un Balanced Load, referred to as mixed load as hybrid load in this work. The proposed system implements the Shunt Active Power Filter using a Main / Bulk capacitor charged / discharged by a -Arm Universal Bridge, Controlled by a PI (Proportional Integral) Controller with a Current Hysteresis Controller.

6. REFERENCES

[1] A. Bouhouta, S. Moulahoum, N. Kabache, and I. Colak, "Simplicity and Performance of Direct Current Control DCC Compared with other Identification Algorithms for Shunt Active Power Filter," 7th International Conference on Renewable Energy Research and Applications (ICRERA), pp. 1352-1357, 2018.

[2] Y. Haroen and S. Riyadi, "Analysis of Instantaneous Representative Active Power Equality based Control Method for Three Phase Shunt Active Power Filter," International Conference on Power Electronics and Drives Systems, vol. 1, pp. 542-547, 2005.

[3] S. Rahmani, K. Al-Haddad, and F. Fnaiech, "A Three-Phase Shunt Active Power Filter for Damping of Harmonic Propagation in Power Distribution Systems," IEEE International Symposium on Industrial Electronics, vol. 3, pp. 1760–1764, 2006.

[4] K.N.M. Hasan and M.F. Romlie. "Comparative study on combined series active and shunt passive power filter using two different control methods," IEEE International Conference on Intelligent and Advanced Systems, pp. 928-933, 2006.

[5] S. G. Seifossadat, R. Kianinezhad, A. Ghasemi, and M. Monadi, "Quality improvement of shunt active power filter, using optimized tuned harmonic passive filters," IEEE International Symposium on Power Electronics, Electrical Drives, Automation and Motion, pp. 1388-1393, 2008.

[6] J. Wang, "Simulation of three-phase three-wire shunt active power filter," IEEE International Conference on Sustainable Power Generation and Supply, pp. 1-4, 2009.

[7] S. Leng, I.-Y. Chung, and D. A. Cartes, "Distributed operation of multiple shunt active power filters considering power quality improvement capacity," IEEE The 2nd International Symposium on Power Electronics for Distributed Generation Systems, pp. 543-548, 2010.

[8] P.J. Paul, "Shunt active and series active filters-based power quality conditioner for matrix converter," Advances in Power Electronics, 2011.

[9] D. V. Sangu Ravindra, V. Reddy, D. S. Sivanagaraju, and D. G. Kumar, "Design of Shunt Active Power Filter to eliminate the harmonic currents and to compensate the reactive power under distorted and or imbalanced source voltages in steady state," International Journal of Engineering Trends and Technology, vol. 2, issue 3, 2011.

[10] C. N. Kiran, S. S. Dash and S. P. Latha, "A few aspects of power quality improvement using shunt active power filter," International Journal of Scientific & Engineering Research, vol. 2, issue 5, pp. 23-31, 2011.

[11] I. Lachkar, F. Giri, A. Abouloifa, J. M. Guerrero, R. Grino, F. Z. Chaoui and H. Elfadil, "Nonlinear Control of Single-Phase Shunt Active Power filter Theoretical analysis of closed-loop performances," IFAC Proceedings Volumes, vol. 44, issue 1, pp. 4954-4959, 2011.

[12] M. Anzari, R. Chandran and R. ArunKumar, "Single-phase shunt active power filter using indirect control method," Advance in Electronic and Electric Engineering, vol. 3, issue 1, pp. 81-90, 2013.

[13] S. Rahmani, A. Hamadi, K. Al-Haddad and L. A. Dessaint, "A combination of shunt hybrid power filter and thyristor-controlled reactor for power quality," IEEE Transactions on Industrial Electronics, vol. 61, issue 5, pp. 2152-2164, 2014.

[14] H. Usman, H. Hizam and M. A. M. Radzi, "Simulation of single-phase shunt active power filter with fuzzy logic controller for power quality improvement," IEEE Conference on Clean Energy and Technology (CEAT), pp. 353-357, 2013.

[15] B. V. Siva, "Design of Shunt Active Power Filter for Improvement of Power Quality with Artificial Intelligence Techniques," International Journal of Advanced Research in Electrical Electronics and Instrumentation Engineering, vol. 3, Issue 8, 2014.

[16] D. S. Kumar and G. V. Madhav, "Power quality improvement with a shunt active power filters using MATLAB/ Simulink," International journal of innovative research in electrical, electronics, instrumentation and control engineering, vol. 3, issue 1, 2015.

[17] F. Belloni, R. Chiumeo and C. Gandolfi, "Shunt Active Power Filter with Selective Harmonics Compensation for LV distribution grid," in International Conference on Renewable Energy and Power Quality, 2015.

[18] H. Vanjani, U. K. Choudhury, M. Sharma and B. Vanjani, "Takagi-sugeno (TS)-type fuzzy logic controller for three-phase four-wire shunt active power filter for unbalanced load," IEEE 7th Power India International Conference (PIICON), pp. 1-4, 2016.

[19] S. U. Bhople, "Reduction of Harmonics using Shunt Active Power Filters" International Journal of Engineering Research & Technology (IJERT), vol. 4, issue 07, 2015.

[20] S. A. Taher, M. H. Alaee and Z. D. Arani, "Model predictive control of PV-based shunt active power filter in single phase low voltage grid using conservative power theory," IEEE 8th Power Electronics, Drive Systems & Technologies Conference (PEDSTC), pp. 253-258, 2017.

[21] D. M. Soomro, S. C. Chong, Z. A. Memon, M. A. Uqaili and F. Abbasi, "Performance of shunt active power filter based on instantaneous reactive power control theory for single-phase system," International Journal of Renewable Energy Research (IJRER), vol.7, issue 4, pp. 1741-1751, 2017.

[22] K. K. Pedapenki, S. P. Gupta and M. K. Pathak, "Experimentation of shunt active filters," Int. J. Pure Appl Math, vol. 114, issue 7, pp. 65-75, 2017.

[23] S. S. Patil, R. A. Metri and O. K. Shinde, "Shunt active power filter for MV 12-pulse rectifier using PI with SMC controller," International Conference on Circuit, Power and Computing Technologies (ICCPCT), pp. 1-6, 2017.

[24] M. S. S.Managule and E. V. Kumar, "The Shunt Active Power Filter to Compensate Reactive Power and Harmonics with optimized PI controller in a 3 Phase 3 Wire Distribution System. International Journal of Engineering and Technical Research, vol. 8, issue 7, 2018

[25] A. Chebabhi, K. Abdelhalim, F. M. K. Fellah and A. Fayssal, "Self tuning filter and fuzzy logic control of shunt active power filter for eliminates the current harmonics constraints under unbalanced source voltages and loads conditions," Journal of Power Technologies, vol. 98, issue 1, p. 1, 2018.

[26] M. Dellahi, A. Mouhsen, H. Maker, A. Mouhsen and E. A. Hernandez, "Three-phase four wire shunt active power filter based on Simplified Backstepping technique for DC voltage control," Renew Energy Power Qual J, vol. 1, issue 16, pp. 554-559, 2018.

[27] G. Jegadeswari, "Performance Analysis of power quality Improvement using Shunt Active Power Filter," International Journal of Recent Technology and Engineering, vol. 7. issue 5, pp. 1-5, 2019.