International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Intelligent Controller Based Shunt Active Power Filter for Enhancement of Power Quality Problems

Ms.P. Praphulla Gayathri[1], Ms.R. Bhuvaneswari[2], Mr. K. Sriram[3] , Mr. B. Raghavendra[4]

[1]*Department of Electrical and Electronics Engineering, School of Engineering, Anurag University, Hyderabad*
[2]*Department of Electrical and Electronics Engineering, School of Engineering, Anurag University, Hyderabad*
[3]*Department of Electrical and Electronics Engineering, School of Engineering, Anurag University, Hyderabad*
[4]*Department of Electrical and Electronics Engineering, School of Engineering, Anurag University, Hyderabad*

---***---

***Abstract* -** Power Quality is a major concern now. It depends on voltage, current, and frequency parameters. Power quality issues is defined as “any occurrence manifested in current, voltage, and frequency deviations that results in damage, upset or failure of end-use equipments. The excessive use of non-linear loads causes the power quality To mitigate this Power quality issue a Shunt Active Power Filter is used. It produces compensating current which is equal and phase opposition to the harmonic currents. The switching pulses are produced by the hysteresis current controller. This paper gives detailed analysis of study on the Id-Iq control scheme. This control scheme is carried out by using matlab / simulink Toolbox and Simulation results are observed.

***Key Words*:** power quality, shunt active filter, hysteresis current controller, non-linear load, d-q Method.

1.INTRODUCTION

Power quality is a problem caused by the modern use of power electronic devices. These devices use the diodes, thyristors, IGBTs and other devices. Because of the rapid turning on and off i.e. switching many distortions are introduced. These distortions cause changes in the line currents and voltages and hence the currents at the source side also varries and changes. The abrupt change of the source side current causes abrupt movements in the generator shaft which reduces its life. These current and voltage distortions need to be rectified. Earlier passive filters were used. But they couldn’t control the reactive power. These devies were banks of capacitors that were switched on/off manually and had many limitations including their large size. The active power filters use a control that is based on the harmonic sensing.In paper we are using active power filter and an intelligent control using fuzzy logic is done. In active power filters generally non liner systems are considered. It is not so difficult to design a linear control system but it’s difficult to design a non-linear control system. In intelligent control fuzzy logic, neural networks, fuzzy-neural network are the basic tools. Intelligent control is a challenging. In linear system we express the system model either using state space or using transfer function. For example we have a plant that we want to control i.e. we regulate some of the variables like speed of motor, the ph value of a reactor or the voltage level of power system bus bar. Mathematical models are derived using basic laws that we have in physics, chemistry and science. Systems are generally non-linear. Uncertainties in the model should be taken care by the intelligent control. The model should be adaptive to the changes in the variables of the environment. The intelligent control should be distributed in nature.

2. Proposed System Modeling

The proposed Active Shunt Filter (ASF) with Fuzzy Logic Controller (FLC) is designed to compensate harmonics, improve power factor, and regulate voltage stability in a power system. The methodology involves system modeling, control strategy design, simulation, and performance evaluation.

2.1. System Modeling

The power system under study consists of Power Source AC supply (230V, 50Hz).Nonlinear Load: Rectifiers, variable frequency drives, and power electronics-based loads introducing harmonics.

Active Shunt Filter (ASF): A Voltage Source Inverter (VSI)-based filter that injects compensating currents to mitigate harmonics. Current Sensors: To measure source current and detect harmonic distortions. Fuzzy Logic Controller (FLC): Intelligent control mechanism that dynamically adjusts ASF operation. Hysteresis PWM Controller: Generates switching signals to VSI for real-time harmonic compensation.

2.2. Control Strategy Design

A. Harmonic Extraction Method

The Instantaneous Reactive Power Theory (p-q Theory) is used to extract the harmonic components.

Load current is transformed using Clarke transformation (abc to αβ0) to separate fundamental and harmonic components. The extracted harmonic components are fed into the ASF for cancellation.

B. Fuzzy Logic Controller (FLC) Implementation

The FLC is designed as follows Inputs Error (E) and Change in Error (de) of the supply current.

Fuzzification Inputs are converted into fuzzy linguistic variables (Negative Large, Negative Medium, Negative Small, Zero, Positive Small, Positive Medium, Positive Large).Rule Base A 7×7 fuzzy rule matrix is created based on if-then logic. Inference Engine Determines the required control action for the ASF. Defuzzification Centroid method is used to generate a precise output for the Pulse Width Modulation (PWM) controller.

Results and Analysis

Simulation and experimental studies have been conducted to analyze the performance of **SAPF with FLC**. The key findings are:

- **Harmonic Reduction:**
  - The **Total Harmonic Distortion (THD)** of the supply current is significantly reduced from **above 20% to less than 5%**, complying with IEEE 519 standards.
- **Power Factor Improvement:**
  - The system achieves near **unity power factor**, eliminating reactive power demand from the grid.
- **Dynamic Performance:**
  - The FLC-based SAPF exhibits faster response time and better adaptation to varying loads compared to PI-based controllers.
- **Voltage and Current Waveform Enhancement:**
  - The voltage and current waveforms become more sinusoidal, ensuring a stable power supply.

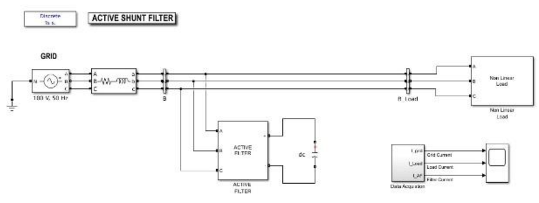

Fig: Power Quality Improvement By Active Shunt Filter With Intelligent Controller

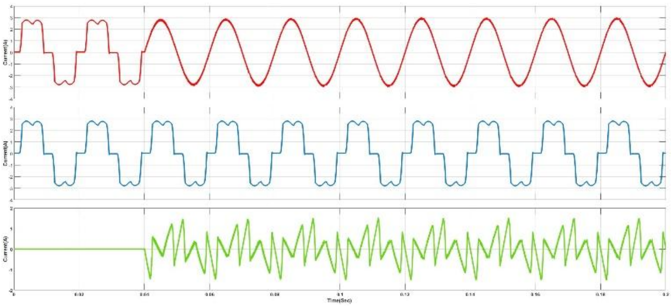

Fig: Output phase Current of PI

This diagram presents the Initially, the load current and source current contain harmonics, indicating poor power quality. The active shunt filter injects compensating current (green waveform) to cancel out the harmonics. After compensation, the source current (third graph) improves but may still contain minor distortions. A well-tuned intelligent PI controller can further optimize harmonic mitigation and power factor correction

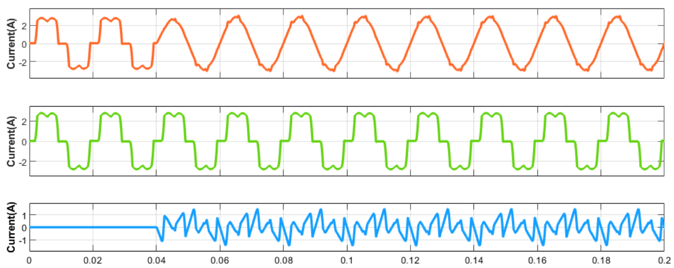

Fig::Output phase current of Fuzzy

The image appears to represent the current waveforms in a power system where a **Fuzzy Logic Controller (FLC) based Active Shunt Filter** is used for power quality improvement. Let's analyze the graphs in relation to the fuzzy logic control method

3. CONCLUSIONS

The integration of an **intelligent PI controller** with an **active shunt filter** proves to be an efficient solution for mitigating power quality issues.

The system ensures **harmonic suppression, power factor correction, and improved voltage regulation**, leading to enhanced stability and efficiency in power systems.

Compared to conventional PI controllers, the **intelligent PI controller** provides **adaptive tuning**, making the system more **robust and responsive** to dynamic load conditions.

 Overall, the proposed method offers a **cost-effective and reliable** solution for improving power quality in industrial and commercial power networks.

 The Fuzzy Logic Controller successfully **reduces harmonics** and **improves the source current quality** after compensation.

 The **compensated current is more sinusoidal**, though some distortions still exist, which may be improved by further tuning the fuzzy rules or using hybrid control techniques.

 The **active filter injects compensating current efficiently**, adapting in real-time to load variations.

 Overall, **FLC outperforms traditional PI controllers** by providing **better dynamic response and adaptability to nonlinear loads**.

ACKNOWLEDGEMENT

We extend our sincere gratitude to our mentors and faculty members for their valuable insights and guidance throughout this research. We also thank our peers for their support and collaborative efforts in testing and improving the system.

REFERENCES

[1] Abdeldjabbar M. K, Tayeb Allaoui , Mouloud Denai, George Pissanidis , "Grid power quality enhancement using fuzzy controlbased shunt active filtering", SAI Intelligent Systems Conference (IntelliSys), 2015.

.[2] 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

[3] Shyamaladevi.E, Vijayakumar.G, "Fuzzy Controller based Hybrid Active Power Filter for Energy Saving", International Journal of Computer Applications, 2012.

[4]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

[5] 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.

[6] 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..

[7] Rao, K. V. G., Kumar, M. K., Goud, B. S., Devi, T. A., Rao, G. S., Giriprasad, A., ... &Kalyani, T. V. S. (2023). A new brushless DC motor driving resonant pole inverter optimized for batteries. *Int. J. Power Electron. Drive Syst*, *14*(4), 2021-31.

[8] 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

[9] 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.

[10] 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

[11] V Muneer , Avik Bhattacharya, "Shunt Hybrid Active Filter By Using Cascaded H Bridge Multilevel Inverter", 14th IEEE India Council International Conference (INDICON), 2017.

[12] Zhengyou Ma, "The Design of Hybrid Active Power Filter based on Harmonics Detection and Its Simulation Research", Chemical Engineering Transactions, VOL. 51, 2016

[13] 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.

[14] 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

[15] 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

[16] 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 .

[17**]** 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.

[18] 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.

[19] Shyamaladevi.E, Vijayakumar.G, "Fuzzy Controller based Hybrid Active Power Filter for Energy Saving", International Journal of Computer Applications, 2012

[20] Bhattacharya, S., & Divan, D. (1995). *Design and Implementation of Active Filters for Power Quality Improvement*. IEEE Transactions on Industry Applications, **32(3)**, 530–541.

[21] Singh, B., Chandra, A., & Al-Haddad, K. (1999). *A Review of Active Filters for Power Quality Improvement*. IEEE Transactions on Industrial Electronics, **46(5)**, 960-971.

[22] Ghosh, A., & Ledwich, G. (2002). *Compensation of Distribution System Voltage Using DVR and Active Filters*. IEEE Transactions on Power Delivery, **17(4)**, 1030-1036.

[23] Dash, S. S., Mishra, S., & Ghosh, A. (2006). *A Hybrid Fuzzy-PI Controller for Voltage Regulation in Distribution Networks with Active Filters*. IEEE Transactions on Power Electronics, **21(4)**, 1194-1203.

[24] El-Habrouk, M., Darwish, M. K., & Mehta, P. (2000). *Active Power Filters: A Review*. IEE Proceedings - Electric Power Applications, **147(5)**, 403-413.

[25] Karthikeyan, R., & Palanisamy, K. (2013). *Optimal Placement of Active Power Filters for Harmonic Minimization Using Firefly Algorithm.* Journal of Electrical Engineering & Technology, **8(5)**, 723-732.

[26] Rajesh, P., & Kumar, M. (2021). *Performance Analysis of Fuzzy Logic and PI Controller for Shunt Active Power Filter in Power Quality Enhancement.* International Journal of Electrical and Computer Engineering, **11(3)**, 2150-2160.