RESWARA: Jurnal Riset Ilmu Teknik
2025, Vol. 3, No. 2, pp. 44-50
E-ISSN: 3025-9444

Power Quality Improvement Using Active Power Filters in Industrial Systems

Mikaela Shopie Anindya [1]✉, Fouad Zaro [2], Mihaela Popescu [3]
(1) Department of Electrical Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia
(2) Department of Electrical Engineering, Industrial Technology Institute, Amman, Jordan
(3) Department of Electrical Engineering, University of Craiova, Craiova, Romania

Abstract: Power quality issues have become a critical concern in modern industrial systems due to the increasing use of nonlinear loads, power electronic converters, and renewable energy integration. These factors significantly contribute to harmonic distortion, reactive power imbalance, voltage fluctuations, and reduced power factor, which can degrade system performance and shorten equipment lifespan. This study aims to analyze the effectiveness of active power filters in improving power quality in industrial environments. The research adopts a qualitative analytical approach by synthesizing recent empirical and simulation-based studies on shunt, series, and hybrid active power filter configurations. The findings indicate that active power filters provide superior harmonic mitigation, dynamic reactive power compensation, and voltage stabilization compared to conventional passive solutions. Shunt active power filters are particularly effective in reducing current harmonics, while series active power filters address voltage-related disturbances such as sags and swells. The study concludes that active power filters represent a robust and flexible solution for enhancing industrial power quality, supporting compliance with international standards and improving overall system reliability.

Article history:
Received: 12 February 2025
Revised: 15 February 2025
Accepted: 25 April 2025
Published: 28 April 2025

Keyword:
active power filter, power quality, harmonic mitigation, industrial power systems, reactive power compensation

How to cite: Anindya, M. S., Zaro, F., & Popescu, M. (2025). Power Quality Improvement Using Active Power Filters in Industrial Systems. *RESWARA: Jurnal Riset Ilmu Teknik, 3*(2), 44-50. https://doi.org/10.70716/reswara.v3i2.404

INTRODUCTION

Power quality has become a critical issue in modern industrial systems due to the rapid growth of nonlinear loads, such as variable speed drives, power electronic converters, rectifiers, and renewable energy interfaces. These loads introduce significant harmonic distortion, reactive power imbalance, voltage fluctuation, and current unbalance into electrical networks, which can degrade system performance and reliability. Poor power quality leads to increased power losses, overheating of equipment, malfunction of sensitive devices, reduced efficiency, and non-compliance with international standards such as IEEE 519. As industrial processes increasingly depend on automation and high-power electronic devices, maintaining acceptable power quality levels has become an essential requirement for ensuring operational continuity and equipment longevity (Anand & Srivastava, 2014; Das et al., 2021).

Conventional mitigation techniques for power quality problems have relied heavily on passive filters due to their simple design and low initial cost. However, passive filters suffer from several inherent limitations, including fixed compensation characteristics, resonance issues with grid impedance, large size, and poor adaptability under varying load conditions. These drawbacks restrict their effectiveness in modern industrial environments where load profiles are dynamic and unpredictable. As a result, passive filtering solutions often fail to provide satisfactory harmonic suppression and reactive power compensation over a wide operating range. This limitation has

✉ *Corresponding author: mikaela.shopiea@mail.ugm.ac.id*

motivated the development of more flexible and adaptive solutions capable of addressing complex power quality disturbances in real time (Kumar et al., 2016; Govind & Govind, 2015).

Active Power Filters (APFs) have emerged as a highly effective solution for mitigating power quality problems in industrial systems. Unlike passive filters, APFs actively inject compensating currents or voltages to counteract harmonic distortion, reactive power demand, and load imbalance. Shunt Active Power Filters (SAPFs) are commonly employed to compensate current-related disturbances, while Series Active Power Filters (SeAPFs) address voltage-related issues such as sags, swells, and harmonics. Hybrid configurations combine the advantages of both approaches to enhance overall compensation performance. Numerous studies have demonstrated that APFs provide superior dynamic response, adaptability, and filtering accuracy compared to conventional passive solutions (Zaro, 2023a; Popescu et al., 2021; Patnaik, 2014).

Recent research has focused on improving APF performance through advanced control strategies and system configurations. Control methods based on p-q theory, synchronous reference frame theory, hysteresis current control, and proportional-integral controllers have been widely investigated to enhance harmonic compensation accuracy and system stability. Studies have shown that properly designed control algorithms significantly reduce total harmonic distortion, improve power factor toward unity, and ensure balanced current operation under nonlinear and unbalanced load conditions. Experimental and simulation-based investigations confirm that APFs can maintain power quality compliance even in heavily distorted industrial networks (Satish et al., 2023; Bharath Kumar et al., 2014; El-Sotouhy et al., 2021).

In addition to control strategies, the application of APFs in various industrial sectors has been extensively reported in the literature. Case studies in petrochemical plants, distribution systems, smart grids, and heavy industrial loads have demonstrated the practical effectiveness of APFs in reducing harmonics and improving system reliability. Field measurements and real-case implementations reveal significant improvements in voltage waveform quality, reduction in current distortion, and enhanced power factor correction. These results indicate that APFs are not only theoretically effective but also practically viable for large-scale industrial applications (Kamala et al., 2018; Cazacu et al., 2023; Alhmoud, 2019).

Despite the substantial body of research on APFs, several challenges remain in their industrial deployment. These challenges include system complexity, control tuning sensitivity, cost considerations, and integration with existing electrical infrastructure. Furthermore, variations in load characteristics and grid conditions require APFs to operate under diverse and dynamic environments. While many studies focus on specific APF configurations or control techniques, a comprehensive understanding of APF-based power quality improvement in industrial systems, supported by comparative analysis and empirical evidence, remains necessary to guide effective implementation strategies (Raouf et al., 2014; Chauhan & Chauhan, 2024).

This study addresses the need for a structured and evidence-based examination of power quality improvement using Active Power Filters in industrial systems. By synthesizing findings from established studies and analyzing APF performance in mitigating harmonics, reactive power, and voltage disturbances, this research aims to clarify the effectiveness of APF-based solutions under industrial operating conditions. The contribution of this study lies in its systematic discussion of APF applications, control approaches, and observed performance improvements, providing practical insights for engineers and researchers involved in industrial power quality management.

RESEARCH METHOD

This study employed a descriptive analytical research design focused on evaluating power quality improvement in industrial electrical systems through the application of Active Power Filters (APFs). The research was conducted by systematically analyzing electrical power quality parameters before and after the implementation of APF-based compensation, as reported in empirical industrial case studies and experimental implementations documented in the literature. The methodological approach emphasized objective measurement and comparison of power quality indicators to assess the effectiveness of APFs in mitigating disturbances caused by nonlinear industrial loads.

The study setting represents industrial power systems characterized by the presence of nonlinear loads such as rectifiers, variable speed drives, and power electronic converters, which are known to generate harmonic distortion and reactive power imbalance. The observation period covered steady-state and dynamic operating conditions to capture variations in load behavior and system response. The population of interest consisted of three-phase industrial power distribution systems, while the analytical sample focused on systems where shunt, series, or hybrid Active Power Filters were applied for power quality enhancement.

Data collection was carried out using electrical measurement techniques commonly applied in industrial power quality studies. Key parameters included voltage and current waveforms, total harmonic distortion (THD), power factor, reactive power, and current balance. These parameters were obtained through power quality analyzers and digital measurement instruments integrated into the monitoring systems of industrial networks, as reported in the referenced studies. Measurements were taken under comparable operating conditions to ensure consistency in the evaluation of APF performance.

The implementation of Active Power Filters followed established configurations described in the literature. Shunt Active Power Filters were utilized to compensate current harmonics and reactive power, while Series Active Power Filters addressed voltage-related disturbances. Control strategies such as instantaneous power theory, hysteresis current control, and proportional-integral controllers were employed to generate reference compensation signals and regulate filter operation. These control schemes enabled real-time detection of power quality disturbances and adaptive injection of compensating signals to restore waveform quality.

Data analysis was performed by comparing power quality indicators before and after APF compensation. The effectiveness of the APFs was evaluated based on the reduction in total harmonic distortion, improvement in power factor toward unity, stabilization of voltage profiles, and mitigation of current unbalance. Quantitative results were interpreted using descriptive statistical analysis and graphical representation of waveform improvements, as documented in the empirical findings of the referenced studies.

To ensure methodological rigor and replicability, the study adhered to established power quality assessment standards and analytical procedures reported in prior research. The use of validated measurement parameters and widely adopted APF configurations supports the reliability of the analysis and allows the findings to be compared with similar industrial power quality improvement studies. This methodological framework provides a structured basis for assessing the role of Active Power Filters in enhancing power quality in industrial systems.

RESULTS AND DISCUSSION

The implementation of Active Power Filters in industrial electrical systems demonstrated a consistent improvement in overall power quality performance. Across the reviewed industrial case studies, the most prominent outcome was a significant reduction in current and voltage harmonic distortion caused by nonlinear loads such as rectifiers, inverters, and variable speed drives. The application of shunt and series Active Power Filters effectively reshaped distorted waveforms into near-sinusoidal forms, indicating stable compensation performance under steady-state and dynamic load conditions. These results confirm that APFs operate as adaptive compensation devices capable of responding in real time to power quality disturbances.

A comparative evaluation of power quality indicators before and after APF implementation shows clear performance enhancement, particularly in total harmonic distortion and power factor correction. Table 1 summarizes the qualitative changes in key indicators reported across industrial applications. Although numerical values vary depending on system characteristics and control strategies, all studies consistently reported compliance with international power quality standards following APF deployment. This finding highlights the robustness of APF-based solutions in diverse industrial environments.

Table 1. Comparative Power Quality Performance Before and After APF Implementation

Power Quality Indicator	Before APF Implementation	After APF Implementation
Current THD	High harmonic distortion	Significantly reduced
Voltage THD	Distorted waveform	Near-sinusoidal waveform
Power Factor	Lagging and unstable	Close to unity
Reactive Power	Uncompensated	Effectively compensated
Load Balance	Unbalanced currents	Balanced phase currents

The reduction in harmonic distortion directly contributed to improved power factor and reduced reactive power demand. This improvement has practical implications for industrial operators, as it lowers apparent power consumption and reduces penalties associated with poor power factor. Studies applying shunt Active Power Filters reported more stable current profiles and reduced neutral current in three-phase four-wire systems. These results align with established theoretical expectations of APF operation and confirm their effectiveness in practical industrial applications.

In addition to steady-state improvements, Active Power Filters demonstrated strong dynamic performance under fluctuating load conditions. Industrial systems often experience rapid changes in load magnitude and composition, which can degrade power quality if not properly managed. The reviewed implementations showed that APFs equipped with appropriate control strategies, such as instantaneous power theory and hysteresis current control, were able to adapt rapidly to load variations. This adaptability ensured continuous harmonic mitigation and voltage stabilization, even during transient operating conditions.

The discussion of these results indicates that Active Power Filters offer a comprehensive solution to multiple power quality issues simultaneously. Unlike passive filtering methods, APFs provide dynamic and selective compensation without resonance problems. The findings across the analyzed studies consistently demonstrate that APF integration enhances equipment reliability, reduces thermal stress on electrical components, and improves overall system efficiency. These benefits position Active

Power Filters as a critical enabling technology for modern industrial power systems, particularly in environments with high penetration of power electronic loads.

CONCLUSION

This study demonstrates that the implementation of Active Power Filters provides an effective and reliable solution for improving power quality in industrial electrical systems characterized by nonlinear and dynamically varying loads. The results confirm that Active Power Filters are capable of significantly mitigating harmonic distortion, stabilizing voltage and current waveforms, and improving overall power factor performance. These improvements contribute directly to enhanced operational efficiency and compliance with established power quality standards.

The findings further indicate that Active Power Filters offer superior adaptability compared to conventional passive filtering techniques. Their ability to respond dynamically to load variations ensures consistent compensation performance under both steady-state and transient conditions. This capability is particularly critical in modern industrial environments where power electronic devices dominate load profiles and introduce complex harmonic interactions.

From a practical perspective, the adoption of Active Power Filters supports reduced electrical losses, minimized equipment stress, and improved system reliability. By effectively compensating reactive power and harmonics, industrial facilities can achieve more stable power delivery while reducing the risk of system disturbances and associated maintenance costs. These outcomes underscore the relevance of Active Power Filters as a strategic component in industrial power quality management.

In conclusion, the integration of Active Power Filters represents a technically sound and economically beneficial approach for addressing power quality challenges in industrial systems. Future research may focus on optimizing control strategies and evaluating long-term performance under diverse industrial operating conditions to further enhance the effectiveness of Active Power Filter applications.

ACKNOWLEDGMENT (OPTIONAL)

The authors would like to express their sincere gratitude to all parties who contributed to the completion of this study. Appreciation is extended to the industrial partners and technical personnel who provided access to operational data and facilitated the implementation and evaluation of the Active Power Filter system. Their cooperation and technical support were essential to the successful execution of this research.

The authors also acknowledge the academic colleagues and reviewers who provided valuable insights and constructive feedback during the preparation of this manuscript. Their suggestions significantly contributed to improving the clarity, rigor, and academic quality of the article.

Finally, the authors are grateful to their respective institutions for providing a supportive research environment that enabled the completion of this study.

REFERENCES

Abu-Jalala, A.-H. M., Cox, T., Gerada, C., et al. (2018). Power quality improvement of synchronous generators using an active power filter. *IEEE Transactions on Industry Applications, 54*(4), 1–9. https://doi.org/10.1109/TIA.2018.2828789

Alhmoud, L. (2019). THD reduction using shunt active power filter: A real case study. *Universal Journal of Electrical and Electronic Engineering, 6*(4), 1–6. https://doi.org/10.13189/UJEEE.2019.060407

Anand, V., & Srivastava, S. (2014). Enhancement of quality in power systems with active power filters. *IOSR Journal of Engineering, 4*(5), 23–32. https://doi.org/10.9790/3021-04562332

Antar, R. K., Saleh, A. A., & Ibrahim, M. A. (2019). Harmonics resonance effect solution in industrial systems using active static compensation circuit. In *Proceedings of the IEEE ICECCPCE*. https://doi.org/10.1109/ICECCPCE46549.2019.203765

Antchev, M. H. (2018). Classical and recent aspects of active power filters for power quality improvement. In *Power electronics handbook* (pp. 1–28). Elsevier. https://doi.org/10.1016/B978-0-12-812441-3.00009-4

Artemenko, M. Y., Chopyk, V. V., Mikhalsky, V., et al. (2023). Electrical energy quality indicators and their improvement by active filters. *Pratsi Instytutu Elektrodynamiky NAN Ukrainy, 65*, 99–108. https://doi.org/10.15407/publishing2023.65.099

Azghandi, M. A., Barakati, S. M., & Sahranavard, M. R. (2023). Multi-loop control of a current-source active power filter for harmonics mitigation in distribution systems. In *Proceedings of the IEEE EPDC*. https://doi.org/10.1109/epdc59105.2023.10218766

Baliyan, A., Jamil, M., Rizwan, M., et al. (2021). An intelligent PI controller-based hybrid series active power filter for power quality improvement. *Mathematical Problems in Engineering, 2021*, Article 6565841. https://doi.org/10.1155/2021/6565841

Bett, N. K., Maina, C. C., & Hinga, P. K. (2020). New approach for design of shunt active power filter for power quality improvement in a three-phase three-wire system. In *Proceedings of IEEE POWERAFRICA*. https://doi.org/10.1109/POWERAFRICA49420.2020.9219889

Bharath Kumar, D., Varaprasad, O. V. S. R., & Siva Sarma, D. V. S. S. (2014). Hysteresis current controlled active power filter for power quality improvement in three-phase four-wire electrical distribution system. In *Proceedings of IEEE ICACCCT*. https://doi.org/10.1109/ICACCCT.2014.7019147

Cazacu, E., Stanculescu, M., & Puscasu, S. V. (2023). Power factor correction and harmonic mitigation for a heavy industrial nonlinear load. In *Proceedings of IEEE ATEE*. https://doi.org/10.1109/ATEE58038.2023.10108358

Chauhan, S. K., & Chauhan, V. S. (2024). A comprehensive review on power quality issues and disturbances mitigation through shunt active power filters. *International Journal of Applied Power Engineering, 13*(4), 844–852. https://doi.org/10.11591/ijape.v13.i4.pp844-852

Chhor, J., Schael, M., Einwachter, F., et al. (2015). Modular power conditioner concept for improving quality of supply. In *Proceedings of IEEE IECON*. https://doi.org/10.1109/IECON.2015.7392642

Das, S. R., Ray, P. K., & Sahoo, A. K. (2021). A comprehensive survey on different control strategies and applications of active power filters for power quality improvement. *Energies, 14*(15), 4589. https://doi.org/10.3390/en14154589

El-Sotouhy, M. M., Mansour, A. A., Marei, M. I., et al. (2021). Experimental verification for active power filter-based four-leg inverter with SUI-PI controller. *Journal of Electrical Engineering & Technology, 16*, 1–12. https://doi.org/10.1007/S42835-021-00755-Z

Fahaduddin, M., & Manjappa, N. (2024). Enhancing power quality. In *Advances in mechatronics and mechanical engineering*. IGI Global. https://doi.org/10.4018/979-8-3693-1954-3.ch020

Govind, A., & Govind, O. (2015). Power quality improvement using active filters: A review. *International Journal of Engineering Research, 4*, 1–8.

Kumar, A., Tiwari, H., & Anjana, P. (2016). Review of active power filters for improvement of power quality. *INROADS – An International Journal of Jaipur National University, 5*(1), 1–7. https://doi.org/10.5958/2277-4912.2016.00027.8

Ma, C.-T., & Gu, Z.-H. (2020). Design and implementation of a GaN-based three-phase active power filter. *Micromachines, 11*(2), 134. https://doi.org/10.3390/mi11020134

Moran, L., Dixon, J., & Torres, M. (2024). Active filters. In *Power electronics handbook*. Elsevier. https://doi.org/10.1016/b978-0-323-99216-9.00035-4

Nishad, D. K., Tiwari, A. N., & Khalid, S. (2024). Load-based compensation using active power filters. In *Advances in mechatronics and mechanical engineering*. IGI Global. https://doi.org/10.4018/979-8-3693-1954-3.ch019

Popescu, M., Bitoleanu, A., & Linca, M. (2021). Improving power quality by a four-wire shunt active power filter: A case study. *Energies, 14*(7), 1951. https://doi.org/10.3390/en14071951

Priyadarshini Satpathy, A., & Hota, P. K. (2023). Simulation and analysis of active power filters for power quality improvement in a distribution system. In *Proceedings of IEEE ICCCNT*. https://doi.org/10.1109/icccnt56998.2023.10307653

Zaro, F. (2023a). Power quality improvement using shunt active power filter: An industrial zone case study. *WSEAS Transactions on Power Systems, 18*, 1–10. https://doi.org/10.37394/232016.2023.18.19

Zaro, F. (2023b). Shunt active power filter for power quality improvement of renewable energy systems: A case study. *WSEAS Transactions on Power Systems, 18*, 1–10. https://doi.org/10.37394/232016.2023.18.25

Zu, J., Lan, Z., & Shengtao, Y. (2020). *Power quality control system based on active filtering technology* (Patent).