International Journal of Advanced Trends in Engineering and Management
(ISSN 2583-7052)

Vol. IV, No. 06, pp. 12-21, June

Mitigating Power Quality Issues in Utility Grids: A Comprehensive Survey

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ABSTRACT: The increasing use of dispersed energy supplies, industrial automation, and nonlinear loads have made Power Quality (PQ) a major problem for utility systems. Voltage sags, swells, flickers, harmonics, and transients are caused by these disturbances, which impair system performance and end-user dependability. This paper presents a comprehensive examination looking into the origins and effects of PQ disruptions, as well as the mitigation measures used to ensure grid stability and compliance with PQ requirements. Each method is evaluated according to its response time, ability to rectify certain disturbances, and appropriateness for integration into the grid infrastructure. The review further highlights recent developments in power electronic converter topologies and modulation techniques that enhance PQ performance under dynamic grid conditions. This review serves as a foundational resource to optimize grid reliability, improve operational resilience, and ensure adherence to internationally recognized PQ standards.

Keywords: Power Quality, Active and Passive Power Filter, Distributed Generators, Static VAR Compensator, Optimizations.

1. Introduction

In modern industries, homes, and commercial settings, many devices such as computers, medical equipment, automated machinery, and communication systems are highly sensitive to even minor disturbances in voltage, current, or frequency [1]. The need for high PQ stems from the growing dependence on precision-controlled, microprocessor-based equipment in industries, healthcare, data centers, and smart homes. These systems require a clean, stable, and uninterrupted power supply to function accurately and efficiently. With the rise of renewable energy integration, electric vehicle charging, and power-electronic-driven loads, electrical networks are more vulnerable to issues like harmonics, voltage fluctuations, and transients [2-3].

1.1 PQ Issues

Poor power quality, caused by issues like harmonics, voltage sags/swells, flickers, and interruptions, can lead to equipment malfunction, unexpected shutdowns, data loss, increased energy consumption, and higher maintenance costs.

1.2 Voltage Sags/Swells

It usually occurs when a heavy load, such as a large motor or industrial equipment, is suddenly switched on, causing a temporary drop in voltage across the power system. A voltage swell is is the opposite of a voltage sag and commonly occurs due to events such as the sudden disconnection of large loads, switching off heavy equipment, or faults in the neutral line of the power system.

Voltage swells are especially harmful to sensitive electronic devices, leading to overheating, insulation damage, data corruption, or even complete equipment failure [4].

1.3 Harmonics

In electricity systems, harmonics are waveforms of electricity or voltage that vary from a perfect smooth shape because they contain multiple integer multiples of the fundamental frequency. Total Harmonic Distortion (THD) is a measure of the distortion present in a waveform due to the presence of harmonics. These unwanted frequencies are generated primarily by nonlinear loads such as computers, LED lighting, inverters, and other power electronic devices.

1.4 Flickers

Flickers are rapid and repetitive fluctuations in voltage magnitude that cause noticeable and often irritating variations in the brightness of lighting and performance of sensitive electronic equipment. These voltage variations typically last from milliseconds to several seconds and are caused by sudden changes in load demand such as arc furnaces, large motors, or welding machines that draw fluctuating currents from the power supply [5-7].

1.5 Momentary Interruption

A momentary interruption is a brief loss of power supply that typically lasts from a few milliseconds up to 1 or 2 seconds. During this time, the voltage drops to zero or near zero and then quickly recovers. These interruptions are usually caused by events such as faults on the transmission or distribution lines, lightning strikes, switching operations, or equipment failures. Momentary interruptions are often confused with voltage sags, but the key difference is that in a momentary interruption, the voltage drops entirely, whereas in a sag, it remains at a reduced level [8-9]. These issues also shorten the lifespan of electrical devices and result in reduced system efficiency. PQ detection devices are essential in monitoring and improving the reliability of electrical systems by identifying and addressing PQ issues [10]. Therefore, this paper presents a survey of mitigating PQ issues in utility grids for improving the reliability. In this work, the following contributions are achieved:

- To analyze the various filters and their types for PQ issues detection.
- To explore the different optimization techniques in improving the performance of PQ issues detection.
- To evaluate the benefits and downsides of various optimization algorithms for PQ issues detection.

The order in which the paper is given is shown in the list below: Section II covers the most recent work. Section III provides a detailed review of filters. Section IV presents the review of optimization techniques. The comparative analysis is shown in Section V. Section VI provides a conclusion.

2. Recent Works

Rami Moustafa *et al* (2025) [11] have presented a design and development of a low-cost, real-time Power Quality and Energy Monitoring Device (PQEm). It offers a cost-effective and user-friendly solution to monitor PQ issues with greater precision. It helps maintain a stable power supply and extends equipment life. Moreover, it requires professional setup and calibration, especially in large systems.

Nirmal Mukundan C M *et al* (2022) [12] have developed a Multilevel Inverter (MLI)-based grid-connected Solar Power Transfer Unit (PTU) for PQ enhancement. It provides instant visibility into voltage, current, frequency, harmonics, etc. Moreover, harmonics and PQ problems may arise due to the use of power electronic converters, necessitating advanced filtering techniques.

Yang Wang *et al* (2023) [13] have proposed a control strategy for harmonic and unbalanced power allocation among Distributed Generators (DGs) in microgrids. It provides peak load shaving, voltage regulation, and frequency support. Additionally, it identifies PQ issues before they cause equipment damage. Further, it has maximum grid integration challenges, and it requires sophisticated control and protection systems for synchronization.

Poras Khetarpal *et al* (2023) [14] have presented a Deep Auto-encoder (DAE) networks are proposed for Power Quality Disturbance (PQD) classification. It tracks energy consumption patterns, helping in load management and energy cost reduction. Nevertheless, it requires regular updates, recalibration, and sometimes hardware servicing.

Subhadip Chakraborty *et al* (2024) [15] have developed a battery interfaced to a Solar Photovoltaic (SPV) array-based grid connected microgrid. It enables centralized monitoring of multiple sites with cloud-based access. Moreover, possible harmonics, voltage fluctuations, or frequency instability if poorly managed.

3. Review of PQ Devices for PQ Issues Detection

PQ devices play a crucial role in monitoring and improving the reliability of electrical systems by identifying and addressing PQ issues. These devices, which include digital signal processors, smart meters, power analyzers, and Intelligent Electronic Devices (IEDs), are designed to detect and record PQ disturbances in real time. Recent advancements have led to the integration of filters and optimization algorithms into PQ devices, enhancing their accuracy and responsiveness. In this way, various PQ device performances are followed by the below.

3.1 Passive Power Filter

A PPF is a widely used solution for mitigating PQ issues, particularly harmonic distortions in electrical power systems. The working principle of this filter is based on resonance and impedance matching to eliminate or reduce specific harmonic frequencies from the power system. It works by shunting harmonics away from the main power line through resonance-tuned circuits, thus improving overall PQ without any active control mechanism.

3.1.1 Passive Shunt Filter

Shunt passive filter, is a type of harmonic filter connected in parallel with the load to mitigate PQ issues, particularly harmonic distortion. Passive shunt filter diagram is shown in Figure 1.

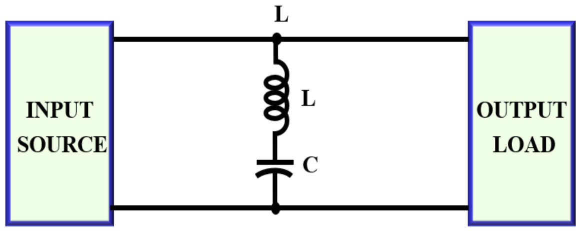

Figure 1: *Passive Shunt Filter*

It consists of passive components mainly inductors and capacitors tuned to specific harmonic frequencies. When harmonic currents are present in the system, the filter provides a low-impedance path, diverting these unwanted currents away from the power supply and sensitive equipment. This helps maintain sinusoidal waveforms of voltage and current, ensuring efficient and reliable operation of electrical systems.

3.1.2 Passive Series Filter

It is a type of harmonic filter connected in series with the power line to suppress voltage-related PQ issues, such as harmonic voltages, voltage sags, and transients. The passive series filter is seen in Figure 2.

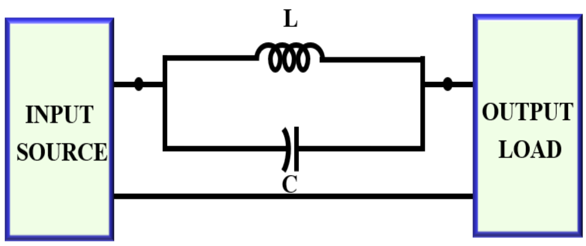

Figure 2: *Passive Series Filter*

The parallel filters that shunt harmonic currents, the series passive filter blocks the propagation of unwanted harmonic voltages by presenting high impedance at specific harmonic frequencies. It is configured to impede the flow of harmonics while allowing the fundamental frequency to pass through with minimal loss [7].

3.2 Active Power Filter

APF is an advanced PQ device used to eliminate harmonics, correct power factor, and compensate for reactive power in electrical systems. The working principle of an active power filter is based on sensing the load current, extracting the harmonic content using control algorithms for neutralize the distortion. Although more expensive and complex than passive filters, active power filters offer superior performance and flexibility, making them ideal for critical industrial and commercial applications where high PQ is essential.

3.2.1 Shunt Active Power Filter

It is a type of active filter connected in parallel with the load to eliminate current-based PQ issues such as harmonics, reactive power, and unbalanced currents. Its working principle involves continuously monitoring the load current, identifying the harmonic and reactive components using real-time control algorithms, and generating a compensating current through a VSI. Figure 3 displays the shunt active power filter.

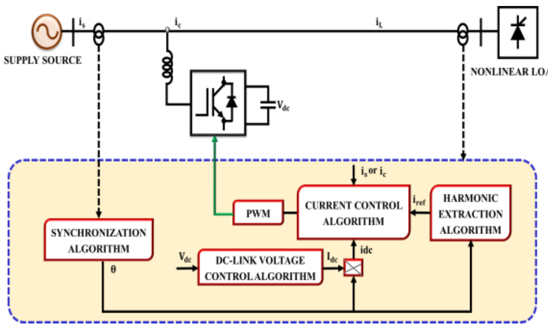

Figure 3: *Shunt Active Power Filter*

This compensating current is injected back into the power line in such a way that it cancels out the undesired components, allowing only the fundamental frequency current to flow from the source.

3.2.2 Series Active Power Filter

It is a PQ device connected in series with the power line to mitigate voltage-related disturbances such as voltage harmonics, sags, swells, flickers, and transients. The working principle of this filter involves sensing data, detecting any distortion or imbalance, and then generating an equal and opposite voltage to cancel out the disturbance. It ensures that the voltage supplied to the load remains clean and sinusoidal, even if the source voltage is distorted or unbalanced. Series active power filter architecture is shown in Figure 4.

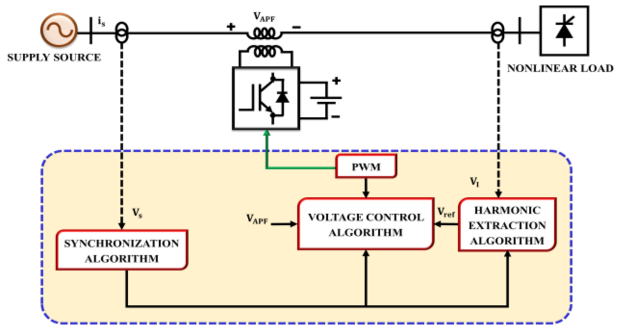

Figure 4: *Series Active Power Filter*

It provides dynamic voltage compensation makes them highly valuable in industrial and commercial applications with stringent voltage quality requirements. It mitigates harmonics, solutions such as passive filters, active power filters, and tuned LC circuits are employed [8].

3.3 Static VAR Compensator

SVC is a type of reactive power compensation device used in power systems to regulate voltage levels, improve power factor, and enhance system stability. It is a part of the Flexible AC Transmission System (FACTS) family and operates by dynamically injecting or absorbing reactive power without mechanical switching components. Figure 5 shows the SVC architecture.

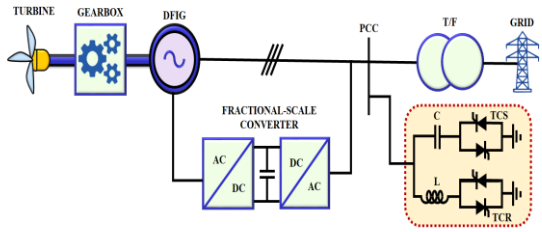

Figure 5: *SVC Architecture*

The working principle of an SVC involves the use of power electronic devices such as Thyristor-Controlled Reactors (TCR) and Thyristor-Switched Capacitors (TSC). By adjusting the firing angle of thyristors, the SVC can control the amount of inductive or capacitive reactive power supplied to the system in real time. When the voltage drops below a certain level, the SVC supplies capacitive VARs to support the voltage, it absorbs reactive power to bring the voltage down. This rapid response capability makes the SVC highly effective in stabilizing voltage during load variations, mitigating flickers, and reducing losses in transmission networks. Due to its fast and precise control, the SVC is widely used in industrial power systems, renewable energy integration, and transmission grids to enhance overall PQ and system reliability [9].

3.4 Dynamic Voltage Restores

DVR is a power electronic device used to protect sensitive loads from voltage sags, swells, and short-duration disturbances in power distribution systems. The working principle of a DVR involves continuously monitoring the incoming supply voltage; when a disturbance such as a sag or swell is detected, the DVR quickly generates a compensating voltage using a VSI and injects it through a series transformer. DVR diagram is illustrated in Figure 6.

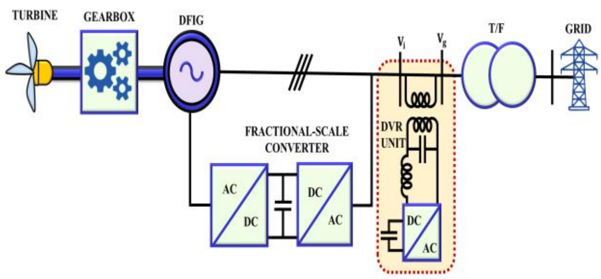

Figure 6: *DVR Architecture*

Further, it handles various voltage disturbances, DVRs are an essential component in modern electrical systems focused on reliability and uninterrupted operation. It mitigates voltage swell issues, protective devices like surge protectors, voltage regulators, and DVRs are employed to stabilize the voltage and shield critical loads from damage [10].

4. Review of PQ Optimization Technique for PQ Issues Detection

As power systems increasingly incorporate distributed energy resources and nonlinear loads, traditional threshold-based and rule-driven approaches become insufficient for precise and adaptive PQ management. Modern optimization techniques are enabling the development of smart systems that detect and also predict PQ disturbances before they impact critical operations. These methods optimize the configuration and control of power filters, voltage regulators, and compensators in real time by learning from system behavior patterns. A variety of optimization performances are described below.

4.1 Particle Swarm Optimization

PSO method that draws inspiration from fish schools and flocks of birds. It is widely used to solve complex optimization problems in engineering, including PQ improvement, control system tuning, and load balancing. The position and velocity of the particles are updated using equations (1) and (2) once particle best $(Pbest)$ and global best $(Gbest)$ have been determined,

$$v_i^k = wv_i^k + c_1 r_1 \left(Pbest_i^k - x_i^k\right) + c_2 r_2 \left(Gbest_i^k - x_i^k\right) \quad (1)$$

where x_i^k is the ith particle's present solution, and v_i^k is the ith particle's velocity. While c_1 and c_2 are positive variables, r_1 and r_2 are two random variables having a uniform distribution between 0 and 1. The flowchart of PSO is shown in Figure 7.

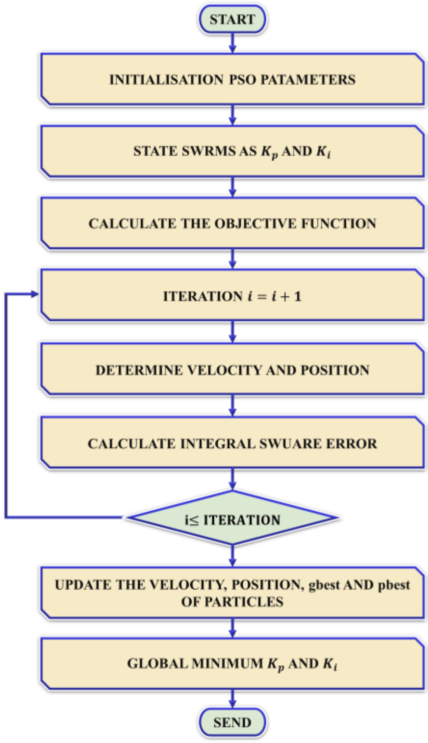

Figure 7: *The flowchart of PSO*

In PQ applications, PSO is often used to optimize parameters of controllers, filters, or compensators, ensuring accurate detection and effective mitigation of voltage and current distortions [16].

4.2 Whale Optimization Algorithm (WOA)

WOA technique based on the unique hunting behavior of humpback whales, particularly their bubble-net feeding strategy. Designed to solve complex, nonlinear optimization problems, WOA mimics the way whales encircle prey and create spiral-shaped bubble nets to trap it. In the encircling phase, whales estimate the position of the optimal solution and update their positions accordingly. In the bubble-net attacking phase, a spiral updating position mechanism is used to simulate the whale's helical movement toward the prey. In the search phase, whales explore the search space by randomly selecting other candidate solutions to avoid local optima.

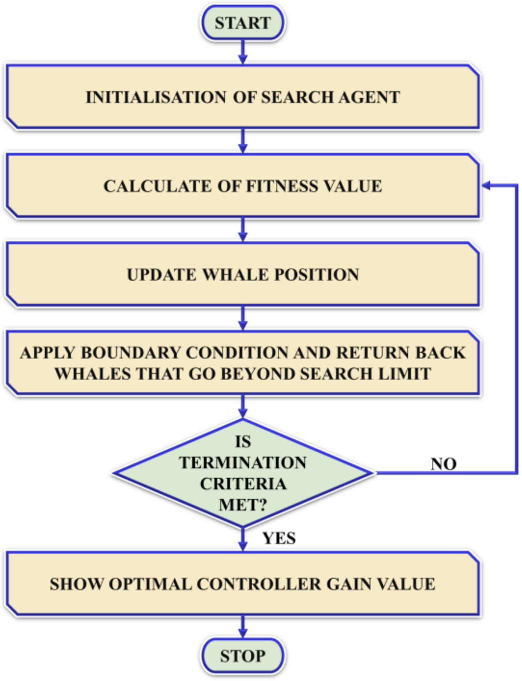

Figure 8: *The flowchart of WOA*

The flowchart of WOA is shown in Figure 8. This balance between exploration and exploitation allows WOA to efficiently converge on global solutions. Due to its simplicity, adaptability, and ability to handle high-dimensional optimization tasks, WOA has been widely applied in PQ improvement, controller tuning, and renewable energy optimization, where precise and adaptive decision-making is essential for maintaining system reliability and efficiency [17].

4.3 Cuckoo Search Optimization

It is a nature-inspired metaheuristic optimization technique based on the brood parasitism behavior of certain cuckoo species, which lay their eggs in the nests of other birds. The core principle of CS lies in mimicking this natural strategy, where each "cuckoo egg", and the goal is to replace less optimal solutions (host eggs) with better ones. One of the key features of the algorithm is the use of Lévy flights, a random walk mechanism with large jumps. The control signal (D) appears to represent an outcome that may be modified using Levy flight in the manner described below.

$$D_i^{(t+1)} = D_{best}^{(t)} + \alpha \oplus Levy\ flight(\lambda) \qquad (2)$$

The step length is estimated using Levy dispersion and the power function, from which:

$$Levy\ (\lambda) \approx u = L^{-\lambda} \tag{3}$$

Where t is the number of iterations, α is the staging process, and $D_{best}^{(t)}$ represents the best duty cycle among the fitness.

The CS algorithm operates by generating new candidate solutions using Lévy flights, evaluating their fitness, and then replacing weaker solutions with stronger ones in a process that mimics natural selection.

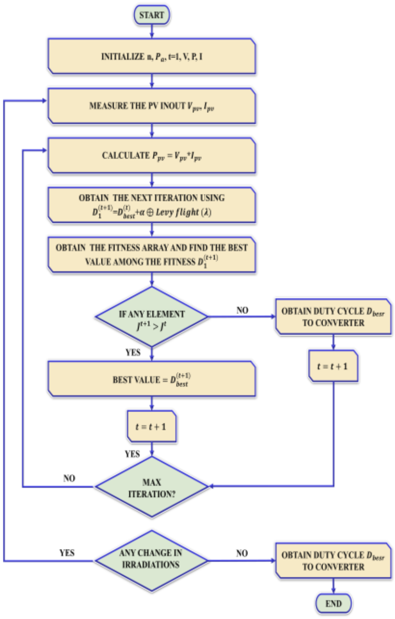

Figure 9: *The flowchart of CS*

Figure 9 presents the flowchart of the CS. A probability factor is also included to simulate the chance of a host bird discovering an alien egg and abandoning the nest, which helps maintain diversity in the population. Due to its strong global search capability and simple implementation, Cuckoo Search has been effectively applied in PQ management, particularly in optimizing filter parameters, controller settings, and fault detection algorithms, enabling efficient and adaptive mitigation of power disturbances in smart grid environments [18].

4.4 GWO

It is mimics the leadership hierarchy and hunting behavior of grey wolves in nature. This algorithm is designed to solve complex optimization problems by modeling the social dominance structure of wolves. The working principle of GWO revolves around three main steps: encircling prey, hunting, and attacking the prey. During optimization, wolves adjust their positions based on the positions of α, β, and δ, which guide the search direction. The following is the predicted behavior of the GWOT mathematical model,

$$\begin{cases} D = C.X_p(k) - X(k) \\ X(k+1) = X_p(k) - A.D \end{cases} \tag{4}$$

Where, $X_p(k)$ is prey position vector, $X(k)$ wolf position vector and the current iteration number is indicated by k. The following is the definition of the coefficients A and C.

$$\begin{cases} A = (2r_1 - 1)a \\ C = 2r_2 \end{cases} \tag{5}$$

The updated position can be expressed as,

$$X(k+1) = \frac{1}{3}\sum_{g=\alpha}^{\delta}\left(X_g(k) - A.D_g\right) \tag{6}$$

The algorithm simulates the encircling mechanism by updating each wolf's position relative to these three leaders. It particularly effective for solving nonlinear, high-dimensional, and multi-objective problems.

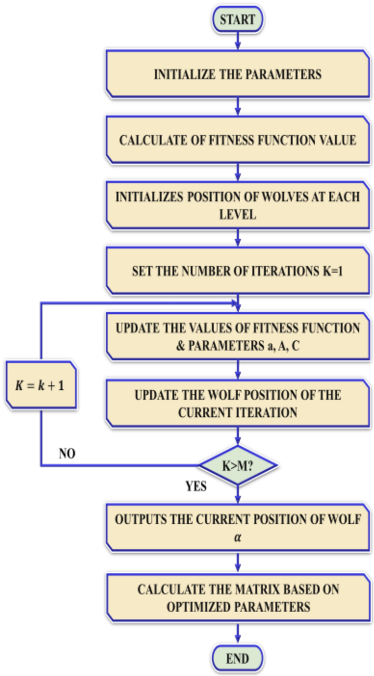

Figure 10: *The flowchart of GWO*

Figure 10 displays the flowchart of the GWO. In the context of power quality, GWOs is widely used to optimize the tuning of active and passive filters, control parameters in FACTS devices, and intelligent detection algorithms, enabling robust and adaptive responses to harmonics, voltage fluctuations, and other disturbances in electrical networks. In PQ applications, GWO is widely used to optimize parameters of controllers, power filters, and energy management systems, ensuring efficient mitigation of harmonics, voltage instability, and other PQ issues in both grid-connected and renewable energy systems [19 - 20].

5. Comparative Analysis

In this part, evaluate and compare the survey of the advantages and drawbacks of different optimization techniques.

Table 1: *Comparison performance of various techniques*

SL. NO	Author/Year of Publication	Technique	Benefits	Downsides
1.	Mitra Nabian Dehaghani et al [2025] [5]	Genetic Algorithms (GA)	Good at escaping local minima, especially in complex, nonlinear problems common in PQ systems.	Requires careful tuning of crossover and mutation rates
2.	Anurag Tiwar et al [2023] [17]	Whale Optimization	It performs well in PQ systems with fluctuating loads or integration of renewable energy.	May need hybrid techniques for fine-tuning or precision tasks
3.	Nagwa F. Ibrahim et al [2023] [18]	Cuckoo Search Optimization	It is effective in optimizing filter parameters and adaptive PQ systems.	High computational cost for large populations.
4.	Tatireddy Rav et al [2023] [19]	Grey Wolf Algorithm	It's easy to use for tuning filters or optimizing energy compensation systems.	Requires fine-tuning of probability and step size for optimal performance.

A comparison of the various techniques used for PQ issues detection is presented, as shown in Table 1.

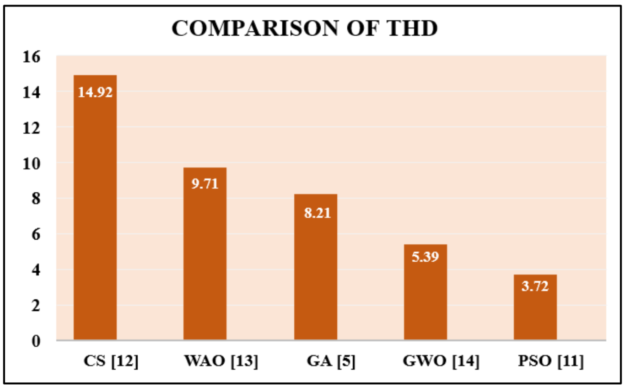

Figure 11: *Comparison of Performance*

Figure 11 represents the performance of a comparison performance of various optimizations. When contrasting to other methods like GWO, GA, and WAO, the PSO produced the best results and the lowest THD.

6. Conclusion

Ensuring optimal PQ is a technical requirement, and it is a critical component of building a sustainable, resilient, and future-ready power infrastructure. Thus, this paper discusses and analyzes the PQ issues and issue detection techniques for improving reliable application. Various distributed generators, power filters and their types are analysed to remove the harmonics and other PQ errors. The optimization techniques have significantly advanced the field of PQ issue detection, providing more accurate solutions to safety digital electronics. Meanwhile, PSO optimization algorithms have attained the minimum THD value, and it has proven to be the most effective design for PQ issue detection. Thus, ensuring optimal power quality is a technical requirement and it is a critical component of building a sustainable, resilient, and future-ready power infrastructure. Further, this paper improves PQ and supports the development of resilient, intelligent, and sustainable power systems that meet the growing demands of modern society.

Reference

1. Pragnyashree Ray; Pravat Kumar Ray; Santanu Kumar Dash, Year: 2022, "Power Quality Enhancement and Power Flow Analysis of a PV Integrated UPQC System in a Distribution Network", in IEEE Transactions on Industry Applications, Vol: 58, No: 1, pp. 201-211.

2. Wenyuan Baip; Guofeng Zhuang; Xiuzhen Zhao; Zhanhong Wei, Year: 2024, "High-Precision Intelligent Identification of Complex Power Quality Disturbances Based on Improved KST and CNNs", in IEEE Access, Vol: 12, pp. 86434-86443.

3. Isa Hafidz; Ardyono Priyadi; Margo Pujiantara; Dimas Okky Anggriawan; Mauridhi Hery Purnomo, Year: 2023, "Development of IoT-Based Portable Power Quality Monitoring on Microgrids by Enhancing Protection Features", in IEEE Access, Vol: 11, pp. 49481-49492.

4. Elmer O. Hancco Catata; Pedro Jose Dos Santos Neto; Marcelo Vinicius De Paula; João Pedro Carvalho Silveira; Tárcio André Dos Santos Barros; Ernesto Ruppert Filho, Year: 2022, "In-Loop Adaptive Filters to Improve the Power Quality of Switched Reluctance Generator in WECS", in IEEE Access, Vol: 10, pp. 2941-2951.

5. Mitra Nabian Dehaghani; Tarmo Korõtko; Argo Rosin, Year: 2025 "AI Applications for Power Quality Issues in Distribution Systems: A Systematic Review", in IEEE Access, Vol: 13, pp. 18346-18365.

6. Hongchuan Li; Bin Li; Zhongge Luo; Hang Li; Yu Zhao; Ting Wang; Yanfei Sun, Year: 2022, "Power Supply Reliability Enhancement for Low-Voltage Distribution Area With Power Quality Improvement Function", in IEEE Access, Vol: 10, pp. 130619-130631.

7. Mohib Ullah; Yajuan Guan; Yun Yu; Sanjay K. Chaudhary; Juan C. Vasquez; Josep M. Guerrero, Year: 2025, "Dynamic Performance and Power Quality of Large-Scale Wind Power Plants: A Review on Challenges, Evolving Grid Code, and Proposed Solutions", in IEEE Open Journal of Power Electronics, Vol: 6, pp. 1148-1173.

8. Ziad M. Ali; Martin Ćalasan; Francisco Jurado; Shady HE Abdel Aleem, Year: 2024, "Complexities of Power Quality and Harmonic-Induced Overheating in Modern Power Grids Studies: Challenges and Solutions", in IEEE Access, Vol: 12, pp. 151554-151597.

9. Rajendran Boopathi; Vairavasundaram Indragandhi, Year: 2024, "Experimental Investigations on Photovoltaic Interface Neutral Point Clamped Multilevel Inverter-Based Shunt Active Power Filter to Enhance Grid Power Quality", in IEEE Access, Vol: 12, pp. 74482-74498.

10. Prakash K. Ray; Harish Kumar Sahoo; Asit Mohanty; Javed Khan Bhutto; Abdulwasa Bakr Barnawi; Abdulmjeed Ali Alshaya, Year: 2024, "Robust H-Infinity Filter and PSO-SVM Based Monitoring of Power Quality Disturbances System", in IEEE Access, Vol: 12, pp. 39041-39057.

11. Rami Moustafa; Hussain Shareef; Madathodika Asna; Rachid Errouissi; Jeyraj Selvaraj, Year: 2025, "A Smart Web-Based Power Quality and Energy Monitoring System With Enhanced Features", in IEEE Access, Vol: 13, pp. 88458-88471.

12. Nirmal Mukundan; V. Sangeetha; P. Jayaprakash; O. V. Asokan; Ahmed Al-Durra; Hatem Zeineldin;

Tarek HM El-Fouly, Year: 2022, “A New Multilevel Inverter Based Grid Connected Reliable Solar Power Transfer Unit With Power Quality Enhancement”, in IEEE Transactions on Industry Applications, Vol: 59, No: 2, pp. 1887-1900.

13. Yang Wang; Junmiao Tang; Jiandong Si; Xianyong Xiao; Peter Zhou; Jinshuai Zhao, Year: 2023, “Power Quality Enhancement in Islanded Microgrids Via Closed-Loop Adaptive Virtual Impedance Control”, in Protection and Control of Modern Power Systems, Vol: 8, No: 1, pp. 1-17.

14. Poras Khetarpal; Neelu Nagpal; Mohammed S. Al-Numay; Pierluigi Siano; Yogendra Arya; Neelam Kassarwani, Year: 2023, “Power Quality Disturbances Detection and Classification Based on Deep Convolution Auto-Encoder Networks”, in IEEE Access, Vol: 11, pp. 46026-46038.

15. Subhadip Chakraborty; Gaurav Modi; Bhim Singh; Bijaya Ketan Panigrahi; Souvik Das; Suvom Roy, Year: 2024, “Peak Shaving and Duck Curve Mitigation With BES Based Ramp Rate Limit Strategy for Power Quality Enhancement of SPV-BES Microgrid”, in IEEE Transactions on Industry Applications, Vol: 61, No: 1, pp. 1234-1245.

16. Ravinder Kumar; Hari Om Bansal; Aditya R. Gautam; Om Prakash Mahela; Baseem Khan, Year: 2022, “Experimental Investigations on Particle Swarm Optimization Based Control Algorithm for Shunt Active Power Filter to Enhance Electric Power Quality”, in IEEE Access, Vol: 10, pp. 54878-54890.

17. Nagwa F. Ibrahim; Mohamed Metwally Mahmoud; Ali MH Al Thaiban; Abdulwasa B. Barnawi; Zakaria M. Salem Elbarbary; Ahmed Ibrahim Omar; Hany Abdelfattah, Year: 2023, “Operation of Grid-Connected PV System With ANN-Based MPPT and an Optimized LCL Filter Using GRG Algorithm for Enhanced Power Quality”, in IEEE Access, Vol: 11, pp. 106859-106876.

18. Anurag Tiwari; Ruchi Agarwal, Year: 2023, “Optimal control for a photovoltaic integrated grid system using PSO and modified whale optimization to enhance power quality”, Engineering Research Express, Vol: 5, No: 2, pp. 025001.

19. Tatireddy Ravi; K. Sathish Kumar, Year: 2023, “Detection and Classification of Power Quality Disturbances Using Stock Well Transform and Improved Grey Wolf Optimization-Based Kernel Extreme Learning Machine”, in IEEE Access, Vol: 11, pp. 61710-61727.

20. Veramalla Rajagopal; Danthurthi Sharath; Gundeboina Vishwas; Jampana Bangarraju; Sabha Raj Arya; Challa Venkatesh, Year: 2022, “Optimized Controller Gains Using Grey Wolf Algorithm for Grid Tied Solar Power Generation with Improved Dynamics and Power Quality”, in Chinese Journal of Electrical Engineering, Vol: 8, No: 2, pp. 75-85.