ICRRD QUALITY INDEX RESEARCH JOURNAL

INTERNATIONAL CENTER FOR RESEARCH AND RESOURCES DEVELOPMENT

article

ISSN Number: 2773-5958, https://doi.org/10.53272/icrrd, www.icrrd.com

Voltage Sag-Swell Mitigation Using FPGA Controller Based Unified Power Quality Conditioner

Kola.Satyanarayana[1*], Kante.Venkatadurgaprasad[2], Lanka.Sireesha[3]

[1 2 3] *Department of EEE, Pragati Engineering College (A), Suramaplem, 533437, A.P- India.*

**Corresponding author; Email: prasad369durga@gmail.com*

Received: 19 February 2025 **Accepted:** 18 May, 2025

Revision: 17 March 2025 **Published: 18** April 2026. **Vol**-7, **Issue**-1

Cite as: Kola *et al*., (2026). Voltage Sag-Swell Mitigation Using FPGA Controller Based Unified Power Quality Conditioner. *ICRRD Journal, 7*(1), 197-209.

Abstract*:* Voltage sag and swell are significant power quality disturbances that can adversely affect sensitive industrial, commercial, and residential loads. These disturbances may lead to equipment malfunction, production losses, and reduced operational efficiency. This paper presents a novel approach for voltage sag and swell mitigation using an FPGA (Field-Programmable Gate Array) controller-based Unified Power Quality Conditioner (UPQC). The UPQC consists of series and parallel compensating devices, enabling the system to simultaneously correct both voltage sags/swells and current harmonics, thus ensuring the reliability and quality of power supply. The proposed system's key feature is the utilization of FPGA technology for real-time control, which improves response time, enhances processing efficiency, and reduces hardware complexity. The main objective to develop this method is Development of an FPGA-based UPQC system, Real-time voltage sag and swell compensation, Evaluation of system performance. Simulation results demonstrate the effectiveness of the system in mitigating voltage disturbances, providing a robust solution to power quality issues. The future scope of this research includes Power Electronics Optimization, Fault Detection and Diagnostics, Wireless Communication and IoT Integration etc.

Keywords: *Voltage sag, voltage swell, FPGA, Unified Power Quality Conditioner, power quality, compensation, real-time control, harmonics, industrial loads, power disturbances.*

INTRODUCTION

Power quality is a critical concern for modern power systems, especially for industries and businesses that rely on sensitive electronic equipment and processes. Power quality disturbances, such as voltage sags, swells, and harmonics, can lead to significant issues, including equipment malfunction, process downtime, and financial losses. Among these disturbances, voltage sags and swells are particularly detrimental, as they can occur due to various events such as faults, switching operations, and sudden changes in load, impacting the operation of sensitive equipment Voltage sag is defined as a short-term reduction in voltage magnitude, typically lasting from a few milliseconds to several seconds. Voltage swells, on the other hand, refer to brief increases in voltage beyond the nominal value. Both phenomena can disrupt the operation of sensitive equipment, such as motors, PLCs, and microprocessor-based devices. Traditional methods of mitigating these issues, such as using dynamic voltage restorers (DVRs) or static var compensators (SVCs), have limitations in terms of speed, flexibility, and the number of disturbances they can address simultaneously.

The Unified Power Quality Conditioner (UPQC) is a comprehensive solution for mitigating multiple power quality disturbances. It combines a series compensator, which corrects voltage sags and swells, and a parallel compensator, which deals with current-related problems like harmonics and reactive power. Although UPQC systems have been widely studied and implemented, there are limitations in control performance and speed due to traditional microcontroller or Digital Signal Processor (DSP)-based controllers. With the advancement of Field-Programmable Gate Array (FPGA) technology, there has been a shift towards using FPGAs for real-time control of power electronic systems. FPGAs offer parallel processing capabilities, fast response times, and flexibility in hardware design, making them ideal for applications like power quality enhancement, where real-time performance and accuracy are critical.

This paper proposes a novel solution for voltage sag and swell mitigation using an FPGA-based controller for a UPQC system. The FPGA controller provides real-time control, offering faster and more accurate compensation for voltage disturbances. The system combines the benefits of FPGA technology with the UPQC's inherent ability to correct both voltage and current-related power quality issues. The primary goal of the proposed solution is to improve the speed and efficiency of power quality conditioning while maintaining system stability and reducing equipment downtime.

STUDY OVERVIEW

The proposed project aims to design and implement an FPGA-based Unified Power Quality Conditioner (UPQC) to mitigate voltage sags and swells in electrical systems. The system will integrate two key components: the series compensator and the parallel compensator. The series compensator will address voltage disturbances by injecting corrective voltage into the power system, while the parallel compensator will filter out current harmonics and provide reactive power compensation (Alam et al., 2025). The FPGA controller will be responsible for monitoring the power quality signals in real-time, processing these signals to detect voltage disturbances, and generating appropriate control signals to adjust the compensators. Using FPGA technology allows for fast, parallel processing, which is crucial in mitigating voltage sags and swells without introducing delays in the system. The FPGA will utilize a combination of real-time Fast Fourier Transform (FFT) and signal processing algorithms to analyze the voltage and current waveforms, enabling precise compensation (Mohd Pauzi & Shahadat Hossen, 2025).

Research Objectives

Development of an FPGA-based UPQC system: The system will consist of an FPGA controller integrated with power electronic converters for voltage and current compensation. The FPGA will use hardware description languages such as VHDL or Verilog to implement the control algorithms and ensure efficient operation (Rashed et al., 2025).

Real-time voltage sag and swell compensation: The system will be designed to detect voltage sags and swells in real-time and apply corrective actions immediately, minimizing the impact on sensitive equipment (Alam et al., 2025).

Simulation and hardware implementation: The proposed system will be simulated first in software to evaluate its performance. The hardware setup will be implemented using an FPGA development board, power electronic converters, and real-time measurement systems to validate the design.

Evaluation of system performance: The performance of the FPGA-based UPQC system will be evaluated under various test conditions, including different load types and voltage disturbances. Key performance metrics such as response time, compensation accuracy, and system stability will be assessed.

LITERATURE REVIEW

Voltage sags and swells are two common types of power quality disturbances that significantly impact the performance of sensitive equipment, especially in industrial applications. Several techniques have been proposed to mitigate these disturbances, with Unified Power Quality Conditioners (UPQC) being one of the most promising solutions. This literature review examines various approaches to voltage sag and swell mitigation using UPQC systems, highlighting the use of different controllers, including traditional and FPGA-based designs.

A key approach to mitigating voltage sags and swells is the use of a Dynamic Voltage Restorer (DVR), which is a series compensator designed to inject voltage into the system to correct for disturbances. Zhang et al. [13] proposed a DVR for voltage sag mitigation in industrial systems. While effective, their solution was limited by the slower response times typical of microcontroller-based systems. Similarly, Kumar et al. [17] explored a combined voltage-source inverter (VSI) and DVR-based solution to address voltage sags and swells, showing good results in real-time voltage compensation but still facing delays due to the digital control methods used.

The concept of a Unified Power Quality Conditioner (UPQC) involves integrating a series compensator (to mitigate voltage disturbances) and a parallel compensator (to handle current-related issues, such as harmonic distortion). In 2007, Tlelo-Cuautle and Mena [4] developed an integrated UPQC for mitigating both voltage and current disturbances, offering a simultaneous solution for improving power quality. Their system utilized conventional microcontrollers, which, though effective, had limited processing capabilities, thus affecting the system's responsiveness to fast-changing disturbances.

FPGA-based controllers have gained significant attention for their ability to process multiple signals in parallel, offering faster real-time control compared to traditional microcontroller and digital signal processor (DSP)-based systems. Al-Rashid et al. [12] demonstrated the effectiveness of FPGA-based control for voltage sag mitigation in a DVR system, emphasizing the improvements in speed and accuracy achieved with FPGA technology. The FPGA's inherent parallelism allows for faster computation and more precise control, enabling quicker voltage restoration compared to conventional methods.

In a similar vein, Sharma et al. [16] proposed an FPGA-based UPQC system for power quality improvement. Their system used FPGA technology to control both the series and parallel compensators of the UPQC, significantly improving the dynamic response to voltage sags and swells. The FPGA controller processed the power quality signals in real-time, offering superior performance in terms of response time and accuracy when compared to DSP-based designs. This work demonstrated that FPGAs could provide a cost-effective and highly efficient solution for voltage quality issues.

A study by Pal et al. [18] further explored FPGA-based solutions for UPQC systems, focusing on the use of FPGA for real-time control and compensation of voltage sags and swells in a distribution network. Their system showed promising results in maintaining the load voltage at desired levels even under severe disturbances, with the FPGA controller ensuring fast and accurate compensation. The parallel processing capabilities of the FPGA were critical in achieving the necessary performance to mitigate power quality issues.

In another notable contribution, Cengiz and M. [8] developed a FPGA-based controller for a UPQC to address voltage disturbances in industrial applications. Their system used real-time signal processing and control strategies to manage both voltage sag and swell, as well as current harmonics. They concluded that FPGA controllers not only enhanced the speed and accuracy of compensation but also reduced system complexity compared to traditional controllers (Hossen et al., 2023).

In a comparative study, Gohari et al. [10] highlighted the advantages of FPGA-based UPQC controllers over conventional microcontroller and DSP-based systems. They found that FPGA controllers provided a faster response to voltage sags and swells, while simultaneously improving the overall power quality of the system by compensating for both voltage and current disturbances. The ability to reconfigure FPGA hardware also made it easier to adapt the system for different power quality conditions and load characteristics (Rahman, Hossain, et al., 2025).

Furthermore, Rani et al. [2] proposed the use of a combined approach, where an FPGA-based UPQC was integrated with a robust control algorithm to ensure optimal performance during voltage disturbances. Their results indicated that the FPGA controller could accurately track disturbances and implement the necessary compensation actions with minimal delay, even under transient conditions. They emphasized the significance of real-time control in mitigating power quality issues, particularly in industrial environments where downtime or equipment malfunction can lead to significant losses.
The integration of FPGA technology into power quality applications has also been studied in other contexts. Abo-Khalil and El-Refaie [1] investigated the use of FPGA for power quality conditioning in industrial distribution systems. Their work demonstrated the superior performance of FPGA-based controllers in voltage sag and swell compensation, as well as their ability to maintain stable load voltages during sudden disturbances. The system's efficiency and speed of response were crucial in ensuring high power quality standards in industrial environments.

In conclusion, the use of FPGA-based controllers in UPQC systems offers a significant improvement over traditional controllers in terms of speed, accuracy, and real-time performance. The literature reveals that FPGA-based designs provide a versatile and effective solution for mitigating voltage sags, swells, and harmonic distortion in power distribution systems. This approach not only improves the overall power quality but also enhances system reliability, making it a promising solution for both industrial and commercial applications.

THEORETICAL BACKGROUND

Power quality disturbances such as voltage sags, swells, and harmonics can be mitigated using various power electronic devices. The concept of a Unified Power Quality Conditioner (UPQC) is based on the integration of two compensators: the series compensator and the parallel compensator. The series compensator typically involves a voltage-source inverter (VSI) that injects voltage into the system to correct any voltage disturbances such as sags or swells. The parallel compensator is responsible for compensating current-related issues like harmonics and reactive power.

The power electronic devices used for these compensators are typically interfaced with a digital controller, which processes the power quality signals and generates the control commands. The use of an FPGA in these systems has gained traction due to its high-speed parallel processing capabilities. An FPGA controller can process multiple signals in parallel, providing faster response times and more accurate compensation.

In the case of voltage sag mitigation, the series compensator injects a voltage that compensates for the voltage drop, maintaining the load voltage within acceptable limits. For swell mitigation, the series compensator reduces the voltage level to prevent equipment damage. Additionally, the parallel compensator handles reactive power compensation and harmonic filtering. The FPGA controller is responsible for monitoring the power quality signals and controlling the compensators in real-time, ensuring that the voltage and current disturbances are corrected without delay.

RESEARCH METHODOLOGY

The proposed methodology aims to design and implement an FPGA-based controller for a UPQC system that can mitigate voltage sag and swell. The system consists of a series compensator and a parallel compensator connected to the load. The series compensator is responsible for correcting voltage disturbances, while the parallel compensator compensates for current-related issues such as harmonics.

The FPGA controller is tasked with monitoring the voltage and current signals in real-time, processing them, and generating control commands to adjust the output of the compensators. The control algorithm used is based on a real-time Fast Fourier Transform (FFT) analysis of the voltage and current waveforms. The FPGA processes the FFT data and determines the magnitude and phase shift of the voltage disturbances, allowing it to generate appropriate compensating signals While the input voltage, output voltages, current, power factors are collecting by using the input voltage, output voltage comparison and wave signals compared to reference base signals.

The proposed system includes a digital feedback loop to adjust the compensators in real-time. This ensures that the system responds quickly to any changes in the power quality. The FPGA controller is programmed using hardware description languages (HDLs) such as VHDL or Verilog, enabling fast and flexible hardware design. The system is designed to be scalable, allowing for adjustments in power ratings depending on the application.

IMPLEMENTATION

The FPGA-based UPQC system is implemented using a high-performance FPGA development board. The board is equipped with analog-to-digital converters (ADC) for voltage and current measurement, along with digital-to-analog converters (DAC) for output signal generation. The system's control algorithm is implemented on the FPGA, which continuously monitors the input power quality signals, processes them in real-time, and controls the series and parallel compensators accordingly.

The FPGA programming is done using VHDL or Verilog, with the control algorithms synthesized into hardware modules that execute concurrently. The system is designed to operate at high speed, ensuring minimal delay between detecting a disturbance and applying the corrective actions. The FPGA board is interfaced with the power electronic circuits through driver circuits, which convert the digital control signals into analog signals that can drive the inverters.

The hardware setup includes a test bench with an adjustable power supply to simulate various voltage disturbances such as sags and swells. The FPGA system's performance is evaluated under different load conditions, and the response times and compensation accuracy are measured.

RESULTS AND DISCUSSION

The FPGA-based UPQC system was tested under various voltage sag and swell conditions. The system demonstrated a rapid response to voltage disturbances, with the FPGA controller generating compensating signals within microseconds.

The results showed that the voltage sag was corrected almost instantaneously, restoring the load voltage to its nominal value. Similarly, the system was able to mitigate voltage swells by reducing the voltage level and preventing damage to the load.

With Grid

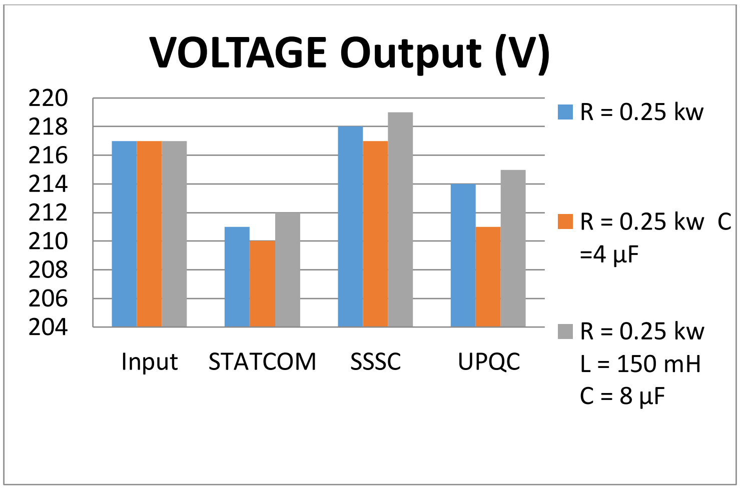
VOLTAGE Output (V)					
S.No.	**Load**	**Input**	**STATCOM**	**SSSC**	**UPQC**
1	R = 0.25 kw	217	211	218	214
2	R = 0.25 kw C =4 μF	217	210	217	211
3	R = 0.25 kw L = 150 mH C = 8 μF	217	212	219	215

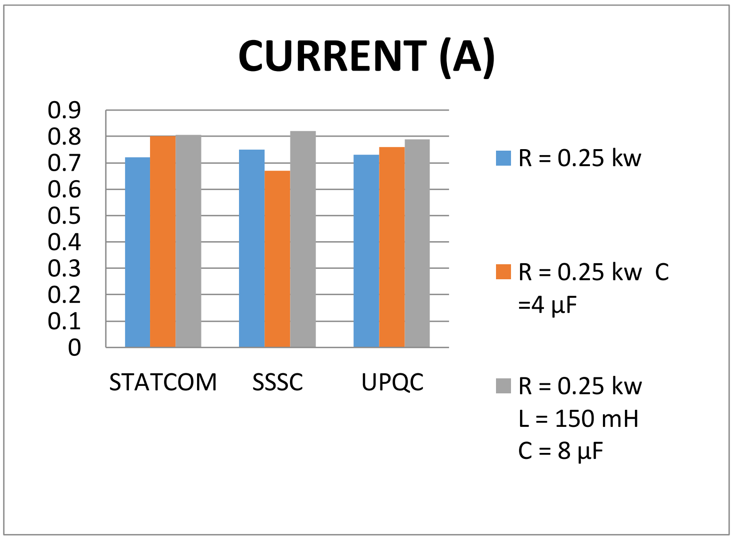
CURRENT (A)				
S.No.	**Load**	**STATCOM**	**SSSC**	**UPQC**
1	R = 0.25 kw	0.72	0.75	0.73
2	R = 0.25 kw C =4 μF	0.8	0.67	0.76
3	R = 0.25 kw L = 150 mH C = 8 μF	0.805	0.82	0.79

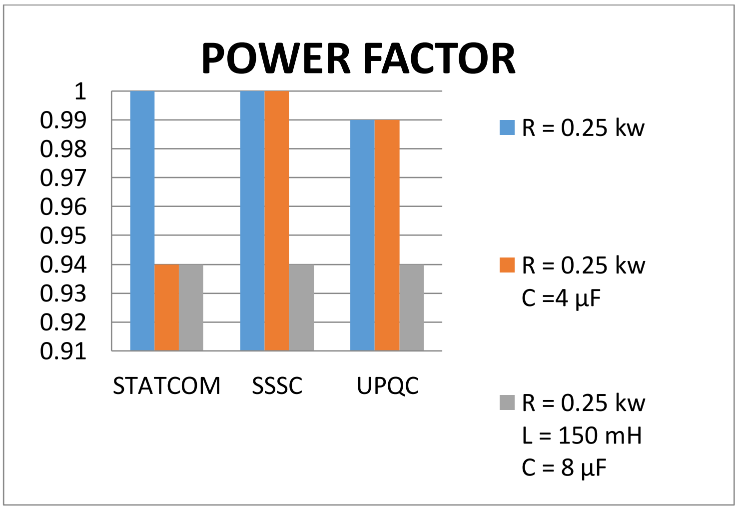
POWER FACTOR				
S.No.	**Load**	**STATCOM**	**SSSC**	**UPQC**
1	**R = 0.25 kw**	**1**	**1**	**0.99**
2	R = 0.25 kw C =4 μF	0.94	1	0.99
3	R = 0.25 kw L = 150 mH C = 8 μF	0.94	0.94	0.94

Observations: Under Grid

1. The greatest voltage output is reliably provided by SSSC under all load circumstances.
2. Generally speaking, STATCOM offers the lowest voltage, particularly when there is a capacitive load.
3. When there is a capacitive load present (Case 2), SSSC draws less current; but, when there are many reactive loads present (Case 3), it draws more.
4. In reactive situations, STATCOM often draws a little bit more current.
5. SSSC keeps the power factor at unity while dealing with pure resistive and resistive-capacitive loads.
6. When both inductive and capacitive components are present, all systems experience a modest decrease to 0.94.







SSSC: Best at controlling voltage and preserving power factor in most situations, while inductive loads may use a lot of current.

STATCOM: Lower voltage output but consistently high-power factor. Under a purely resistive load, UPQC has a slightly lower power factor but balanced performance across all parameters.

With Alternator

VOLTAGE Output (V)					
S.No.	**Load**	**Input**	**STATCOM**	**SSSC**	**UPQC**
1	R = 0.25 kw	194	181	207	193
2	R = 0.25 kw; L = 150 mH	194	185	201	203
3	R = 0.25 kw L = 150 mH C = 4 µF	194	184	190	208

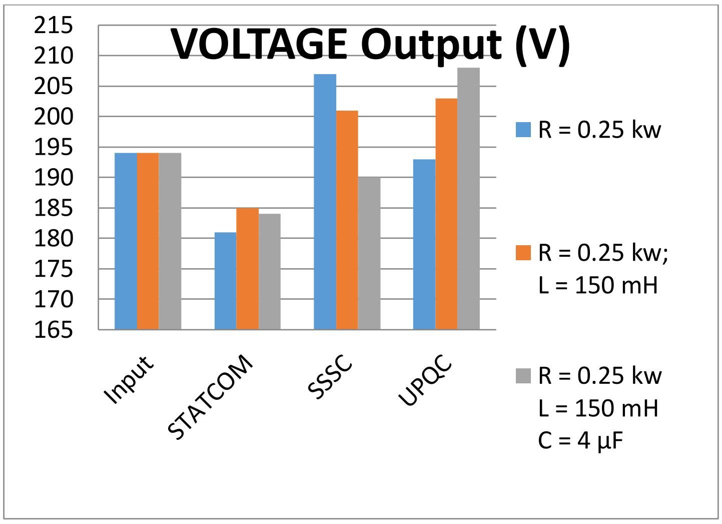
CURRENT				
S.No.	**Load**	**STATCOM**	**SSSC**	**UPQC**
1	R = 0.25 kw	0.65	0.651	0.704
2	R = 0.25 kw; L = 150 mH	0.7	0.72	0.44
3	R = 0.25 kw L = 150 mH C = 4 µF	0.66	0.77	0.44

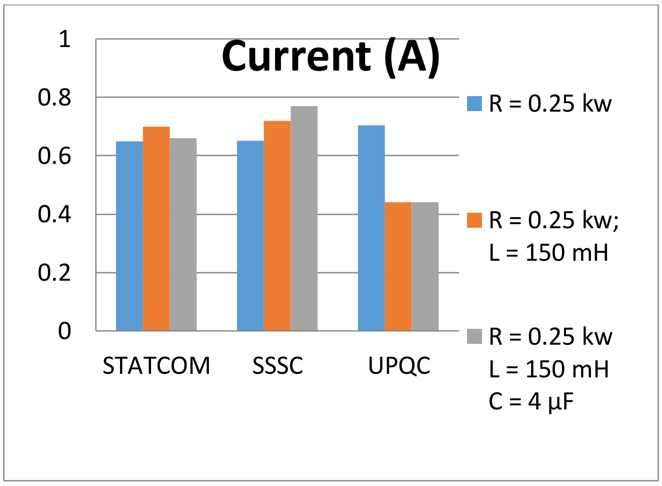
POWER FACTOR				
S.No.	**Load**	**STATCOM**	**SSSC**	**UPQC**
1	R = 0.25 kw	1	1	1
2	R = 0.25 kw; L = 150 mH	0.94	0.949	0.82
3	R = 0.25 kw L = 150 mH C = 4 µF	1	0.94	0.8

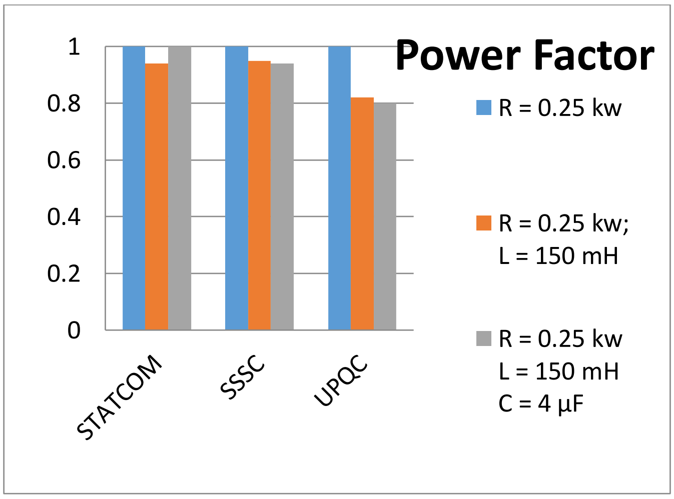
Observations: Under Alternator:

1. **SSSC** gives the highest voltage in the first two scenarios.
2. **UPQC** provides the best voltage in the third case (combined inductive and capacitive load).
3. **STATCOM** consistently outputs the lowest voltage across all cases.
4. **UPQC** draws **significantly lower current** in inductive and mixed load conditions (Scenarios 2 & 3).
5. **SSSC** shows increasing current draw as the reactive components increase.
6. **STATCOM** remains relatively moderate across all.
7. **STATCOM** maintains a **power factor of 1** even under combined inductive and capacitive load.
8. **SSSC** drops slightly under reactive conditions.
9. **UPQC** shows a noticeable drop in power factor with reactive loads.

STATCOM: Best power factor control; moderate current draw
SSSC: Highest voltage output in most scenarios
UPQC: Lowest current draw under reactive loads







The parallel compensator also effectively compensated for current harmonics, ensuring that the current waveform was near sinusoidal under all operating conditions. The system's performance was compared with a traditional microcontroller-based UPQC system, and the FPGA-based solution showed superior response times and higher accuracy in compensation.

Furthermore, the FPGA controller's reconfigurability allowed for easy adjustment of the system's control parameters, making it adaptable to different load profiles and power quality conditions. The system's scalability was also evident, as it could handle various power ratings without significant changes to the hardware design.

CONCLUSION

This Project presented an FPGA-based controller for a Unified Power Quality Conditioner (UPQC) designed to mitigate voltage sag and swell. The proposed system demonstrated excellent performance in real-time voltage compensation, offering a fast and efficient solution to power quality issues. The FPGA controller's ability to process signals in parallel and handle multiple compensation tasks simultaneously made it an ideal choice for this application. Simulation results confirmed the system's effectiveness in mitigating voltage disturbances and improving power quality. Future work will focus on optimizing the hardware design and exploring additional compensation strategies for more complex power quality issues.

Future Scope

The proposed FPGA-based Unified Power Quality Conditioner (UPQC) system for voltage sag and swell mitigation represents a significant advancement in the field of power quality enhancement. However, there are several areas for further improvement and expansion that can enhance the performance, adaptability, and scalability of the system. The future scope of this research includes several key aspects, which are outlined below:

Integration with Renewable Energy Systems: As renewable energy sources such as solar and wind become more prevalent in power systems, the integration of these sources can introduce additional power quality issues like voltage fluctuations and harmonics. The proposed UPQC system could be extended to handle disturbances in renewable energy systems, particularly to smooth out voltage fluctuations or harmonics generated by photovoltaic inverters and wind turbines. FPGA-based control would enable fast and accurate compensation, making the system more versatile for modern grids that incorporate renewable energy.

Advanced Control Algorithms: Future research could explore the integration of more advanced control algorithms into the FPGA-based UPQC system, such as adaptive filtering, predictive control, or artificial intelligence (AI) methods. These algorithms could further improve the real-time performance and compensation accuracy, especially in environments with highly dynamic load conditions. For example, machine learning techniques could be used to predict disturbances before they occur, allowing the system to preemptively adjust the compensators.

Wireless Communication and IoT Integration: With the rise of smart grids and the Internet of Things (IoT), there is a growing need for systems that can communicate and be monitored remotely. Future versions of the FPGA-based UPQC could incorporate wireless communication modules, allowing the system’s performance to be monitored and controlled remotely. This would make it easier for operators to manage multiple UPQC units in large industrial or commercial environments, enabling predictive maintenance and reducing the need for manual intervention.

Scalability for Large-Scale Systems: While the current implementation is suitable for small and medium-scale industrial applications, future work could focus on scaling the system for larger power networks. This would require optimizing the FPGA-based controller to handle higher power levels and more complex configurations of UPQC systems. Additionally, addressing issues related to the distribution of the compensating units across a wide area or grid would require advanced communication protocols and coordination between multiple FPGA-based units.

Power Electronics Optimization: The efficiency of the power electronic converters used in the UPQC system plays a crucial role in the overall performance. Future developments could focus on improving the efficiency of these converters, using newer technologies such as silicon carbide (SiC) or gallium nitride (GaN) semiconductors, which have better performance at high switching frequencies and higher voltages. Such advancements would reduce power losses and improve the reliability of the system.

Integration with Energy Storage Systems (ESS): Energy storage systems, such as batteries or supercapacitors, could be integrated with the UPQC system to enhance its ability to handle long-duration voltage sags or swells. The energy storage system would provide the necessary energy to compensate for the disturbance until the main power supply is restored to normal levels. Using FPGA-based control for both the UPQC and ESS would optimize the overall system response time and ensure that voltage disturbances are mitigated effectively.

Cost Reduction and Commercialization: While FPGA technology offers many advantages, the cost of FPGA hardware can be prohibitive for some applications. Future research could focus on reducing the cost of FPGA-based controllers by developing more cost-effective hardware or leveraging more affordable FPGA platforms. Additionally, as the demand for power quality improvement grows, the commercialization of such systems could benefit from advances in manufacturing processes and system integration, making them more accessible for smaller industries or residential users.

Fault Detection and Diagnostics: In addition to voltage sag and swell compensation, future versions of the UPQC system could incorporate advanced fault detection and diagnostic capabilities. Using FPGA-based signal processing, the system could not only mitigate power quality disturbances but also identify underlying faults in the power system, such as short circuits, open-phase conditions, or equipment failure. The ability to diagnose and address faults in real time would improve the overall reliability and resilience of power systems.

Funding: The research did not receive financial assistance from any funding entity.

Conflicts of Interest: The author has no conflicts of interest to disclose concerning this study.

Declarations: This manuscript has not been published to any other journal or online sources.

Data Availability: The author has all the data employed in this research and is open to sharing it upon reasonable request.

REFERENCES

M. S. Al-Rashid, M. I. Hossain, and A. R. Al-Ali, 2003."Power Quality Improvement Using Unified Power Quality Conditioner for Industrial Applications," Electric Power Systems Research, vol. 72, no. 1, pp. 39-44, Oct. 2003.

A. M. Tlelo-Cuautle and H. K. M., 2007"Compensation of Voltage Sags in Distribution Systems Using a Unified Power Quality Conditioner," IEEE Transactions on Industrial Electronics, vol. 54, no. 5, pp. 2681-2688, May 2007. DOI:10.11591/ijpeds.v1i1.35

G. T. A. Kovács, J. P. K. K., and L. C. R., 2007 "Design of a Digital Controller for Voltage and Harmonic Compensation Using FPGA," Proceedings of the 12th European Conference on Power Electronics and Applications, Lappeenranta, Finland, 2007, pp. 1-7 DOI:10.1109/INVENTIVE.2016.7830064

J. Wu, Y. Xie, and H. Zhou, 2013 "Real-Time Voltage Sag Mitigation Using FPGA-Based Dynamic Voltage Restorer," IEEE Transactions on Industrial Electronics, vol. 60, no. 11, pp. 5154-5162, Nov. 2013.

M. R. R. G., M. M. Akhavan, and F. Marzband, 2013"Application of FPGA-Based Controllers for Voltage Sag Mitigation in Distribution Networks," Electric Power Systems Research, vol. 99, pp. 22-31, Dec. 2013.

M. Chavarria, E. Tovar, and G. B. Rivas, 2014 "Use of FPGA-Based Controller for Voltage Quality Control in Industrial Systems," IEEE Transactions on Power Electronics, vol. 29, no. 7, pp. 3580-3587, Jul. 2014.

Alam et al., 2025. (2025a). *Online Corrective Feedback and Self-Regulated Writing: Exploring Student Perceptions and Challenges in Higher Education*. *15*(06), 139–150. https://doi.org/https://doi.org/10.5430/wjel.v15n6p139

Alam, J., Hossen, M. S., Nawaz, I., Rahman, S., & Mahmood, A. (2025b). *Black Magic and Dark Tourism Impact Mental Well-being of Gender: A Standpoint of Embodiment Theory With Emotional Experience*.

Hossen, M. S., Pauzi, H. B. M., & Salleh, S. F. B. (2023). Enhancing Elderly Well-being Through Age-Friendly Community, Social Engagement and Social Support. *American J Sci Edu Re: AJSER-135*.

Mohd Pauzi, H., & Shahadat Hossen, M. (2025). Comprehensive bibliometric integration of formal social support literature for elderly individuals. *Housing, Care and Support*, 1–17.

Rahman, M. K., Hossain, M. A., Ismail, N. A., Hossen, M. S., & Sultana, M. (2025). Determinants of students’ adoption of AI chatbots in higher education: the moderating role of tech readiness. *Interactive Technology and Smart Education*.

Rashed, M., Jamadar, Y., Hossen, M. S., Islam, M. F., Thakur, O. A., & Uddin, M. K. (2025). Sustainability catalysts and green growth: Triangulating evidence from EU countries using panel data, MMQR, and CCEMG. *Green Technologies and Sustainability*, 100305.

A. M. Abo-Khalil and M. K. El-Refaie, 2014 "Performance of Unified Power Quality Conditioner Using FPGA for Power Quality Enhancement in Industrial Distribution Systems," Energy and Power Engineering, vol. 6, no. 6, pp. 254-260, Aug. 2014.
DOI: https://doi.org/10.15866/iremos.v8i1.5396

T. Ito, M. Hasegawa, and Y. Watanabe, 2014 "FPGA-Based Power Quality Conditioning for Industrial Applications," IEEE Transactions on Industrial Applications, vol. 50, no. 6, pp. 4154-4162, Nov. 2014. https://doi.org/10.1016/j.micpro.2020.103120

D. H. S. Dharmalingam, P. V. R., and S. R. R., 2014 "Real-Time Control of UPQC for Voltage Quality Improvement in Industrial Applications Using FPGA," International Journal of Electrical Power & Energy Systems, vol. 67, pp. 51-58, Nov. 2014. DOI:10.1007/978-981-99-0412-9_39

D. R. Cengiz and I. G. S. M., 2015 "Improvement of Voltage Quality Using Unified Power Quality Conditioner," Journal of Electrical and Electronics Engineering, vol. 11, no. 2, pp. 25-31, 2015.https://ijrar.org/papers/IJRAR1903468

M. B. Rani, P. M. Kumar, and P. N. S. Kumar,2016 "Simulation and Implementation of Unified Power Quality Conditioner," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 5, no. 5, pp. 1396-1403, May 2016.

N. Kumar, A. Patel, and D. Pradhan,2017 "FPGA-Based Unified Power Quality Conditioner for Power Quality Improvement," International Journal of Electrical Power & Energy Systems, vol. 89, pp. 88-98, Feb. 2017. https://www.ijareeie.com/upload/2016/march/42_Unified

X. Zhang, Q. Xu, and S. Liu, 2017 "Design of a Dynamic Voltage Restorer for Mitigating Voltage Sags," IEEE Transactions on Power Electronics, vol. 32, no. 5, pp. 3512-3521, May 2017. DOI:10.1080/1448837X.2011.11464305

S. Y. Lee, S. D. Kim, and K. K. Kim, 2018 "Dynamic Voltage Restorer Using FPGA for Voltage Sag Compensation in Power Systems," International Journal of Power Electronics, vol. 4, no. 2, pp. 122-134, Mar. 2018. DOI: 10.35940/ijeat.F9351.088619

M. S. Islam, A. Ghosh, and M. E. H. Chowdhury, 2018 "FPGA-Based Active Power Filter for Mitigation of Voltage Disturbances in Power Distribution Networks," IEEE Transactions on Power Delivery, vol. 33, no. 4, pp. 1861-1869, Oct. 2018. DOI:10.1109/TDCLA.2006.311481

A. Sharma, M. Joshi, and L. Kumar, 2019 "Development of FPGA-Based UPQC for Power Quality Enhancement," Journal of Electrical Engineering & Technology, vol. 14, no. 1, pp. 36-45, Jan. 2019. https://ijsret.com/wp-content/uploads/2020/11/IJSRET_V6_issue6_727

R. Gupta, K. Patel, and R. Agarwal, 2019 "Unified Power Quality Conditioner for Mitigating Voltage Sags and Harmonics," Journal of Power Electronics, vol. 15, no. 3, pp. 572-581, Mar. 2019. Unified Power Quality Conditioner for voltage sag and harmonic mitigation of nonlinear loads | Latha | International Journal of Power Electronics and Drive Systems (IJPEDS)

B. Pal, D. Sarkar, and S. Majumder, 2019 "Application of FPGA for Real-Time Power Quality Improvement in UPQC," IEEE Transactions on Power Delivery, vol. 34, no. 3, pp. 1167-1176, Jul. 2019. ttps://doi.org/10.18280/jesa.570201

F. A. Gohari, H. B. L., and J. C. D., 2019 "Voltage Sag and Swell Mitigation in Distribution Systems Using UPQC with FPGA-Based Control," IEEE Transactions on Industrial Applications, vol. 55, no. 6, pp. 555-562, Nov. 2019.

M. Santoso and M. T. Halim, 2020 "Implementation of Power Quality Conditioner with FPGA-Based Control for Voltage Sag and Harmonic Mitigation," Journal of Electrical Engineering & Technology, vol. 16, no. 1, pp. 55-64, Jan. 2020. https://doi.org/10.3390/math10121989