Fuzzy Systems and Soft Computing
ISSN : 1819-4362

A Wireless EV Charging-Enabled Solar PV-Battery Integrated UPQC System for Improved Power Quality and Grid Stability

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ABSTRACT
This study proposes a Unified Power Quality Conditioner (UPQC) system integrated with a solar PV and battery setup, featuring wireless electric vehicle (EV) charging, aimed at improving grid stability and overall power quality. The system combines renewable energy generation and storage with advanced power conditioning to mitigate voltage sags, swells, and harmonics while supporting seamless EV charging. The wireless charging system offers convenience and efficiency, reducing dependency on physical connections. Real-time monitoring and control enhance system reliability, making it a sustainable and robust solution for modern grid-connected applications.

Keywords: Grid reliability, contactless EV charging, integrated power quality management (UPQC), solar PV systems, battery storage solutions, improvement of power quality, and integration of renewable energy sources.

INTRODUCTION

The integration of renewable energy sources, energy storage, and electric vehicles (EVs) has become essential to meet growing energy demands while ensuring environmental sustainability. Solar photovoltaic (PV) systems offer a reliable and sustainable energy source when combined with battery energy storage. However, their integration with the power grid often introduces power quality issues such as voltage sags, swells, and harmonic distortions. Complex solutions are required to resolve these problems and ensure grid stability and efficient energy use. The Unified Power Quality Conditioner (UPQC) is a helpful tool for lowering power quality issues in grid-connected systems. By combining the capabilities of active power filters, the UPQC ensures stable power supply and seamless energy transfer. This paper

https://doi.org/10.36893/FSSC.2025.V20I01.063

proposes a novel system that integrates Solar PV, battery storage, and a UPQC with wireless EV charging functionality. Wireless charging offers a contact-less, efficient method of energy transfer, enhancing convenience for EV users while reducing wear and tear on physical connections. This integrated system not only addresses power quality issues but also enhances grid reliability and flexibility. With real-time monitoring and control, the proposed solution provides a sustainable framework for renewable energy utilization and EV charging, supporting the transition to a greener energy future.

PV-UPQC SYSTEM WITH WIRELESS POWER TRANSFER FOR ELECTRIC VEHICLE CONFIGURATION

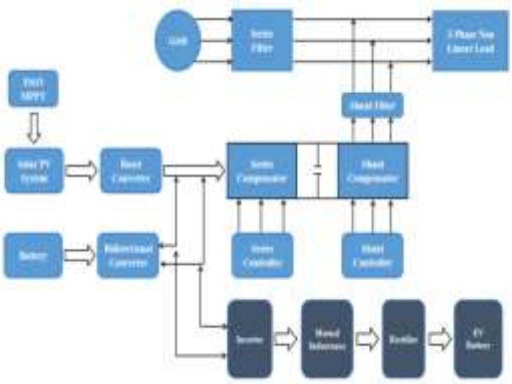

Figure 1: Coordination of Solar PV and Battery Energy Storage with a UPQC System Incorporating Wireless EV Charging

The PV-Battery integrated UPQC system, equipped with wireless power transfer, unifies solar photovoltaic generation, energy storage, and power quality conditioning to improve grid stability and ensure efficient, contactless charging for electric vehicles. By reducing problems like voltage sags, swells, and harmonics, the UPQC guarantees a clean and steady power source. Wireless power transfer provides an efficient and reliable method of charging EVs without the need for physical connections. This system promotes renewable energy integration, supports sustainable EV adoption, and ensures seamless grid operation.

SYSTEM DESIGNING

SOLAR PV AND BATTERY SECTION

The solar PV and battery design focuses on efficient renewable energy generation and storage. Solar PV panels convert sunlight into electricity, while the battery system stores excess energy for use during low solar generation or peak demand. The design ensures reliable power availability, enhances grid stability, and supports sustainable energy utilization. Proper sizing of PV panels and batteries is crucial to meet load requirements and optimize system efficiency.

In order to supply power during times of low sunlight or at night, a solar battery stores extra energy produced by solar panels for later use. It helps optimize energy utilization, increases self-consumption, and ensures a reliable power supply. Solar batteries enhance system efficiency, reduce reliance on the grid, and contribute to sustainable energy management. Proper sizing is key to ensuring adequate storage capacity and performance.

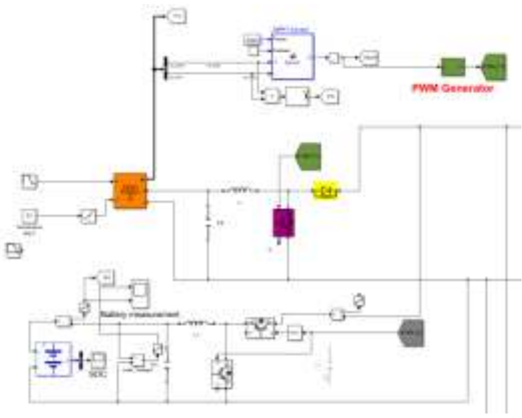

Figure 2 : System for Combining Batteries and Solar PV

THE UPQC SYSTEM

A device known as a Unified Power Quality Conditioner (UPQC) is designed to improve the power quality of electrical systems by mitigating issues such as voltage sags, swells, harmonics, and transients. It combines a series compensator and a shunt compensator. to regulate both voltage and current, ensuring a stable and clean power supply. UPQC is essential for maintaining grid stability, protecting sensitive equipment, and enhancing overall system performance in industrial and commercial applications.

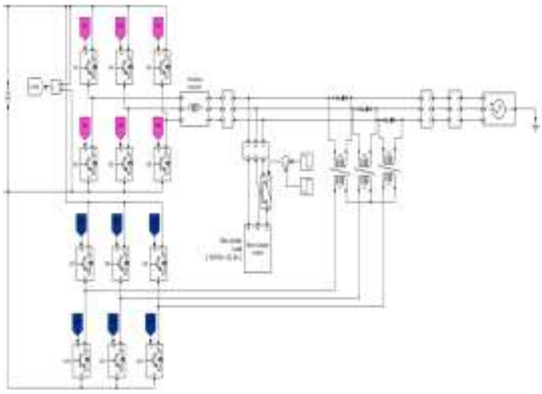

Figure 3 : UPQC and Grid Integrated System

WIRELESS POWER TRANSFER SYSTEM FOR ELECTRIC VEHICLE CHARGING STATIONS

Wireless power transfer (WPT) systems enable electric vehicle (EV) charging by transmitting energy from a charging pad to the vehicle using magnetic induction or resonant coupling, eliminating the need for physical connectors. The system consists of a primary coil (in the charging station) and a secondary coil (in the EV) that transfers power efficiently through an electromagnetic

https://doi.org/10.36893/FSSC.2025.V20I01.063

field. WPT offers convenience, reduces wear on connectors, and enhances user experience by enabling contact-less, automated charging, making it an ideal solution for future EV infrastructure.

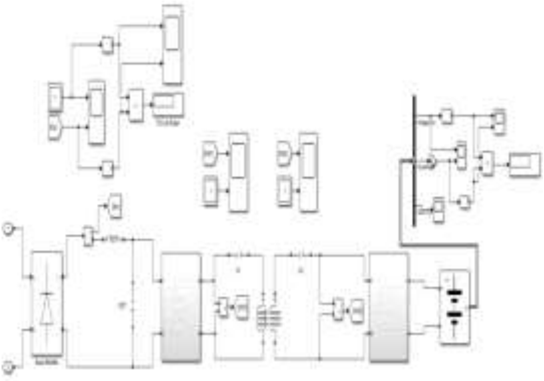

Figure 4 : WPT System For EV Charging

SYSTEM PERFORMANCE AND CONTROL

Mppt Controller

One tool used in solar energy systems to maximize the power output from solar panels is a Maximum Power Point Tracking (MPPT) controller. To ensure that the solar panel operates at its maximum power point, it continuously adjusts the operating point to account for changes in sunlight, temperature, and load conditions. This increases the efficiency of the system by optimizing the energy collected from the solar panels. MPPT controllers are required for solar power systems to function more Efficiently Overall.

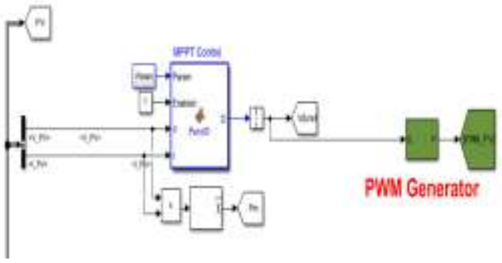

Figure 5 : MPPT Controller

The performance of the integrated Solar PV-Battery UPQC system with wireless EV charging is evaluated based on its capability to enhance power quality and maintain grid stability. The system effectively manages power flow from solar PV generation, battery storage, and the UPQC, ensuring minimal disturbances such as voltage sags, swells, and harmonic distortions. The control strategy involves real-time monitoring and regulation of voltage, current, and power flow to optimize energy use and prevent grid instability.

The UPQC dynamically adjusts to mitigate power quality issues, while the wireless EV charging system is managed to ensure efficient and safe energy transfer. The battery storage acts as a buffer, providing energy during periods of low solar generation and ensuring consistent power supply for EV charging. Control algorithms are employed to balance energy generation,

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storage, and consumption, maximizing system efficiency and ensuring reliable, stable operation, even under fluctuating grid conditions. The system's control framework enhances overall performance, ensuring seamless integration of renewable energy, storage, and electric vehicle charging.

Series Controller: A series controller is used in power quality systems like UPQC to regulate voltage by injecting or absorbing voltage in series with the load. It helps mitigate voltage sags, swells, and transients, ensuring stable and clean power delivery to sensitive equipment.

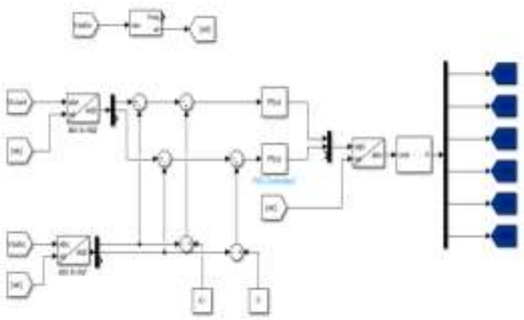

Figure 6 : Series Controller

Shunt Controller: A shunt controller is used to regulate current by injecting or absorbing current in parallel with the load. By increasing the power factor and decreasing harmonic distortion, it mainly corrects for current-related problems like harmonics, improving the system's overall power quality.

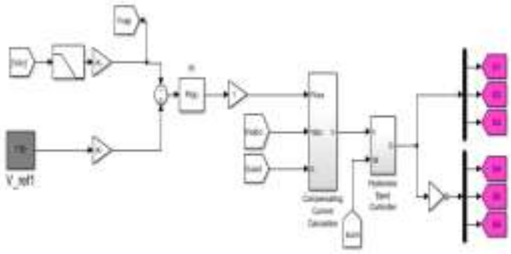

Figure 7 : Shunt Controller

OVERALL SYSTEM PERFORMANCE AND RESULTS

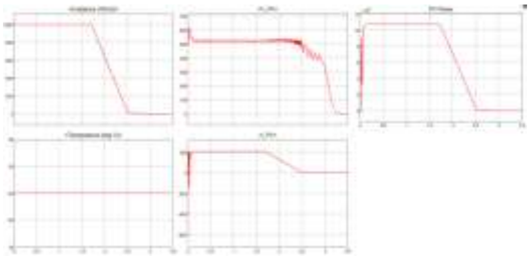

Figure 8 : Solar PV Output Waveform For Different Irrandiance

The ability of the Integrated Solar PV-Battery UPQC System with Wireless EV Charging to optimize energy generation, storage, and consumption while maintaining a steady power quality is the basis for evaluating its performance. In spite of power quality problems like harmonics, swells, and voltage sags, the system efficiently makes use of the UPQC to guarantee a clean and steady power source. The battery stores the renewable energy produced by the solar PV system for later use, ensuring a steady supply of power even during times of high demand or little sunlight. The real-time monitoring system enables

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adaptive control, which optimizes power flow and increases system efficiency.

The wireless EV charging module further enhances system convenience and performance by enabling contact-less energy transfer to electric vehicles. This not only eliminates physical connectors but also supports efficient charging, reducing losses and ensuring safety. The integration of solar energy and battery storage provides an eco-friendly solution, reducing dependency on the grid and increasing self-consumption. The system demonstrates a significant reduction in grid disturbances and improves energy utilization by balancing generation and consumption through advanced control strategies.

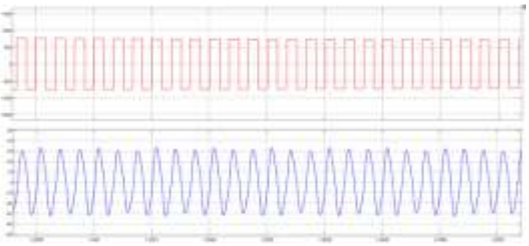

Figure 9 : Primary Side V-I Waveform

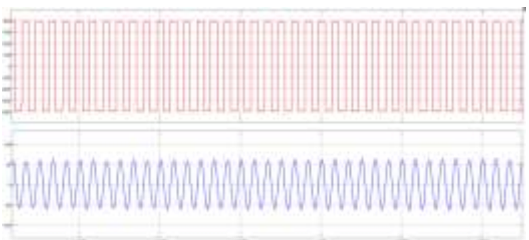

Figure 10 : Secondary Side V-I Waveform

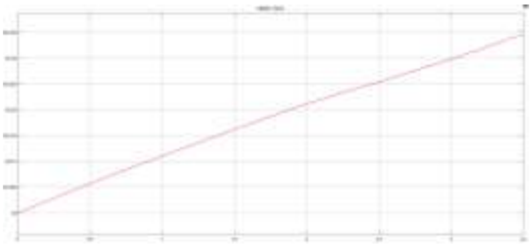

Figure 11 : EV Battery SoC Output Waveform

Results from simulations and practical implementations show that the system performs optimally under varying conditions. It successfully mitigates power quality issues and ensures that both renewable energy generation and electric vehicle charging can coexist seamlessly. The overall system contributes to grid stability, enhances the user experience with wireless EV charging, and supports sustainable energy practices, making it a viable solution for future grid-connected applications.

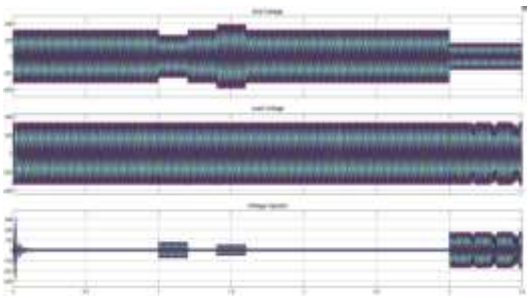

Figure 12 : Overall Final Output Of Grid System

CONCLUSION

The Solar PV-Battery Integrated UPQC system with wireless EV charging presents a unified approach to tackling

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major challenges in today's power networks, such as improving power quality, ensuring grid stability, and supporting the use of renewable energy. Through the integration of solar power generation, energy storage, and advanced power quality control, the system delivers a clean, consistent, and dependable electricity supply while addressing disturbances like voltage fluctuations and harmonic distortions. Additionally, the inclusion of wireless electric vehicle charging offers a seamless, efficient, and contact-free charging experience, encouraging broader adoption of eco-friendly technologies.

The system's real-time monitoring and adaptive control strategies optimize energy flow, ensuring efficient use of renewable resources and enhancing grid stability. Through the seamless integration of these technologies, the proposed solution not only contributes to reducing grid dependence but also supports the growth of electric vehicles, making it a crucial step toward a cleaner and more efficient energy future. This integrated approach demonstrates the potential to transform energy systems by combining renewable energy, energy storage, and smart grid technologies in a way that is both practical and scalable.

REREFENCES

1) Singh, B., & Verma, A. (2014). "A Review on Unified Power Quality Conditioner (UPQC) for Power Quality Improvement in Power Systems." IEEE Transactions on Power Electronics, 29(3), 1580-1591.
2) Jiang, H., & Li, G. (2017). "Design and Control of a Wireless Power Transfer System for Electric Vehicle Charging." IEEE Transactions on Industrial Electronics, 64(7), 5657-5665.
3) Pillay, P., & Raj, M. (2018). "Modeling and Control of Hybrid Solar-Battery Systems for Efficient Power Management." Renewable Energy, 122, 407-417.
4) Cheng, X., & Zhou, X. (2020). "A New Control Strategy for Hybrid PV-Grid Systems with Battery Storage and EV Integration." IEEE Transactions on Smart Grid, 11(2), 1395-1404.
5) Xie, L., & Yu, L. (2019). "Power Quality Improvement in Smart Grids Using UPQC and Renewable Energy Sources." Journal of Electrical Engineering & Technology, 14(3), 1181-1192.
6) Rathore, M., & Gupta, S. (2020). "Advanced Control Strategies for Integration of Renewable Energy

Sources with Battery Storage and Electric Vehicle Charging." International Journal of Electrical Power & Energy Systems, 114, 105389.