

Performance of Hybrid controller in PV-BS Integrated MLC based Unified Power Quality Conditioner

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Abstract— This research proposes a novel method of integrating solar battery systems with Unified electricity Quality Conditioners (UPQC) to improve electricity utilities' performance. Optimization techniques are employed in the proposed multi-level controller design for ensuring optimal energy management and enhancement of power quality. The system attempts to reduce power losses, ameliorate voltage sags/swells, and improve the overall efficiency of the stadium's electrical network by intelligently coordinating the functioning of solar batteries and UPQC. Power researchers have developed novel controllers and techniques in response to the challenges of attaining power quality caused by the mix of renewable sources, power electronic devices, non-linear, and unbalanced loads. This work uses the Boost and Buck Boost converters to produce an optimal tuned hybrid controller for the unified power quality conditioner connected to solar power and battery storage systems, based on an algorithm used in football leagues. SLO optimizes the Kp and Ki values of the shunt and series controllers as control variables in order to accomplish the intended purpose. The SLOHC performance study involved four test studies for different combinations of unbalanced and balanced loads Multilevel Inverter (MLI) arrangements were used by the UPQC. Through simulation tests, the efficacy of the suggested solution is illustrated, underscoring its potential to support more energy-efficient energy use and better power quality.

Index Terms—Solar PV system, battery storage system, soccer league optimization, Unified Power Quality Conditioner.

I. INTRODUCTION

Due to the increasing usage of renewable energy sources and the development of sophisticated electronic gadgets, modern power systems require a high-quality power supply. Power quality problems, such as voltage sags, swells, harmonics, and interruptions, not only compromise the dependability and stability of the grid but also impact the operation of essential loads. In this case, Unified Power Quality Conditioners (UPQCs) have proven helpful in eliminating power quality outages and boosting system performance. Power quality control is made more difficult by the incorporation of Distributed Generation (DG) units into power distribution systems. Even while distributed generation (DG) units have several advantages, such higher efficiency, lower losses, and environmental sustainability, power quality problems can be made worse by voltage and frequency oscillations brought on by their intermittent nature and variable output characteristics. The integration of UPQCs with DG units has attracted a lot of attention recently as a solution to these problems. Furthermore, the efficiency of UPQCs' control mechanisms is a major factor in their efficacy.

Promising control strategies for UPQCs include model-based predictive direct power control (MPDPC) and model-learning control (MLC), which provide improved dynamic response and robustness to system uncertainty. However, when it comes to handling intricate and nonlinear power quality disturbances, traditional MPDPC and MLC techniques could show their limitations.

A. Literature Review

The research presented here presents the SOI-QSG PLL, the PSO algorithm-based performance increase of the PV-UPQC controller, and a literature survey of UPQC integrated systems. The system controller must be perfectly tuned whenever there are different grid disruptions [1]. The construction and dynamic functioning of three-phase PVUPQC were investigated in respect to varying irradiance and grid voltage sags and swells. Experiments conducted on a scaled-down laboratory version have proven the system's efficiency. [2]. PV-UPQC has developed and been put into practice. The goal has been to eliminate current issues with quality and enhance power quality when there are different voltage quality challenges. The end user can choose the power quality level appropriate to their demands using the platform that is offered by the current system. [3] The creation of three-phase UPQC was explored in the context of complicated power quality challenges, which include harmonics, voltage swell and sags, and voltage interruption under unbalanced and distorted voltage grid conditions. Integrating the BESS and PV with the UPQC adds active power capability to the network. [4] To increase the power of the PV-WE-ESS-EV system, the authors of the research developed a technique that makes use of FLC and UPQC controllers. Maximizing the power extraction from PV and WE systems is the aim of FLC-based MPPT algorithms.

For a range of loading conditions, the UPQC offers support for voltage regulation. [5]. The average active power of the load, the active power to provide dc-link regulation of voltage, and the average reactive power to regulate the grid-bus voltage define the currents produced through the series converter in the updated iUPQC controller. Consequently, apart from having the power-quality modification features of a traditional UPQC [6]. The unified energy from sustainable sources system can adapt to changes in load demand and supply. Findings imply that grid-integrated HRES are capable of using the recommendations provided by IUPQC. IUPQC has the ability to modify load voltages in order to protect the loads from system voltage disturbances. [7].

II. PROPOSED PVBS-UPQC

Using additional assistance from an array of batteries and solar PV system connected to the DC-link, the UPQC concept is depicted in Figure 1. We added a three-level series and a shunt converter to improve the system's power quality. In the present investigation, the PI controller updated the three-level series based on SLO. The TLSC reduces supply voltage distortions and imbalances by supplying an adequate compensating voltage V_{se} through an isolating transformer. This circuit is comprised of a series resistor (R_{se}), a series inductor (L_{se}), and a series capacitor (C_{se}).

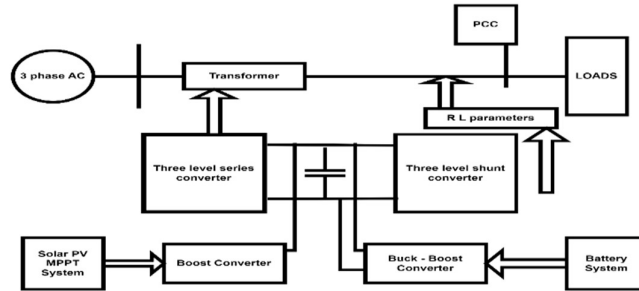


Fig 1. Structure of solar PV and BS integrated UPQ

The shunted-interfacing inductor L_{sh} , shunt-resistance R_{sh} , and shunt-capacitance C_{sh} make up the shunt side TLSC. By injecting a sufficient compensating shunt current, it eliminates harmonics in the current waveform and maintains a constant voltage (V_{dc}) in the DC-link capacitor despite the load and radiation fluctuations. The Unified Power Quality Conditioner (UPQC) systems that are solar-battery integrated can perform better thanks to a new innovation called football league optimization. The dynamics of a football team serve as their source of inspiration. Every part of the solar-battery integrated UPQC system is compared to a player on a football team in this optimization technique, with distinct duties and goals. The system dynamically modifies its parameters to maximize power quality, improve energy efficiency, and reduce disturbances in the electrical network through

iterative optimization iterations that are similar to football matches. The football league optimization technique offers a promising avenue to improve the efficiency and dependability of renewable energy integration within power grids, thereby contributing to a more resilient and sustainable energy infrastructure. This is achieved by utilizing the synergy between solar generation, battery storage, and UPQC functionalities. Everyone's performance can be improved by competing with other players, which will strengthen the team. This research proposes an optimal design for the SLO adjusted PI controller, which will improve the THD and PF and minimize voltage distortions.

A. Dc-Link

The PV and battery storage act as the DC-Link's external assistance to reduce PQ issues and maintain constant DC-Link voltage throughout changes in load and solar irradiation, as seen in figure 2. The U-PVBS power balancing equation at

$$P_{PV} + P_{BS} - P_{dlink} = 0 \quad (1)$$

where P_{BS} and P_{PV} denote the output power of the battery and solar systems, respectively. P_{dlink} indicates the DC-Link power demand.

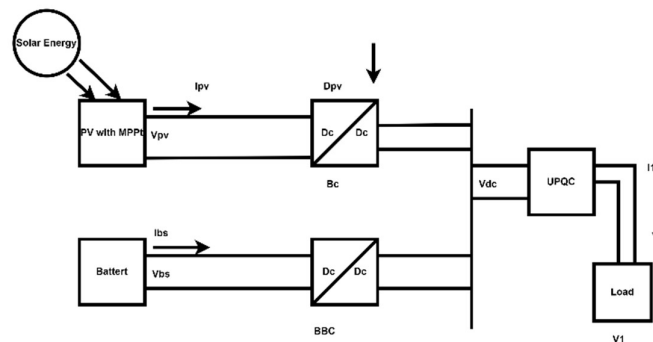


Fig 2. External support of DC-Link

B. Solar PV System

Since solar energy is numerous, clean, and emission-free, it is the recommended non-conventional energy source. Distributed energy resources like fuel cells, wind, and solar energy, etc., can be linked to the UPQC. For the following reasons, PV is linked at the DC-link element in this study: It lowers supply side demand, enhances QQ at the utility grid, and isolates the loads from grid interruptions. It improves the converter's stress ratings and voltages. In order to provide the necessary DC power, PV panels usually connect in series or parallel. BC may be useful in raising it to the optimum level. But when the load alters, the SP additionally swaps power but also charges the DC-Link capacitor.

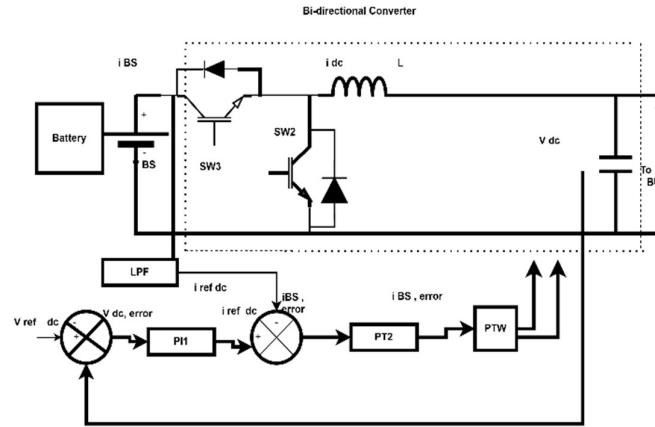
C. Battery Storage System

Improving power quality and grid stability can be achieved in a number of ways by integrating a battery storage system with a Unified Power Quality Conditioner (UPQC). When demand is low or renewable energy generation is strong, the battery storage system can be connected in parallel with the UPQC to store excess energy. The UPQC can then be supported by this stored energy during times of peak demand or when there are grid disruptions. By draining the batteries at times of high demand, the integrated system can conduct peak shaving, which lowers the total demand from the grid. This lessens the burden on the grid infrastructure and may save utility companies money. The battery storage system can support voltage during voltage swells or sags by injecting or absorbing reactive power as necessary. This enhances the quality of power for linked loads and helps keep the grid voltage within reasonable bounds.

Shunt Converter

In order to guarantee efficient power management and quality, a hybrid controller for a solar energy storage system integrated unified power quality conditioner (UPQC) based on football league optimization must have a shunt converter. Addressing power quality issues in the distribution system, such as voltage sags, swells, flickers, and harmonics, is the purpose of the UPQC system.

The objective of this configuration is to improve the sustainability and dependability of power distribution networks by integrating solar energy storage with UPQC technology. The shunt converter within this system acts as a key component for regulating voltage and compensating reactive power. Through sophisticated control algorithms, such as those derived from soccer league optimization, the hybrid controller orchestrates the operation of the shunt converter alongside other elements of the UPQC system.



D. Series Converter

Using a series converter in a soccer league's optimization is similar to fine-tuning a hybrid controller for an integrated solar battery-powered Unified Power Quality Conditioner (UPQC). The hybrid controller enhances the efficiency of the UPQC by cleverly controlling power flow and quality, much like a series converter modifies the energy flow in a system. This parallel can be further elucidated when considering the intricacies of both systems. In a soccer league, teams are akin to different components in an electrical system, each with its strengths and weaknesses.

The series converter acts as a regulator, balancing the power dynamics between these teams. Similarly, in a solar battery integrated UPQC, the hybrid controller orchestrates the interaction between the solar panels, batteries, and the power grid, ensuring efficient energy utilization and maintaining power quality.

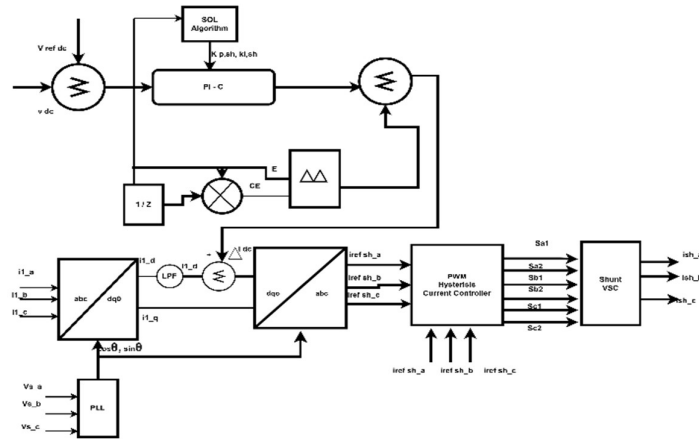


Fig 4.SLO based hybrid controller for shunt converter

E. Simulation Results

The Fuzzy Logic-based BS-PV Integrated UPQC's simulation findings showed encouraging results for improving power quality and integrating renewable energy sources. The performance of the projected PVBSIUPQC was looked into on a grid-tied 3- ϕ AC distribution system. In Matlab2021a, the Simulink model for various loads has evolved. The PVBSIUPQC's performance was analysed considering sag/swell/disturbance and change in irradiation for nonlinear/unbalanced loads.

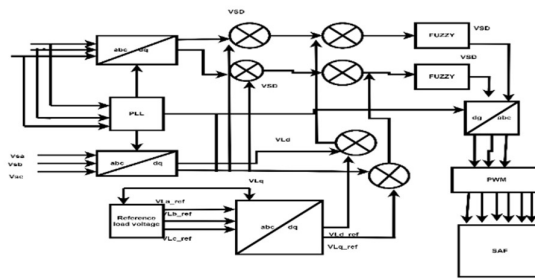


Fig 5. SLO Based hybrid controller for series converter

Case I: The source voltage declined by 30% between 0.4 and 0.5 seconds; the recommended PVBSIUPQC injects the necessary voltage to raise the load voltage. In addition, by injecting a proper compensated voltage and enhancing both the sinusoidal compensating voltage and the sinusoidal source current, the proposed PVBSIUPQC smoothly minimizes sags.

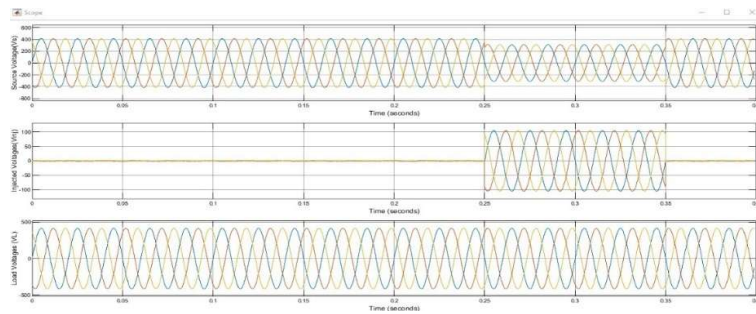


Fig 6. Wave-forms for the source voltage, injected voltage, and load voltage

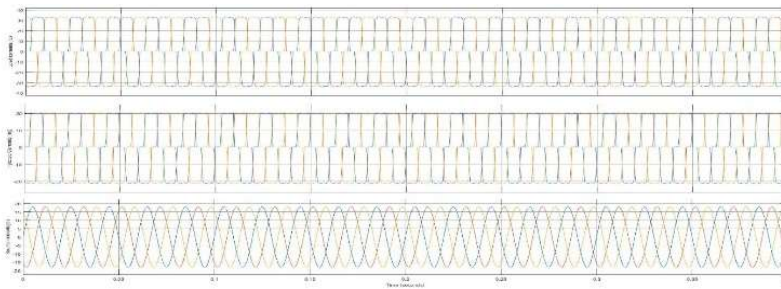


Fig 7 Wave- forms for load current, injected current, and source current

Case 2: A tiny portion of voltage constantly exits across the series converter at steady state, even if the suggested technique successfully eliminates the voltage sag in the present case, which happened between 0.4 and 0.5 seconds. In this case, adding enough adjusting voltage increased the sinusoidal source current.

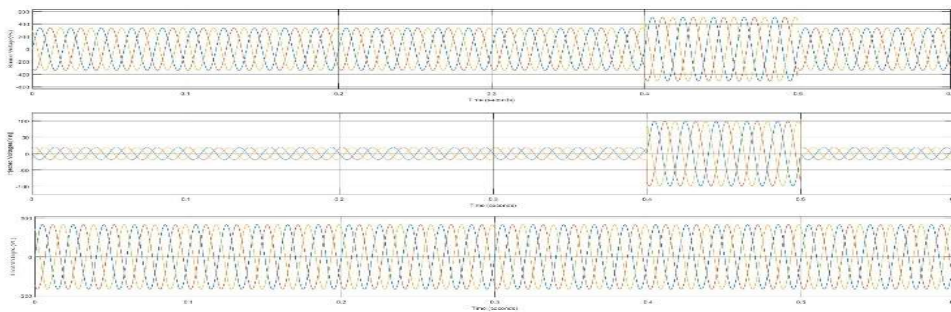


Fig 8 Wave-forms for the source voltage, injected voltage, and load voltage

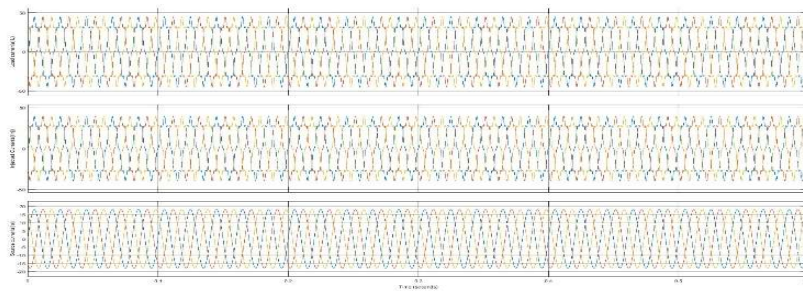


Fig 9. Wave- forms for load current, injected current, and source current

Case 3: The source voltage experienced a significant voltage disturbance between 0.6 and 0.7 seconds. Nonlinear and unbalanced loads resulted in an unbalanced and non-sinusoidal load current. It is clear that the PVBSIUPQC was able to significantly lower THD, increase the PF value, and effectively eliminate voltage disturbances through the use of an appropriate compensatory voltage

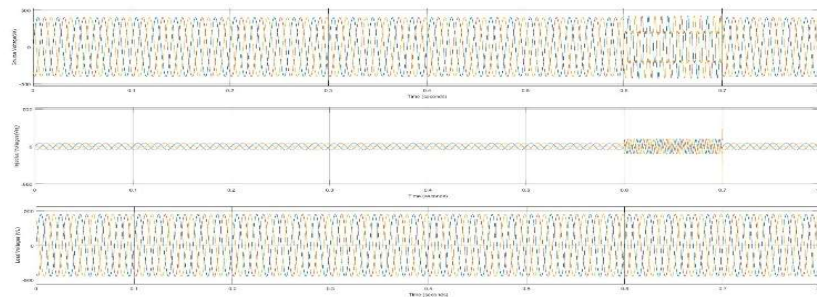


Fig 10 Wave-forms for the source voltage, injected voltage, and load voltage



Fig 11. Waveforms for Load current, injected current, Source current

Case 4: The suggested PVBSIUPQC effectively supplies balanced load voltage, hence the unbalanced supply voltage was considered. The load current appears to be unbalanced and sinusoidal in this case. The THD was reduced and the PF increased by the SLO adjusted Controller

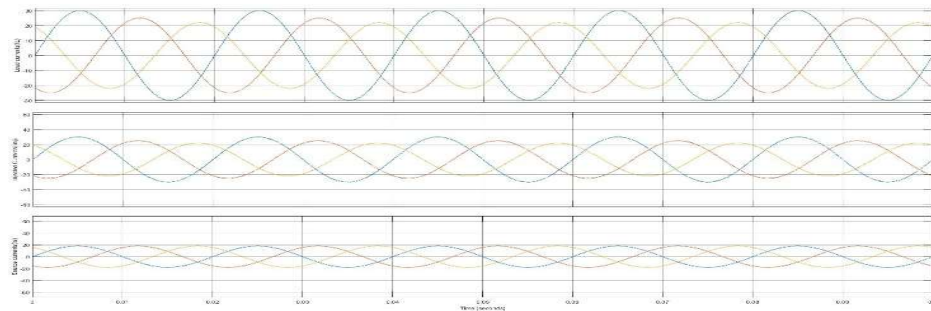


Fig 12 Wave-forms for the source voltage, injected voltage, and load voltage

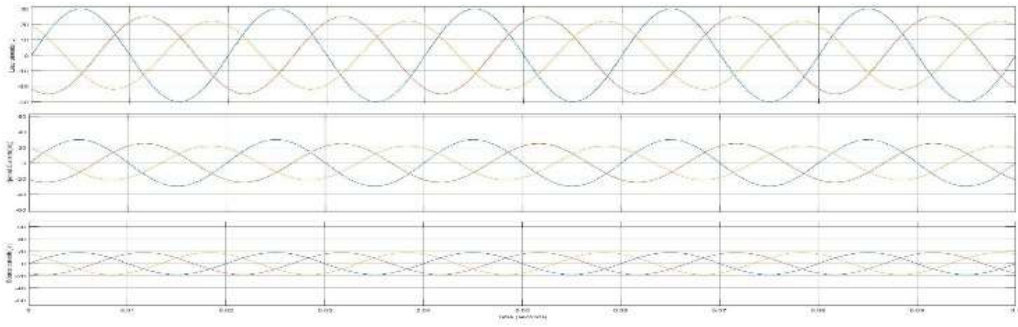


Fig 13. Wave- forms for load current, injected current, and source current

The proposed method's efficiency was tested at a constant temperature of 25°C with sun irradiation that ranged from 1000 W/m² to 800 W/m² and 800 W/m² to 1000 W/m².

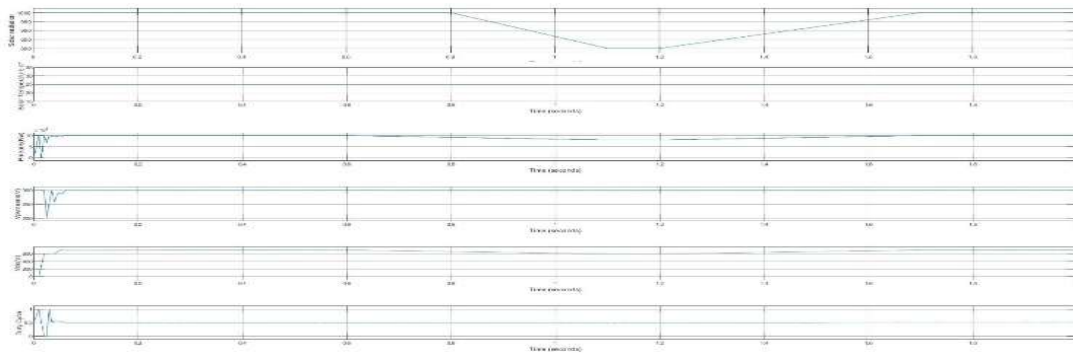


Fig 14. Waveforms of solar irradiation, Temperature, solar output power, Solar voltage, DC-Link voltage, Duty cycle

Overall, the simulation study on "Fuzzy Logic-Based BS-PV Integrated UPQC" aims to demonstrate the proposed system's effectiveness, efficiency, and reliability in enhancing power quality and integrating renewable energy sources into the grid.

III. CONCLUSIONS

In this research, we proposed a unique technique to improving power quality by including a Fuzzy Logic-based BS-PV Integrated Unified Power Quality Conditioner (UPQC). We demonstrated the successful implementation of the suggested system in reducing several power quality problems, including voltage sags, voltage swells, and harmonics, as well as smoothly integrating energy from renewable sources into the grid, through exhaustive simulations and analysis. The application of Fuzzy Logic control algorithms ensured the UPQC system's stability and flexibility to changing operating conditions, resulting in optimal performance in dynamic scenarios. Our findings demonstrate the possibility for combining renewable energy sources with power quality improvement devices to produce more robust and sustainable power systems. Future research can explore further optimizations and real-world implementations of the proposed system to address the growing demand for reliable and efficient power distribution networks.

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