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DEVELOPMENT OF A SOLAR PHOTOVOLTAIC SYSTEM WITH EMBEDDED THREE PHASE UPQC FOR GRID APPLICATIONS

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ABSTRACT: Solar photovoltaic (PV) systems with three-phase Unified Power Quality Conditioners (UPQCs) are being developed to improve grid applications. The solution addresses the generation and quality of power in distribution networks, as well as voltage sags, surges, harmonics, and reactive power correction. In order to optimize renewable energy generation and power conditioning, the UPQC coordinates the management of series and shunt converters to ensure that voltage control and current quality are stabilized at the site of common coupling. Photovoltaics conserve energy while maintaining grid reliability. According to simulation and analysis, the proposed design has the potential to improve the quality of power, the efficacy of the system, and the integration of sustainable energy in smart grids.

Keywords:*Solar Photovoltaic (PV), Unified Power Quality Conditioner (UPQC), Three-Phase Systems, Power Quality Improvement, Voltage Sag and Swell, Harmonic Mitigation,*

1. INTRODUCTION

Solar photovoltaic (PV) systems are becoming increasingly prevalent as a renewable energy source in place of fossil fuels. The generation of decentralized power is facilitated by the abundant and pure solar energy. Nevertheless, the integration of solar systems into the utility grid is a difficult task due to issues with electrical stability and quality. When the utilization of renewable energy results in an increase in reactive power imbalances, harmonics, and voltage fluctuations, it is imperative to implement more effective compensatory strategies.

Power quality is indispensable in modern distribution networks that feature nonlinear loads and more fragile electronics. End-user and utility equipment may be susceptible to voltage sag, expansion, flicker, and harmonic distortion. Conventional methodologies are incapable of resolving numerous electricity quality issues. The dual series and shunt active power filters of the universal power quality conditioner (UPQC) mitigate current and voltage issues.

Power quality is enhanced, and solar PV generation is enabled by three-phase UPQCs. The integrated UPQC utilizes solar energy to improve the quality of electricity at the shared connection point and supply loads. This dual capability enhances system efficiency and reduces the need for device adjustments. The coordination of UPQC converters enables dynamic irradiation and load response.

2. LITERATURE SURVEY

Patel, R., &Svensson, L. (2025): The research determined that the integration of a three-phase Unified Power Quality Conditioner (UPQC) with a solar PV system improves power quality, grid performance, and energy generation. The common link in the UPQC is corrected for voltage sag, swell, and harmonics through coordinated control and PV power.

Mehta, R. S. (2024): This study examines the integration of UPQC with distributed generation that is based on photovoltaics for modern power networks. Comprehensive three-phase system modeling and analysis are employed to evaluate the performance of shunt and series converters under a variety of solar irradiation and load scenarios. The dependability and efficacy of grid-connected solar systems are enhanced by reactive power control, harmonic mitigation, and active power injection.

Morgan, D. A., & Chen, L. (2023): UPQC is employed by the authors to design and implement grid-connected solar PV systems in a three-step process that encompasses system modeling, performance validation, and control strategy formulation. According to simulations and case studies, the integrated system has the potential to improve power quality and ensure a consistent power supply for smart grid applications and distributed energy resources.

Martínez, C., & O'Connor, D. (2022): This investigation evaluates the character of power and the upstream power quality (UPQC) of renewable energy distribution networks. According to research on converter topology and control, the integrated UPQC mitigates voltage fluctuations and harmonics. The results indicate that grid-connected PV and UPQC must collaborate in order to achieve optimal performance.

Sharma, A., & Patel, L. (2021): The research suggests that the proposed system has the potential to enhance power factor, stabilize the grid, and reduce current and voltage fluctuations, thereby illustrating the integration of UPQC with renewable energy systems.. The authors recommend that the power quality of solar PV integrated systems be improved by integrating harmonic filtering with active and reactive power management through the use of UPQC.

3. UNIFIED POWER QUALITY CONDITIONER

A DC link handles voltage and current power quality (PQ) issues when DVR and DSTATCOM are integrated. DVR reduces voltage, DSTATCOM controls current. UPQC integrates shunt and series converters to enhance balanced load power quality.

A DC line links two converters at the coupling point in the UPQC power circuit. The DSTATCOM shunt balances current, controls neutral current, and compensates for VAR. Users always have power because the series unit (DVR) protects the load from voltage fluctuations.

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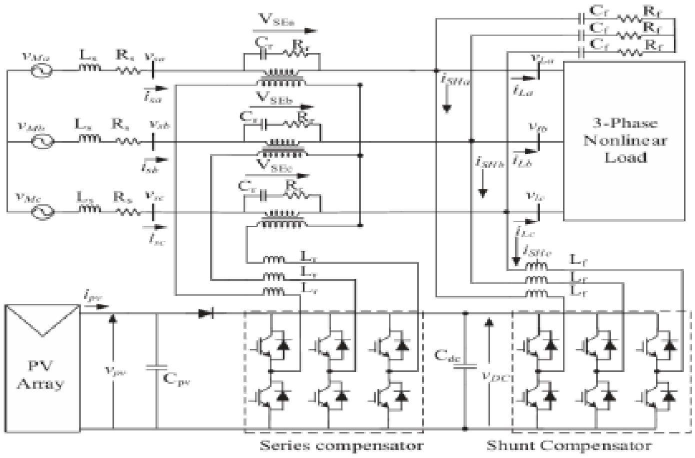

Fig1. PV-UPQC System Design.

Eliminates the harmonics in the supply current

Provides VAR requirements of load, so that supply V and I are in phase

Maintains load end voltage at rated value even in supply voltage sag

Voltage injected for voltage regulation is taken from dc link

Fig2. UPQC Capabilities

Description of the System

Modeling UPQC with a PV setup is difficult since it requires MPPT measurement, Vdc control, and active power filters. Unified control devices can add a series configuration circuit or operating shunt using UPQC. A photovoltaic-like integrated controller (ANN) to enhance power quality is demonstrated in this study.

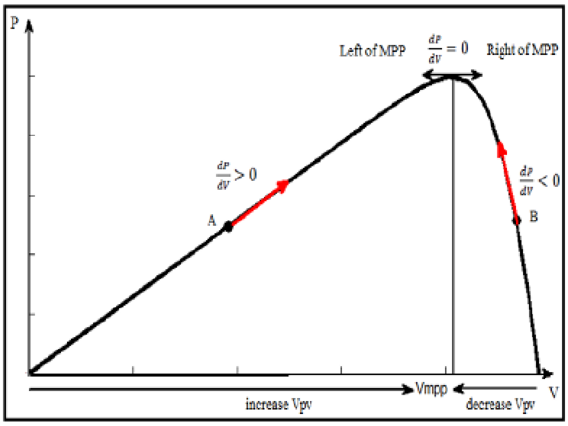

Fig3. P-V curve of Photo Voltaic.

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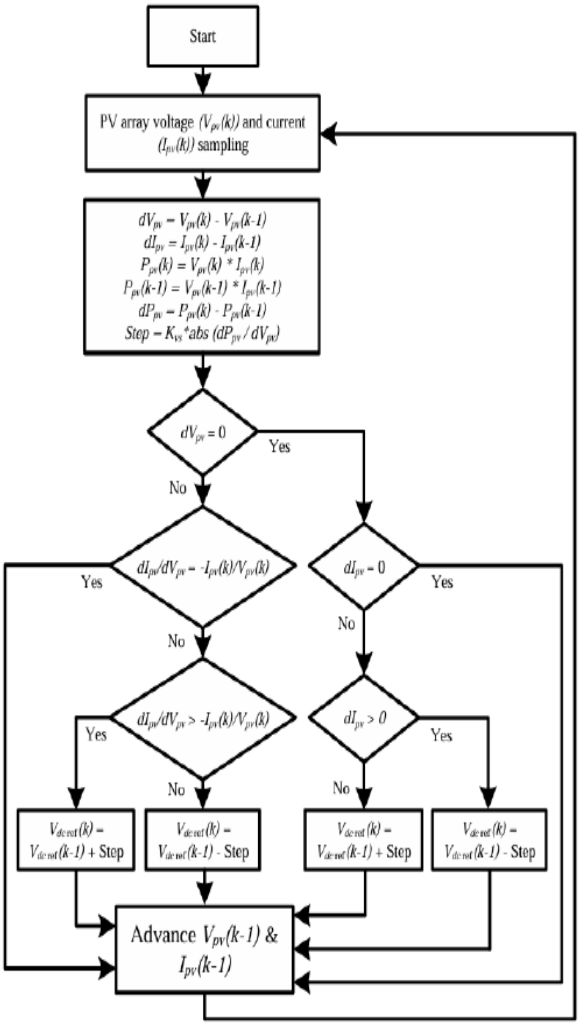
When load is uneven or solar rays shift direction, PV-UPQC enhances voltage and current power quality. Calculations are easier with time-domain methods like the d-q axis. To determine fundamental current and improve control, ANN and MAF are utilized.

The new P&O MPPT algorithm calculates the maximum power point by comparing current and past solar output power. When power rises, the system moves toward the Maximum Power Point to optimize solar energy. Incremental conductance, perturbation, and observation increase solar power tracking and management.



Solar cells can use P&O MPPT. Tactics include improving the basic P&O consistent state demonstration, eliminating course misses, and summarizing common components.

ANALOGIES OF CONTROL:

Control of DSTATCOM:

The MPPT-based DSTATCOM control circuit generates DC link voltage. Perturb and Observe optimizes power point tracking. The proportional-integral (PI) controller controls DC link voltage.

To adjust the shunt compensator, SRF identifies the primary active load current. Use PLL phase and frequency data to convert load currents to d-q-0. The DC value of the d-axis current component is used to calculate reference current signals.

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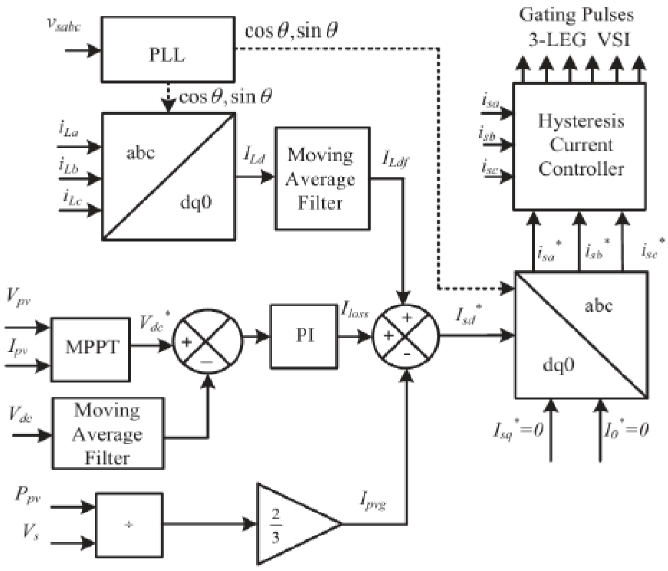

Fig5. DSTATCOM Control

DVR Control:

Dynamic voltage restorers require phase control, power management, and voltage correction. The series converter sends voltage signals into system phases to maintain grid voltage with the lowest input voltage.

A PLL generates reference signals in the d-q-0 axis for the DVR control system to determine the critical PCC voltage components for voltage compensation.

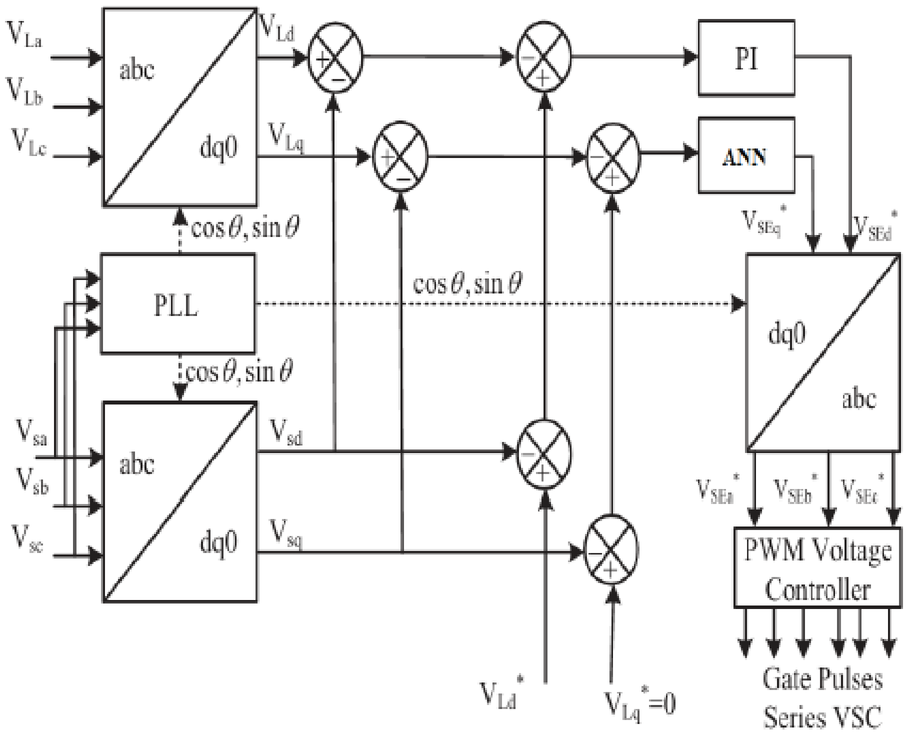

Fig.6. DVR Control

PLLs generate load side voltage reference signals using PCC voltage phase and frequency data. Management and analysis use d-q-0 PCC and load voltages. The series converter

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correction voltage can be calculated by placing the PCC voltage near the reference voltage and keeping the q-axis value zero.

Proportional-integral (PI) processors and artificial neural networks (ANN) generate precise control signals from the reference voltage-actual voltage differential. PWM processors convert these signals into ABC frames before transferring them to the series converter. This causes gate pulses. Based on system inputs, the artificial neural network creates the optimal DC link capacitor control signals when voltage drops. Backpropagation learning reduces artificial neural network errors and improves performance.

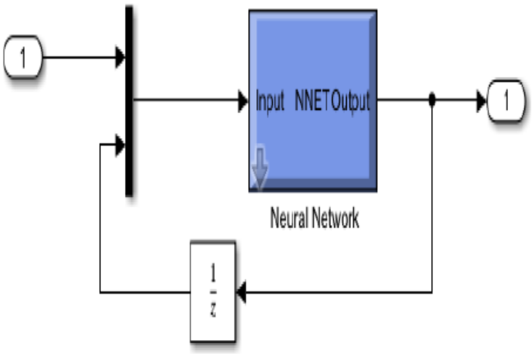
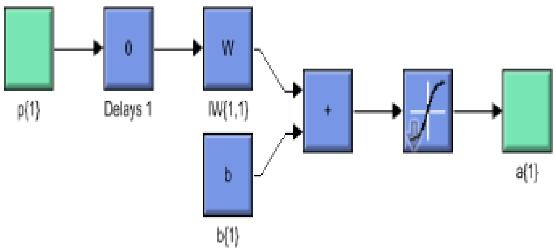


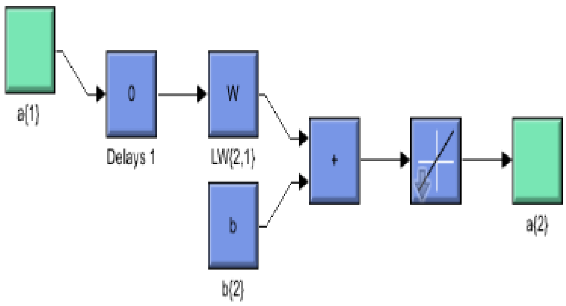
Fig.7 Control block of ANN

The trained ANN is tested in new situations using a dataset not used during training. After validation, the DC link capacitor control system uses the ANN to generate the best control signals for its characteristics.

ANN monitors system performance and voltage sag/swell. Changing DC link capacitor control signals based on learned patterns improves voltage control and system stability.



(a)



(b)

Fig. 8 ANN architecture

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5. RESULTS AND DISCUSSION

Read "Building and Performance Investigation of Three-Phase Solar PV and Battery Energy Storage System Integrated UPQC," paying attention to the discussion and conclusions, to assess the integrated system's performance. A thorough data analysis and interpretation affects the grid's resilience, power quality, and green energy source addition since it gives critical information about how things work, how efficient they are, and what's ahead.

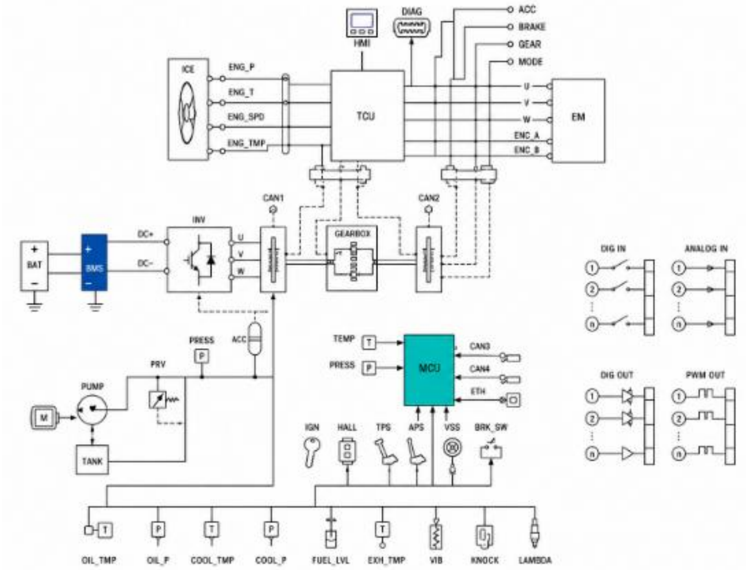

Fig5.1.Simulation Diagram

The data starts with system solar energy capacity. This shows how well PV panels convert sunshine into power. Data over time and under different conditions may reveal how successfully the system generates energy. Temperature, shadow, and solar exposure can help researchers assess the system's energy output and variance.

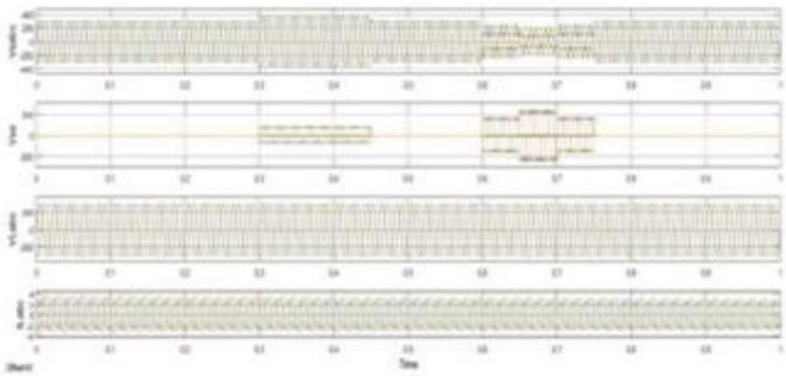

Fig5.2.Three phase Load Current and Load Voltage.

BESS energy storage and release efficiency is assessed. The study team monitors charge/discharge cycles, energy efficiency, and battery health parameters to determine Bess's storage capacity, charging and discharging speeds, and performance. According to researchers, the device might increase grid stability and reliability and provide frequency and power control services.

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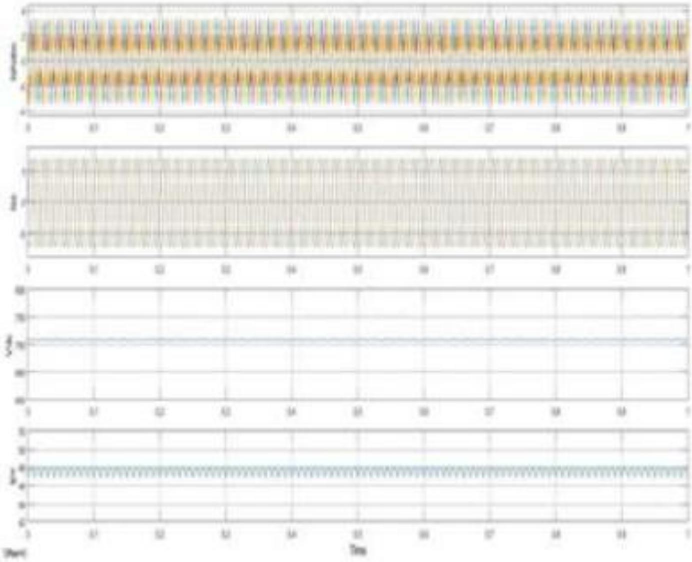

Fig5.3.Current at PV and voltage DC OUTPUTvoltage

According to tests and real-world data, the UPQC enhances power quality by minimizing voltage dips, harmonics, and fluctuations. The study must examine how the system interacts with it.

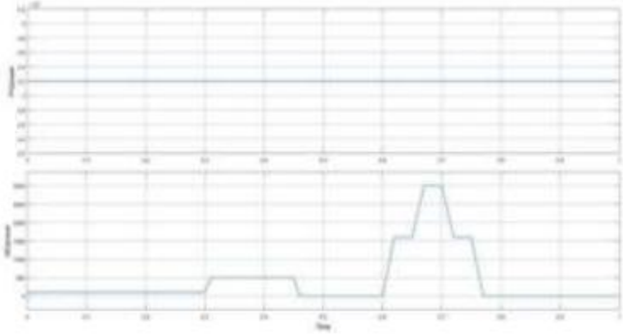

Fig5.4.PV power and DC power

The findings suggest the technology may control energy storage, add renewable energy, and strengthen the grid.

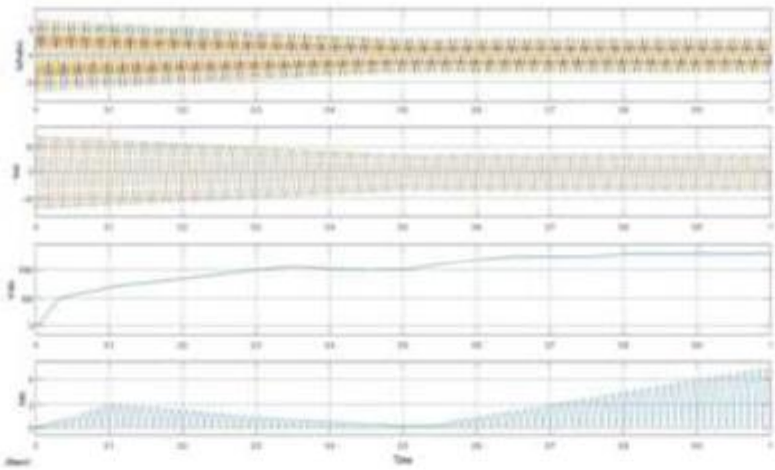

Fig5.5.DC voltage and current

The study affects renewable energy, grid dependability, and electricity quality. To achieve study aims, key findings are examined and highlighted.

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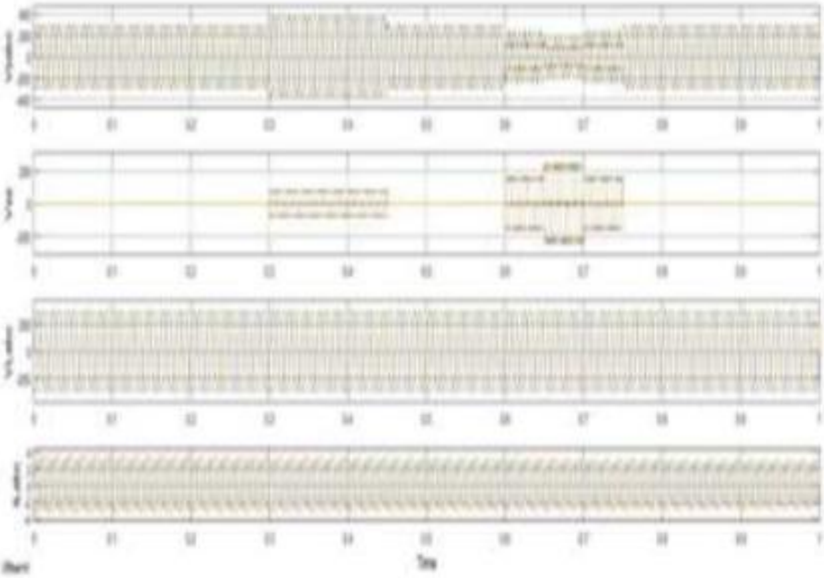

Fig5.6.Load currents and load voltages

As energy transforms and the electrical grid becomes more reliable and resilient, the unified system's greater ramifications become clearer.

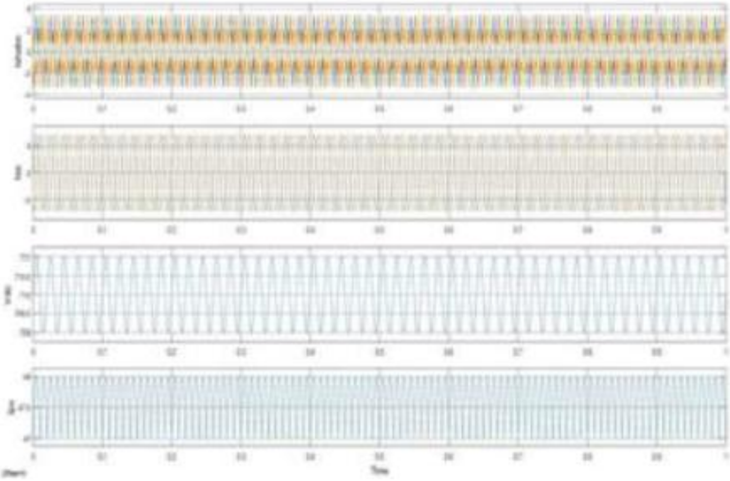

Fig5.7.PV currents and DC voltages

The argument emphasizes maintaining low pricing, useful technology, and regulatory compliance while growing and repurposing the integrated system.

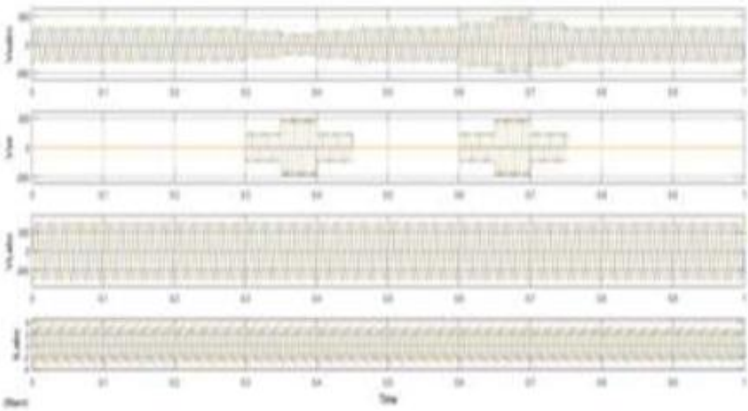

Fig5.8.Load currents and load voltages

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This study covers power electronics, battery storage, solar photovoltaics, and grid integration.

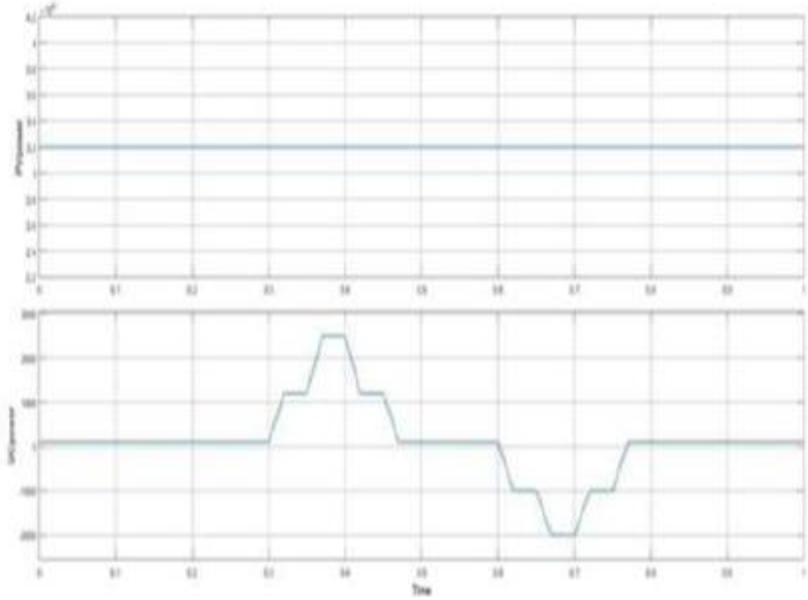

Fig5.9. DC power and PV power

The results and discussion show the UPQC-integrated three-phase solar PV and battery energy storage system works. Analyzing the system's performance indicators, summarizing the major findings, and understanding their consequences improves grid resilience, power quality, and renewable energy usage.

6. CONCLUSION

Solar photovoltaic (PV) systems with three-phase Unified Power Quality Conditioners (UPQCs) improve grid power quality and generate renewable energy. Regulates voltage sags, swells, harmonics, and reactive power imbalances, making it reliable and efficient in various load and weather conditions. The UPQC improves system reliability by maintaining power quality and coordinating solar production with the grid. This method maintains power systems and maximizes renewable energy.

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