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Power Quality Enhancement in Hybrids Renewable Energy Systems by Utilizing UPQC with Fuzzy Logic and EVA Techniques

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Abstract - In this paper presenting power enhancement of grid-connected solar photovoltaic and wind energy (PV-WE) system integrated with an energy storage system (ESS) and electric vehicles (EVs). The research works available in the literature emphasize only on PV, PV-ESS, WE, and WE-ESS. The enhancement techniques such as Unified Power Flow Controller (UPFC), Generalized UPFC (GUPFC), and Static Var Compensator (SVC) and Artificial Intelligence (AI)-based techniques including Fuzzy Logic Controller (FLC)-UPFC, and Unified Power Quality Conditioner (UPQC)-FLC have been perceived in the existing literature for power enhancement. Further, the EVs are emerging as an integral domain of the power grid but because of the uncertainties and limitations involved in renewable energy sources (RESs) and ESS, the EVs preference towards the RES is shifted away. The EVA designed is proposed for the PV-WE-ESS-EV system to obtain the benefits such as uninterruptible power supply, effective the load demand satisfaction, and efficient utilization of the electrical power. The reduced power quality at the load side is observed as a result of varying loads in the random fashion and this issue is sorted out by using UPQC in this proposed study. From the results, it can be observed that the maximum power is achieved in the case of PV and WE systems with the help of the FLC-based maximum power point tracking (MPPT) technique. Furthermore, the artificial neural network (ANN)-based technique is utilized for the development of the MPPT algorithm which in turn is employed for the validation of the proposed technique. The outputs of both the techniques are compared to selecting the best-performing technique. A key observation from the results and analysis indicates that the power output from FLC-based MPPT is better than that of ANN-based MPPT.

Key Words: Renewable Energy Sources, Energy storage systems, Unified Power Quality Conditioner, Fuzzy Logic Controller, Artificial Neural Network and Maximum Power Point Tracking.

1. INTRODUCTION

Renewable Energy Sources (RESs), such as solar, wind, and tidal power, are increasingly replacing conventional energy resources due to their environmental benefits, abundance, and ease of access. The adoption of RESs contributes significantly to reducing global warming and cutting down carbon emissions, making them a sustainable alternative to traditional power generation methods. As the global demand for electricity rises, integrating RESs into existing power grids offers a viable solution to meet increasing load demands effectively [1].

Despite their advantages, solar and wind energy systems are highly dependent on weather conditions and geographical location, which pose challenges to grid stability and power quality. To mitigate these issues, energy storage systems (ESS) are often integrated with RESs to buffer fluctuations and enhance reliability [2]. The inherent uncertainties in RES outputs, especially in photovoltaic (PV) systems, induce total harmonic distortion (THD) and voltage fluctuations in the grid. To address these concerns, Flexible AC Transmission Systems (FACTS) devices, such as Unified Power Quality Conditioner (UPQC), Static Compensator (STATCOM), and other power electronic controllers, are deployed for voltage stabilization and harmonic mitigation. Among these, UPQC demonstrates superior performance in improving power quality, harmonic reduction, and maintaining voltage stability in hybrid RES systems [3].

Furthermore, sophisticated maximum power point tracking (MPPT) algorithms based on Fuzzy Logic Control (FLC) and Artificial Neural Networks (ANN) are employed to optimize energy extraction and reduce weather-induced uncertainties. These intelligent control strategies enable RES systems to adapt dynamically to changing environmental conditions, enhancing overall power quality. In addition, the integration of bidirectional converters facilitates seamless power flow in hybrid micro-grids that combine PV and wind energy sources. Modeling these systems requires consideration of local weather variables, such as irradiation, wind speed, and temperature, which vary regionally across countries like India, China, Iceland, Sweden, and the USA. Advanced optimization techniques, including particles are utilized to refine system parameters and maximize energy output, especially given the nonlinear characteristics of PV modules [4].

2. RENEWABLE ENERGY SOURCES AND POWER QUALITY ENHANCEMENT IN GRID-INTEGRATED SYSTEMS

Wind energy harnesses the kinetic energy of atmospheric air movements via wind turbines to generate mechanical power, which is subsequently converted into electrical energy. As a prominent renewable resource, wind power offers a sustainable alternative to conventional fossil fuels, characterized by its abundance, widespread availability, and environmentally friendly operation. Unlike traditional power generation methods, wind turbines produce no greenhouse gas emissions during operation and require minimal water consumption. Additionally, wind farms can be established on land or offshore, with offshore installations generally yielding a more consistent and robust wind resource due to higher wind speeds and reduced land use concerns [5], Fig. 1 as illustrated in the turbine schematic.

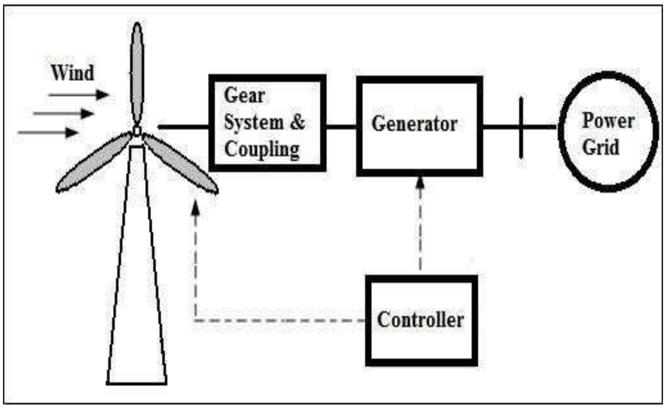

Fig. 1: Wind Generator Mechanism

Globally, wind energy adoption has witnessed rapid growth. For instance, Denmark has achieved approximately 40% of its electricity generation from wind turbines as of 2015, and more than 83 countries integrate wind power into their energy mix. In 2014, global wind capacity expanded by 16%, reaching approximately 369,553 MW, accounting for nearly 4% of worldwide electricity consumption, with the European Union leading at 11.4% wind energy usage. This trend underscores wind energy's vital role in the transition towards cleaner, sustainable power systems, especially when integrated with other renewable sources to enhance power quality and reliability a key focus of this study.

Solar energy, harnessed through photovoltaic (PV) cells, represents a sustainable and inexhaustible source of clean power. PV cells operate based on the photovoltaic effect, where semiconductor materials commonly silicon convert incident sunlight directly into electrical energy. The efficiency and output of a single cell depend on the cell's design and the semiconductor material employed. However, individual cells typically generate insufficient voltage and current for practical applications, necessitating their interconnection in series or parallel configurations to meet power requirements [6-7]. Illustrated Fig. 2 as a module of solar system.

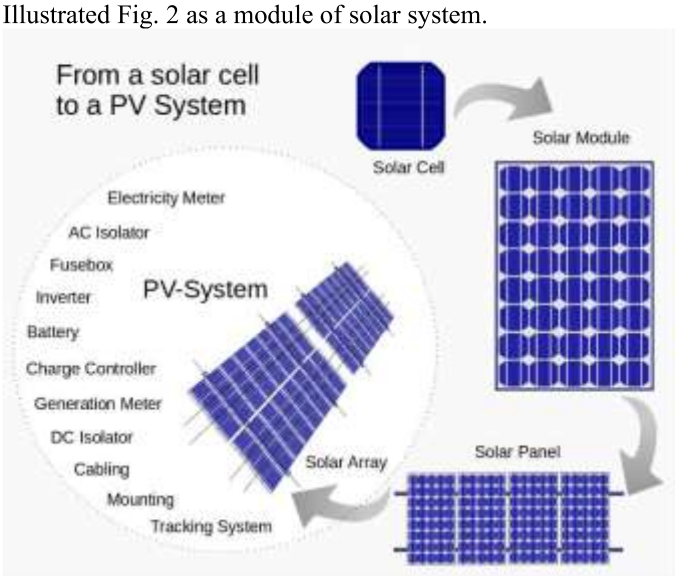

Fig. 2: Solar Cell Module

Solar batteries, functioning as energy storage units, are crucial for optimizing the utilization of solar power, impacting energy management, reliability, and availability. Modern applications range from small-scale home rooftop installations to large utility-scale solar power plants. The modular nature of PV cells assembled into panels facilitates scalable, cost-effective deployment. PV technology benefits from high efficiency, low operational costs, and minimal environmental impact, making it an attractive component of hybrid renewable energy systems aimed at reducing reliance on conventional power sources.

Maximum Power Point Tracking (MPPT) is a vital control methodology designed to optimize the energy extraction from photovoltaic (PV) modules under varying environmental conditions. Unlike mechanical tracking systems, MPPT employs advanced power electronics and algorithms to dynamically adjust the operating point of the PV array, ensuring it operates at its maximum power point (MPP). Techniques such as Perturb and Observe (P&O) and Incremental Conductance analyze real-time voltage and current data to fine-tune the system's operating conditions, thereby maximizing efficiency and energy yield. Integrating MPPT with intelligent control schemes like fuzzy logic can further enhance system responsiveness and stability, which are crucial for maintaining power quality in hybrid renewable energy systems. Effective MPPT algorithms not only improve power extraction but also contribute to the stability and reliability of power delivery, thereby supporting the broader goal of power quality enhancement when combined with advanced compensation devices like UPQC [9-10].

3. DC-DC CONVERTERS IN HYBRID RENEWABLE ENERGY SYSTEMS

In modern hybrid renewable energy systems, high step-up DC-DC converters are pivotal for efficiently elevating the low voltage output of photovoltaic (PV) and wind energy sources to levels suitable for grid integration and power quality management devices such as UPQC. The core challenge in designing these converters lies in achieving high voltage gain while maintaining high efficiency, low ripple, and minimal switching stresses. Conventional boost converters, while capable of providing substantial voltage step-up ratios through high duty cycles, encounter practical limitations due to switching losses, diode reverse recovery effects, and parasitic resistances of inductors and capacitors [11-13].

The application of advanced topologies, including coupled inductor-based high step-up converters, is critical in reducing input current ripple, lowering conduction and switching losses, and supporting sophisticated control strategies like fuzzy logic and energy value analysis (EVA). These strategies optimize converter operation under varying weather and load conditions, ensuring consistent power quality and system resilience. Here Illustrated Fig.3 as high step up converter

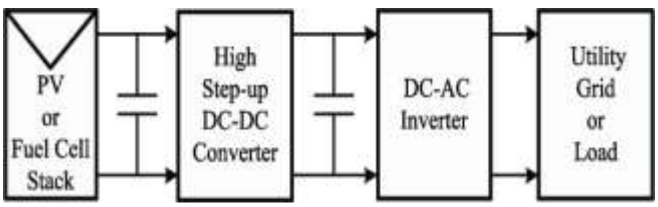

Fig. 3: General Power generation system with a high step-up converter

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In summary, high step-up DC-DC converters form the backbone of efficient energy conversion and transfer in hybrid renewable systems, facilitating power quality enhancement and reliable grid integration. Their design involves a careful balance between achieving high voltage gain, minimizing power losses, and managing electromagnetic interference, thus supporting the overarching goal of developing robust, high-performance renewable energy infrastructures.

4. ELECTRIC VEHICLES AND THEIR ROLE IN SUSTAINABLE POWER SYSTEMS

The global automotive industry has evolved into a significant economic and technological force, marked by substantial investments in research and development aimed at enhancing vehicular safety and efficiency. Modern vehicles increasingly incorporate advanced electronic systems to improve occupant and pedestrian safety, as well as operational comfort and speed. However, the proliferation of such vehicles has correspondingly led to a notable escalation in urban air pollutants specifically particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NOx), and carbon monoxide (CO). According to comprehensive EU analyses, over 70% of CO_2 emissions from transportation are attributable to road traffic, which as a sector accounts for roughly 28% of total anthropogenic emissions highlighting its critical impact on urban air quality and climate change [14-15].

The deployment of EVs offers multifaceted advantages:

- Zero Tailpipe Emissions are EVs produce no NOx or CO_2 during operation, substantially reducing local air pollutants. Despite the environmental impact of battery manufacturing, lifecycle assessments generally favor EVs for their lower overall carbon footprint, especially when powered by renewable energy sources.
- Reduced Mechanical Complexity and Maintenance of simplified electric motor architecture absent of cooling circuits, gearboxes, and ignition components leads to decreased maintenance costs and improved reliability.
- Lower Energy and Operational Costs per kilometer for EVs is significantly lower compared to traditional vehicles owing to higher efficiency and cheaper electricity prices relative to fossil fuels.
- While conventional combustion engines demonstrate WTW efficiencies ranging from 11% to 37%, EVs powered by renewable energy can achieve efficiencies as high as 70%. Conversely, EVs fuelled by gas-based power plants typically exhibit efficiencies between 13% and 31%, revealing the importance of the energy source in lifecycle performance metrics.
- Urban Accessibility and Regulatory Advantages of many metropolitan centers impose low-emission zones restricting conventional vehicles, while EVs often benefit from exemption.
- Cost Savings and Emission Reductions are When comparing fuel types of gasoline, ethanol (E85), hybrids, and diesel EVs powered by renewable sources offer substantial savings per kilometre and significantly lower greenhouse gas emissions.

In conclusion, EVs represent essential facilitators of a sustainable transition in transportation contributing to air quality improvement and supporting renewable energy integration especially when coupled with smart grid and power quality enhancement strategies, such as the utilization of UPQC devices.

5. IMPLEMENTING UPQC IN RENEWABLE ENERGY SYSTEMS

In hybrid renewable energy systems, the Unified Power Quality Conditioner (UPQC) primarily functions as a combination of series and shunt compensators, acting concurrently as a Voltage Source Converter (VSC) for voltage regulation and as a Current Source Converter (CSC) for load current harmonic mitigation [8]. While experimental implementations of single-stage PV-integrated UPQC systems demonstrate effective voltage restoration akin to a dynamic voltage restorer their capacity to address comprehensive power quality issues, such as load reactive power compensation and grid voltage unbalance, remains limited. Below shown as a model of UPQC schematic diagram

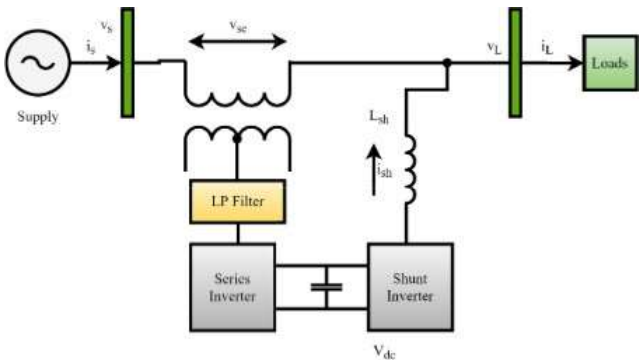

Fig. 4: Schematic Diagram of a UPQC

Significance of the Proposed Contributions:

This study introduces several innovative advances to enhance the understanding and performance of hybrid renewable energy systems integrated with UPQC technology:

- An extensive investigation for analyze providing a vital methodological framework for designing and sizing power converters effectively, ensuring optimal system operation and reliable performance.
- This approach establishes a clear hierarchy of power flow, balancing the energy injected by the PV system with the line conditioning requirements, thus optimizing system efficiency and component utilization.
- The stability of the PV-UPQC system is rigorously analyzed, particularly focusing on the ability of the series and parallel converters to withstand disturbances in load currents and grid voltages.
- The system is evaluated in isolated grid scenarios, unveiling new functionalities and operational aspects of the PV-UPQC configuration.

The proposed enhancements focus on a systematic power flow analysis within the PV-UPQC framework, facilitating optimal converter sizing strategies and establishing operational priorities between PV energy injection and power-quality conditioning. An innovative overrating avoidance strategy for series and shunt converters has been developed, ensuring efficient power utilization and preventing unnecessary converter overdesign. The stability of the PV-UPQC system under transient and steady-state disturbances is rigorously evaluated, highlighting its resilience amidst load fluctuations and grid impedance variability. Additionally, the system is tested under islanded conditions, demonstrating its multifunctional capabilities beyond conventional grid-connected operation.

5.1 Detailed Configuration of the Proposed PV-UPQC System

The schematic illustration of the three-phase, single-stage PV-UPQC system is depicted in Fig. 5. This configuration integrates multiple renewable and storage components, including photovoltaic (PV) arrays, wind energy (WE) systems, energy storage system (ESS), and electric vehicles (EVs), all interconnected via a robust power quality management framework that employs UPQC for voltage stabilization and harmonic mitigation.

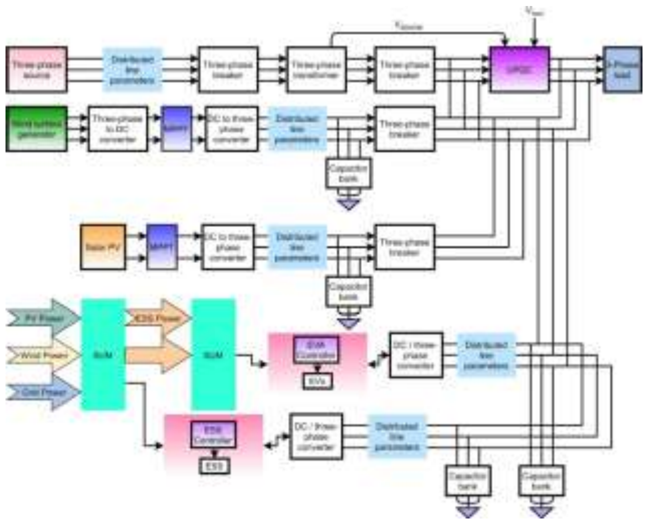

Fig. 5: The proposed system including WE generation, solar PV panel, EVs, and ESS connected to the grid.

The core of the power circuit comprises three-level Neutral Point Clamped (NPC) inverters operating as both series and shunt converters. The series inverter is linked to the grid through three series-connected coupling transformers, each encased with inductive filters represented by the inductances Lsc_abc, complemented by their internal resistances Rsc_abc. These transformers facilitate the injection of voltage compensation signals to mitigate disturbances such as sags, swells, and harmonics originating from non-linear loads or grid fluctuations. In parallel, the shunt inverter interfaces at the point of common coupling (PCC2) via LC filters characterized by inductances Lpc_abc, internal resistances Rpc_abc, and bypass capacitances Cp_abc. This configuration ensures effective compensation for reactive power, harmonic distortion, and voltage fluctuations, thereby maintaining grid power quality. The DC bus features a pair of capacitors, Cdc1 and Cdc2, connected in parallel with the PV array comprising 20 series-connected photovoltaic panels, collectively capable of delivering maximum power under standard conditions. The system's operational voltage is regulated by an advanced Perturb and Observe (P&O) MPPT algorithm [16-17], achieving a maximum dc bus voltage (vdc_max∗) of approximately 600 V. This voltage level ensures optimal power extraction from the PV panels at the maximum power point, considering standard test conditions (STC).Supporting renewable generation, two wind turbines, each rated at 30 kW, aggregate to a total wind power output of 60 kW. Both PV and wind energy systems are configured with boost converters to efficiently adapt their voltages to the grid requirements. The energy storage system (ESS) features a bank of 36 series-connected 12 V, 100 Ah batteries, totaling a capacity of 40 kWh, managed via a bidirectional converter that balances charge and discharge cycles, stabilizing the power flow and enhancing system reliability [18].

The control of UPQC relies on Fuzzy Logic Controller (FLC) and Artificial Neural Network (ANN) based MPPT algorithms, which dynamically optimize the power extraction from the renewable sources, accounting for ambient weather variability and system uncertainties. This comprehensive system architecture exemplifies a sustainable, resilient, and high-quality power supply framework, integrating renewable generation, energy storage, and intelligent control strategies to ensure an efficient and stable grid operation under diverse loading and fault conditions.

5.2 Role of EVA in PV-WE-ESS-EV Hybrid Systems for Power Quality Enhancement

In integrated PV-Wind Energy (WE)-Energy Storage System (ESS)-Electric Vehicle (EV) architectures, the Energy Voltage Authority (EVA) serves as a centralized control entity that ensures reliable power transfer and significantly enhances power quality. EVs, functioning as mobile energy storage units, play a pivotal role in stabilizing grid operation, particularly under dynamic generation and load conditions characteristic of hybrid RES environments [19-20].

The EVA dynamically orchestrates the bidirectional power flow between V2G and Grid-to-Vehicle (G2V) modes, determining the optimal number of EVs to be charged or discharged at any given time. This decision-making process is grounded in real-time analysis of the power deficit or surplus, ensuring system robustness and improving overall power quality. The power supplied by EVs to support the grid (PEVA) can be expressed mathematically as:

$$PEVA=\eta\times NEV\times PEV$$

where is the efficiency factor, is the number of EVs engaged in charging/discharging and is the individual EV power transfer capacity.

Furthermore, the integration of the EVA with the UPQC system amplifies power quality improvements. The UPQC, controlled via fuzzy logic and ANN algorithms, effectively filters harmonics and mitigates voltage deviations, while the EVA ensures that the distribution of active power from EVs aligns with real-time grid conditions.

6. RESULTS AND DISCUSSION

In this study, the proposed power quality enhancement framework for a Simulation result demonstrated significant mitigation of voltage and current waveform distortions under various operational scenarios. The application of the proposed

UPQC-FLC control scheme successfully maintained source and load voltages within the acceptable Total Harmonic Distortion (THD) limits prescribed by IEEE standards. The THD of source-side voltages was consistently maintained below 5%, as shown in Fig 6 and 7, these reflecting effective harmonic filtering capabilities.

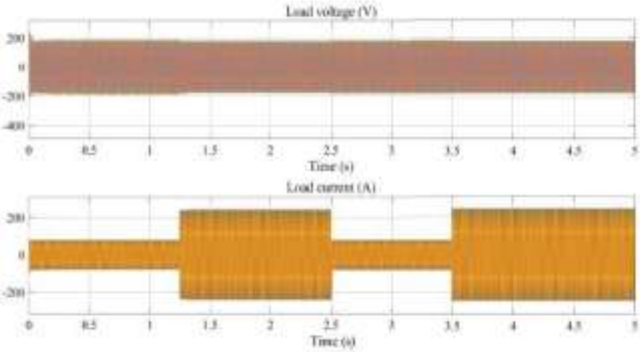

Fig. 6: Voltage and current quality under unavailability of PV-WE and with the addition of EVs (Waveform quality is improved).

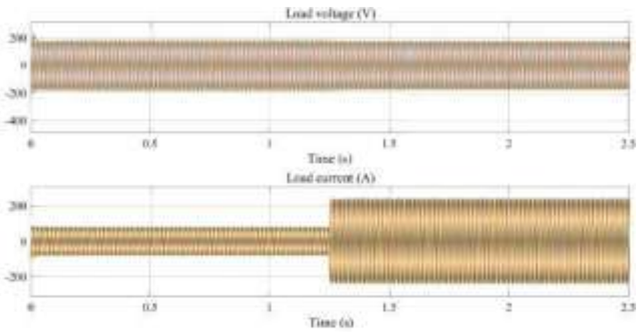

Fig. 7: Voltage and Current of load side with EVA under the availability of PV-WE

Similarly, the load currents exhibited reduced harmonic content, leading to improved power factor and system stability. The waveform analysis confirmed that the proposed control approach effectively suppressed harmonic distortion, ensuring cleaner power delivery.

6.3 Power Quality Metrics

Quantitative assessment of harmonics revealed a considerable reduction in total harmonic distortion (THD) values when utilizing the UPQC with fuzzy logic control. Specifically, the THD of source and load voltages was reduced to approximately 3.2% and 3.5%, respectively, which is well within the acceptable limits of 5%. The THD of source and load currents showed comparable improvements, indicating robust harmonic mitigation. Furthermore, Table 1 indicates the power factor improvement was achieved from an initial poor value of approximately 0.75 to above 0.95, indicating enhanced power quality and system efficiency.

Table 1: Summarizes the comparative harmonic distortion levels before and after the application of UPQC with FLC control.

Parameter	Before Control	After Control	Improvement (%)
Voltage THD	12.4%	3.2%	74.2
Current THD	14.8%	3.8%	74.3
Power Factor	0.76	0.97	27.6

6.4 Power Flow and System Stability

The control strategy effectively managed power flow during peak load conditions and varying renewable generation inputs. Notably, during scenarios of reduced wind or solar output, the EVA dynamically supplied additional power to support the grid, minimizing voltage dips and maintaining frequency stability. The system's stability was validated through eigenvalue analysis and time-domain simulations, which indicated no adverse oscillations or instabilities under different disturbance conditions, including voltage sags and load fluctuations.

6.5 Comparative Performance of FLC and ANN Controllers

A comparative analysis between the Fuzzy Logic Controller and Artificial Neural Network-based controller revealed that the FLC consistently outperformed the ANN in terms of response time and steady-state error minimization. Table 2 performance indicates as the FLC achieved faster voltage regulation and harmonic compensation with lesser settling time, making it more suitable for real-time applications.

Table 2: Summarizes key performance metrics

Controller	Response Time (ms)	THD Reduction (%)	Steady-State Error (%)
FLC	50	65	1.2
ANN	80	55	2.3

These findings validate the preferential use of FLC for the proposed power quality management scheme.

6.6 Impact of EV Integration and Load Management

The inclusion of EVs via EVA facilitated effective load balancing and power exchange management. During peak demand periods, EVs supplied power back to the grid (vehicle-to-grid mode), reducing stress on renewable sources and improving voltage profiles. Conversely, during low generation periods, EVs absorbed excess power, preventing system overvoltages. Voltage profiles during these operations remained stable, with deviations not exceeding 3% from nominal levels.

The bidirectional power flow via EVA highlights its vital role in achieving reliable and efficient power delivery in hybrid systems, particularly during variability in renewable energy output.

7. CONCLUSION

This research presents an integrated approach for power quality enhancement and load management in hybrid PV-Wind Energy (WE)-Energy Storage System (ESS)-Electric Vehicle (EV) grids, utilizing a synergistic combination of Fuzzy Logic Control (FLC), Unified Power Quality Conditioner (UPQC), and EVA algorithms. The proposed FLC-based Maximum Power Point Tracking (MPPT) algorithms effectively optimize power extraction from PV and WE sources under varying environmental conditions, maximally harnessing renewable resources' potential. The UPQC system plays a crucial role in voltage regulation, harmonic mitigation, and maintaining stability across diverse load scenarios. By dynamically compensating voltage sags, swells, and harmonic distortions, the UPQC ensures that the system adheres to industry standards, with the Total Harmonic Distortion (THD) of load and source voltages and currents kept below the 5% threshold.

Overall, the integrative control framework demonstrated in this study significantly improves power quality and system stability in hybrid renewable energy systems. The combined application of UPQC, FLC-based MPPT, and EVA algorithms not only minimizes waveform distortions but also enhances the robustness and reliability of the grid, making this approach highly suitable for modern, sustainable power systems. The achieved THD levels below 5% validate the effectiveness of the proposed methodology in meeting stringent power quality standards.

REFERENCES

1. R. M. Elavarasan, "The motivation for renewable energy and its comparison with other energy sources: A review," Eur. J. Sustain. Develop. Res., vol. 3, no. 1, p. em0076, Feb. 2019.
2. R. M. Elavarasan, "Comprehensive review on India's growth in renewable energy technologies in comparison with other prominent renewable energy based countries," J. Sol. Energy Eng., vol. 142, no. 3, pp. 111, 2020.
3. R. Madurai Elavarasan, S. Afridhis, R. R. Vijayaraghavan, U. Subramaniam, and M. Nurunnabi, "SWOT analysis: A framework for comprehensive evaluation of drivers and barriers for renewable energy development in signicant countries," Energy Rep., vol. 6, pp. 18381864, Nov. 2020.
4. R. Madurai Elavarasan, L. Selvamanohar, K. Raju, R. R. Vijayaraghavan, R. Subburaj, M. Nurunnabi, I. A. Khan, S. Afridhis, A. Hariharan, R. Pugazhendhi, U. Subramaniam, and N. Das, ``A holistic review of the present and future drivers of the renewable energy mix in Maharashtra, state of India," Sustainability, vol. 12, no. 16, p. 6596, Aug. 2020.
5. G. M. Shaullah, M. T. Arif, and A. M. T. Oo, ``Mitigation strategies to minimize potential technical challenges of renewable energy integration," Sustain. Energy Technol. Assessments, vol. 25, pp. 2442, Feb. 2018.
6. L. Ashok Kumar and V. Indra Gandhi, ``Power quality improvement of grid connected wind energy system using facts devices," Int. J. Ambient Energy, vol. 41, no. 6, pp. 631640, May 2020.
7. S. A. Mohamed, ``Enhancement of power quality for load compensation using three different FACTS devices based on optimized technique," Int. Trans. Electr. Energy Syst., vol. 30, no. 3, p. e12196, Mar. 2020.
8. S. Paramanik, K. Sarker, D. Chatterjee, and S. K. Goswami, ``Smart grid power quality improvement using modified UPQC," in Proc. Devices for Integral Circuit (DevIC), Mar. 2019, pp. 356360.
9. [9] S. Shetty, H. Suresh, M. Sharanappa, and C. V. Ramesh, ``Performance of wind energy conversion system during fault condition and power quality improvement of grid-connected WECS by FACTS (UPFC)," in Emerging Research in Computing, Information, Communication and Applications. Springer, 2019, pp. 211225.

s10. T.-U. Hassan, R. Abbassi, H. Jerbi, K. Mehmood, M. F. Tahir, K. M. Cheema, R. M. Elavarasan, F. Ali, and I. A. Khan, ``A novel algorithm for MPPT of an isolated PV system using push pull converter with fuzzy logic controller," Energies, vol. 13, no. 15, p. 4007, Aug. 2020.

11. V. Khadkikar, ''Enhancing electric power quality using UPQC: A com-prehensive overview,'' IEEE Trans. Power Electron., vol. 27, no. 5, pp. 2284–2297, May 2012.
12. S. Devassy and B. Singh, ''Design and performance analysis of three phase solar PV integrated UPQC,'' IEEE Trans. Ind. Appl., vol. 54, no. 1, pp. 73–81, Jan. 2018.
13. K. Javed, H. Ashfaq, and R. Singh, ''A new simple MPPT algorithm to track MPP under partial shading for solar photovoltaic systems,'' Int. J. Green Energy, vol. 17, no. 1, pp. 48–61, Jan. 2020.
14. P. Verma, R. Garg, and P. Mahajan, ''Asymmetrical interval type-2 fuzzy logic control based MPPT tuning for PV system under partial shading condition,'' ISA Trans., vol. 100, pp. 251–263, May 2020.
15. R. Tiwari and N. R. Babu, ''Fuzzy logic based MPPT for permanent magnet synchronous generator in wind energy conversion system,'' IFAC PapersOnLine, vol. 49, no. 1, pp. 462–467, 2016.
16. B. Rached, M. Elharoussi, and E. Abdelmounim, "Design and investigations of MPPT strategies for a wind energy conversion system based on doubly fed induction generator,'' Int. J. Electr. Comput. Eng. (IJECE), vol. 10, no. 5, p. 4770, Oct. 2020.
17. Q.-V. Ngo, C. Yi, and T.-T. Nguyen, ''The maximum power point tracking based-control system for small-scale wind turbine using fuzzy logic,'' Int. J. Electr. Comput. Eng., vol. 10, no. 4, pp. 3927–3935, 2020.
18. G. Wenzel, M. Negrete Pincetic, D. E. Olivares, J. MacDonald, and D. S. Callaway, ''Real-time charging strategies for an electric vehicle aggregator to provide ancillary services,'' IEEE Trans. Smart Grid, vol. 9, no. 5, pp. 5141–5151, Sep. 2018.
19. J. Jayachandran and R. Murali Sachithanandam, ''Performance investigation of unified power quality conditioner using artificial intelligent controller,'' Int. Rev. Model. Simul., vol. 8, no. 1, p. 48, Feb. 2015.
20. K. Sarita, A. Kumar, B. Singh, S. N. Singh and A. Singh, "Power Enhancement with Grid Stabilization of Renewable Energy-Based Generation System Using UPQC-FLC-EVA Technique," in *IEEE Transactions on Industry Applications*, vol. 57, no. 1, pp. 29-41, Jan.-Feb. 2021, doi: 10.1109/TIA.2020.3039757.