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IMPLEMENTATION OF POWER ECHANCEMENT WITH GRID STABILIZATION OF RENEWABLE ENERGY BASED GENERATION SYSTEM USING UPQC-FLC-EVA TECHNIQUE

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ABSTRACT: Increasing the efficiency of grid-connected solar and wind power systems in conjunction with energy storage systems (ESS) and electric vehicles is the main goal of the study that is being suggested. Only the study findings relating to PV, PV-ESS, WE, and WE-ESS are emphasised in the literature. Unified Power Flow Controller (UPFC), Generalized UPFC (GUPFC), Static Var Compensator (SVC), Fuzzy Logic Controller (FLC)-UPFC, and Unified Power Quality Conditioner (UPQC-FLC) are just a few of the AI-based technologies that are now in use. In the literature, performance-boosting techniques are discussed. In addition, because to the dangers and constraints they provide, electric vehicles and trucks are still distant from RES and ESS, despite their growing significance to the energy system. The grid-connected PV-WE-ESS-EV system has to have its power quality upgraded since it hasn't yet been put to the test and verified using power quality enhancement techniques. Electric vehicle aggregators (EVAs) are being developed to efficiently govern the bidirectional energy transfer from cars to the grid (V2G) and from the grid to vehicles (G2V). An estimated EVA is offered for the PV-WE-ESS-EV system in order to take advantage of stable power supply, effective load demand response, and efficient power usage. In addition to regulating the flow of electricity from source to load and from one source to another, FLC permits effective use of power both during peak and off-peak times. You can observe the power quality worsening close to the load when the loads are unsteady. The suggested study that deals with this topic makes use of UPQC. The results show how the FLC-based MPPT (Maximum Power Point

Tracking) method improves the efficiency of PV and WE systems. Additionally, the recommended techniques are evaluated using the MPPT algorithm, which is built using a technique based on artificial neural networks (ANNs). The outcomes of the two strategies are compared in order to decide which is more successful. The data and analysis's main finding is FLC-based power production.

ANN-based MPPT is inferior than MPPT. Energy usage that is wise and effective is supported by FLC and UPQC. When adequate control mechanisms and grid integration are in place, electric vehicles may considerably improve system flexibility and stability during peak and off-peak hours.

INDEX TERMS : PV system, Energy storage system (ESS), electric vehicles (EVs), UPQC, grid stability, fuzzy logic control (flc), electric vehicle aggregator (EVA), Fuel cell energy MPPT, power improvement

1. INTRODUCTION

Conventional energy sources are being replaced by renewable energy sources (RESs), such as solar, wind, tidal, and many more. The accessibility, availability, and cleanliness of RES all help to explain why their usage is becoming more and more common. Utilizing renewable energy has also been demonstrated to provide the following prospective advantages: B. Cutting down on CO2 emissions to slow global warming. RES is preferred to traditional resources. The present power system may contain RE in order to fulfil the rising load demand. [1]. Even though solar and wind energy offer numerous benefits, their location and reliance on the environment are significant barriers to the adoption of renewable energy. By combining RES and ESS, grid stability may be increased, which is significantly impacted by these threshold levels.

The papers [2] to [4] in the links above go into great depth on many of the issues with RES and how to fix them. The PV system's Total Harmonic Distortion (THD), which affects the grid, is unknowable. As a result, aberrations in voltage and current occur at the consumer. To address issues with voltage stability and THD, devices referred to as FACTS (Flexible AC Transmission System) are deployed. To enhance power quality, FACTS devices including the UPFC, UPFCFLC, GUPFC, UPQC, and SVC are often utilised. Voltage stability may be maintained using FACTS devices that enhance mains power quality [5]–[7]. Grid stability and THD are enhanced when STATCOM and ESS are used together [5]. It is possible to see similar voltage and THD instabilities in wind power producing systems. A STATCOM is now part of a grid-tied WE system [6]. Three devices—Dynamic Voltage Recovery (DVR), Distribution STATCOM (DSTATCOM), and UPQC—are utilised to enhance power quality and voltage stability [7]. UPQC's potential to enhance power quality in grid-tied PV systems has been researched [8]. An integrated WE-grid system has examined using UPQC [9]. To enhance the power quality supplied by grid-tied RES, a number of MPPT algorithms based on FLC and ANN may be applied. Additionally, RES uncertainty may be decreased by using FLC-based MPPT algorithms.

The PV-UPQC system is managed by a proportional-integral (PI), FLC, or neural network (NN) based algorithm. Utilizing battery storage systems (BSS), PV-UPQC systems, and FLC technology improves power quality [27, 30]. In comparison to other PI-based methodologies, the FLC methodology produces the best results for the

PV-UPQC-BSS system, according to the authors' evaluation of the PI and FLC approach necessary to run the PV-UPQC. There is a structure. It has been explored how to employ the NN approach in PV-UPQC to enhance grid quality [31, 32]. This technique has to be thoroughly tested and assessed before being deployed in the electrical system. Although it takes the system longer to examine the initial response, the outcomes are precise and helpful. ESS-integrated, grid-tied renewable energy may be used in conjunction with EVs to boost the calibre of the power supply. The performance, charging procedure, and benefits of electric cars are covered in [33]–[35]. Due to the fact that electric vehicles are largely used for transportation, it is unclear if they will be broadly accessible. Scheduling the hours for charging and discharging electric vehicles linked to the grid helps address this issue [36, 37]. I got Eve.

The charging and discharging procedures between the network and the automobile are mediated and managed by the network system. It assists in maintaining the load balance of the grid system while lowering THD and enhancing voltage profile under different load imbalance scenarios. For grid-connected EV systems, a number of control and optimization solutions have been put forward [38, 39].

Fig. 1 displays a thorough block diagram of the proposed system. PV, WE, ESS, and EV are connected to a three-phase, three-wire network using a phase inverter. Line-to-line voltage and frequency for the system are 254.4 V and 50 Hz. Voltage disturbances are brought on by voltage peaks, voltage valleys, and non-linear loads. A UPQC is built and linked to the grid for voltage control in order to address this issue. Together, the two systems enable us to generate up to 60 kW of power. The combined output of these two systems is 30 kW. 36 12V, 100Ah batteries arranged in series and linked to the grid make up an ESS battery bank. The 40 kWh ESS system is connected to the grid through a bi-directional converter. PV system output is 100 kW. PV and WE systems are connected to the grid via boost converters. Each electric vehicle in this study produces 29 kW of electricity. MPPT algorithms based on FLC and ANN may be used in PV and WE systems. The issue description, the research project's contributions, and its goals are used to organise the next section.

2. SYSTEM CONFIGURATION

2.1 PROBLEM FORMULATION

UPQC, UPQC-PI, UPQC-FLC, and UPQC-NN have all been utilised to enhance the power quality of PV, WE, PV-ESS, and WE-ESS systems, according to the literature study. Since the PV-ESS system just recently included electric vehicles, it must solve the difficulties of enhancing power quality. EVA controls the power transfer between EV, ESS, and PV systems. Therefore, it is essential to raise power quality. Therefore, the main contribution of this work is to enhance the PV-WE-ESS-EV system's power quality. It focuses on electric cars and how UPQC aids in the deployment of energy and the sustainability of the grid. According to studies, ESS and electric vehicles might help the grid meet the rising power consumption during peak hours. It also takes into account the worst-case situation, in which there is

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not enough RES power to match the load's demand. In this instance, EVA manages the electric vehicles to manage the grid-tied load's energy usage. In order to govern and regulate the power flow from EVs to the grid or from the grid to EVs, the EVA controller employs a demand forecasting system, a power production forecasting system for RES, and local charging stations. This paper includes thorough explanations of how UPQC and EVs enhance power and voltage stability. The major objective of implementing EVA is to restrict the usage of EVs as mobile, transient battery storage systems, suggesting that the energy may be utilised for transportation when it is not required to be used as an ESS. The suggested approach in this research is based on the FLC method, and the outcomes are contrasted with those attained using the ANN method. The FLC is altered once every 0.01 seconds to boost current and stabilise the grid.

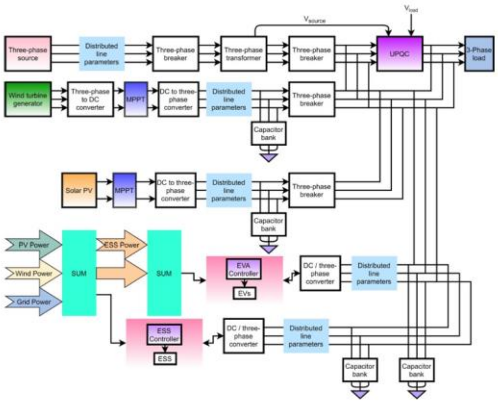

Fig 1: The proposed system with PV ESS WE ad UPQC.

The following are the primary goals of the suggested grid-based and renewable energy strategy

Enhancement of the PV-WE-ESS-EV system's performance.

• A decrease in grid voltage and current THD.

• Handle voltage well under a variety of load circumstances.

• To provide urgent power demands when renewable energy sources are unable to do so.

• Using electric cars as ESS during times of high power availability and as a source of energy during times of peak grid demand. The MPPT algorithm is particularly useful for producing the most electricity possible in a variety of weather situations. This research project develops fuzzy and ANN-based controllers for PV and WE systems on the MATLAB platform. In the end, it is to identify whether simulation produced better results, the outcomes of both are compared. The capacity of each EV battery is 29 kW. (12 volts). Systems for load balancing and managing EV batteries employ EVA. The EVA is built, and its performance is assessed, using fuzzy and ANN. Because RES power is non-linear, integrating a hybrid PV-WE system into the grid remains difficult. As proposed by this research, phase-locked loops, voltage regulators, and current regulators are included into grid integration controller designs. A controller based on a voltage source converter is necessary to synchronise the RES with the grid. The PV-WE-ESS-EV system is controlled by UPQC-FLC in the proposed control approach, together with WE, ESS, and EVs linked to the grid. By lowering the grid's voltage and current THD below the ANSI/IEEE-519 (1992) standard, this method enhances overall power quality. In the PV-WE-ESS-EV system, FLC and ANN techniques are utilised, and the results are compared to determine the most effective strategy to raise power quality, grid voltage, and frequency stability. Table 2 provides an overview of the techniques outlined in the literature and how they were put into practise. The following section provides a summary of the research's key conclusions and contributions.

With UPQC-FLC-EVA, grid stability and improved performance are attained.

• For PV and WE systems, FLC-based MPPT algorithms perform better than ANN-based MPPT algorithms.

• AI-based EVA (FLC and ANN) manages flow in both directions (V2G and G2V).

• AI-based controllers are in charge of ESS and EV charge (SoC) and discharge states (SoD). • To prevent voltage sags and swells, UPQC regulates voltage under a variety of load circumstances, including underload, overload, linear, and non-linear loads.

• Integration of UPQC, FLC, and EVA to enhance system performance in general. The UPQC-FLC-EVA combo procedure is thus named.

• UPQC, ANN, and EVA combined to assess the suggested strategy against UPQC-ANN-EVA.

• It is discovered that the FLC-based method effectively enhances the power quality of the proposed system when comparing the outcomes of UPQC-FLC-EVA with UPQC-ANN-THD EVA's reduction and power quality enhancement experiments.

2.2 MODELLING OF PV SYSTEM

To acquire the greatest performance from a PV module, several scientists have written on the development of modelling PV and MPPT algorithms [40]–[45]. Figure 2 depicts a schematic of a typical PV system. Equation 1 was created by the authors of [46] to describe the I-V properties of a PV module. In [46], Equation 1 is extensively explained. Equation 1 states that IL, the panel output current, and IS, the solar panel current, respectively. Diode Constant (C), Matching Series and Parallel Arm Resistance (Rseries and Rparallel), Thermal Voltage (VT), Reverse Saturation Current (ISAT), and Idiode Current (Idiode).

$$I_L = I_S - I_{sat}[exp(\frac{V_t + R_{series}I_L}{cV_T} - 1] - \frac{V_t + R_{series}I_L}{R_{parallel}}$$

2.3 MODELLING OF WE SYSTEM

To power wind turbines, we use Permanent Magnet Synchronous Generators (PMSG). Considering efficiency, cost, control, and dependability, PMSG outperforms DFIG. For WE systems, mathematical WE and FLC-based MPPT models have been provided.

$$\begin{aligned} R_{st} &= \frac{\omega R_b}{V_w} \\ P_{mout} &= 0.5\rho\pi R_b^2 C_{pc} V_w^3 \\ P_{mout} &= T_{mout}\omega \\ C_{pc} &= (0.44 - 0.0167\theta_p) sin\frac{3.14(N_r - 2)}{13 - 0.3\theta_p} \end{aligned}$$

2.4 MODELLING OF EVA CONTROLLER

It is necessary to satisfy the load demands, and also to maintain the power quality so as to make the grid system reliable and efficient. The ESS system is required to achieve the need for extra power demand and also to store the surplus power. As the solar and wind energy sources are weather, place, and time-dependent, the ESS system is an alternative to these RESs. The ESS system contains battery banks which are subjected to ageing effect, and life degradation issues. Therefore, the ESS system is also less efficient and reliable.

. Specifications and parameters of system components.

Parameter	Value	Unit
Rated Power of WE1	30	kW
Rated Power of WE2	30	kW
Total rated power of WE	60	kW
Base wind speed	12	m/s
Pitch angle	0	degree
Stator resistance (per phase)	0.05	Ω
Inductance (armature)	0.000635	H
Inertia	0.011	J
Pole pairs (PMSG)	4	
Grid transformer rating	100	kVA
Grid line-to-line voltage	254.4	V
Frequency of system	50	Hz
Solar PV rating	100	kW
Battery rated capacity	40	kWh
Capacity of each EV	29	kW
Different Loads	50, 55, 60, 70, 90, 100, 150	kW
Load (voltage sag)	50,30,50 (one-phase loose)	kW
Load (voltage swell)	50, 1	kW
Non-linear load	150, (+20,-10)	kW, (kVAR)
Line resistance	2	Ω
Line inductance	0.002	H

2.5 DEVELOPMENT OF FLC-BASED PV-WE-ESS-EV SYSTEM

The control of power flow to the load from different sources available and also from charging-discharging of ESS and EVs in the system is achieved by the use of FLC. The most important part of FLC is the selection of membership functions, rules, input, and output parameters which are shown in Fig. 14. Five membership functions are taken in this work named as very low, low, medium, high, and very high (full). The input parameters for FLC are SOC of ESS, SOC of the battery bank in EV charging stations, load forecasted data, and power generation data from PV-WE. The outputs of FLC are charging-discharging of ESS, EV charging stations, load power management from RESs, and grid. The developed FLC algorithm for power flow management and chargingdischarging of ESS and EVs is illustrated in Fig. 15. The main objective of the FLC algorithm is to utilize the power generated from the RESs and stored energy of ESS and EVs for achieving the economical operation of the system during peak load demand. This way the power quality is improved and grid load demand is balanced. The system performance is dependent on the load condition and availability of different sources of supply. During peak load demand, if the power generated from RESs is larger than the load demand then ESS is charged if the SOC of ESS is lesser than 98%. If the battery is fully charged and the SOC of EVs are lesser than 98% then, the EVs are charged. In case when both ESS and available EVs are fully charged, the surplus power from RESs is sent to the grid. If the power generated from RESs is lesser than the load demand and SOC of ESS is greater than 35%, the load is supplied power from the RESs and the ESS. If the SOC of ESS is lesser than 35% or if the summation of power from RESs and ESS is lesser than the load then, the EVs are discharged (if SOC of EVs is greater than 35%). If excess EV power is available, ESS is charged when the SOC of ESS is lesser than 35%. In case when both ESS and EVs are discharged, power is supplied from the grid to the load, and the excess loads are removed under worst-case when none of RESs, ESS, and EVs is available. During off-peak load, if the power generated from the RESs is greater than the load power and the SOC of ESS is lesser than 98%, the ESS is charged. When the ESS is fullycharged, the EVs are charged if the SOC of EVs is lesser than 98%. If both ESS and EVs are fully charged, the surplus power from RESs is sent

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to the grid. In case when the power generated from the RESs is lesser than the load demand, the power is supplied from the grid to satisfy the load demand as it will not cost more during off-peak time as compared to the peak time power cost. The ESS and EVs are also charged from the grid power during off-peak load if the SOCs are lesser than 98% because the ESS and EVs should be fullycharged and prepared for the peak load demand of the grid. V. RESULTS AND DISCUSSION The proposed work focuses on the power enhancement and harmonic reduction for the PV-WE-ESS-EV system connected to the grid. The UPQC is able to handle the non-linear and different undesired types of loads. The whole system is refreshed and checked by FLC in every 0.01 second. In this Section, the outcomes of the two techniques are discussed. The first is based on FLC, and the second one is based on the ANN approach. It is observed that FLC is giving better results as compared to ANN to achieve maximum power from the PV-WE system, to get good voltage regulation, and to reduce the THD values of voltages and currents. Also, ANN requisites learning data and time to perform better and accurate. The learning of ANN techniques is time-consuming and also need various historical data to learn from them.

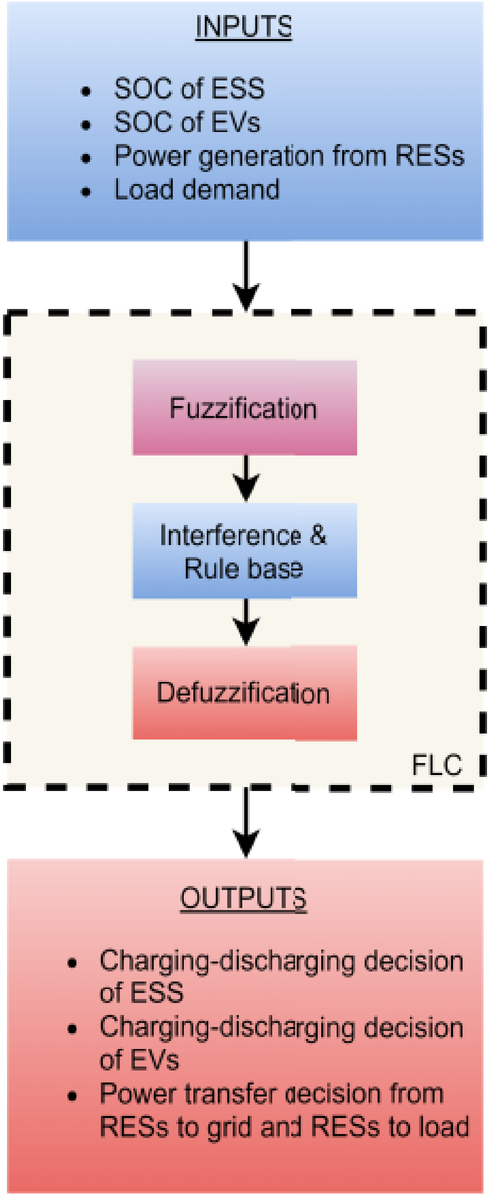
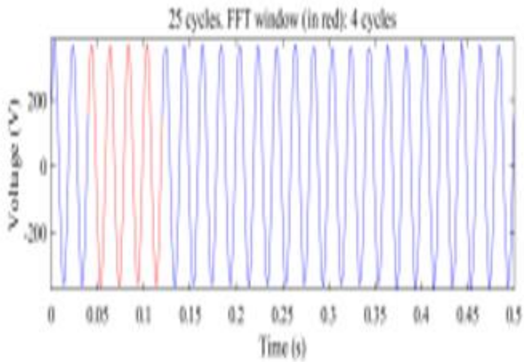


Fig 2. FLC-based control of PV-WE-ESS-EV system.

3. SIMULATION STUDIES



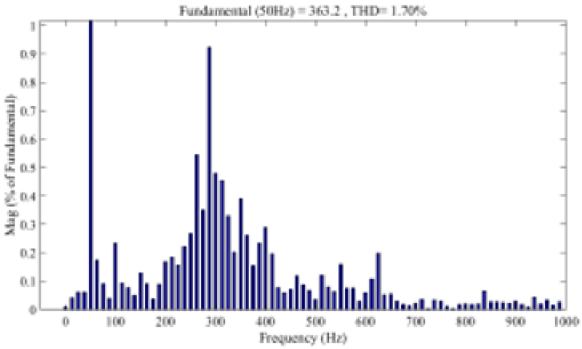


Fig 3. (a) Voltage signal of the source side, and (b) THD of source side voltage of the grid in % of 50 Hz.

The ANN-based controller also gives better performance in power enhancement and THD reduction. The demerits associated with ANN are the need for strong learning from historical data, and time consumption for learning. The technique used for controlling the complicated grid system should be fast and accurate. In this work, a two-layer neural network has been designed to model the controller. The output power of the PV panel at an irradiation value of 1000 W/m 2 is shown in Fig. 26. In this output, it is observed that the MPPT power output is lesser as compared to FLC-based MPPT. The output power of WE using the ANN-based MPPT algorithm is presented in Fig. 27. The load voltage under different loading conditions is shown in Fig. 28a, 28b, 29a, and 29b. The voltage quality is kept almost constant by the UPQC, ESS, and EVA under different loading conditions in the case

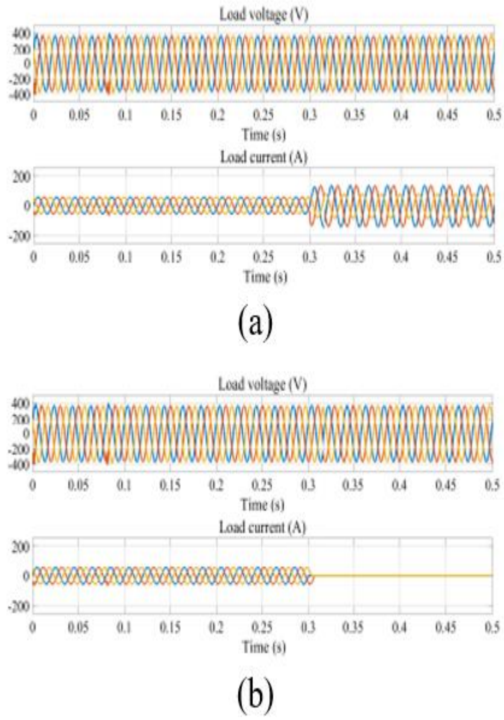


Fig 4. (a) Waveforms of the load-side voltage and current when the voltage sags over the load voltage. When employing UPQC-FLC-EVA, UPQC maintains (a) voltage and current waveforms of load-side undervoltage increase and (b) load-enhanced voltage quality of voltage sag without requiring ESS and EVA. By enhancing voltage increase using ESS and EVA, UPQC preserves voltage quality

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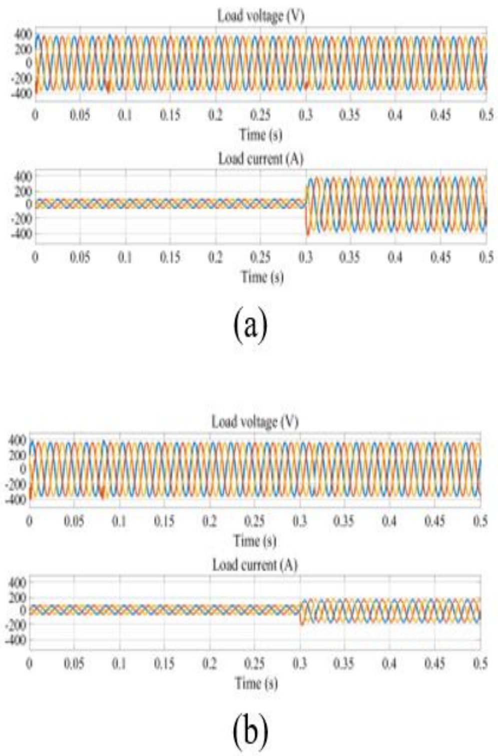

Fig 5. (a)Using UPQC-FLC-EVA, "(a) load side voltage and current waveforms under grid underload and overload circumstances, and (b) load side voltage and current waveforms under linear and non-linear grid load conditions.

4. CONCLUSION

The authors suggested a technique to enhance the performance of the PV-WE-ESS-EV system using FLC and UPQC controllers. FLC-based MPPT algorithms are created to maximise PV and WE performance. Under many forms of stress, UPQC offers support for stress management. The EVA algorithm intends to offer load balancing and assistance for weather-based PV and WE systems by linking the necessary number of electric cars. The projected PV-WE-ESS-EV system would improve system power quality and assure grid dependability as more electric vehicles are linked to the grid. The UPQC-FLC-EVA method is further shown to prevent distortions in voltage and current waveforms. The suggested approach satisfies the IEEE-519 (1992) standard's THD criteria by achieving less than 5% THD of load and source voltages and currents. In conclusion, performance-wise, the UPQC-FLC-EVA approach surpasses the ANN-based control strategy. It is anticipated that future studies would use additional research tools than this.

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