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Ant-Lion Optimization Algorithm Based Optimal Performance of Micro Grids

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ABSTRACT

In the operational state of an electrical power system, ensuring efficient utilization and high-quality power usage is essential. Various quality enhancement measures, such as linear and adaptive filters, are implemented to improve the current's quality. Additionally, power flow controllers are employed to mitigate losses and enhance fault tolerance. However, the escalating demand for power supply, driven by rapid industrial and urban growth, often exceeds the capacity of existing generation systems. To address this challenge, supplementary subunits are integrated into the power system. This proposal's main objective is to introduce a weight-defined parameter monitoring system for power scheduling within a multi-parameter monitoring framework. The aim is to enhance the conventional preference-based scheduler by incorporating intelligent control techniques, including Unified Power Quality Conditioner (UPQC) with the ANT-LION Optimization (ALO) algorithm, which will be compared to a Fuzzy Logic controller. UPQC plays a pivotal role in addressing power quality issues within the system, combining a shunt active power filter with an Artificial Neural Network (ANN) controlled by the ALO algorithm. Our research demonstrates the effectiveness of this proposed system, particularly in microgrid applications, with validation conducted using MATLAB/Simulink.

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1. INTRODUCTION

The electrical power system currently lacks dispensing devices, nonlinear loads, or utilities used for compensation. This setup directs the power system towards an unstable energy source [1]. To address this issue, complex energy systems called "smart grids" (SGs) have been introduced. Smart grids utilize two-way communication between distributed generation (DG), control systems, and loads to enhance voltage stability, optimize the use of renewable energy sources (RES), self-repair systems in case of problems, and enable customers to manage their electricity consumption and reduce maintenance costs [2]. Despite the complexity of most attacks, the Energy station stands out as a unique target within the smart grid [3].

Series and shunt compensators are combined in UPQC. Upgraded maximum frequencies, dynamic reactive and active energy control, voltage sag, voltage disbalance, voltage flicker, and voltage are all outcomes of its use [4]. Including off-grid, the total global RE integration in 2018 was 2364.4 GW, according to a report from the statistics department of the International Renewable Energy Agency (IRENA) that was released in March 2019. Among different kinds of Renewable Energy (RE) sources [5]. Even from the end-perspective, the user's Photovoltaic (PV) technology has become the most enticing. Due to its dependability and simplicity, applications. However, scheme intricacies like load variations and parameter modifications may prevent

Proportional and Integral (PI)/ Proportional Integral Derivative (PID) control from functioning normally even when it is perfectly aligned [6]. As an outcome of the power system's unsteady or disruption of synchronization, Due to a lack of dissipative torque, these vibrations become more intense [7].

The major of the scheduling approach is defined as a time-based operational, or demand based. In these systems, the power scheduling is operated based on the measurement of demanded power and the available generation. Where advanced algorithms were deployed for proper decision-making, all the existing approaches were based on discrete parameter monitoring. Here, the characteristic of the demand variation is not been considered. Longer periodic observation of the demand may lead to the more accurate switching performance of the generation units.

The foremost contribution of the proposed methodology

- This proposal's major objective is to establish a weight-defined parameter monitoring system for power scheduling in a multi-parameter monitoring system [8].
- UPQC with ANT-LION optimization (ALO) algorithm is proposed and compared with fuzzy Logic Controller FLC to develop a weight-specified parameter tracking of power planning in multi-parametric monitoring, where the past method of priority scheduler is to be established [9].
- UPQC performance can be improved by easing concerns about current and voltage Power Quality (PQ) by using a ANN with an ALO-based controller [10].

Few relevant works on intelligent controllers for smart grid performance are examined.

Rahbari, O, et.al., [11] examines the integration of renewable energy sources (RES) and electric vehicles (EVs) into the electric grid through an adaptive intelligent controller. Addressing challenges like intermittent generation and variable energy usage, the study proposes innovative solutions including optimal parking lot placement and a sophisticated control unit for efficient grid operation and EV management. By utilizing advanced optimization techniques and considering technical aspects such as minimizing total active power loss and voltage deviation, the proposed approach aims to seamlessly integrate RES and EVs into the grid infrastructure while ensuring stability and maximizing the utilization of renewable energy resources, thus advancing the transition towards a sustainable and efficient energy ecosystem.

Irfan, M. et.al., [12] increasing demand for power globally, along with the integration of Distributed Renewable Energy Sources (DRES), requires a significant overhaul of electricity infrastructure. Traditional grids struggle with the load, necessitating a shift to smart autonomous systems. This paper reviews smart grid control advancements, focusing on robust strategies for managing overloads and optimizing power distribution. It also covers power generation, storage, and scheduling techniques, alongside recent developments in Information and Communication Technologies (ICT). Countries like Pakistan, abundant in renewable energy resources like solar, wind, hydro, and biomass, stand to benefit from smart grid technologies to address energy shortages sustainably.

Bayindir, R. et.al.,[13] By exploring data transmission methods and energy efficiency in smart grids, this study aims to provide valuable guidance for stakeholders in the field. It offers insights that can assist researchers and engineers in understanding the complexities of smart grid implementation, while also aiding transmission and distribution system operators in making informed decisions during their transition. Ultimately, the findings of this study are anticipated to contribute to the advancement of smart grid technology, fostering a more efficient and sustainable energy infrastructure worldwide.

Derakhshan, G. et.al.,[14] highlights the effectiveness of advanced optimization techniques like TLBO and SFL algorithms in efficiently scheduling electricity consumption to minimize costs and enhance grid stability. As renewable energy adoption grows, demand response becomes crucial in balancing supply and demand dynamics. By leveraging these methods, utilities can better manage peak periods and integrate renewable resources, shaping the future of smart grids towards sustainability.

He, Y., et.al. [15] use of computing and communication intelligence enhances smart grid monitoring and control but increases vulnerability to false data injection (FDI) attacks, compromising data integrity. This paper employs deep learning to recognize FDI attack patterns using historical data and detects them in real-time, achieving high accuracy without relying on specific attack scenarios. Additionally, we propose an optimization model to address FDI attacks targeting limited power system measurements for electricity theft, demonstrating the effectiveness and scalability of our approach through simulations on IEEE test systems.

Keshtkar, A. et.al, [16] This paper introduces a fuzzy logic approach (FLA) using wireless sensors and smart grid incentives to reduce residential HVAC system loads. Programmable communicating thermostats (PCTs) control HVAC systems while FLA enhances them with intelligence for load reduction without sacrificing comfort. Simulated PCTs evaluate FLA performance, showing energy and cost savings compared to standard PCTs.

Kanellos, F.D. et.al. [17] Research on All Electric Ships (AES) and onboard DC grids has gained momentum due to their promising prospects. This study aims to systematically outline how onboard DC distribution systems, smart grids, and the AES concept can significantly enhance ship efficiency. It discusses emerging technical challenges, future prospects, and summarizes the state-of-the-art, while proposing a comprehensive research roadmap for further exploration in this field.

Howell, S. et.al., [18] The paper reviews the transition from centralized to distributed energy systems, discussing concepts like 'smart grid' and 'microgrid'. It highlights the need for a new generation of holonic energy systems to manage the interplay between distributed energy resources and prosumers. Emphasizing sustainability and resilience, future research focuses on interoperability and secure control.

Chin, W.L. et.al., [19] This study emphasizes the importance of carefully managing energy big data and providing early security warnings to mitigate potential threats in IoT-based smart grids. By demonstrating the feasibility of stealthy energy big data attacks using replay schemes, we underscore the urgency of implementing robust security measures. Additionally, our work elucidates intuitive geometric viewpoints for understanding these attacks, facilitating improved defense strategies against malicious activities. Overall, this research contributes to advancing the resilience and security of smart grid systems in the face of evolving cybersecurity threats.

Utkarsh, K. et.al.,[20] In real-time large-scale optimization, like in smart grids, centralized algorithms struggle with fast-changing conditions and handling numerous variables. Consensus-based distributed strategies have been proposed, but distributed computational intelligence (CI) techniques offer faster, near-optimal solutions. This paper introduces a consensus-based dimension-distributed CI technique for optimal control in smart distribution grids with many DGs and CLs. Each DG or CL is treated separately within the framework, improving alignment with smart grid optimization needs. Simulations on 30-node and 119-node distribution test systems show the effectiveness of the proposed approach compared to centralized and benchmark algorithms.

All the aforementioned methods struggle to use intelligent controllers for optimal performance of Microgrids. Additionally, the specifics of this work are explored in more sections; section 2 covers the findings, and the section below provides an examination of relevant existing work that uses the proposed model. The recommended technique for the work is presented in section 3, and the experimentation and analysis of the work follow. The work's control strategy is covered in section 4. Section 5 displays the findings and conclusions. Section 6 of this document covers the conclusion and further work.

2. RESEARCH METHOD

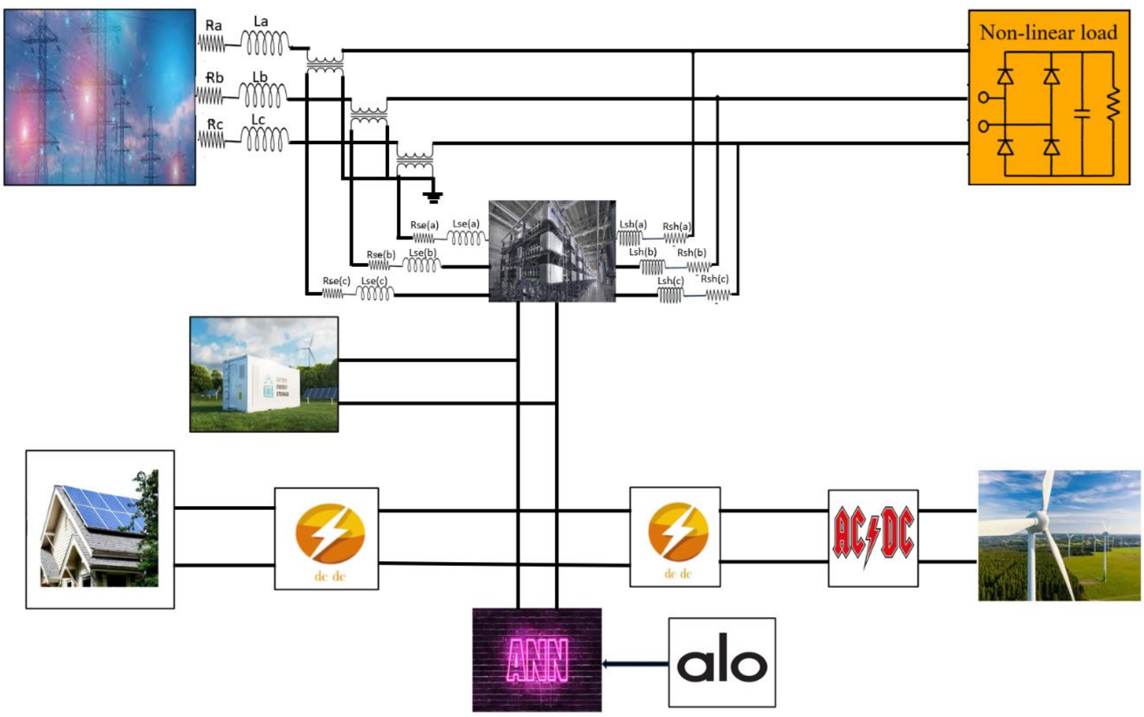


Figure 1. UPQC structure with microgrid connectivity and RES

The system's load demand increases as a result of the increased utility use brought on by urbanization and industrialization. Regarding protection and energy reliability and performance troubles, integrated approach sources are unable to satisfy the required energy needs in today's modern power grid. To resolve these issues, dispersed energy resources and RES have been utilized. The most cutting-edge technology currently in use, the RES system, can boost system steadiness and effectiveness. The RES can be connected to the distribution system to meet end-user load requirements, but this poses a danger to the stabilization and versatility of the power quality [21]. Among the most practical remedies for PQ problems like voltage sag, sale, and fluctuation is the Flexible AC transmission (FACT) system. Therefore, UPQC is employed in the RES in this paper to address these power quality issues. A PV system that is linked to the smart grid makes up the suggested RES. The RES is linked to a smart grid, which results in issues with power quality due to nonlinear loads, critical loads, and unexpected loads [22]. This results in a problem with reactive power mismatch and more voltage instability. The UPQC may be the best tool for dealing with power quality issues and enhancing voltage regulation in RES linked to the smart grid. The design of ALO algorithm enhances the effective control of UPQC.

2.1. Method for storing energy in batteries

Systems that store energy in batteries are utilised to meet load demands when RES power supply is insufficient. The comparison autonomy day (ad^*). using equation to calculate the battery energy storage system capacity depending on the system's required power consumption (1) [23].

$$\text{Battery } y^{b} = \frac{ad^* \times P^*{}_j}{\varepsilon^*{}_j \times \varepsilon^*{}_B \times DOD^*} \tag{1}$$

ad^* = Autonomy day,
$\varepsilon^*{}_B$= Battery efficiency,
$\varepsilon^*{}_j$= Efficiency of an inverter,
$P^*{}_j$ = Demand power,
DOD^* = depth of discharge rate of the battery.

The battery's capacity to generate enough energy to meet the requirement on all days is known as autonomy day. Equation shows the battery's output power (2).

$$b^*{}_P = p^*{}_{PV}(t) + p^*{}_{WT}(t) - \frac{\boldsymbol{P^*{}_I(t)}}{\varepsilon^*{}_i} \tag{2}$$

$P^*{}_I(t)$ = Demand for system load,
$b^*{}_P$ = Battery power.

An important battery feature known as the State of Charge (SOC) is linked to RES's inability to produce enough energy and excessive power production. The SOC formula is shown in equation (3).

$$soc^*(t) = \begin{Bmatrix} soc^*(t-1)(1-\vartheta^*) + \left(p^*{}_{PV}(t) + p^*{}_{WT}(t) - \frac{P^*{}_I(t)}{\varepsilon'{}_I}\right) \times \varepsilon^*{}_{B*} & p^*{}_{PV}(t) + p^*{}_{WT}(t) > P^*{}_I(t) \\ soc^*(t-1)(1-\vartheta^*) + \left(\frac{P^*{}_I(t)}{\varepsilon^*{}_I} - p^*{}_{PV}(t) + p^*{}_{WT}(t)\right) \times \varepsilon^*{}_{B*} & p^*{}_{PV}(t) + p^*{}_{WT}(t) < P^*{}_I(t) \end{Bmatrix} \tag{3}$$

ϑ^* = Self-discharge rate of a battery.

2.2. PV cell analogous circuit

The quantity of solar panels interconnected in a Photovoltaic system in series and parallel determines the voltage, current, open-circuit voltage & short-circuit current [24]. The analogous circuit for a photovoltaic cell is shown in Figure 2. The crucial elements consist of a parallel diode, series resistors, and a current source. The anticipated power is provided by the PV cells that are contemporaneously put together to create PV modules using a mixture of series and parallel. The symbol for the quantity of PV cells in series is U' a, whereas the sign for the quantity of PV cells in parallel is U' p. It is possible to depict the correlation between the output current and voltage as

$$I^*{}_{PV} = N^*{}_P I^*{}_G - N^*{}_P I^*{}_S \left(exp\left[\frac{q^*}{AKT_C} \left(\frac{v^*{}_{PV}}{N^*{}_S} + \frac{R_S I^*{}_{PV}}{N^*{}_P} \right) \right] - 1 \right) \tag{4}$$

Photocurrent $I^*{}_G$ is created by solar irradiation, as demonstrated below:

$$I^*{}_G = \left(I^*{}_{SC} + k_I (T_C - T_{ref}) \right) \frac{s}{1000} \tag{5}$$

According to the correlation shown below, $I^*\ s$ is the saturation current of a PV cell that changes with temperature [25]:

$$I^*{}_S = I^*{}_{rs} \left[\frac{T_C}{T_{ref}} \right]^3 exp\left[\frac{q^* E_g}{AK} \left(\frac{1}{T_{ref}} - \frac{1}{T_C} \right) \right] \tag{6}$$

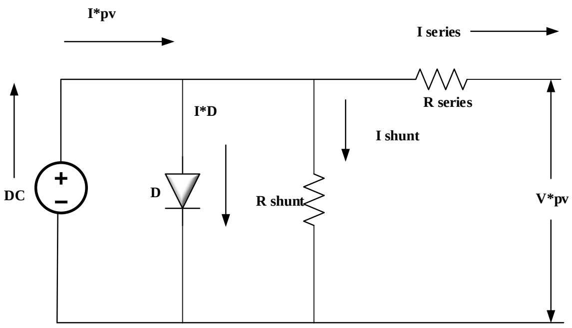


Figure 2. PV cell analogous circuit

2.3. DC-DC converter analogous circuit

Figure 3 shows a circuit equivalent to a DC-DC boost converter. Switch 1 is initially closed, while switch 2 is initially in the open position. Inductor L's (IL) current is now starting to rise from zero. The inductor current flows to the load at this point while the capacitor stores the charges, & switch-two is closed and switch-one is opened. When the output voltage V* O is stable, the ON-OFF states of switches 1 and 2 fairly represent the contingent excessive value of the output voltage.

The above equations display the voltage correlations between the input and output of a DC-DC converter with a duty cycle[26].

$$\frac{V^*{}_O}{V^*{}_{IN}} = \frac{1}{1-d^*{}_{DUTY}} \tag{7}$$

$$\frac{V^*{}_O}{V^*{}_{IN}} = \frac{T^*{}_{RISE}}{T^*{}_{FALL}} + 1 \tag{8}$$

$$d^*{}_{DUTY} = \frac{T^*{}_{RISE}}{T^*{}_{RISE}+T^*{}_{FALL}} \tag{9}$$

$d^*{}_{DUTY}$ = duty cycle,
$T^*{}_{RISE}$= Switch 1 is currently closed during the time for raising the inductor current.
$T^*{}_{FALL}$= Switch 1 is open at the moment when the inductor current is decreasing.

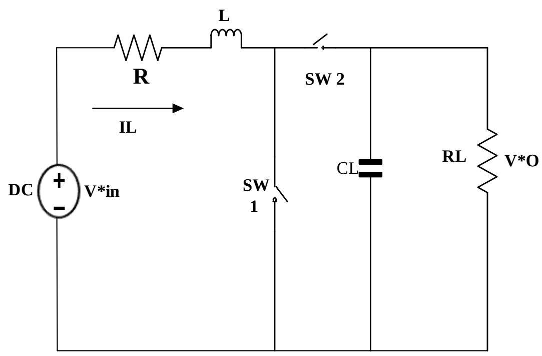


Figure 3. DC-DC converter analogous circuit

2.4. Load (smart grid, AC load):

` The three-phase electric power system is the industry standard for generating, distributing, and transmitting alternating current (AC). It is a type of polyphase system, and in most cases, the most widely used way to transfer power in the world's electrical grids. It is also possible to use to power large motors and other heavy loads. On the same power line to ground voltage, a two-wire single-phase equivalent circuit performs better than a three-wire three-phase circuit. The energy is saved in the smart grid for later usage after the power quality has been increased and the loss has been made up. Power for three-phase loads and the smart grid are both delivered by the transmission line [27]. Consequently, by using the suggested methodology, we were able to accomplish effective power compensation.

2.5. CONTROL STRATEGY:

2.5.1 UPQC:

The UPQC is the FACTS device with the greatest adaptability and versatility. Three compensator characteristics—namely, impedance, voltage magnitude, & phase angle—are combined to create a more thorough compensate.

2.5.2 Construction of UPQC:

Two series and shunt voltage source converters are joined by a common dc connector to form the UPQC [28]. Reactive power is supplied to an ac system using shunt converters, commonly known as static synchronised compensators (STATCOM), in addition to the dc power required by both inverters, whereas series converters, they are also referred to as Dynamic Voltage Restorer (DVR), and they are employed to add controlled voltage magnitude and phase angle in series with the line DVR. Transformers and electronic power converters are both present in each branch. These voltage source converters made the decision to share a DC capacitor.

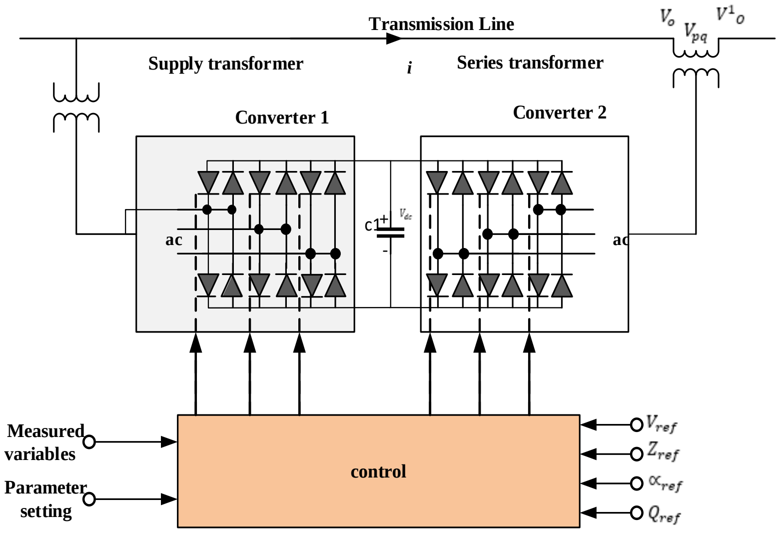


Figure 4. Diagrammatic representation of the three-phase UPQC linked to the transmission line.

The normal power storage capacity of this dc link capacitor is modest. The active power generated by the series converter & shunt converter should be the same as a consequence. The power flow regulation is more flexible since the reactive power of the shunt or series converter may be selected separately. The gadget is connected to the system via the pairing transformer.

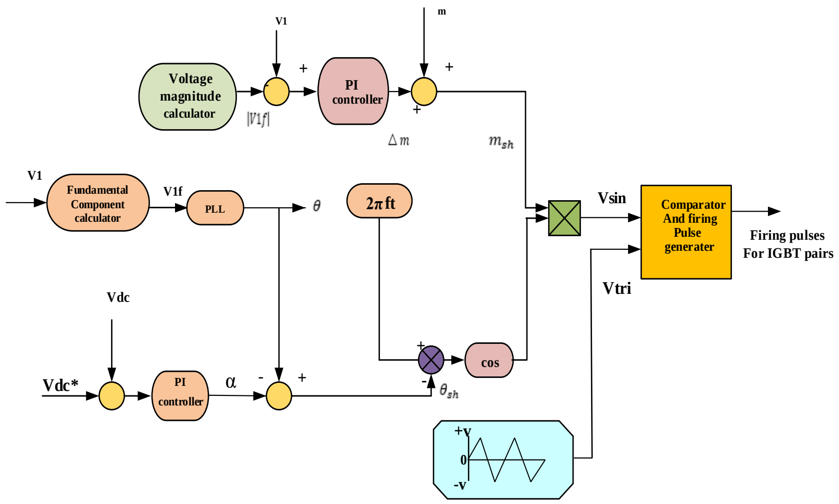


Figure 5. Diagram of the shunt inverter controller in block form

The transmission line was linked to the UPQC is shown schematically in Figure 4 Figure 6 depicts a block design for a series inverter controller, whereas Figure 5 depicts a schematic representation for a shunt inverter controller. By combining a series voltage with a particular amplitude and then a phase shift, the power flow direction may be adjusted.

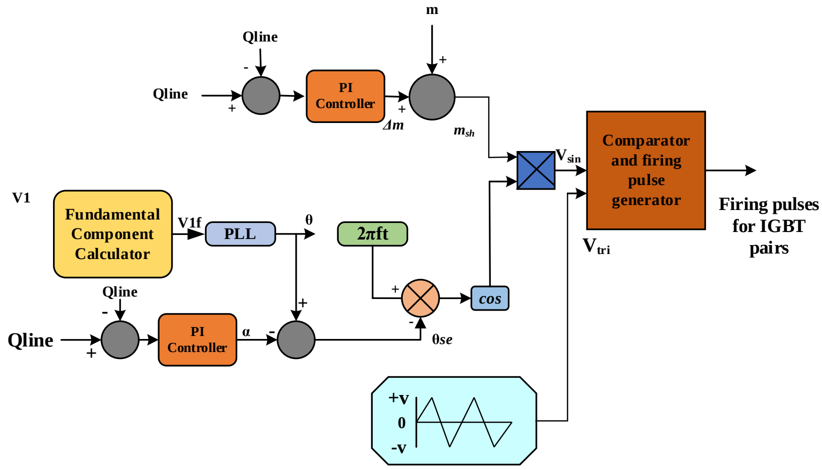
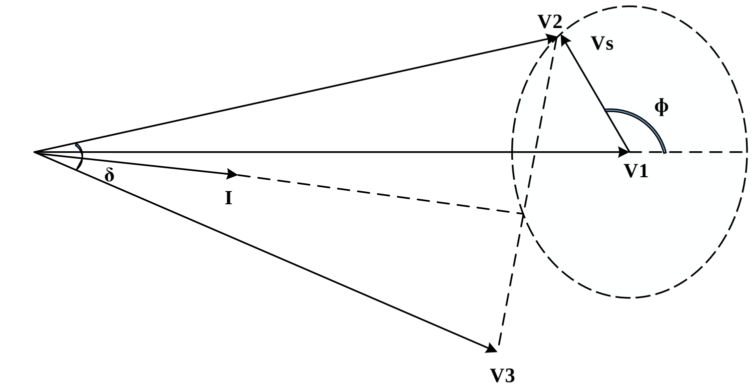


Figure 6. Block diagram of the series inverter controller



$$P = \frac{V_2 \times V_3 \times \sin\delta}{x}$$

$$Q = \frac{V_2 \times (V_2 - V_3 \cos\delta)}{x}$$

Figure 7. Single-line UPQC with voltage- & current-phasor diagrams

A single line chart of a UPQC with voltage and current phasors to V_1 is shown in Figure 7. As a result, a second line voltage, V_2, is produced. Its magnitude and phase shift are different from the first line voltage. Voltage and current both change phase as the angle between V_2 and V_3 changes. Both reactive and active power can be distributed by UPQC thanks to the two converters. The following equation can be used to determine active and reactive power:

$$P_{12} = \frac{v_1 v_2 \sin\delta}{x_{12}} \tag{10}$$

$$Q_{12} = \frac{v_1 v_2 (\cos\delta + 1)}{x_{12}} \tag{11}$$

2.6 ANT-LION OPTIMISATION ALGORITHM (ALO)

A new smart optimization technique called Ant Lion Optimizer was proposed in 2015 by an expert by the name of Mirjalili [29]. It performs better in terms of exploration and growth than conventional algorithms. It considerably reduces the likelihood of becoming stuck in local optimization. The ALO algorithm's precise optimization phases are as follows:

Step 1. **An ant walks at random**:

The description of how randomly the ants move in exploration space is as follows:

$$y(u) = [0, cumsum(2s(u_1) - 1), \ldots, cumsum(2s(u_U) - 1)] \tag{13}$$

U - iteration count,

consume - sum of all step lengths,

u - step of the random walk, and the random function s(u) is defined as:

$$s(u) = \begin{cases} 0, & random \leq 0.5 \\ 1, & random > 0.5 \end{cases} \quad (14)$$

In this case, the random value between 0 and 1 is represented. Locations and fitness of Ant and Antlion are saved in the related matrix in this iteration. The random walks are secured and normalized during the exploration phase as follows:

$$y_j^u = \frac{(y_j^u - p_j)\times(O_j^u - r_j^u)}{(Q_j - p_j)} + r_j^u \quad (15)$$

Here,

p_j and q_j -low and high points of the random walk of the j^th variable, respectively, r_j^u and o_j^u - minimum bound & maximum+ bound points of the random walk of the j^th variable in the u^th repetition.

Step 2. Trap construction by Antlions:

The ALO algorithm selects an antlion based on fitness to build a trap. The roulette rigorous evaluation of genetic variation by giving ant lions so many possibilities to hunt ants.

Step 3. Getting caught in a trap:

Here are how the traps affected the ant's random walk:

$$r_j^u = antlion_j^u + r^u \quad (16)$$

$$O_j^u = antlion_j^u + O^u \quad (17)$$

Here, Antlion u_j is the j^th antlion location at u^th iteration, r^u and o^u are the Minimum and Maximum bounds among all elements in the u^th cycle, correspondingly.

Step 4. Ants slide to the antlion:

The perimeter of a trap shrinks dramatically when an ant is caught inside, making escape impossible. This process is illustrated as:

$$r^u = \frac{r^u}{J} \quad (18)$$

$$O^u = \frac{O^u}{J} \quad (19)$$

$$J = 10^v \frac{u}{U} \quad (20)$$

$$v = \begin{cases} 2, & u > 0.10U \\ 3, & u > 0.50U \\ 4, & u > 0.75U \\ 5, & u > 0.90U \\ 6, & u > 0.95U \end{cases} \quad (21)$$

In this case, u stands for the current iterations, U for the maximum iterations, and v for the iteration's constant.

Step 5. Elitism scheme:

Elitism is a key feature of evolutionary algorithms, enabling them to preserve the best solution(s) achieved during optimization. In this study, the top antlion found in each iteration is saved and designated as an elite. As the elite represents the fittest antlion, it influences the movements of all ants during iterations. Consequently, each ant randomly navigates around a chosen antlion using the roulette wheel selection method, while also considering the elite simultaneously.

$$ant_j^u = \frac{s_P^u + s_g^u}{2} \quad (22)$$

Here, the location of al$_j$ in the t^th iteration of the i^th ant, $\boldsymbol{s_P^u}$ and $\boldsymbol{s_g^u}$ portray the location of the antlion determined at random by the roulette wheel, in addition to elite antlion in the t^th iterative process, respectively.

Step 6. Reconstructing traps for catching ants:

After the antlion has captured it, the ant's new location will be evaluated once more. These ants provide better fitness over the equivalent antlion, here the prey is caught by the antlion and reconstructed the trap again. In new traps, the possibility of catching the ants is much better. This process is expressed as follows:

$$aL_k^u = at_j^u \ if \ h(at_j^u) > h(al_k^u) \quad (23)$$

3.0. RESULTS AND DISCUSSION

The effectiveness of the suggested methodology is examined and verified in this section. To address PQ issues, RES, which is connected to the grid, is being developed. The controller improves system stability and suggests ways to reduce PQ problems. The technique is applied to utilize MATLAB/Simulink 2022-Ra. In Table 1, the implementation parameters are listed. System PQ issues, such as voltage, sag, and harmonic distortion, are presented and analyzed. The main sources for supplying the required amount of power are thought to be the PV and battery.

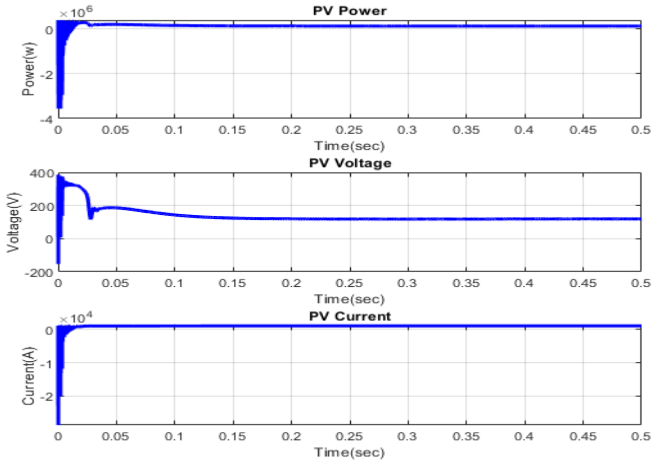


Figure 8. Outcomes of PV panel

Table 1. The PV Implementation Parameters

Description	Parameters	Values
	Maximum Irradiance Level	1000 w/m^2
	Standard Operating Temperature	25^o C
PV panel	Voltage or current at max power	39.80V/5.40A
	Total series cells	03
	Total parallel cells	190

As a result, In Figure 8, a PV panel's voltage, current, and power are shown. PV power is shown in this image at 124 KW, PV voltage is shown at 120V, and PV current is shown at 1035A. Figure 9 showed the battery's results, with the discharging voltage of the battery reaching 162V in 0.05 seconds, the current of the battery reaching 232A, and the SOC of the battery decreasing from 100 to 99.83. In this study, lithium-ion batteries of the nominal voltage and rated capacity are used, and they are detailed in a table 2.

The large battery system can absorb surplus energy from variable renewable sources like PV during periods of oversupply and release it during times of high demand or low renewable generation, facilitating higher renewable energy penetration levels without compromising grid stability. Enhance grid resilience and flexibility, and accelerate the transition towards a sustainable, low-carbon energy future.

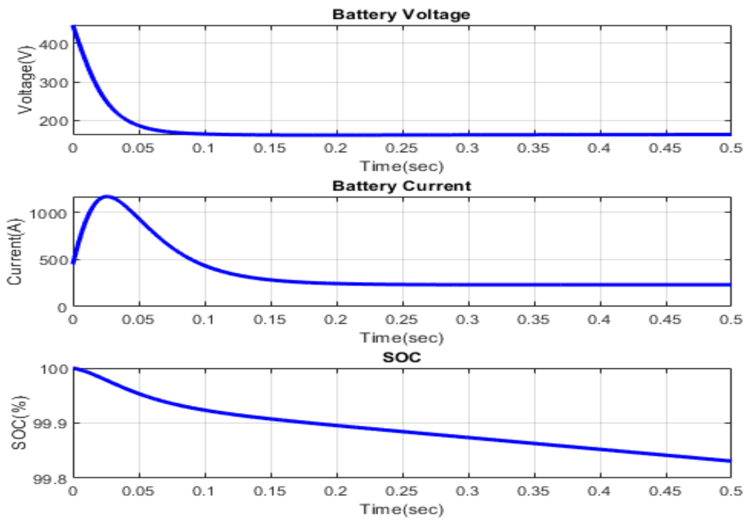


Figure 9. Outcomes of Battery

Table 2. Details of Li-ion battery

Li-ion battery	Rated capacity	350Ah
	Open circuit voltage	48.3V
	Max capacity	450Ah
	Full charge voltage	162 V
	Short circuit current	5.8A
	Nominal voltage	150 V

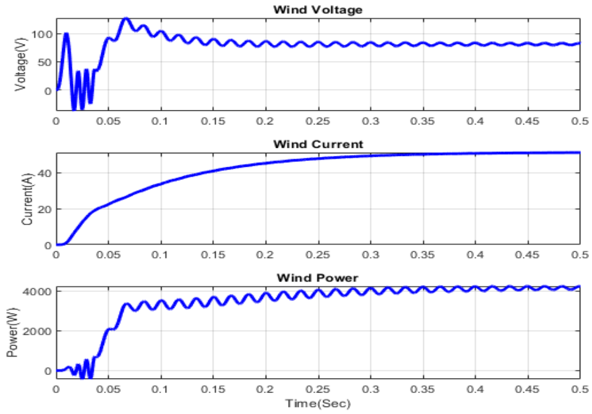


Figure 10. Outcomes of WT

Table 3. The WT Implementation Parameters

Wind	Rated power	4.3 kW
	Frequency	50Hz
	Voltage	85 V
	Cut in Speed	3 m/s
	Speed	12 m/s
	Cut Out Speed	20 m/s
	Pitch Angle	1°
	Air Density	1.225 kg/m^3
	Torque	2.8Nm
	Rated Speed	2500RPM

Figure 10 showed the results of the Wind Turbine (WT); the WT voltage is set at 85V, the battery current is attained at 51A, and the battery power is then reached at 4335W and Table 3 shows the WT Implementation Parameters

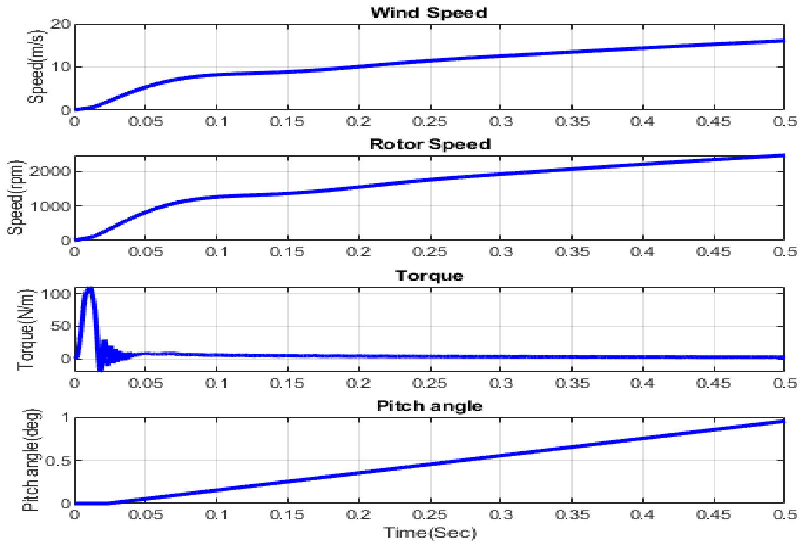


Figure 11. Outcomes of WT parameters

Figure 11 showed the results of the WT parameters when the wind speed was 12 m/s. Pitch angle is 1 degree, torque is 2.8 Nm, and the rotor speed is set at 2500 rpm. The DC link voltage, which is achieved at 163V, was shown in Figure 12.

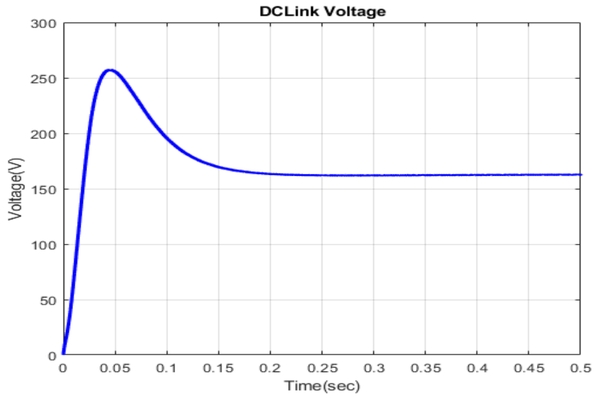


Figure 12. Voltage of DC Link

Figures 13 and 14 show the real and reactive power of the load as well as the real and reactive power of the transmission line's source.

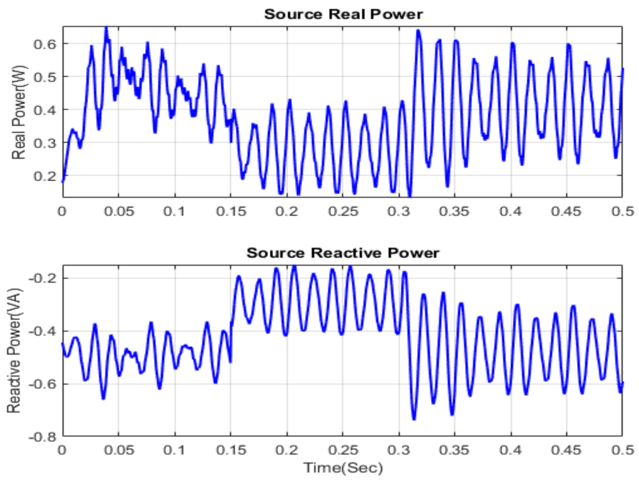


Figure 13. Real power and Reactive power of source wave form

In this image, the source's actual power is depicted from 0 to 0.5 seconds, during which 0.15 to 0.3 seconds the sag signal appears. In 0.15 to 0.3 seconds, the swell issue caused by reactive power appears. Figure 15 shows the load's real and reactive power. For a specific time, range of 0.15 to 0.3 seconds, both real and reactive power are shown as swell concerns.

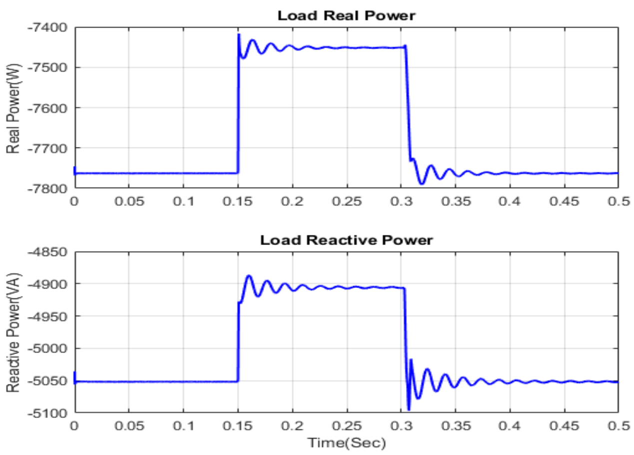


Figure 14. Real and Reactive power of load

Case 1: Mitigation of Sag signal

The voltage sag to be corrected in order to ensure linear and consistent system operation. By providing the necessary voltage with the help of UPQC, to meet the needs of the load, the voltage is rectified. The voltage from source, injection voltage, and load voltage are all shown in a sag analysis in Figure 15. Immediately following the source voltage, the signals from the injected voltage and the fixed voltage sag are analysed.

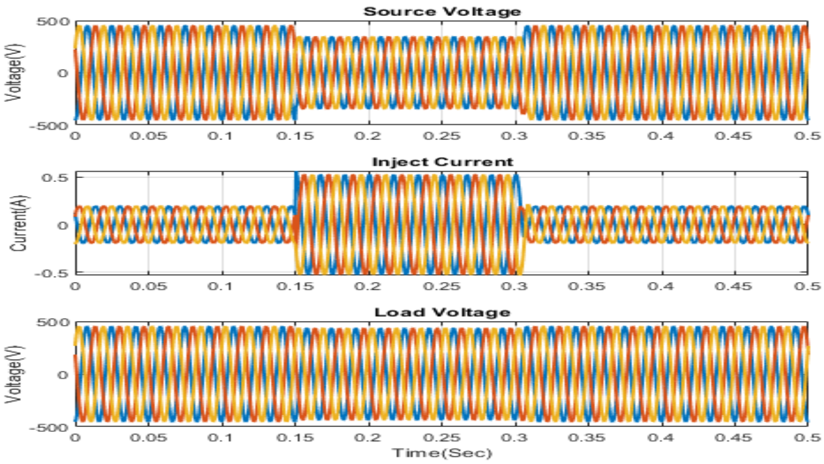


Figure 15. Compensation of Sag Voltage

Adaptive Neuro Fuzzy Inference System (ANFIS) is contrasted with the modified sag signal produced by the proposed method. Signals that are already in use include Adaptive FLC. The suggested method corrects the sag signal in a time window of 0.15 to 0.3 seconds. Regarding sag correction, the suggested method performs better than convolutional alternatives.

Case 2: Mitigation of Swell signal

The performance of the suggested method is estimated using the swell condition. By combining the flaw with the source, the swell condition is introduced into the system. Examining the swell state, varying the sources, and rating the performances. Additionally, the injected voltage for the swell signal is compensated using the ANFIS built on the UPQC, and the compensated load voltage is ultimately reached at 440 V. The swell signal is decreased in the suggested method over a time interval of 0.15 to 0.3 sec.

In comparison to other techniques, the effectiveness of voltage swell alleviation as can be observed from this graph, the proposed method is better than ANFIS, Adaptive FLC. In comparison to ANFIS, Adaptive FLC the swell signal is greatly diminished.

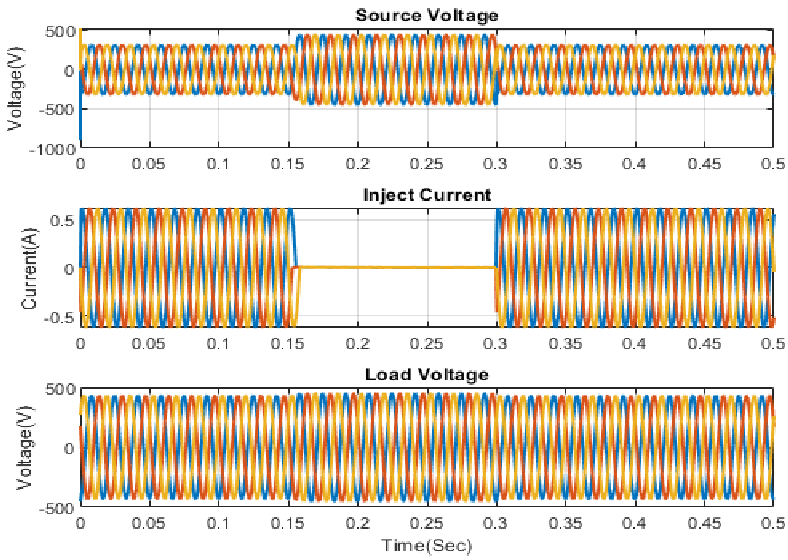


Figure 16. Compensation of Swell Voltage

Case 3: Compensation of Voltage Fluctuations

The system's performance is assessed under fluctuating circumstances caused by a source problem. As demonstrated in Figure 17, the source voltage, injection voltage, and load voltage all affect voltage fluctuations. In order to make up for the voltage drop, the UPQC injects voltage into the load side. The load voltage, on the other hand, stabilises. The proposed approach takes into account the signal fluctuation between 0.15 and 0.3 seconds.

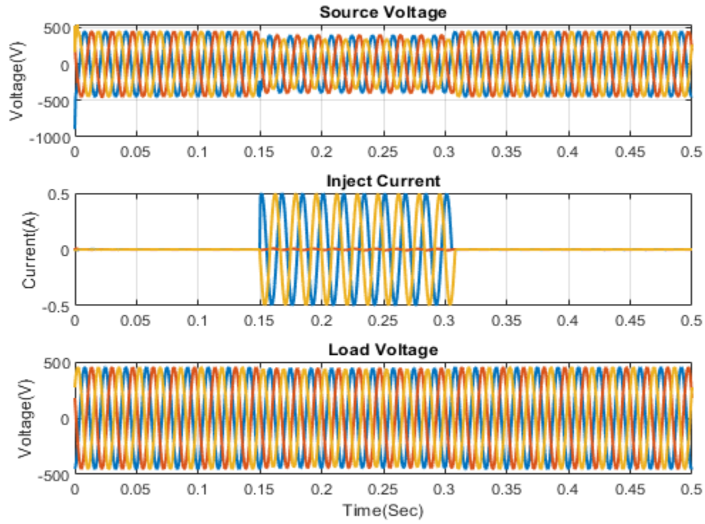


Figure 17. Compensation of the Fluctuation signal

Convolutional approaches are compared to voltage fluctuation reduction. When compared to other existing methodologies such as ANFIS, Adaptive FLC, the fluctuation signal adjustment is successful.

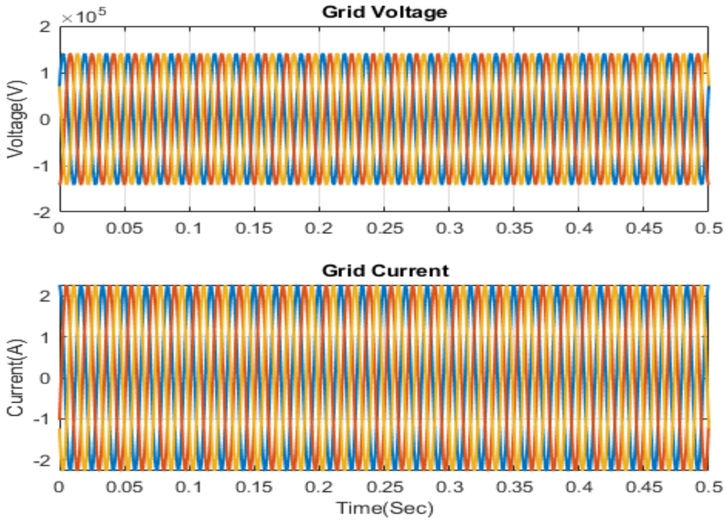


Figure 18. Outcomes of Grid

Figure 18 shows the results of the grid system; the waveforms of the voltage and current are collected from the grid system.

3.1 Table 4: Total Harmonic Estimation

Methods	Mag (% of fundamental)
Proposed	0.13%
Adaptive FLC [30]	1.72%
ANFIS [31]	21.77%

In the proposed method, it accounts for only 0.13% of the fundamental frequency. On the other hand, the Adaptive FLC (Fuzzy Logic Controller) method contributes to 1.72% [30] of the fundamental frequency. In contrast, the ANFIS (Adaptive Neuro-Fuzzy Inference System) method has a significantly higher magnitude percentage of 21.77% [31] compared to the fundamental frequency. These percentages provide insights into the relative impact or influence of each method on the overall system or phenomenon being studied. The suggested technique's Total harmonic distortion (THD) is depicted in table 4. The proposed UPQC with ANT-LION optimization algorithm technique is unquestionably better than the methods currently in use.

4 CONCLUSION

This paper described the improvement of PQ carried out by the proper design of control techniques in a grid-connected RES with the load. The RES's irregularity causes PQ problems, which the ANT-LION optimization algorithm methodology attempts to address. The simulation results are used to analyse the various PQ troubles, such as voltage sag and harmonics, to show how superior the proposed work is. The proposed work's mitigation level is greater than that of the current algorithms. The percentage of THD, which is 2.07%, is also examined and contrasted with the THDs of traditional algorithms. In comparison to traditional algorithms, the suggested technique's UPQC with ANT-LION optimization algorithm is more effective.

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