Power Quality Enhancement in PV Fed UPQC using Adaptive Lizard Algorithm

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Abstract- Nowadays distributed generation (DG) is gaining more importance to fulfill the required demand for electrical power by overcoming the effects on the environment with the utilization of fossil fuels. Power quality (PQ) is the major issue affecting consumers and utilities. PQ issues mainly occur with renewable energy sources (RES) when integrated into the grid with the help of power electronic devices. A unified power quality conditioner (UPQC) is widely used to mitigate the PQ issues caused due to abnormal voltage, current, or frequency. In this paper, PV-fed UPQC with an Adaptive Lizard Algorithm (ALA) is introduced. ALA-based PI controller is designed to maintain constant DC link voltage of the UPQC for the elimination of harmonics. The proposed system is designed using MATLAB/Simulink tool and performances were studied. Various cases such as sag, swell, and total harmonic distortion (THD) were analyzed. The results of the proposed system show the best performance when compared with the various other traditional methods such as Fuzzy logic controller (FLC), Adaptive fuzzy logic controller (AdFLC), Sliding mode controller (SMC), and Synergetic controller (SC). The obtained results of the PV-fed UPQC mitigate voltage sag, swell effectively, and compensate the harmonics adhering to IEEE-519 standards.

Keywords Photovoltaic, unified power quality conditioner, adaptive lizard algorithm, harmonic compensation

1. Introduction

In today's world providing reliable power is challenging due to nonlinear loads, unbalanced loads, asymmetrical operations, and oscillations. The main reason for the PQ issues is the utilization of nonlinear loads which leads to current and voltage-related problems such as sag, swell, interruptions harmonics, etc. These factors lead to many other problems like decreasing the life span of the equipment, power factor, and efficiency. To overcome such problems usage of UPQC design has been prominently gaining importance to mitigate PQ issues more effectively and increase the system performance [1-3]. The increase in demand is also leading to greater changes in traditional power systems by developing DGs to meet the huge requirements of power which is also reducing global warming by reducing the usage of fossil fuels.

This research adds to our understanding of an important fact that impacts the reliability, cost, and safety of the DG. Because of nonlinear loads such as rectifiers and variable-frequency drives, they experience PQ problems due to which equipment can become overheated, lose efficiency, or even fail due to harmonics. Protective relays, sensitive electronics, and system reliability can all be negatively affected by brief voltage variations [4-7]. Component failures, poor PFs caused by inductive loads, and increased losses are consequences of power system imbalances. Passive filters and other conventional methods of reducing PQ are not effectively reduced due to the varied and ever-changing loads [8-10].

UPQCs actively inject voltages and currents to make the system more comprehensive [11-13]. When nonlinear loads are subject to fast changes, PI and hysteresis control may be unreliable and sluggish [14-16]. The production of harmonics due to nonlinear loads, voltage variations, and power factor problems has been extensively studied [17-18]. The PI and hysteresis-based UPQC control strategies work well for changing loads but not so well for fast-changing loads [19-20].

2. Brief Literature Review

Contribution	Reference
• This study introduces an Inductive Hybrid UPQC (IH-UPQC), which enhances harmonic isolation and voltage regulation, which are suitable for moderate voltage applications. • The proposed system employs an Inductive Filtering Method, a Double Resonant Passive Filter (DRPF), and a Neutral Point Converter (NPC) to improve power quality. • The study concludes that the IH-UPQC reduces DC-link voltage requirements, enhances harmonic suppression, and provides better voltage regulation, making it effective in premium power applications.	[21]
• This research integrates a PV system and BESS into a UPQC framework to improve power reliability. • The system is designed using a Self-Tuning Filter (STF) combined with a Unit Vector Generator (UVG) to regulate power supply and synchronization. • The study finds that the proposed hybrid system enhances power reliability, reduces the dependency on a Phase-Locked Loop (PLL), and provides improved voltage support during power interruptions.	[22]
• Proposed fuzzy and integral sliding mode hybrid controller (FISMHC) for solar system and fuel cell-based UPQC for enhancement of PQ. • Mainly focused on maintaining constant DC link voltage without any oscillations, grid fluctuations, and THD reductions both in source currents and load voltages.	[23]
• In this paper, they designed a multivariable resonant observer-based control strategy of a UPQC system. • Without losing the closed-loop performance the tuning of the proposed controller is designed. The designed controller tuning. • Designed experimental setup for a 1-phase system the PQ mitigations were observed for different cases such as elimination of sags/swells, THD compensation, and power factor correction.	[24]
• This research develops an SSLKF-based control system for UPQC, which improves grid synchronization and power quality under distorted conditions. • The control strategy includes a Steady-State Linear Kalman Filter (SSLKF) combined with a Bat Optimization Algorithm to optimize system response. • The results indicate that the proposed method provides a faster dynamic response, efficiently compensates for grid disturbances, and ensures optimized PI controller tuning for improved stability.	[25]
• This study proposes a Soccer League Optimization (SLO) algorithm-based controller, which optimally tunes a hybrid solar-battery UPQC system to enhance power quality. • The system employs a Fuzzy Logic Controller (FLC) combined with a Soccer League Optimization (SLO) algorithm to dynamically tune the PI controller. • The study finds that the proposed optimization technique reduces Total Harmonic Distortion (THD) below 2.5%, enhances power factor, and improves the system's transient response.	[26]
• They proposed Multi Converter UPQC with the help of synchronous reference frame (SRF) theory. • Focused on mitigation of voltage sag, swell, and interruptions using two series voltage course converters for power transfer between feeders. • Implemented FLC in SRF using hybrid algorithm Beetle Swarm-based Butterfly Optimization Algorithm (BS-BOA), which combines Beetle Swarm Optimization (BSO) and Butterfly Optimization Algorithm (BOA) • The main aim of the optimized FLC-based MC-UPQC is to minimize THD in source and load side voltages and currents.	[27]
• The paper introduces a DC-link capacitor-free dual UPQC-PV system, which improves reliability and reduces system complexity. • The proposed system uses a Dual-Fuzzy Sugeno (FS) Controller combined with a Proportional-Integral (PI) Controller to regulate power quality. • Simulation results reveal that eliminating the DC-link capacitor simplifies the system, while the dual-fuzzy Sugeno control method enhances power quality by reducing THD.	[28]
• This research enhances UPQC performance by applying an adaptive filtering technique based on an improved Least Mean Square (LMS) method. • The system incorporates Improved Zero-Attracting Normalized LMS (IRZA-NLMS) and Self-Adaptive Multi-Population Rao (SAMP-Rao) Optimization. • The study finds that the proposed method accelerates convergence, improves steady-state error reduction, and enhances the mitigation of power quality issues.	[29]
• This paper presents an online PI controller tuning strategy using Particle Swarm Optimization (PSO) for UPQC systems integrated with Distributed Generation (DG). • The control method combines PSO with the Ziegler-Nichols (ZN) Method to achieve optimal real-time tuning. • The study demonstrates that the PSO-based controller provides adaptive PI tuning, enhances system response time, and improves power stability under dynamic load variations.	[30]

The proposed system consists of PV-UPQC for mitigation of PQ issues in the DG with the proposed novel ALA technique. PV with the common DC link is connected via a DC-DC boost converter. PV system generally provides active power to the load. To obtain a constant DC link voltage constant the ALA approach is implemented.

The main contribution of the proposed work is as follows:

- Designed UPQC with PV source.
- The novel ALA technique is used to modify the UPQC's DC link voltage control parameters.
- Developed ALA for controlling the system and mitigating PQ issues related to current, voltage, and THD.

An error value is formulated as the fitness function from the ALA approach.

The proposed system performance is simulated and analyzed using MATLAB/Simulink. Further, the paper is organized as follows; section 3 is about the proposed PV-UPQC with ALA technique, section 4 control strategy of UPQC, section 5 proposes the ALA technique, section 6 results and discussion, and finally a conclusion.

3. Proposed PV-UPQC with ALA Technique

The designed system is as depicted in Fig.2 which consists of PV connected to UPQC and interfacing the grid through a DC link capacitor via a DC-DC boost converter. With the help of the ALA technique, the reference DC link is created. The error generated from the reference direct current link (V_{dc}*) and actual direct current link voltage (V_{dc}) is provided to the PI controller to control the change in error with the proposed ALA technique. ALA generates the parameters of K_p and K_i depicted in Fig.1.

The equation of the DC Link capacitor is written as

$$C_{DC} = \frac{P_{DC}/V_{DC}}{2\omega V_{dcrip}} \quad (1)$$

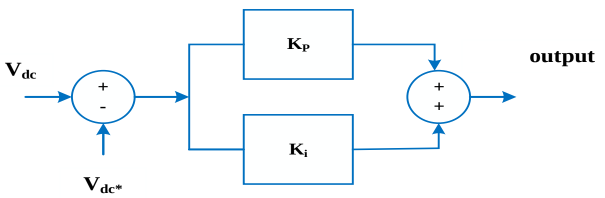


Fig. 1. PI Controller.

4. Control Strategy of UPQC

To improve electrical system power quality, the multipurpose UPQC uses a mix of series and SAPF [31]. To fix reactive power, load imbalances, and current harmonics, the UPQC's SAPF branch applies compensatory currents. However, the SAPF branch links potential in series with the power supply to rectify voltage drops, spikes, and distortions caused by harmonics. The UPQC's efficiency is dictated by the control mechanisms employed in these two branches [32]. The shunt and series active filter branches of the UPQC, together with their modeling and control, will be covered in the following sections.

Fig.3 displays the UPQC system's structural diagram. A three-phase unbalanced system's source current $V_{grid}(t)$ is composed of fundamental and harmonic elements in the positive, negative, and zero sequences. Eq. (2) determines the system's current for the analog circuit.

$$V_g(t) = V_{g+}(t) + V_{g-}(t) + V_{g0}(t) + V_{sh} \quad (2)$$

where $V_{g+}(t)$, $-V_{g-}(t)$, $V_{g0}(t)$ are components of V_{sh}. The voltage that the serial compensator induces is specified by eq. (2).

$$V_{secomp}(t) = V_L(t) - V_{grid}(t) \quad (3)$$

The system voltage, load voltage, and series compensation factor are all represented as $V_{g(t)}$, $V_{L(t)}$, and $V_{secomp(t)}$, respectively. Eq. (4) determines the shunt compensated current, which is the difference between the load current and the grid current.

$$I_{sh}(t) = I_L(t) - Ig(t) \quad (4)$$

where $I_g(t)$ is grid current,

The compensating current is $I_{sh}(t)$, while the load current is $I_L(t)$. The grid obtains current injection from the shunt compensator. The injected current possesses negligible harmonic content. Eq.5 yields the distorted load current.

$$I_L(t) = I_{L+}(t) + I_{L-}(t) + I_{L0}(t) + I_{sh}(t) \quad (5)$$

When the load current is positive (represented by $I_L(t)$, negative (represented by $I_L(t)$), and the null (represented by $I_{L0}(t)$) component is the load current, $I_{sh}(t)$ is the Shunt Compensation current.

a. Series Converter

It eliminates voltage disturbances such as voltage dips and sag, hence improving the quality of power. The voltage is consistently sustained using the series converter. With the use of a series injection transformer, the series converter is accountable for injecting current into the PCC [33]. The series converter charges the DC-link element while converting the AC amount to DC quantity. The transfer of actual power

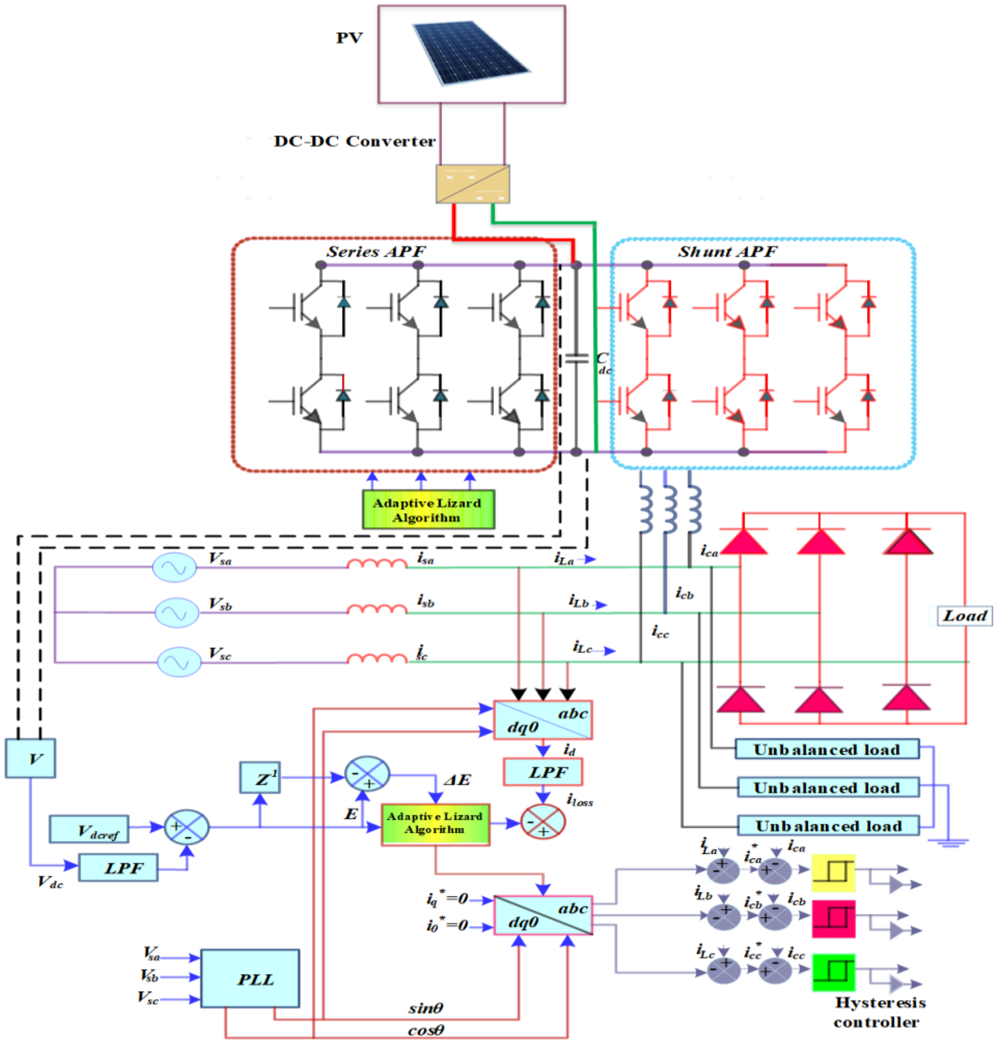


Fig. 2. Proposed PV-UPQC system.

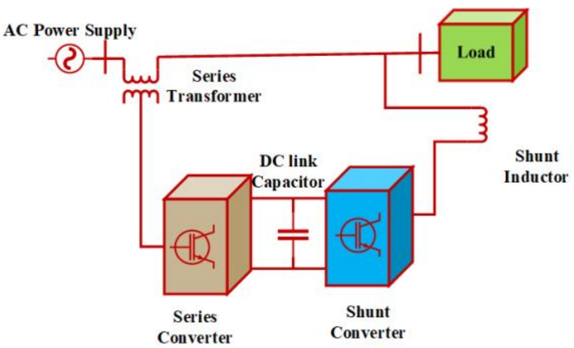


Fig. 3. Configuration of the UPQC system.

is also made possible by the series converter. An example of a vectorial unit model is the main converter in a series control mechanism. Voltage sensors measure the inaccurate and essential voltage component at the point of common coupling (PCC) as represented in Eq.6

$$V_{Max} = \sqrt{\frac{2}{3}}(V_{a\_s} + V_{b\_s} + V_{c\_s}) \quad (6)$$

Three phases can be synchronized with frequency using the PLL circuit. The inaccurate potential is divided by the maximum tension before entering the PLL. The equation indicates that the phase vectors must be separated by a difference in phase angle (7,8,9).

$$V_{PLL\_a} = \sin(\omega t) \quad (7)$$

$$V_{PLL\_b} = \sin(\omega t - \frac{2\pi}{3}) \quad (8)$$

$$V_{PLL\_c} = \sin(\omega t + \frac{2\pi}{3}) \quad (9)$$

To obtain the reference signals described in Eq. (10), multiply the PLL circuit's output by the fundamental voltage.

$$V^*_{L\_abc} = V_{peak} * V_{PLL\_abc} \quad (10)$$

To create an error signal, the created reference signal is compared to the load signal. A pulse width modulation (PWM) signal generator receives the acquired error signal and then sends the signal's output to the series converter. Fig.4 depicts the control structure of series APF and Fig.5 represents the unit vector template showing the control scheme's construction.

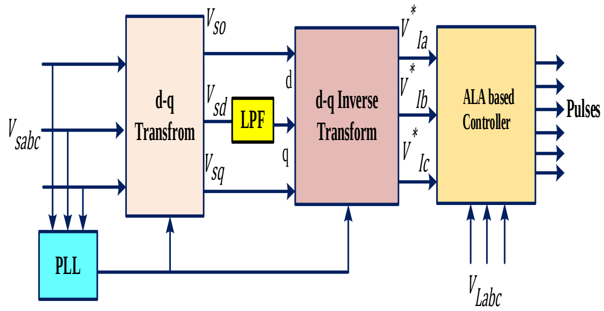


Fig. 4. Control structure of series APF.

b. Shunt Converter

Rectify reactive power and eliminate current harmonics via shunt converters. Shunt Converters supply or absorb power for the DC-Link Capacitor's series converter. A Shunt Converter converts DC-Link-Power-Demand from Series-Converters to AC to enable their operation Shunt converters adjust load power consumption via shunt inductance. Using Clark's transformation the electrical variables from a-b-c converted to α-β using P-Q theory represented in Eq's. 11&12.[34-38]

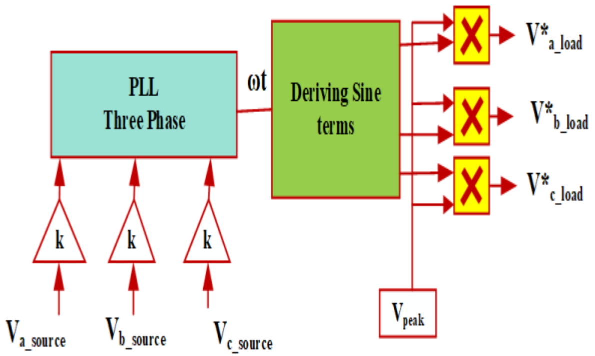


Fig. 5. Working of PLL.

$$\begin{pmatrix} v_{\alpha\_load} \\ v_{\beta\_load} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_{a\_load} \\ v_{b\_load} \\ v_{c\_load} \end{pmatrix} \tag{11}$$

$$\begin{pmatrix} i_{\alpha\_load} \\ i_{\beta\_load} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{a\_load} \\ i_{b\_load} \\ i_{c\_load} \end{pmatrix} \tag{12}$$

Eqs (13) and (14), considering the current and voltage at any point in the coordinates α-β, can be used to find the real and reactive power.

$$p_{load}(t) = v_{\alpha\_load}(t) i_{\alpha\_load}(t) + v_{\beta\_load}(t) i_{\beta\_load}(t) \tag{13}$$

$$q_{load}(t) = -v_{\alpha\_load}(t) i_{\alpha\_load}(t) + v_{\beta\_load}(t) i_{\beta\_load}(t) \tag{14}$$

Similar to the SRFT, the p-q theory comprises a standard component and an oscillatory factor about actual and reactive power, as delineated in Equations (15) and (16).

$$p_{load} = \widetilde{p_{ac\_load}} + \overline{p_{dc\_load}} \tag{15}$$

$$q_{load} = \widetilde{q_{ac\_load}} + \overline{q_{dc\_load}} \tag{16}$$

By applying Eq(17), the generated reference current can be changed from α-β coordinates to a-b-c coordinates.

$$\begin{pmatrix} i^*_{a\_load} \\ i^*_{b\_load} \\ i^*_{c\_load} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} -i_{o\_load} \\ i^*_{\alpha\_load} \\ i^*_{\beta\_load} \end{pmatrix} \tag{17}$$

The voltage at the DC connection must remain constant in the shunt converter. The phase angle ά determines the variation in real and reactive power regulation. By comparing the reference current to the load current, reference signals can be created and sent to the PWM generator. The PWM generator provides the shunt voltage source converter with its gating pulses. The shunt converter's block architecture is shown in Fig.6.

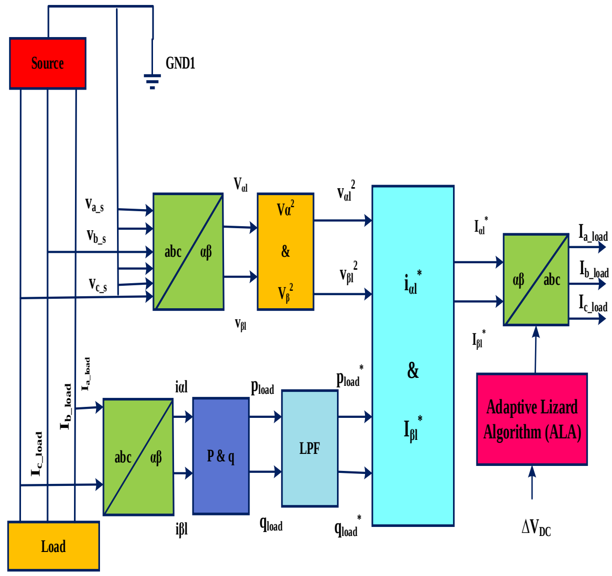


Fig. 6. Block diagram of Shunt APF.

5. Adaptive Lizard Algorithm

To control reactive power (Q_{ref}), the ShAPF is designed using a PI controller. The value is default set to zero to obtain a unity power factor and ensure that source current is utilized for real power transmission. Reactive power measurement (Q) is calculated by analyzing the source current and voltage, with the p-q theory or another method for control scheme analysis.[39]

Error Signal (e):

$$e(t) = Q_{ref} - Q(t) \tag{18}$$

PI Controller Output (u):

$$u(t) = K_p \times e(t) + K_i \times e(t)dt \quad (19)$$

where: K_p Is the proportional gain; K_i is the integral gain.

a. Compensating Current Calculation (Ish):

Before a PWM generator can process this PI controller output, it is typically necessary to transfer it back from the dq0 domain to the a-b-c domain. The controller is used in this study to maximize the performance of the system. Unfortunately, there isn't a precise method for calculating the K_i and K_p, therefore finding the ideal settings for the controller can be difficult. To overcome the challenge of nonlinear continuous optimization, the proposed ALA is an innovative strategy that uses an enhanced search mechanism. Dynamic foraging behavior in autarchoglossan lizards served as inspiration for the ALA algorithm. These lizards can differentiate between high-energy and possibly toxic prey to their unique vomeronasal chemosensory systems. This talent is utilized by autarchoglossans to evade potentially harmful prey and capture extremely active prey. This optimal-choice tendency is mimicked by the ALA algorithm. ALA is proposed to determine the optimal K_p and K_i parameters for the controller. The strategy is based on the idea of optimizing the system's performance. Figure 7 displays the parameter flow diagram. The procedure generates K_p and K_i after doing the calculation, but their initial values are completely arbitrary. Settling time, rise time, and percentage overshoot are three common metrics used to assess an algorithm's performance. After 1000 iterations, the optimization phase is complete and the procedure stops iterating.

$$.D + A + S = 1 \quad (20)$$

For optimal K_p and K_i values, the method takes rising time, % overshoot, and settling time into account. A precedence coefficient of 0.43 for rising and settling times and 0.54 for percentage overshoot is provided. In real-time, optimization of offline ALA decreases computational load. This keeps things simple and keeps things from getting too complicated. The low learning curve and ease of use of the ALA make it a desirable option. Calculation time is drastically cut down with offline processing. The efficiency and appropriateness of the algorithm were validated via simulations. This example shows that ALA is an excellent optimization. Checking the stability of a system is made easier by the eigenvalue theorem. The system under consideration is predicated on the premise that the AC source and AC bus exhibit a phase difference. An ALA-optimized small-scale power system's signal analysis was used to evaluate the model. We used eigenvalues to check if the system was stable. The voltage loop control bandwidth was affected by changes in power step responsiveness. By examining the step response, one can ascertain whether the system is stable. ALA is a new method that takes the place of the old parameter selection method. By optimizing the PI controller, it enhances the system in a way that is both efficient and flexible. The ALA provides a flexible and efficient approach to optimize the PI controller for improved system performance, replacing the previous method of parameter selection.

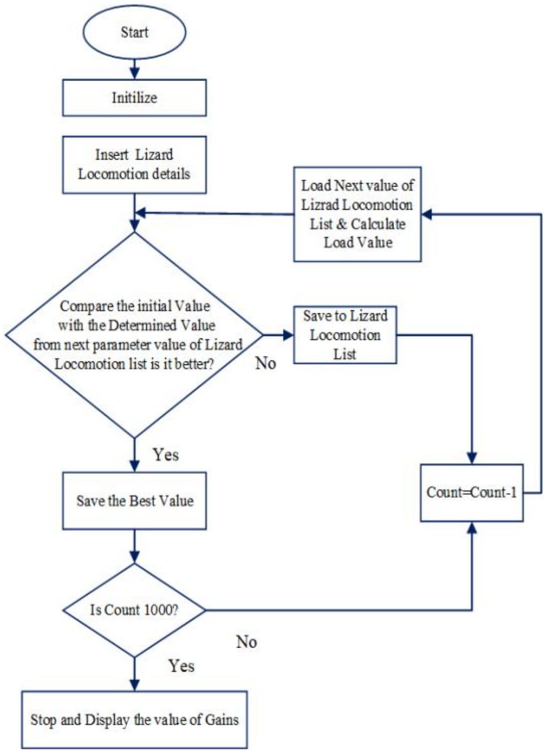


Fig. 7. Flowchart for Adaptive Lizard Algorithm

6. Simulation Results and Discussion

The simulation settings are configured for PE models, like the UPQC system, to achieve an optimal balance between simulation speed and accuracy. The findings are guaranteed to be exact according to the low relative tolerance, and the model stiffness is handled by the implicit solver.

a. Results and discussions based on current profiles

Using Simulink, we tested several ways to control the distribution power system of the UPQC. The capacity of each controller to reduce power quality interruptions was tested.

i. Compensating current

The Shunt Active Power Filter (ShAPF) successfully injected compensatory currents to mitigate power quality issues connected to the current, including harmonics, reactive power, and load unbalanced. Fig. 8 shows the grid current, load current, and filter current which represent the compensating currents using a synergetic controller. Fig. 9 represents the grid current, load current, and filter current which represent the compensating currents using the ALA controller, which can lower the compensatory current's THD, as demonstrated in the simulation results. When the Adaptive Lizard Algorithm is used in the UPQC system, effective harmonic mitigation is achieved by injecting a compensatory current. Fig. 10 and 11 show the current at the source waveform. Fig. 12 and 13 represent the results of

Load Voltage and Load current With the Synergetic controller after Compensation and ALA controller.

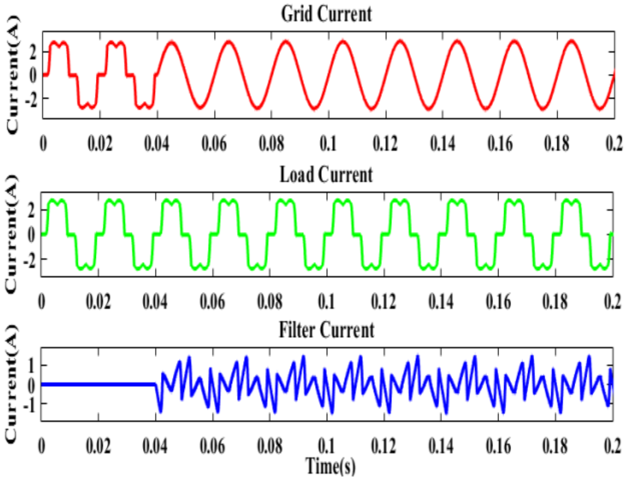


Fig. 8. Results of grid current, load current, and filter current compensation using Synergetic Controller

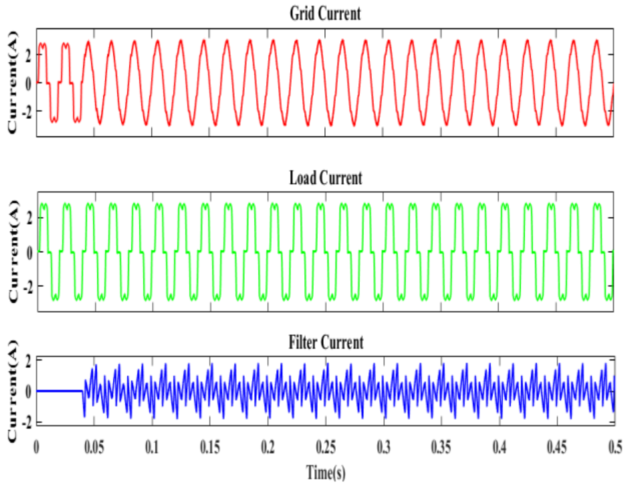


Fig. 9. Results of grid current, load current, and filter current Compensation using ALA

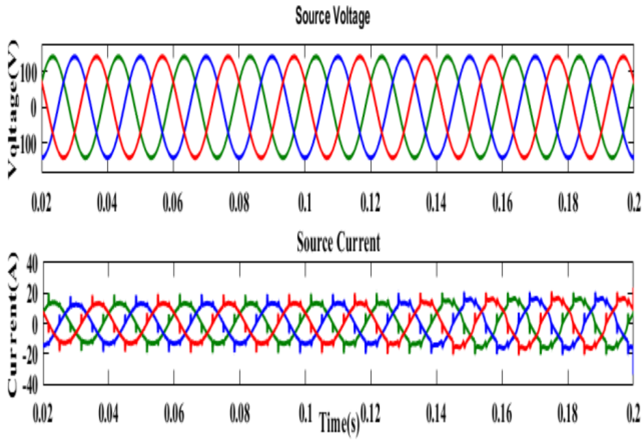


Fig. 10. Source voltage and source current with synergetic controller

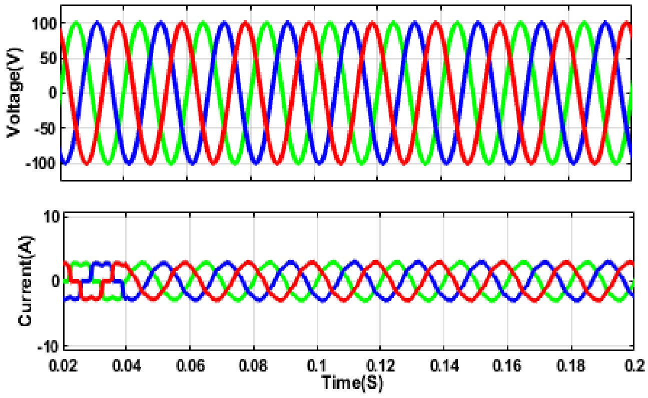


Fig. 11. Source voltage and source current with ALA

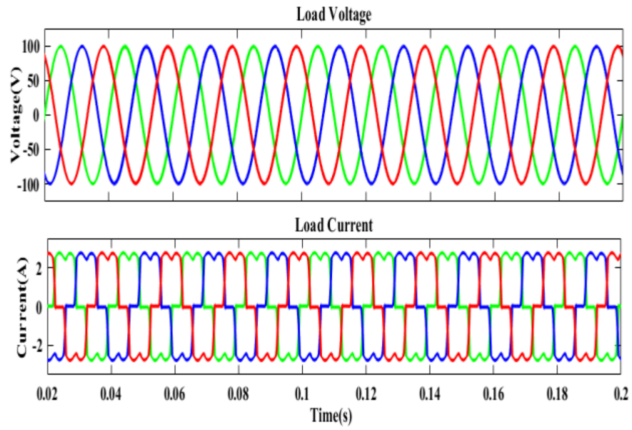


Fig. 12. Load voltage and load current with synergetic controller after compensation

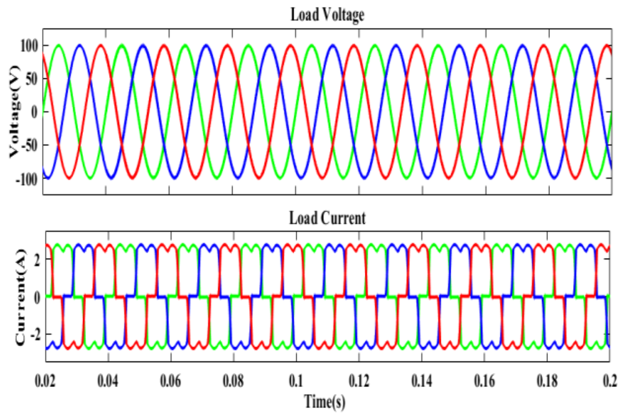


Fig. 13. Load Voltage and Load Current with ALA after Compensation

ii. Voltage sag/swell compensation

The proposed UPQC accomplished the desired performance by decreasing voltage sags and swell using its controllers driven by ALA.

Injecting the necessary compensatory voltages, the ShAPF successfully achieved the load voltage at the required level.

Fig. 14 depicts the condition for voltage swell and sag under fault conditions with the synergetic controller. During the interval of 0.2s-0.4s swell is observed and between intervals, 0.5s to 0.7s voltage sag is observed in the source voltage. As demonstrated in Fig. 15, the ALA successfully decreased the voltage sag/swell. The results of a control method for the UPQC that simultaneously handles voltage sags and swells. The source voltage waveform, represented encompasses the sag range 0.2s-0.4s and the swell range 0.5s-0.7s.

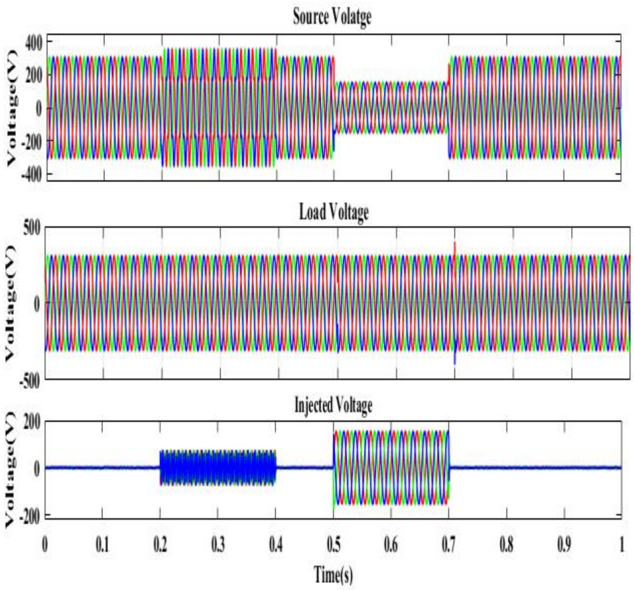
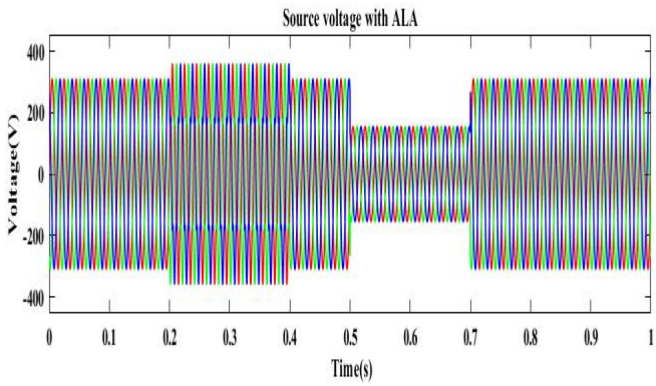
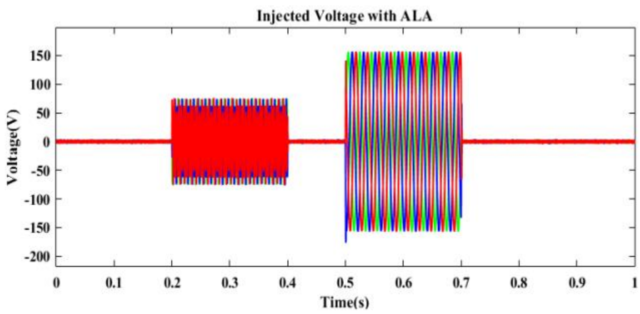


Fig. 14. Voltage compensation with synergetic controllers for sag/wwell condition

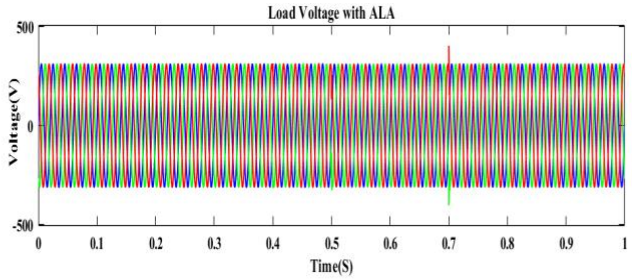
The simulation is executed for one second, as shown for 0.2-0.4 s swell and 0.5-0.7 s sag. UPQC which is based on the ALA can compensate for the load voltage due to voltage surges. Voltage surges can be effectively mitigated using UPQC, which is based on the ALA. The produced results show that the ALA performed the best by minimizing the voltage sag/swell.



(a)



(b)



(c)

Fig. 15. Voltage compensation with ALA for sag/swell condition

iii. Control of DC link

A self-regulated DC bus is achieved by periodically detecting the voltage across the capacitor and modifying it using closed-loop control. The reference value, V_{dc}*, and the DC link voltage, V_{dc}, are measured regularly and compared. A conventional PI controller processes the error signal. To ensure that the source can supply both the active power of the load and the DC bus of the UPQC, a restriction is placed on the controller's output. By harnessing some of the source's active power, an autonomous DC link of UPQC can be established. The DC link uses a shunt inverter to aid the load side and a series inverter to aid the source side. Fig. 16 shows the comparison performance of DC link voltage.

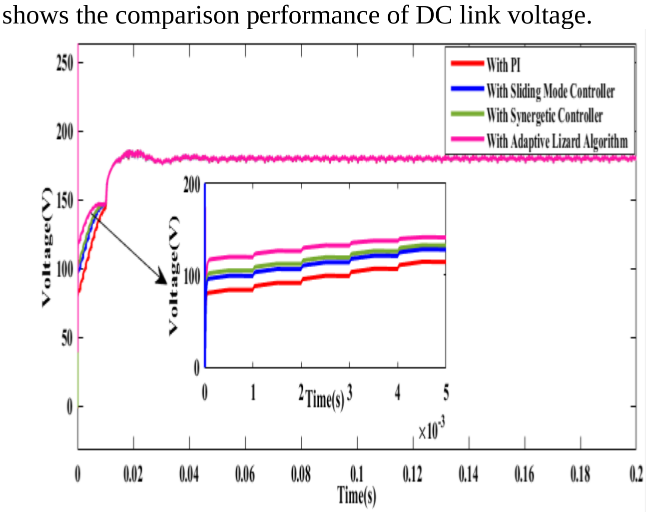


Fig. 16. Comparison of performance of DC link voltage regulation

b. THD performance

i. Synergetic Controller

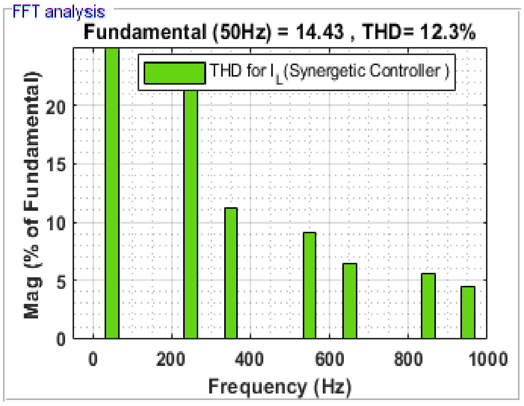
The PQ of the PV-fed distribution system was even further improved once the Synergetic Controller was installed. Reduced harmonic distortion to 2.02% was evidenced by a significant drop in source current THD. A significant aspect of the Synergetic Controller's performance was its ability to precisely model and manipulate the nonlinear dynamics of the system.[40-47]

Using MATLAB Simulink, we tested how well the proposed control techniques for the UPQC performed in a PV-UPQC system. Fig. 17(a) & (b), Fig. 18(a) &(b) depicts

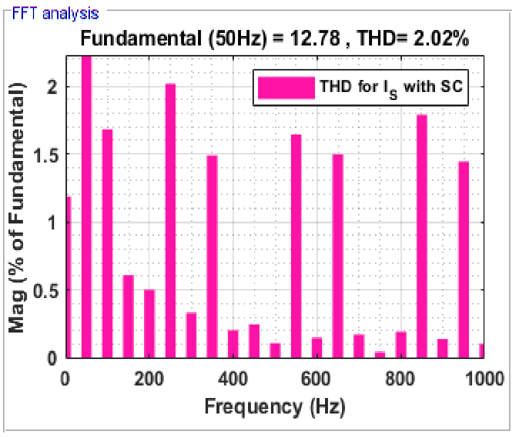
THD for I_L and I_S to be 12.3% and 2.02% V_L and V_S with synergetic Controllers to be 4.42% and 0.18%.

ii. With an adaptive lizard algorithm

The simulation results show the system's PQ was significantly enhanced following the implementation of the ALA. The source current's total harmonic distortion (THD) The optimized controller's success in reducing harmonic distortion is evidence of its ability to address power quality concerns. In comparison to the uncompensated system, the adaptive lizard algorithm was able to tweak the controller parameters to achieve superior performance.

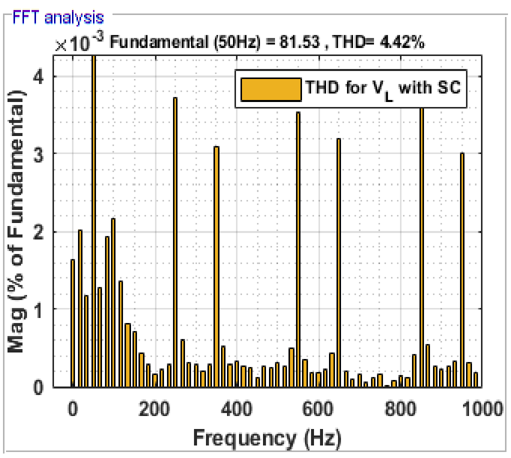


(a)

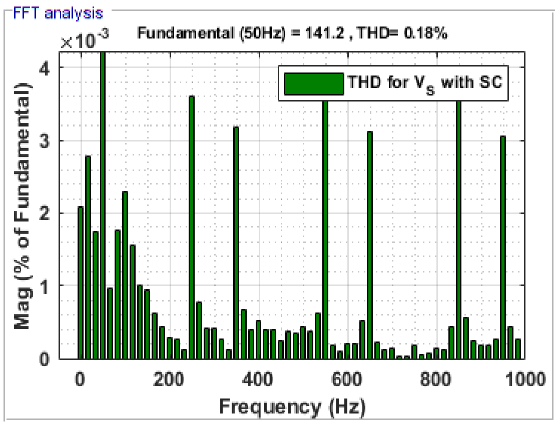


(b)

Figure. 17 THD for (a) I_L and (b) I_S with synergetic controller



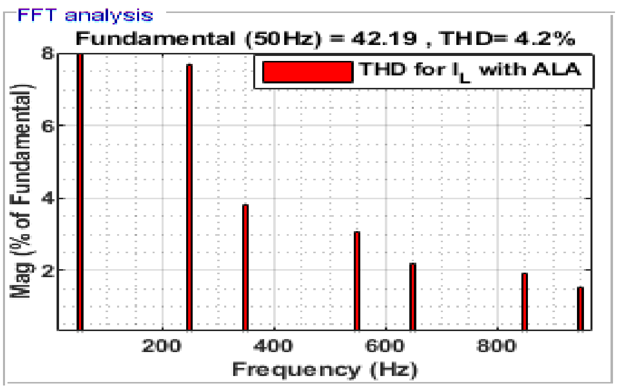
(a)



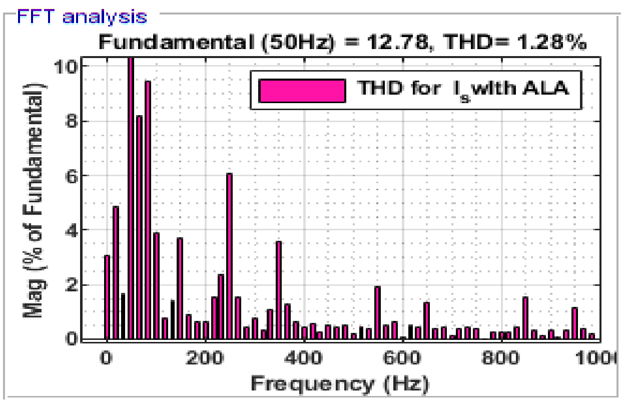
(b)

Fig. 18. THD for (a) V_L and (b) V_S with synergetic controller

A considerable increase in power quality was seen from the 1.28% depicted in Fig. 19 (b) reduction in the THD of the current at the source. The ALA achieved a 4.2% depicted in Fig. 19(a) THD of load current, considerably improving the compensatory current's quality. Similarly, V_L and V_S with synergetic Controllers are 3.25 % depicted in Fig.20(a), and 0.16%. depicted in Fig. 20(b). Table. 2 represents the THD values compared with various controllers. Table. 3 represnets the proposed test system paramters.

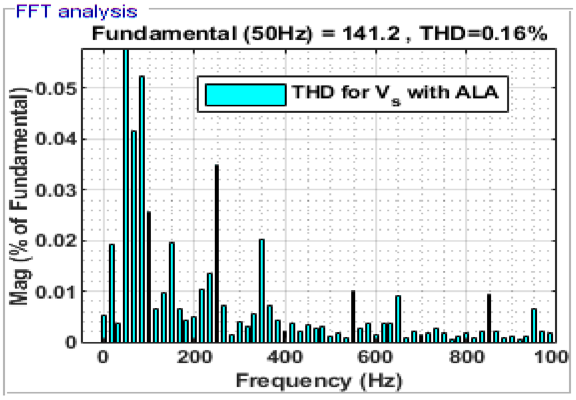


(a)

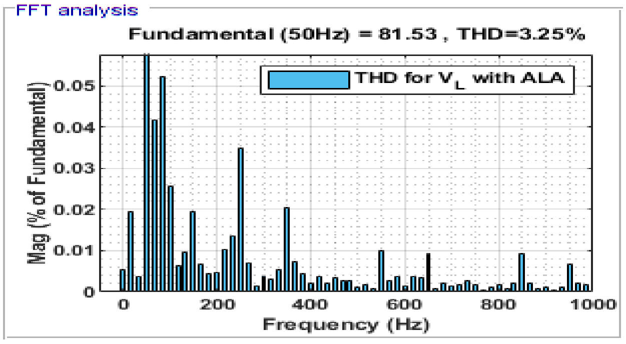


(b)

Fig. 19. THD for (a) I_L and (b) I_S with ALA



(a)



(b)

Fig. 20. THD for (a) V_L and (b) V_S with ALA

Table 1. Comparison of THD with all the controllers

S.No	Controller	THD for Is (%)	THD for IL (%)	THD for Vs(%)	THD for VL(%)
1	With FLC	2.96	20.55	0.79 2	10.62
2	With AdFLC	2.46	19.25	0.49	9.42
3	With SMC	2.08	14.2	0.28	8.65
4	With SC	2.02	12.3	0.18	4.42
5	With ALA	1.28	4.2	0.16	3.25

Table 2. UPQC system parameters specifications

Parameters	Notation	Range
Source voltages	$V_{s,abc}$(L-L)	380 V
Frequency	f_s	50Hz
DC-link voltage	Vdc	750V
Load	R_L, L_L	20Ω, 15mH
SAPF parameters		
Series transformer	Rate	1/3
AC filter	Rf,Cf	5Ω, 3μF
AC inductance	L_c	3.5mH
ShAPFfilter parameters		
AC inductance	L_f	1mH
Proportional Controller	K_p	1.25
Intergral Controller	K_i	25

7. Conclusion

This research paper investigates how to optimize the PQ using PV-UPQC. Advanced control approaches such as synergetic controllers and ALA to reduce source current THD is studied. The ALA achieved better results than the uncompensated system among the three other approaches. The most significant improvement was made by the ALA, which decreased the source current THD from 2.02% to 1.28%. With a THD of 2.02%. Using an ALA improvement of PQ, system reliability, and performance is well justified. The results of the proposed system show the best performance when compared with the various other traditional methods such as Fuzzy logic controller (FLC), Adaptive fuzzy logic controller (AdFLC), Sliding mode controller (SMC) and Synergetic controller (SC). The obtained results of the PV fed UPQC mitigates voltage sag, swell effectively and compensates the harmonics adhering to IEEE-519 standards.

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