Photovoltaic inverters experimentally validate power quality mitigation in electrical systems

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ABSTRACT

Power quality is improved by utilizing solar inverters in electrical grids and this study probes it. A combination of the solar power system with wind energy management using the multi-objective particle swarm optimization (CMOPSO) algorithm is employed in this system. Control calculations are based on Clark and reverse Clark transformations and facilitated by a phase-locked loop (PLL) circuit. STATCOM helps maintain voltage levels and mitigate power quality issues. Power quality (PQ) monitoring tracks voltage variations and noise. Conversely, the study addresses challenges in integrating renewables using the multi-objective multi-verse optimization (MOMVO) algorithm. MATLAB is used for control, monitoring, and analysis. Results show voltage distortion, but the proposed method achieves 92% higher efficiency, demonstrating its effectiveness. This validates the importance of photovoltaic (PV) technology for integrating renewable energy sources.

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1. INTRODUCTION

Increasing interest in solar power (SPV) fuels development in sustainable energy sources. SPV is vital for remote communities, but integrating it into weak AC grids brings power quality (PQ) challenges. Rigorous testing and validation are necessary to assess the effectiveness of PV solar inverters in mitigating power quality issues. The growing integration of energy sources, particularly solar-based power, into the electrical network poses significant trials allied to the quality of power [1]–[5]. Pidikiti *et al.* [6] proposed a crossover framework that alleviates voltage droop/swell, unbalance, and voltage series infusion, which affects wind-associated enrolment generators. Das *et al.* [7] proposed a PV framework that dynamically powers and reduces harmonic distortions using predator-prey-based fire-fly optimization, fuzzy tracking, and adaptive perturb. Benabdelkader *et al.* [8] proposed an effective control approach for a grid-connected single-phase PV system that improves power quality and operates with a maximum power point tracking (MPPT) controller. Paramasivam *et al.* [9] proposed a PV-dynamic voltage restorers (DVR) that relieves voltage hang and swell, interferences, and uneven blackouts using a single MOSFET switch and three inductors with a second-order summed-up integrator-based unit vector layout control. Okwako *et al.* [10] proposed a counterfeit brain network regulator that improves control intricacy and relieves power quality issues using a brain organization to control a shunt dynamic channel of the unified power quality conditioner (UPQC) [11]. The research aims to understand how PV solar inverters can effectively address power quality issues, ensuring a smooth integration of solar energy into existing electrical frameworks [12], [13].

2. PROPOSED RESEARCH METHOD

The comprehensive experimental design integrates real-world scenarios to assess the presentation and capabilities of PV solar inverters in addressing power quality challenges. This approach involves using advanced measuring tools to track the inverter's impact on various power quality factors. These measurements provide a thorough assessment of the device's performance, ensuring an accurate evaluation of its effectiveness. Also, the data collected from these experiments will be analyzed to identify any potential areas for improvement and to validate the inverter's reliability and efficiency under different operating conditions.

2.1. Experimental setup

In this experiment, solar panels connected to the power grid are investigated. The setup includes monitoring the grid handles alongside the solar energy. Also, measurements of voltage, current, and power are conducted to analyze the system's performance. This comprehensive approach ensures a thorough evaluation of the solar panels' integration with the power grid.

2.2. Multi-objective particle swarm optimization

This algorithm is designed to solve problems with multiple conflicting objectives, such as maximizing energy production, minimizing costs, and reducing environmental impact in renewable energy:

$$\begin{cases} V-\max f(x)=[f_1(x),f_2(x),\ldots\ldots..f_n(x)]^T \\ s.t \qquad\qquad X\in R^m \end{cases} \tag{1}$$

where V-max denotes vector maximization; $f_k(x)(k=1,2,\ldots\ldots,n$ denotes the sub-objective of the vector objective function f(x), each sub-objective vector is maximized to the extent possible; x is the answer to the problem and $X\in R^m$ is the constraints then boundaries of MOP:

$$v_i(t+1)=\begin{cases} \omega v_i(t)+c_1r_{1i}(t)\big(y_it-x_i(t)\big) & if\ \ r_3<\delta \\ \omega v_i(t)+c_2r_{2i}(t)\big(y_it-x_i(t)\big) & otherwise \end{cases} \tag{2}$$

where δ is a parameter to control the exploration-exploitation trade-off, and r_3 is a number randomly chosen from [0, 1]. Then, for each particle $p_i, i\in$ {1, . . . , ns} in swarm, two particles randomly picked from an elite set of size γ and the elite particle of objective vector has a smaller angle with pi 's objective vector is the winner and p_i is the loser. For each winner-loser pair, the following equations are applied to create a new particle p_i:

$$v_i'=r_{1i}+r_{2i}(x_\omega-x_i) \tag{3}$$

$$x_i'=x_i+v_i' \tag{4}$$

where, r_1 and r_2 are two vectors randomly selected from nx, ω is the index for the winner (the selected elite particle). The ordinary particles are indexed using i, $i\in$ {1, . . . , n_s}. The polynomial mutation is then applied to x 0 i.

2.3. Controller

It helps to manage electricity flow in power grids. They act like switches for high-voltage lines, adjusting power flow to make the grid more stable and efficient. Interline power flow controllers (IPFCs) can also address issues like voltage fluctuations and imbalances.

2.3.1. Interline power flow controllers and phase-locked loop circuit

IPFC is a multi-terminal FACTS and the framework explains how IPFCs can improve the solidity and consistency of power grids. A key IPFC model is displayed in Figure 1, IPFC of two converters of the calculated model is explained as:

$$P_i=V_n^2g_{nn}-V_iV_n[g_{in}\cos(\theta_n-\theta_i)+b_{in}\sin(\theta_n-\theta_i)]+V_nV_{se_{in}}[g_{in}\sin\big(\theta_n-\theta_{se_{in}}\big)-b_{in}\cos\big(\theta_n-\theta_{se_{in}}\big)] \tag{5}$$

$$Q_i=-V_i^2b_{ii}-\sum_{n=j,k} V_iV_n[g_{in}\sin(\theta_i-\theta_n)+b_{in}\cos(\theta_i-\theta_n)]-\sum_{n=j,k} V_iV_{Se_{in}}\big[g_{in}\sin\big(\theta_i-\theta_{Se_{in}}\big)-b_{in}\cos\big(\theta_i-\theta_{Se_{in}}\big)\big] \tag{6}$$

$$P_{ni} = V_n^2 g_{nn} - V_i V_n[g_{in}\cos(\theta_n - \theta_i) + b_{in}\sin(\theta_n - \theta_i)] + V_n V_{Se_{in}}[g_{in}\sin(\theta_n - \theta_{Se_{in}}) - b_{in}\cos(\theta_n - \theta_{Se_{in}})] \quad (7)$$

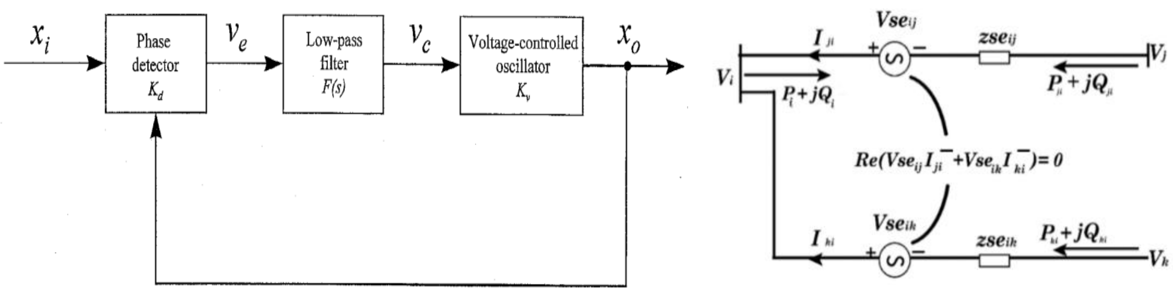
$$Q_{ni} = V_n^2 b_{nn} - V_i V_n[g_{in}\sin(\theta_n - \theta_i) + b_{in}\cos(\theta_n - \theta_i)] + V_n V_{Se_{in}}[g_{in}\sin(\theta_n - \theta_{Se_{in}}) - b_{in}\cos(\theta_n - \theta_{Se_{in}})] \quad (8)$$

As there are no fundamental frameworks, expecting a lossless converter, the dynamic power provided by one converter rises to the dynamic power expected by the other:

$$Re\left(V_{Se_{ij}} I_{ji}^* + V_{Se_{ik}} I_{ki}^*\right) = 0 \quad (9)$$

V_1=$V_1 \llcorner \theta_1$(1=i,j,k) and V_1, θ_1 is magnitude and angle of V_1. Where, $V_{Se_{in}}$ is the complex manageable series-infused voltage source which addresses the series emolument of the converter.

Figure 1 illustrates the circuit representation detailing the topology of the phase-locked loop (PLL) and the mathematical model of the IPFC. Figure 1(a) showcases the PLL's configuration, crucial for synchronizing signals in various applications. Figure 1(b) depicts the IPFC's mathematical framework, essential for controlling power flow in interconnected AC transmission lines.



(a) (b)

Figure 1. Representation of circuit for PLL and IPFC mathematical model (a) topology of the PLL [14] and (b) IPFC mathematical model [15]

The framework explains an issue with IPFCs, devices that manage electricity flow in power grids the grid is synchronized with these devices, and a common tool (PLL) for this can cause instability:

$$w_i - w_0 = K_d K_v cos\ (\theta_i - \emptyset_0) \quad (10)$$

$$\emptyset_0 = \theta_i - cos^{-1}\frac{w_i - w_0}{K_d K_v} \quad (11)$$

$$v_c = \frac{w_i - w_o}{K_v} \quad (12)$$

the Dc signal v_c that changes the VCO frequency from its central value w_0 to the input signal angular frequencyw_i, i.e:

$$w_{inst} = w_0 + K_v v_c = w_i \quad (13)$$

also, represented as:

$$\emptyset_0 = \theta_i - cos^{-1}\frac{w_i - \theta_0}{K_d K_v} \quad (14)$$

the product $K = K_d K_v$ is mentioned as the loop again. When the difference $|w_i - \theta_0|$ exceeds the loop again K in a sinusoidal characteristic for the lock that can no longer maintain the loop falls out of the lock.

2.3.2. STATCOM device for the power controller

STATCOMs are guardians of stable voltage in power grids and act like first responders, swiftly reacting to voltage fluctuations. STATCOMs handle single-handedly larger voltage swings or emergencies like faults, they call on backup from other compensators.

$$\Delta V_2 = \left|V_2 - V_2^{target}\right| = b\Delta Q_1 + a\Delta Q_2 \tag{15}$$

STATCOM is the capacity limit situation in the target voltage $\left(V_2^{target}\right)$ of controlled by only STATCOM. Figure 2 represents the proposed work aimed at addressing power quality issues in photovoltaic (PV) systems. The process begins with a solar PV system connected to a Cuk converter, managed by a controller [16]–[18]. The system utilizes high-penetration renewable integration (HPRI) and multi-objective multi-verse optimization (MOMVO) algorithms to ensure high-penetration without loss of power quality. Additional components include IPFC, Clark and reverse Clark transformations, PLL circuit, and a STATCOM device for maintaining optimal voltage levels [19], [20]. Competitive algorithms like CMOPSO enhance the system's efficiency.

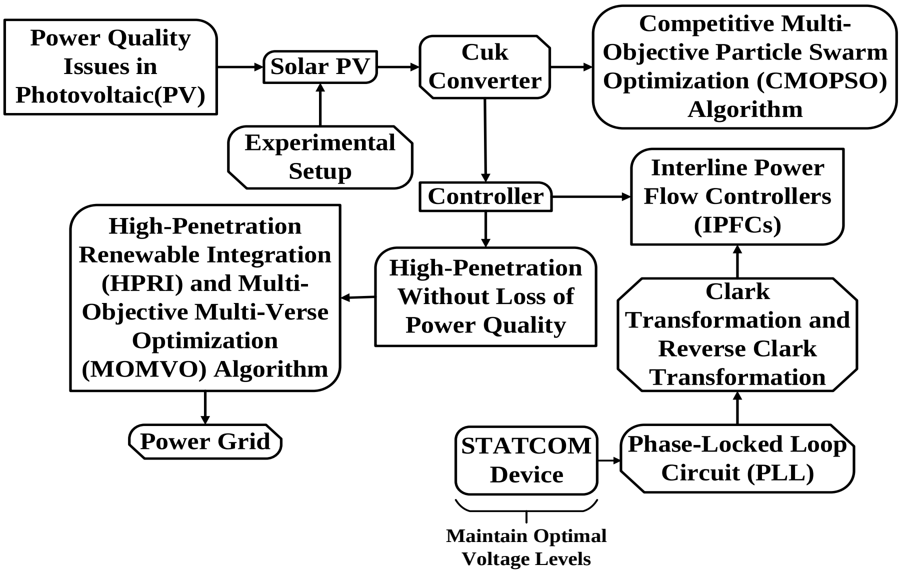


Figure 2. Representation of the proposed work

2.4. High-penetration renewable integration and multi-objective multi-verse optimization

High-penetration renewable integration (HPRI) focuses on integrating large amounts of energy sources like solar and wind into existing power grids.

$$T_a = T_m - T_e = 2H\frac{d\Delta w_m}{dt} \tag{16}$$

(T_a) describes the relation between activation temperature. MOMVO is a new algorithm inspired by the concept of multiple universes [21], [22]. The problem of optimizing a grid at a smaller scale is typically framed in the following formula:

$$f(x) = \begin{bmatrix} f_1(x) \\ f_2(x) \\ \vdots \\ f_n(x) \end{bmatrix} \qquad subjected\ to \quad \begin{pmatrix} G(x) \le 0 \\ H(x) = 0 \end{pmatrix} \tag{17}$$

where, $x = [x_1, x_2, x_3, \dots \dots \dots., x_m]$ is the control vector, and $f(x) = f_1(x), f_2(x), \dots \dots f_m(x)$ are the objective functions' values.

3. EXPERIMENTATION RESULT DISCUSSION

Experimental validation of utilizing a PV solar inverter to reduce problems with the quality of power in electrical systems denotes advancing sustainable energy solutions. MATLAB allowed for precise control of the inverters and detailed monitoring of power quality metrics. The system configuration for the simulation is mentioned in the Table 1. This research work was done using MATLAB of version R2023a with the processor of core i3@ 3.5 GHz and the RAM of DDR3-6 GB.

Table 1. Simulation system configuration

MATLAB	Version R2023a
Operating system	Windows 10 home
Memory capacity	6 GB DDR3
Processor	Intel Core i3 @ 3.5 GHz

Figure 3 illustrates the simulation design of a control system for the PV system, to analyze the performance of the PV system under different conditions. Figure 4 outlines the recurrence conveyance in hertz (Hz) with a dominating worth of 68%. The crucial recurrence addresses the essential wavering in the power signal, and in this specific circumstance, it has a size of 68%.

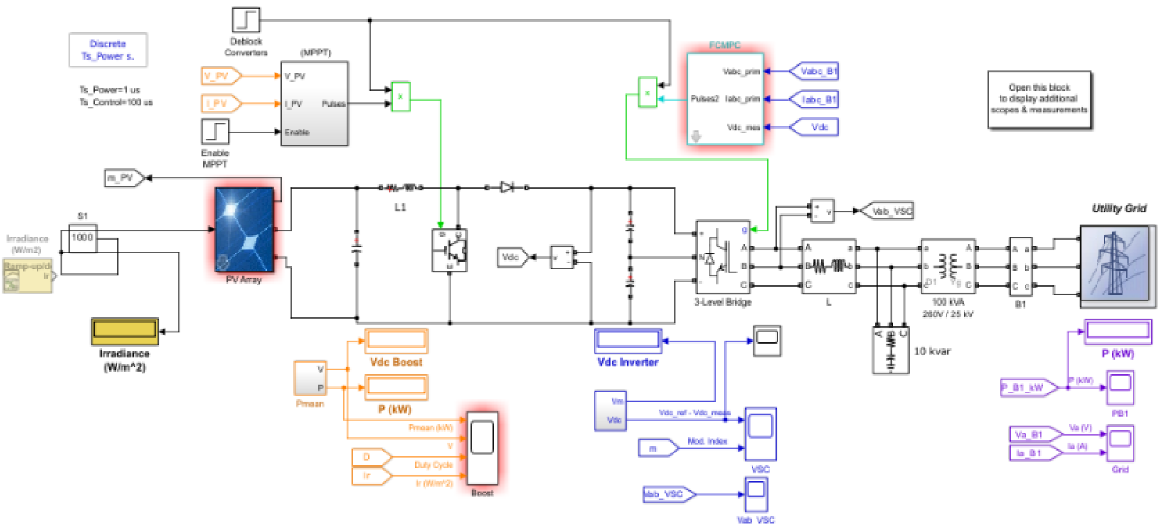


Figure 3. Schematic diagram of the simulation setup [23]–[25]

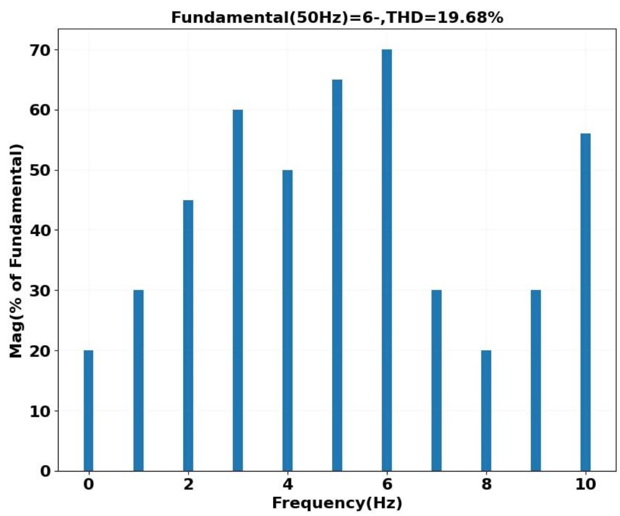
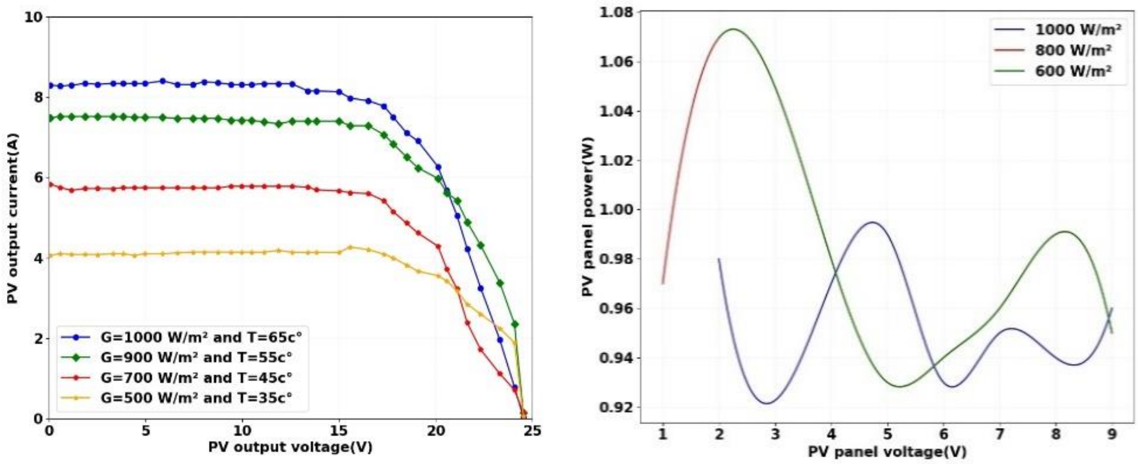


Figure 4. Frequency distribution and harmonic content analysis in power system

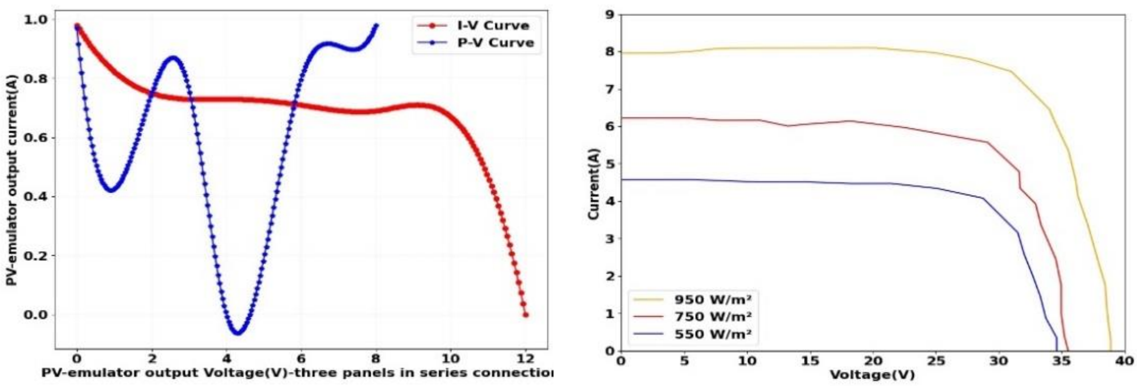
Figure 5 analyses how varying irradiance levels affect PV panel output. Figure 5(a) shows power output current curve, and Figure 5(b) shows PV panel output voltage curve. They show a clear correlation between irradiance and both voltage and power output. As irradiance increases, the voltage produced by the PV panel also decreases.



(a) (b)

Figure 5. Impact of irradiance on photovoltaic panel performance (a) power output current curve and (b) PV panel output voltage curve

Figure 6 depicts the PV system characteristics under series connection and varying irradiance conditions. Figure 6(a) shows the PV-emulator output voltage curve, detailing voltage outputs across different irradiance levels. Figure 6(b) displays the current-voltage (I-V) curve, illustrating how current varies with voltage under varying irradiance conditions.



(a) (b)

Figure 6. Photovoltaic system characteristics of series connection and irradiance (a) PV-emulator output voltage curve and (b) current-voltage (I-V) curve

Figure 7 provides a detailed representation of the electrical features of a PV system under different irradiance conditions. At an irradiance level of 970 W/m², the PV system exhibits a voltage of 0.3365 V with a corresponding power output of 0.3365 W. Under 750 W/m², the voltage and power values increase to 0.3618 V and 0.3618 W.

Figure 8 presents a comprehensive analysis of photovoltaic system performance. Figure 8(a) showcasing voltage curve variations and Figure 8(b) shows a comparative evaluation of different techniques. This visual depiction offers insights into the system's operational efficiency and the effectiveness of various methodologies employed in enhancing performance.

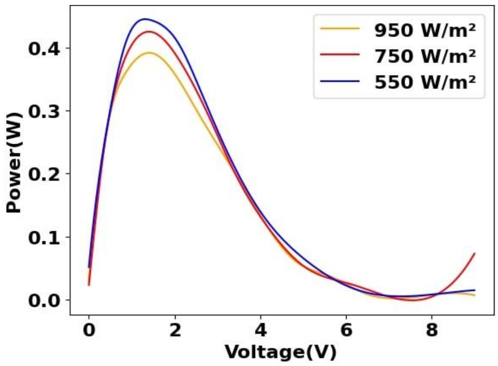
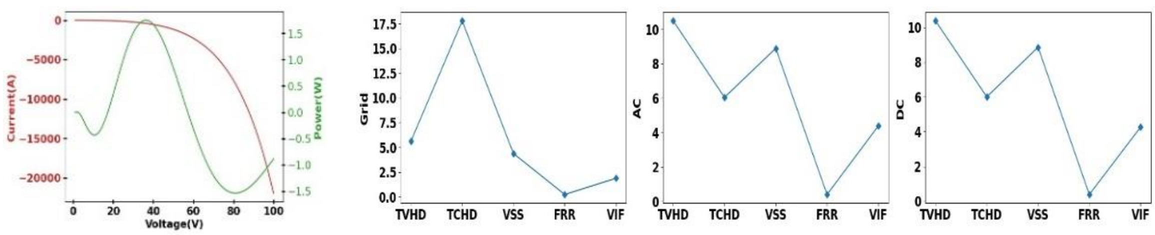


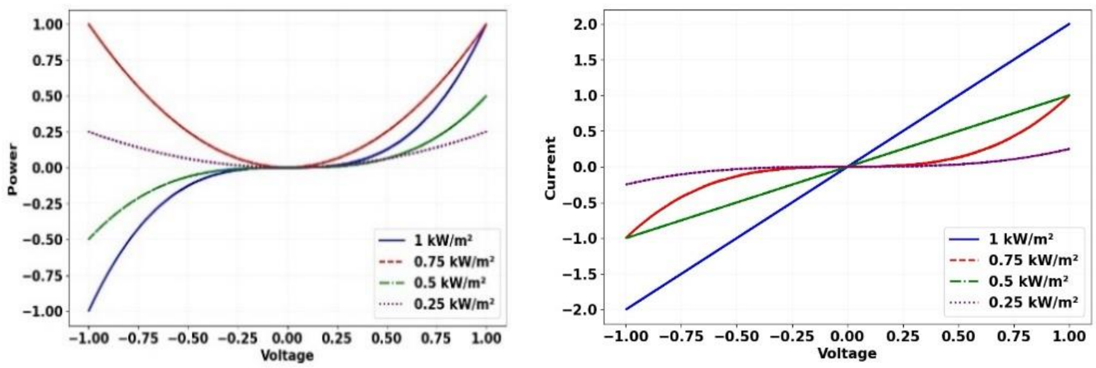
Figure 7. Performance for varied irradiance conditions in photovoltaic system



(a) (b)

Figure 8. Photovoltaic system performance analysis (a) voltage curve and (b) comparison of techniques

Figure 9 depicts the impact of irradiance on photovoltaic system characteristics. Figure 9(a) shows the voltage-power curve and Figure 9(b) shows the voltage-current curve. These graphs highlight how irradiance changes impact the electrical characteristics of the system, crucial for understanding performance under varying environmental conditions. As irradiance reduces from 1 kW/m² to 0.25 kW/m², voltage drops from 0.9031 V to 0.2213 V, and power output follows the same trend.



(a) (b)

Figure 9. Irradiance on photovoltaic system voltage and current (a) voltage-power curve and (b) voltage-current curve

3.1. Comparative analysis

A comparison of several procedures for enhancing the quality of power in electrical systems, including particle swarm optimization (PSO), UPQC, low voltage ride through (LVRT), and a newly proposed approach is implied in this study. Figure 10 compares the effectiveness of various techniques for enhancing power quality and voltage stability in electrical systems. It reveals that the proposed approach achieves the highest efficiency (92%) compared to PSO at 76.0%, UPQC at 89%, and LVRT at 78%.

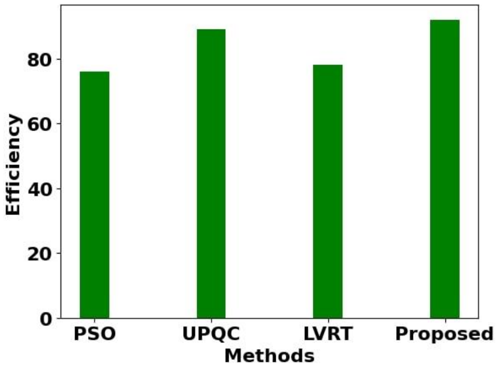


Figure 10. Comparative efficiency analysis of power optimization techniques

4. CONCLUSION

Utilization of PV solar-based inverters for mitigating quality issues of power in electrical systems is a crucial step towards sustainable energy solutions is concluded in this research. The proposed method achieved 92% efficiency, indicating its effectiveness in enhancing power quality. Explore challenges of integrating solar power, such as intermittency, grid stability, and infrastructure compatibility. Algorithms like developing advanced control and grid management strategies for these challenges are addressed. Future research can focus on addressing challenges such as intermittency, grid stability, and compatibility with existing infrastructure, and developing advanced control algorithms and grid management strategies.

REFERENCES

[1] A. Ghayth, Z. Yusupov, and M. Khaleel, "Performance enhancement of PV array utilizing perturb & observe algorithm," *International Journal of Electrical Engineering and Sustainability*, vol. 1, no. 2, pp. 29–37, 2023.

[2] Y. Liu *et al.*, "Coordinated mitigation control for wideband harmonic of the photovoltaic grid-connected inverter," *Applied Sciences*, vol. 13, no. 13, p. 7441, Jun. 2023, doi: 10.3390/app13137441.

[3] A. Aslam, N. Ahmed, S. A. Qureshi, M. Assadi, and N. Ahmed, "Advances in solar PV systems; a comprehensive review of pv performance, influencing factors, and mitigation techniques," *Energies*, vol. 15, no. 20, p. 7595, Oct. 2022, doi: 10.3390/en15207595.

[4] A. C. Kathiresan, P. R. Jeyaraj, B. K. Albert, S. B. Thanikanti, M. K. Nallapaneni, and H. H. Alhelou, "A versatile control of solar DVR for enhanced utilization and power quality improvement in a series-connected wind-solar farm," *IET Renewable Power Generation*, Sep. 2022, doi: 10.1049/rpg2.12592.

[5] Q. Chai, C. Zhang, Z. Tong, S. Lu, W. Chen, and Z. Y. Dong, "PV inverter reliability constrained volt/var control with power smoothing via a convex-concave programming method," *IEEE Transactions on Industrial Informatics*, vol. 19, no. 1, pp. 109–120, Jan. 2023, doi: 10.1109/TII.2022.3165643.

[6] Pidikiti, Tripura, *et al.* "Design and control of Takagi-Sugeno-Kang fuzzy based inverter for power quality improvement in grid-tied PV systems." Measurement: Sensors 25 (2023): 100638.

[7] S. R. Das, P. K. Ray, A. K. Sahoo, and G. Dhiman, "Application of optimisation technique in PV integrated multilevel inverter for power quality improvement," *Computers & Electrical Engineering*, vol. 97, p. 107606, Jan. 2022, doi: 10.1016/j.compeleceng.2021.107606.

[8] A. Benabdelkader *et al.*, "Enhanced power quality in single-phase grid-connected photovoltaic systems: an experimental study," *Energies*, vol. 16, no. 10, p. 4240, May 2023, doi: 10.3390/en16104240.

[9] S. K. Paramasivam *et al.*, "Solar photovoltaic based dynamic voltage restorer with DC-DC boost converter for mitigating power quality issues in single phase grid," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol. 44, no. 1, pp. 91–115, Mar. 2022, doi: 10.1080/15567036.2021.1984614.

[10] O. E. Okwako, Z.-H. Lin, M. Xin, K. Premkumar, and A. J. Rodgers, "Neural network controlled solar pv battery powered unified power quality conditioner for grid connected operation," *Energies*, vol. 15, no. 18, p. 6825, Sep. 2022, doi: 10.3390/en15186825.

[11] R. Potharaju and M. Aruna, "Analysis of physico chemical parameters of medchal lake in Telangana State," *International Journal of Scientific Research in Science and Technology*, vol. 8, no. 2, pp. 369–381, Apr. 2021, doi: 10.32628/ijsrst218257.

[12] S. Surabhi, S. Aayushi, and D. Kirtiraj, "Assessment of environmental condition and its effect on biological parameters of farm women," *National Academy Science Letters*, pp. 1–4, 2024, doi: 10.1007/s40009-023-01377-x.

[13] P. K. Pandey and S. Mohammad, "Magnetic and slant curves in Kenmotsu manifolds," *Surveys in Mathematics and its Applications*, vol. 15, pp. 139–151, 2020.

[14] M. Noroozi, F. Haghjoo, H. Javadi, and M. Reza Zolghadri, "Power quality improvement in single-phase transformerless semi-quasi-Z-source inverters for off-grid photovoltaic systems," *International Journal of Electrical Power & Energy Systems*, vol. 145, p. 108703, Feb. 2023, doi: 10.1016/j.ijepes.2022.108703.

[15] R. Boopathi and V. Indragandhi, "Experimental investigations on photovoltaic interface neutral point clamped multilevel inverter-based shunt active power filter to enhance grid power quality," *IEEE Access*, vol. 12, pp. 74482–74498, 2024, doi: 10.1109/ACCESS.2024.3405533.

[16] A. Hassan, O. Bass, Y. M. Al-Abdeli, M. Masek, and M. A. S. Masoum, "A novel approach for optimal sizing of stand-alone solar PV systems with power quality considerations," *International Journal of Electrical Power & Energy Systems*, vol. 144, p. 108597, Jan. 2023, doi: 10.1016/j.ijepes.2022.108597.

[17] B. Deffaf, N. Debdouche, H. Benbouhenni, F. Hamoudi, and N. Bizon, "A New control for improving the power quality generated by a three-level T-type inverter," *Electronics*, vol. 12, no. 9, p. 2117, May 2023, doi: 10.3390/electronics12092117.

[18] D. Atsu, I. Seres, and I. Farkas, "Power quality assessment and compliance of grid-connected PV systems in low voltage networks using microinverters," *Energy Systems*, pp. 1–32, Apr. 2024, doi: 10.1007/s12667-024-00665-9.

[19] E. Tamrakar, R. N. Patel, A. Kumar, A. K. Sahu, and R. Ruchira, "Experimental investigation and power quality analysis of solar micro-inverter for different operating conditions," *E3S Web of Conferences*, vol. 405, p. 02024, Jul. 2023, doi: 10.1051/e3sconf/202340502024.

[20] W. Guo and W. Xu, "Research on optimization strategy of harmonic suppression and reactive power compensation of photovoltaic multifunctional grid connected inverter," *International Journal of Electrical Power & Energy Systems*, vol. 145, p. 108649, Feb. 2023, doi: 10.1016/j.ijepes.2022.108649.

[21] T. Ravi, K. S. Kumar, C. Dhanamjayulu, B. Khan, and K. Rajalakshmi, "Analysis and mitigation of PQ disturbances in grid connected system using fuzzy logic based IUPQC," *Scientific Reports*, vol. 13, no. 1, p. 22425, Dec. 2023, doi: 10.1038/s41598-023-49042-z.

[22] M. A. Ebrahim *et al.*, "AI-based voltage and power quality control of high-penetration grid-connected photovoltaic power plant," *Frontiers in Energy Research*, vol. 11, Aug. 2023, doi: 10.3389/fenrg.2023.1178521.

[23] A. M. D. S. Alonso, L. Arenas, J. P. Bonaldo, J. D. A. olímpio Filho, F. P. Marafão, and H. K. M. Paredes, "Power quality improvement in commercial and industrial sites: an integrated approach mitigating power oscillations," *IEEE Access*, vol. 12, pp. 50872–50884, 2024, doi: 10.1109/ACCESS.2024.3385991.

[24] N. Patel, A. Kumar, H. R. Pota, R. C. Bansal, and N. Gupta, "Adaptive qXE-LMF filter for improving power quality using grid-supporting photovoltaic system," *IEEE Systems Journal*, vol. 17, no. 2, pp. 2709–2720, 2023, doi: 10.1109/JSYST.2023.3241346.

[25] H. Singh and D. Srivastava, "Sentiment Analysis: Quantitative Evaluation of Machine Learning Algorithms," *Proceedings of the 5th International Conference on Smart Systems and Inventive Technology (ICSSIT 2023)*, DVD Part Number: CFP23P17-DVD; ISBN: 978-1-6654-7466-5

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