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Enhanced Grid Stability through Optimized Photovoltaic Integration Using Low-Voltage Ride-Through and DSTATCOM

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ABSTRACT
The increasing penetration of photovoltaic (PV) systems into modern power grids necessitates effective strategies to maintain grid stability during disturbances. This study investigates the optimization of grid-connected PV systems by incorporating Low-Voltage Ride-Through (LVRT) capability in conjunction with a Dynamic Static Synchronous Compensator (DSTATCOM). LVRT enables PV systems to remain connected to the grid during voltage sags, while DSTATCOM provides dynamic reactive power support, thereby enhancing voltage regulation and overall system stability. The coordinated operation of these technologies is analyzed to assess their impact on mitigating voltage fluctuations and ensuring secure power transfer under fault conditions. Simulation results demonstrate that the combined implementation of LVRT and DSTATCOM significantly improves grid stability compared to conventional PV integration without these control features. The findings highlight the importance of advanced control strategies and grid-supportive technologies for reliable and grid-friendly integration of photovoltaic systems..

Keywords: *Photovoltaic systems, Grid stability, Low Voltage Ride Through (LVRT), Dynamic Static Synchronous Compensator (DSTATCOM), Renewable energy integration, Power grid resilience.*
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1. INTRODUCTION:

Over the past two decades, renewable energy sources integration into power systems has had an unprecedented growth. This surge is due to the global need to shift the world from fossil-based power systems towards a sustainable energy use, a reduction on greenhouse gas emissions and an increase in energy security. As a result, the daily production of photovoltaic (PV) systems is rapidly becoming a major part of the generation mix. While [1] they are clean resources that promise abundant energy, the unmistakable increase in PV penetration is presenting grid operation and stability challenges.

The inherent intermittent nature of solar variability and weather impacts make PV generation subject to fluctuations, creating variations in voltage and frequency levels that inevitably cause deviations from normal power quality levels. These events can influence grid stability and reliability, and will require advanced control strategies and grid-friendly features to make them work.

In particular, ensuring grid stability with increasing levels of PV penetration requires the development of LVRT capability for PV inverters [2]. LVRT allows a PV inverter to remain intact to the grid and continue supplying power. Without this capability, when the voltage in a grid section dips or is momentarily disturbed, inverters will automatically disconnect from the grid. With a significant amount of PV capacity, this disruption can cause widespread blackouts by triggering a chain reaction known as a 'domino' effect, in which a loss of generation in one section leads to grid disruption in another due to the flow of power through circuit breakers. LVRT mitigates this risk, as it [3] allows inverters to retain grid connection, thus reducing the chance of disruption in other grid sections and stabilising grid operation during the transient event.

Besides the LVRT capability, Dynamic Static Synchronous Compensator (DSTATCOM) [4], which can enhance grid stability by providing rapid reactive power support is also becoming increasingly attractive. DSTATCOM is a fast-responding flexible compensator able to provide fault-current-limiting functions, reactive power support, voltage control and harmonic control. DSTATCOM can provide in-phase reactive power support to match the local load and also out-of-phase reactive power support to compensate for the harmonic current, thereby improving power quality and grid stability.

This synergy [5] between LVRT capability and DSTATCOM integration ensures a holistic approach to solve grid stability issues due to high-penetration PV systems. An integrated PV plant design with advanced control algorithms and real-time monitoring coordinate PV inverters and grid-supportive devices to operate without and with any disturbances in a grid environment.

In this paper [6], the integration of LVRT capability with Photo-voltaic system is presented, to improve the stability of the grid. Based on available studies from literature; simulation, and case studies; benefits and drawbacks of

PV system with LVRT integrations will be explained. Furthermore, combination of LVRT capability with DSTATCOM integrations and their synergic effects towards stability and grid resiliency will also be examined.

Real challenges in integrating PV systems into the grid is maintaining stability

Scaling up and integrating photovoltaic systems into the existing grid is complex, and stability is of paramount importance. Here is an outline of why stability is an important issue and what that means

Variability and Intermittency: PV are also intermittent power sources that depend on the amount of sunlight, which is variable throughout the day, year and region [7]. The resulting power generation fluctuates and creates voltage and frequency deviations that must be balanced for the grid to retain stability.

Voltage Regulation: When PV systems are fed into the grid, it will cause fluctuation of the system voltage, which may exceed the present design limits of the grid [8]. The voltage profile along the distribution system networks could be seriously influenced by the high penetration of PV systems. Over-voltages could occur at low load point of a system when solar production is high.

Grid Infrastructure and Capacity: In fact, most of the installed grids were created for centralised power generation sources such as large power plants to provide electricity through a transmission and distribution network [9]. In order to integrate decentralised and volatile aspects of PV systems, the grid infrastructure has to be augmented by adding new transmission lines or upgrading existing transformers and substations to deal with different dynamics of power flow.

Protection Coordination: Distributed generation through PV means that the protection schemes of the grid are no longer bilateral, as power can now flow in multiple directions. The existing protection devices might not detect faults anymore or malfunction due to changed flows [10], which can lead to safety risks or damage equipment.

Frequency Control: All readers know that frequency stability is one of the most imperative aspects of grid management. Large power plants provide an inertial contribution towards this through their inertia. PV panels are not accompanied by inertia by default, and those connected through an inverter do not provide the same inertial contribution. This [11] lack of inertia from PV can lead to faster, more 'noisy' frequency changes, and can cause more trouble in maintaining stable grid frequency (for example, at high penetration levels).

Real-Time Monitoring and Control: Variability and instability are dealt with by adding advanced monitoring and control systems to grids – in the form of smart meters, sensors embedded in power systems and grids, and advanced forecasting systems [12] to predict power output from PV, and allow grids to respond accordingly. The grid should be able to capture and use real time data and controls to balance supply and demand, and grid stability.

Regulatory and Market Structures: Further, integrating PV systems challenges existing regulatory and market structures, all built on the premise of centralised generation, and requires new regulations and market mechanisms for reflecting distribution generation sources, including fair pricing and investment in grid infrastructure upgrades.

Objective

Integrating high-penetration photovoltaic (PV) systems into electrical grid can enormously inject unstable power elements into the grid system, both on grid and circuit levels, which threat a lot to power quality and grid stability significantly. The main concern of this article is to provide an overall view of the related problems and feasible measures. Following are the author's objectives:

Understanding the grid integration challenges: This research is set to deliver a truly deep grasp of the challenges of grid integration of high-penetration PV, covering related technical, infrastructural challenges, such as solar variability, voltage issues, grid integration issues etc.

Survey of Multifunctional Inverters, LVRT Capability, and DSTATCOM: This review will explore the possible advantages and roles of multifunctional inverters, LVRT capability and distribution static compensators (DSTATCOM). These technologies will facilitate improved PV performance and efficiency in a scenario highly penetrated by PVs. Multifunctional inverters convert DC electricity to AC but, at the same time, provide services of reactive power control and harmonic compensation to the grid to stabilize it.

Reviewing Advanced Power Control Methods: Detail of the various advanced power control methods that can be used, such as Controller for Maximum Power Point tracking, Reactive Power for controlling the inductive Reactive component, Voltage for controlling output voltage from the inverter, and Harmonic for compensating and avoiding the harmonic generation from Photovoltaic system. Effective implementation of these methods is necessary to improve the Photovoltaic system operation and to be in accordance with current grid operations.

Recent Advancements and Future Research Directions: At the end of the review, the advancements in the aforementioned control techniques, as well as the future research directions, will be discussed. Consideration of new technologies that will be developed, better methodologies for already developed technologies to increase their efficacy, and new approaches to overcome the persisting PV integration problems with new technological advancements would be included in this section.

Achieving these objectives will enable the research to contribute important insights for integrating sophisticated power control techniques for high penetration opportunities in a selection of different types of PV systems, enabling power generating and distribution to become more resilient and sustainable in the future, which is now more urgent than ever before as communities strive for clean renewable energy systems with high reliability.

2. LITERATURE REVIEW

A comprehensive literature related to the incorporation of high-penetration PV into the electrical power grid shows a variety of research, technology innovations and practical applications of the power system. This study gives a comprehensive view of the technologies, implementation, and control solutions for high electric grid PV penetration.

One of the significant issues pointed to in the literature is grid stability, which is intertwined with the variability of PV systems. Solar power is an intermittent source of energy generation. Power generation fluctuations could cause tremendous volatility in the grid frequency and voltage. Studies reveal that a significant increase in these volatilities above reference levels could compromise the power supply reliability and potentially lead to severe damages to grid infrastructures if not mitigated properly. The issue of variability underlines the need for an adaptive grid management that could detect rapid changes in levels of energy generation.

According to [13], multifunctional inverters are the key technology to tackle these 'integration challenges' in ways that go beyond simply converting DC solar energy into AC grid-quality power supply: Multifunction inverters provide vital services for frequency regulation, voltage support, and load balancing, and these functions are central to providing active grid support and the stability that makes the grid resilient and reliable.

Finally, around a third of the studies focused on yet another widely accepted EU standard, that is, the inverter's LVRT capabilities. LVRT refers [14] to an inverter's ability to continue operation and inject power into the grid during temporary voltage dips, thereby providing grid support and helping to stabilise it. In several case studies, detailed by Zhang et al, LVRT-capable inverters were installed and shown to prevent potential disturbances due to sudden voltage dips, with many documented cases.

Distribution static compensators (DSTATCOM) are also widely discussed in the literature for enhancing power quality in systems with high PV integration by improving power quality factors such as voltage sag, swell and flicker, which are a main problem in distribution networks with high penetration rates of intermittent renewables [13]. Gupta and Kumar (2017) present empirical evidence of the effective use of DSTATCOMs for maintaining the stability of voltage levels during PV curtailments, thus improving the power quality and assisting with the grid integration of PVs.

MPPT is one of the advanced power controller techniques that provide better performance for PV systems by maximising the energy yield by operating at P_{maz} for different solar irradiance profiles and for different temperatures. MPPT techniques [14]work on the principle of perturbation and observation by moving the working point of a PV panel up and down within its I-V curve. It can be further enhanced through the utilisation of mature mathematics, such as advanced optimisation. Many studies have been done using MPPT, for example, Lee and Chen (2019), which revealed that MPPT can enhance the efficiency of PV installations, especially where solar irradiance fluctuates significantly.

The management of reactive power by PV systems is another area of noticeable improvement, helping to keep voltage stable across the grid. For example, [15], when as entire grid area is covered by clouds suddenly, solar power generation would likely drop massively. Without the flexibility of the conversion technologies and stabiliser devices, the change could lead to voltage instability. Reactive power control technology is therefore of paramount importance for attaining high PV penetration while systems retain stable operations Maintaining voltage stability through reactive power control technologies.

The ability of modern PV inverters to regulate voltage is another important aspect of grid integration [16]. This improves the grid's operation by preventing adverse variations in grid voltage levels, which can have an effect on the grid infrastructure as much as on the consumers of it. Some researchers have concluded that including voltage regulation functions in PV inverters is helpful in minimising the risk of these voltage-related problems.

Harmonic compensation is another essential function that these sophisticated inverters deliver. PV systems, like most pieces of electronics equipment, produce electrical harmonics when connected to the grid [17]. In some circumstances, the harmonics can degrade power quality and efficiency. Harmonic compensation techniques are used to minimise these effects. The authors Patel and Agarwal (2018) argue that such techniques and the use of harmonic compensated inverters improve the efficiency of systems, and prolong the life of electrical devices because they are less stressed by poor power quality.

So, even though these new smart and multifunctional control technologies have an abundance of advantages, there might also be some inherent limitations in these technologies [10]. For example, some of the more sophisticated grid control and filtering devices, such as the aforementioned multifunctional inverters and DSTATCOM devices, can be very costly, especially for smaller and rural grid operations. The technical and logistical problems of combining these technologies into already existing grid infrastructures can also be exorbitant.

Additional research goals suggested in these studies include the need for achieving lower costs and more easily implemented technology integration. Standard, global regulatory frameworks and guidelines are also needed to guide local acceptability, regulatory approval and operation.

3. METHODOLOGY

Low Voltage Ride Through and Dynamic Static Synchronous Compensator are two techniques used to improve the stability of a network that might cause a grid collapse. We assessed the performance of both methods using a grid connectivity simulation modelled in MATLAB/Simulink. Our model consists of photovoltaic system, comprising of solar panels and different inverters and control systems that are connected to the grid. The solar panels are modelled using the equation $P= G*A*\eta$, where P denotes power, G is irradiance, A is the area, and η

η represents efficiency. The grid simulation incorporates standard power distribution components, including transformers, power lines represented by the impedance $Z_{line} = R + jX$ (where R is equal to resistance and X is equal to reactance, respectively.), and dynamic load models.

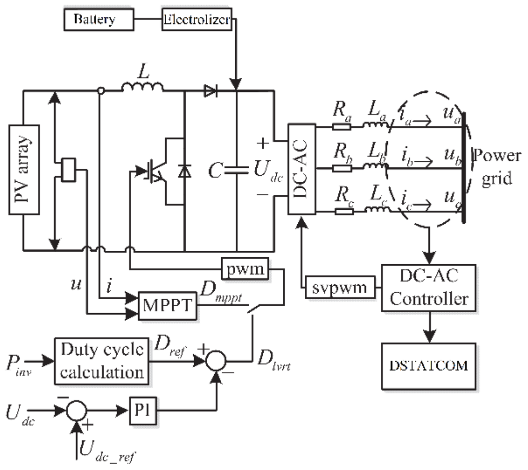

Figure 1 : System structure diagram of active LVRT and DSTATCOM strategy

The proposed grid-connected photovoltaic system consists of 235 strings, with each string comprising 16 modules connected in series. The electrical specifications include a maximum current of 1889.4 A, calculated by multiplying the per-module current of 8.04 A by 235 strings. The system voltage is 796.48 V, determined by the per-module voltage of 49.78 V across 16 modules, resulting in a total dc output power of approximately 1.5 MW (1889.4 A x 796.48 V). Additionally, the open-circuit voltage of the PV array is noted as 960 V, which is the product of 60 V per module and 16 modules in series. The short-circuit current is measured at 2011.6 A, computed from 8.56 A per module across 235 strings.

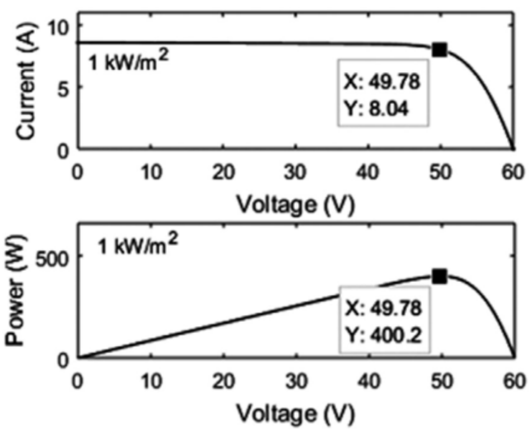

Figure 2 : Characteristics curve of proposed P-V module

The dc-link voltage in the system is kept at 800V, matching the max. power point output voltage of the P-V modules. This alignment is verified using a MATLAB/SIMULINK model of the proposed PV array, as illustrated in Figure 2.

Table 1 : Parameters of PV cell

Specifications Values	
Max. power (*P*max)	400 W
Max. power point voltage (*V*mpp)	49.78 V
Max. power point current (*I*mpp)	8.05 A
Open circuit voltage (*V*oc)	60 V
Short circuit current (*I*sc)	8.56 A
Cell number per module (*N*cell)	96
Temperature coefficient of open circuit voltage (*αv*)	–0.367°C
Temperature coefficient of short circuit current (*αi*)	0.043°C
Series resistance (*R*se)	389.9 Ω
Parallel resistance (Rsh)	0.33 Ω
Ideally factor of diode (n)	1.02

During LVRT mode, the P-V system faces imbalances and transients that impact both the dc side voltage and ac side current. A novel control strategy that combines Proportional-Integral (PI) and Perturb & Observe (P&O) techniques with Indirect Power Transfer (IPT) makes sure that the P-V power plant remains functional during faulty conditions. This method effectively handles overvoltage and overcurrent scenarios, in compliance with the requirements of the Malaysian grid code. Under normal conditions, when the grid voltage is within 90% to 110% of its nominal value, the system operates in its standard mode. However, any deviation outside this voltage range activates the LVRT mode.

During fault conditions or voltage sags, adjusting the reactive current setting is essential to ensure the inverter can inject sufficient amount of active power to restore grid voltage to acceptable levels, as mandated by LVRT protocols. In this system, the reactive current is intentionally kept at zero, prioritizing the stabilization of active power output. Graphical representations highlight the system's performance under these conditions, including the P-V side voltage and power, along with active and reactive power of grid side. These visuals demonstrate the effectiveness of the control of inverter during both symmetrical and asymmetrical faults on the grid side. The data visually underscore the system's robust response and reliability across various challenging operational scenarios.

The harmonic loss in a smart microgrid can be significantly mitigated through the deployment of advanced technologies and control strategies. A key technology in this context is the Distribution Static Synchronous Compensator (DSTATCOM), which plays a crucial role in managing power quality. By injecting compensating currents that are in phase and of equivalent magnitude to the harmonic currents (Icomp = -Iharmonic), the DSTATCOM effectively neutralizes undesirable harmonics. It utilizes the Instantaneous Reactive Power Theory (IRPT) to continuously monitor the load current, identify the harmonic components, and generate corresponding compensating currents in real time.

Additionally, LVRT capability in PV inverters enhances the resilience of the grid. LVRT assists in managing instances of slight voltage dips in the grid, enabling the system to continue injecting reactive power to support and stabilize the grid voltage. This feature not only aids in maintaining grid stability during under-voltage events but also contributes to reducing the harmonic content, further improving the overall efficiency and reliability of the smart microgrid.

Indeed, multifunctional inverters with Voltage Source Converter (VSC) control are key assets for harmonic mitigation. VSC inverters use PWM to produce, when used as grid-connected devices, a smooth sinusoidal output, and may also be implemented as active filters. PWM ensures that the magnitude of the harmonic currents injected into the grid by active inverter loads (for example, power-electronic devices and DC-coupled microgrids) may be minimised. The inverter output current may be written as

$I_{inv}(t) = I_{fund}(t) + I_{filter}(t)$, where $I_{fund}(t)$ is the fundamental current and $I_{filter}(t)$ is the filtering current. Control algorithms which are advanced in nature, such as Model-Predictive Control (MPC), further improves the performance by predicting.

4. RESULT AND DISCUSSION

The system was evaluated under normal operating conditions, and results are showcased in Figure 1. During these conditions, the inverter functioned efficiently, delivering an output voltage of 796.4 V and generating approximately 1504 kW of power from the P-V power plant, while upholding standard grid-side specifications of 33 kV and 1 MW of grid power. Under these regular operational parameters, the maximum possible active current was injected into the grid, and there was no injection of reactive current. However, these operating conditions were disrupted during fault scenarios or voltage sags. Normally, the inverter would disconnect from the grid under such disturbances, but with the adoption of advanced control strategies, it was capable of transitioning to LVRT mode, thus maintaining its grid connection. In this mode, the dc link voltage encouraged the P-V plant to operate at its maximum power point, aligning with the open-circuit voltage of the PV panels.

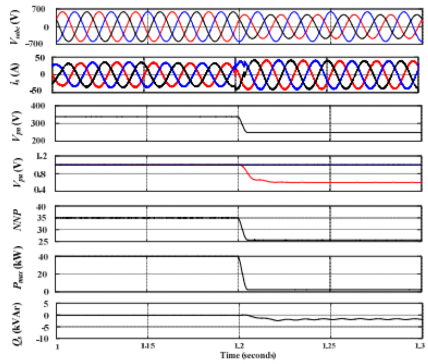

Figure 3 : Simulated results for Line to Ground fault on the grid side network

During these incidents, it was crucial to provide support of substantial active and reactive current to stabilize the grid-side. The implemented control strategies successfully managed to inflow the necessary reactive current, effectively mitigating the disturbances. While the recovery to pre-fault voltage, current, and power levels took longer during the three-phase fault, the system was able to recover more swiftly from the line-to-line fault. This difference in recovery times highlights the varied effectiveness of the proposed control approaches under different types of fault conditions. These observations underscore the robustness of the control system in adapting to and addressing diverse operational challenges within the grid.

5. CONCLUSION

An optimization study on a photovoltaic (PV) system comprising with LVRT capabilities and a Dynamic Static Synchronous Compensator (DSTATCOM) highlights significant potential for enhancing grid stability. These advanced technologies improve grid stability by enabling the PV system to handle grid disturbances effectively and operate under various fault conditions, including voltage sags. Additionally, the PV system is capable of giving reactive power to support the grid.

The study includes simulations conducted under nominal conditions that display the current output of each converter. Managed by a general control unit, the active and reactive powers are dynamically provided to the grid based on predefined control strategies. This setup not only ensures the grid's operational efficiency but also enhances its resilience against disruptions, thereby maintaining consistent power quality and supply.

A simulation of under-voltage conditions concludes that by turning on LVRT, the PV system is able to keep itself on the grid and normalised power transfer, while without LVRT, the power transfer is prevented.

Furthermore, the transient simulation reveals the voltage enhancement by inserting DSTATCOM, if not, the voltage would oscillate.

Going forward, further improvements could include developing more advanced control algorithms for dynamic load and voltage sag mitigation to handle a wider range of grid conditions. Finally, the approach can be applied to other renewable energy systems such as wind turbines and their control. Actual lab- and field-scale pilot testing of the technologies could be performed and their performance as well as real-world challenges would be gathered. Further work could also look at new energy storage technologies; the main objective would be to enhance the resilience and efficiency of grid-connected PV. Modern grid infrastructures could be explored; finally, economic and regulatory studies could be performed to understand the technical feasibilities and economics of the solutions under a range of different grid conditions that span across different regions and situations in the market.

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AUTHOR CONTRIBUTION

This project focuses on optimizing Photo-voltaic (P-V) systems with LVRT capabilities and Dynamic Static Synchronous Compensators (DSTATCOM) for grid stability. Author 1 conceptualized the project, integrated the LVRT, conducted simulations and data analysis, and wrote part of the manuscript. Author 2 integrated the DSTATCOM, optimized its performance, and wrote the remaining sections after conducting a literature survey.

CONFLICTS OF INTEREST

The authors confirm that there are no potential competing interest among the author.

REFERENCES

1. T. E. K. Zidane, A. S. Aziz, Y. Zahraoui, H. Kotb, K. M. Aboras, Kitmo and Y. B. Jember, Grid-Connected Solar PV Power Plants Optimization: A Review, vol. 11, 2023.
2. W. Zhou, Y. Zheng, Z. Pan and Q. Lu, Review on the battery model and SOC estimation method, vol. 9, 2021.
3. H. Zheng, F. Xu, Q. Shu, C. Wang and Q. Zhou, “Estimation of harmonic impedance and harmonic contribution with harmonic complex power in the absence of harmonic phase angle,” IET Generation, Transmission and Distribution, vol. 17, no. 1, 2023.
4. W. Yuan, X. Yuan, L. Xu, C. Zhang and X. Ma, “Harmonic Loss Analysis of Low-Voltage Distribution Network Integrated with Distributed Photovoltaic,” Sustainability (Switzerland), vol. 15, no. 5, 2023.
5. Y. T. Wassie and E. O. Ahlgren, “Performance and reliability analysis of an off-grid PV mini-grid system in rural tropical Africa: A case study in southern Ethiopia,” Development Engineering, vol. 8, 2023.
6. X. Wang and F. Blaabjerg, “Harmonic Stability in Power Electronic-Based Power Systems: Concept, Modeling, and Analysis,” IEEE Transactions on Smart Grid, vol. 10, no. 3, 2019.
7. P. Unruh, M. Nuschke, P. Strauß and F. Welck, “Overview on grid-forming inverter control methods,” Energies, vol. 13, no. 10, 2020.
8. K. H. Tan, M. Y. Li and X. Y. Weng, “Droop Controlled Microgrid With DSTATCOM for Reactive Power Compensation and Power Quality Improvement,” IEEE Access, vol. 10, 2022.
9. U. Subramaniam, S. Vavilapalli, S. Padmanaban, F. Blaabjerg, J. B. Holm-Nielsen and D. Almakhles, “A hybrid PV-battery system for ON-grid and off-grid applications-controller-in-loop simulation validation,” Energies, vol. 13, no. 3, 2020.
10. R. Sharma, A. Zakerian and M. Karimi-Ghartemani, “Local Controller for an Autonomous Grid-Supportive Battery Energy Storage System,” IEEE Transactions on Power Electronics, vol. 37, no. 2, 2022.
11. T. Salameh, A. K. Hamid, M. M. Farag and E. M. Abo-Zahhad, “Experimental and numerical simulation of a 2.88 kW PV grid-connected system under the terrestrial conditions of Sharjah city,” Energy Reports, vol. 9, 2023.
12. D. K. Rukmani, Y. Thangaraj, U. Subramaniam, S. Ramachandran, R. M. Elavarasan, N. Das, L. Baringo and M. I. A. Rasheed, “A new approach to optimal location and sizing of DSTATCOM in radial distribution networks using bio-inspired cuckoo search algorithm,” Energies, vol. 13, no. 18, 2020.
13. D. J. Rincon, M. A. Mantilla, J. M. Rey, M. Garnica and D. Guilbert, An Overview of Flexible Current Control Strategies Applied to LVRT Capability for Grid-Connected Inverters, vol. 16, 2023.
14. I. Murzakhanov, G. M. Vishwanath, K. Vemalaiah, G. Prashal, S. Chatzivasileiadis and N. P. Padhy, “A novel decentralized inverter control algorithm for loss minimization and LVRT improvement,” Electric Power Systems Research, vol. 221, 2023.
15. O. P. Mahela, N. Gupta, M. Khosravy and N. Patel, “Comprehensive overview of low voltage ride through methods of grid integrated wind generator,” IEEE Access, vol. 7, 2019.
16. X. Liu, G. Chang, J. Tian, S. Li and C. Chen, “Regrouping strategy of retired batteries considering SOC consistency,” Energy Reports, vol. 8, 2022.
17. Q. Lagarde, B. Beillard, S. Mazen, M. S. Denis and J. Leylavergne, Performance ratio of photovoltaic installations in France: Comparison between inverters and micro-inverters, vol. 35, 2023.
18. A. Khursheed, M. Ilyas, K. M. Rafi and A. S. Azad, “A Novel Modified PSO Algorithm to Optimise the PV Output Power of Grid-Connected PV System,” SSRG International Journal of Electrical and Electronics Engineering, vol. 10, no. 7, 2023.
19. K. Hasan, S. B. Yousuf, M. S. H. K. Tushar, B. K. Das, P. Das and M. S. Islam, Effects of different environmental and operational factors on the PV performance: A comprehensive review, vol. 10, 2022.
20. A. Harrag and S. Messalti, Variable step size modified P&O MPPT algorithm using GA-based hybrid offline/online PID controller, vol. 49, 2015.
21. Y. Gu and T. C. Green, “Power System Stability With a High Penetration of Inverter-Based

Resources," Proceedings of the IEEE, vol. 111, no. 7, 2023.

22. Z. M. S. Elbarbary and M. A. Alranini, "Review of maximum power point tracking algorithms of PV system," Frontiers in Engineering and Built Environment, vol. 1, no. 1, 2021.
23. G. Dileep, "A survey on smart grid technologies and applications," Renewable Energy, vol. 146, 2020.
24. J. H. Chen, K. H. Tan and Y. D. Lee, "Intelligent Controlled DSTATCOM for Power Quality Enhancement," Energies, vol. 15, no. 11, 2022.
25. S. Chakraborty, S. Mukhopadhyay and S. K. Biswas, "Optimal Placement of PV-DSTATCOM Based EV Charging Stations with Dynamic Pricing," IEEE Transactions on Industry Applications, vol. 59, no. 6, 2023.
26. J. M. Akanto, M. R. Hazari and M. A. Mannan, "Lvrt and stability enhancement of grid-tied wind farm using dfig-based wind turbine," Applied System Innovation, vol. 4, no. 2, 2021.
27. S. M. Ahsan, H. A. Khan, A. Hussain, S. Tariq and N. A. Zaffar, "Harmonic analysis of grid-connected solar PV systems with nonlinear household loads in low-voltage distribution networks," Sustainability (Switzerland), vol. 13, no. 7, 2021.
28. ahmed Ali, R. A. E.-K. El-Kammar, H. F. A. Hamed, A. A. Elbaset and A. Hossam, "A developed IoT technique and P&O-MPPT to enhance the output power of solar cell systems," Journal of Engineering Research, vol. 7, no. 5, 2023.
29. J. Ahmed and Z. Salam, "An improved perturb and observe (P&O) maximum power point tracking (MPPT) algorithm for higher efficiency," Applied Energy, vol. 150, 2015.
30. G. A. Adepoju, S. A. Salimon, I. G. Adebayo and O. B. Adewuyi, "Impact of DSTATCOM penetration level on technical benefits in radial distribution network," e-Prime - Advances in Electrical Engineering, Electronics and Energy, vol. 7, 2024.
31. A. A. Abdelsalam, S. S. M. Ghoneim and A. A. Salem, "An efficient compensation of modified DSTATCOM for improving microgrid operation," Alexandria Engineering Journal, vol. 61, no