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Modeling of Solar Photovoltaic (PV) System Using Matlab/Simulink

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Abstract: *This study presents a MATLAB/Simulink-based Solar Photovoltaic (PV) model for analysing the electrical performance of a PV module under Standard Test Conditions (25°C and 1000 W/m²). The model utilizes temperature and solar irradiance as input parameters to simulate the output voltage, current, and power characteristics of the PV system. The generated Current–Voltage (I–V) and Power–Voltage (P–V) curves effectively represent the operational behaviour of the PV module and facilitate the identification of the Maximum Power Point (MPP). The simulation results demonstrate stable current generation, increasing power output with voltage, and the influence of environmental conditions on PV performance. The developed model provides an accurate and efficient platform for PV system analysis, performance evaluation, and Maximum Power Point Tracking (MPPT) algorithm development. Consequently, it serves as a valuable tool for the design, optimization, and assessment of solar photovoltaic energy systems.*

Keywords: Solar Photovoltaic (PV) System, MATLAB/Simulink, I–V and P–V Characteristics, Maximum Power Point Tracking (MPPT), Solar Irradiance and Temperature.

I. INTRODUCTION

Solar-energy conversion infrastructures now serve as an essential part of contemporary sustainable power technologies, providing clean, renewable energy production. However, the operation and consistency of grid-integrated PV systems depend largely on effective power extraction and dynamic control strategies. MPPT serves a key function in maximizing energy capture from photovoltaic panels by frequently varying their operating point in response to modulating environmental factors. Traditional MPPT techniques commonly face slow response and volatility in rapidly changing irradiance or temperature. To tackle these issues, MPPT algorithms that utilize optimization achieve fast and accurate MPPT, resulting in improved system efficiency

On the control side, grid integration requires robust inverter regulation methods that ensure high power quality and dynamic stability. pace Vector–oriented PWM technique is commonly adopted for its exceptional harmonic efficiency and DC link utilization. When combined with advanced intelligent control methods, such as Recurrent Neural Networks (RNNs), SVPWM-based control can adapt dynamically to system changes, predicting and compensating for nonlinearities and disturbances in real time.

The growing demand for energy and the need to reduce fossil fuel dependence have increased the adoption of solar photovoltaic (PV) systems due to their environmental benefits and sustainability. Grid-connected PV systems support renewable energy integration, distributed generation, and smart-grid functionalities. However, challenges such as fluctuating irradiance, nonlinear system behaviour, voltage variations, harmonic distortion, and reactive power imbalance affect system performance and grid stability. Moreover, advanced control techniques often involve high computational burden, increased hardware costs, and greater controller complexity, limiting their real-time implementation. Therefore, there is a need for efficient and cost-effective control strategies that ensure maximum energy extraction, improved power quality, and reliable real-time operation in grid-connected PV systems. Grid-connected power systems must comply with IEEE 519 and IEC 61000 standards to ensure power quality and reliable

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operation. IEEE 519 recommends that THD at the PCC should not exceed 5%, while IEC 61000 defines limits for harmonic emissions. Excessive harmonics increase losses, reduce efficiency, and degrade power quality. Therefore, harmonic reduction and accurate grid synchronization are essential for stable grid integration and standards compliance. A dual-stage PV-grid system uses a 2-level power-conversion architecture to efficiently transfer energy among the power grid and the PV array while maintaining high energy yield and power quality. In this structure, a boost converter is utilized at the front end of the system that controls the PV operating voltage and applies MPPT, enabling continuous extraction of optimal power at varying temperatures and sun irradiance conditions. The next stage works as an inverter that transforms the DC into grid-compatible AC using SVPWM, a control strategy that improves switching efficacy, reduces THD, and maximizes the applicable use of the DC voltage. This architecture enhances system reliability, provides better dynamic response compared to single-stage systems, and facilitates seamless grid integration, supporting voltage and frequency regulation while enabling the PV system to meet modern grid codes and standards.

II. LITERATURE REVIEW

The growing global need for green and eco-friendly energy has greatly increased the use of photovoltaic (PV) systems in modern power networks. Over time, solar PV technology has grown from small, standalone installations to sophisticated grid-connected systems capable of delivering large-scale power. This advancement has been largely driven by continuous developments in power electronic converters, intelligent control techniques, and optimization-based approaches, aiding efficient energy conversion and reliable grid integration.

Recent review studies, such as those reported in [1] and [2], have provided comprehensive evaluations of PV system architectures, tracking methods, and inverter technologies. These works underline that the functioning of grid-PV systems is dependent on efficient energy tracking mechanisms, advanced inverter control, and precise synchronization with the utility grid. They also highlight the importance of selecting appropriate system configurations based on application needs.

The integration of ESS has emerged as a critical solution to attend the inherent intermittence of solar energy. A detailed review in [3] discussed the role of storage technologies in smoothing power fluctuations and increasing the consistency of PV systems. By storing excess energy in peak generation periods and supplying it in low-generation intervals, ESS significantly improves system dispatchability and grid stability. Furthermore, advancements in two-stage converter topologies were explored in [4], demonstrating improved dynamic performance and adaptability under changing environmental conditions.

Modern grid-connected PV systems are increasingly incorporating multilevel inverter topologies, intelligent control algorithms, and advanced optimization techniques. These systems are designed not only for efficient energy conversion but also for enhanced fault tolerance, improved power quality [5], and effective reactive power support. The integration of such features reflects the ongoing evolution of PV technology as basic energy conversion units to highly adaptive and grid-supportive systems.

In summary, the development of grid-connected PV systems has progressed significantly, transitioning from simple configurations to complex, intelligent architectures. Continuous innovations in control strategies, converter design, and system integration have enabled PV systems to meet the growing needs of modern power grids while ensuring efficacy, stability, and compliance with regulatory standards [6].

MPPT plays a fundamental role in PV systems, as it makes sure that the maximum possible energy is traced under continuously varying environmental conditions like solar intensity and temperature. Since the characteristics of PV modules are nonlinear and highly sensitive to external conditions [7], the operating point must be constantly adjusted to maintain optimal performance. Among the earliest and most widely adopted approaches are conventional techniques such as P&O and Inc Cond, which are favoured for their simplicity, low computational requirements, and ease of execution in practical systems [8].

Over time, several upgrades have been introduced to get the performance of these classical techniques. For instance, modifications to the conventional P&O method were proposed in [9], where the amplitude of oscillations near the optimal operating point was lowered, and the transient response was restored. Similarly, adaptive versions of the Incremental Conductance method were developed in [10] and [11], incorporating variable step-size mechanisms. These approaches adjust the perturbation step based on operating conditions, thereby improving tracking speed while reducing steady-state error. Despite these advancements, traditional methods still face limitations, particularly under rapidly changing environmental conditions [12].

Under uniform irradiance, classical MPPT methods generally perform satisfactorily, providing stable and reliable operation. However, in the presence of partial shading conditions (PSC) [13], the P–V characteristic of the PV array shows multiple local maxima instead of a single global peak. In such scenarios, conventional techniques often fail to decide among local and global maxima, indicating to suboptimal power extraction. This limitation has motivated researchers to explore more state-of-the-art AI-driven and bio-inspired optimization methods.

ANNs have evolved as a promising solution for MPPT owing to their capacity to model intricate nonlinear patterns. Early implementations of neural-network-based MPPT were reported in [14] and [15], primarily focusing on inverter control applications. These approaches were later extended to PV power tracking in [16], where a resilient backpropagation (Rprop)-based neural network demonstrated faster convergence and improved tracking efficacy related to traditional methods. Additionally, ANN-assisted sequential Monte Carlo techniques were introduced in [17], offering enhanced robustness under rapidly fluctuating irradiance conditions by effectively estimating the optimal operating point in real time.

In parallel, metaheuristic optimization methods have gained significant attention for MPPT applications due to their strong global search capabilities and flexibility. The ABC algorithm was applied in [18], showing effective performance in locating the global maximum in partial shading scenarios. Similarly [18], Ant Colony Optimization (ACO) was investigated in [19], leveraging probabilistic search mechanisms inspired by ant foraging behaviour. Genetic Algorithm (GA)-based MPPT strategies were explored in [20], utilizing evolutionary principles like selection, crossover, and mutation to identify optimal operating points. Particle Swarm Optimization (PSO) has also been adopted in MPPT research due to its simplicity and fast convergence characteristics. A PSO-based global MPPT method proposed in [21] demonstrated improved tracking performance under complex shading patterns by enabling particles to converge toward the global optimum. Building upon this, several other nature-inspired algorithms have been introduced to further enhance performance. These include Horse Herd Optimization (HHO) in [22], Coot Optimization in [23], and Falcon Optimization in [5], all of which aim to improve convergence speed, avoid local optima, and enhance tracking accuracy under dynamic conditions.

III. PROPOSED MODEL

The figure illustrates a MATLAB/Simulink-based Solar Photovoltaic (PV) Model developed to analyse the electrical characteristics of a solar PV module under specified environmental conditions. The primary objective of this model is to generate and evaluate the Current–Voltage (I–V) and Power–Voltage (P–V) characteristics of the PV module by varying the operating parameters, namely temperature and solar irradiance. On the left side of the model, two Constant blocks are used as input sources. The first block represents the cell temperature, which is set to 25°C, corresponding to the Standard Test Condition (STC). Temperature significantly affects the performance of photovoltaic cells. As the cell temperature increases, the output voltage decreases, leading to a reduction in the maximum power generated by the PV module. Therefore, temperature is an essential parameter for accurately modelling real-world PV performance.

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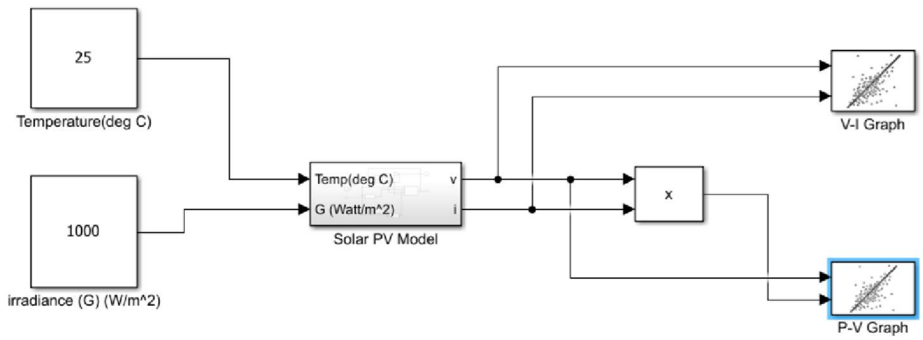

Fig 1 Proposed Model

The second Constant block represents the solar irradiance (G), which is set to 1000 W/m², another standard operating condition for PV testing. Solar irradiance denotes the intensity of sunlight incident on the PV panel. Higher irradiance increases the photocurrent generated within the solar cells, thereby increasing the output current and overall power. Together, temperature and irradiance define the environmental operating conditions of the PV system. Both input signals are connected to the Solar PV Model block, which mathematically represents the electrical behavior of a photovoltaic module. The model is generally based on the single-diode equivalent circuit, incorporating a photocurrent source, diode, series resistance, and shunt resistance. Using the supplied environmental inputs, the PV model computes the corresponding output voltage (V) and output current (I) according to the nonlinear current-voltage equations of the photovoltaic cell. The outputs of the Solar PV Model are divided into two processing paths. In the first path, the voltage (V) and current (I) outputs are directly connected to an XY Graph block labeled V–I Graph. This graph plots the relationship between output current and voltage, producing the characteristic I–V curve of the photovoltaic module. The I–V curve is an important performance indicator because it identifies key parameters such as the short-circuit current (Isc), open-circuit voltage (Voc), and the operating region of the PV module. In the second path, the voltage and current outputs are supplied to a Product (×) block. This block performs a simple multiplication of voltage and current to calculate the instantaneous output power (P = V × I). The calculated power signal, together with the corresponding voltage, is then connected to another XY Graph block labeled P–V Graph. This graph displays the variation of output power with respect to voltage and clearly identifies the Maximum Power Point (MPP), which is the operating point at which the PV module delivers its highest power output. Overall, the Simulink model provides a simple yet effective framework for studying the performance of photovoltaic systems under different environmental conditions. By modifying the temperature and irradiance inputs, users can observe the corresponding changes in the I–V and P–V characteristics, making the model highly useful for PV system analysis, performance evaluation, and the development of Maximum Power Point Tracking (MPPT) algorithms. Consequently, this simulation model serves as a valuable tool for researchers, engineers, and students involved in the design, optimization, and analysis of solar photovoltaic energy systems. The equation are derived as :

1. PV Output Current Equation

The output current of a PV cell is given by:

$$I = I_{ph} - I_D - I_{sh}$$

where:

I= Output current (A)

I_{ph}= Photogenerated current (A)

I_D= Diode current (A)

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I_{sh}= Shunt leakage current (A)
Substituting the diode and shunt current equations:

$$I = I_{ph} - I_o\left[\exp\left(\frac{V + IR_s}{nV_t}\right) - 1\right] - \frac{V + IR_s}{R_{sh}}$$

where:
I_o= Reverse saturation current (A)
V= Output voltage (V)
R_s= Series resistance (Ω)
R_{sh}= Shunt resistance (Ω)
n= Diode ideality factor (typically 1–2)
V_t= Thermal voltage
The thermal voltage is expressed as

$$V_t = \frac{kT}{q}$$

where:
$k = 1.380649 \times 10^{-23}$ J/K(Boltzmann constant)
T= Cell temperature (K)
$q = 1.602176634 \times 10^{-19}$ C(Electron charge)
For a PV module containing $N_s$cells in series,

$$V_t = \frac{N_s kT}{q}$$

2. Photocurrent Equation
The photocurrent depends on irradiance and temperature:

$$I_{ph} = [I_{sc} + K_i(T - T_{ref})]\frac{G}{G_{ref}}$$

where:
I_{sc}= Short-circuit current at STC (A)
K_i= Temperature coefficient of current (A/°C)
G= Solar irradiance (W/m²)

$$G_{ref} = 1000 \text{ W/m}^2$$
$$T_{ref} = 25^{\circ}C$$

3. Reverse Saturation Current

$$I_o = I_{rs}\left(\frac{T}{T_{ref}}\right)^3 \exp\left[\frac{qE_g}{nk}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right]$$

where:
I_{rs}= Saturation current at reference temperature
E_g= Band-gap energy of silicon (≈1.12 eV)

4. PV Output Voltage
Rearranging the current equation gives the voltage expression:

$$V = nV_t\ln\left(\frac{I_{ph} - I}{I_o} + 1\right) - IR_s$$

If the shunt resistance is very high ($R_{sh} \to \infty$), the equation simplifies to

$$I = I_{ph} - I_o\left[\exp\left(\frac{V + IR_s}{nV_t}\right) - 1\right]$$

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5. Power Equation

The electrical output power of the PV module is

$$P = VI$$

where:

P= Output power (W)

V= Output voltage (V)

I= Output current (A)

The maximum power point (MPP) occurs when

$$\frac{dP}{dV} = 0$$

IV. RESULT ANALYSIS & DISCUSION

The Power–Voltage (P–V) graph illustrates the relationship between the output power and terminal voltage of the solar photovoltaic (PV) module under Standard Test Conditions (25°C and 1000 W/m²). In the presented graph, the output power increases almost linearly with increasing voltage, reaching approximately 165–170 W at around 22 V. Since the graph does not show the descending portion beyond the peak, it represents only the operating region before the Maximum Power Point (MPP) is reached. Normally, the P–V curve rises to the MPP and then decreases as voltage approaches the open-circuit voltage. The graph is useful for evaluating PV performance and designing efficient Maximum Power Point Tracking (MPPT). The P-V Graph is represented in Fig 2.

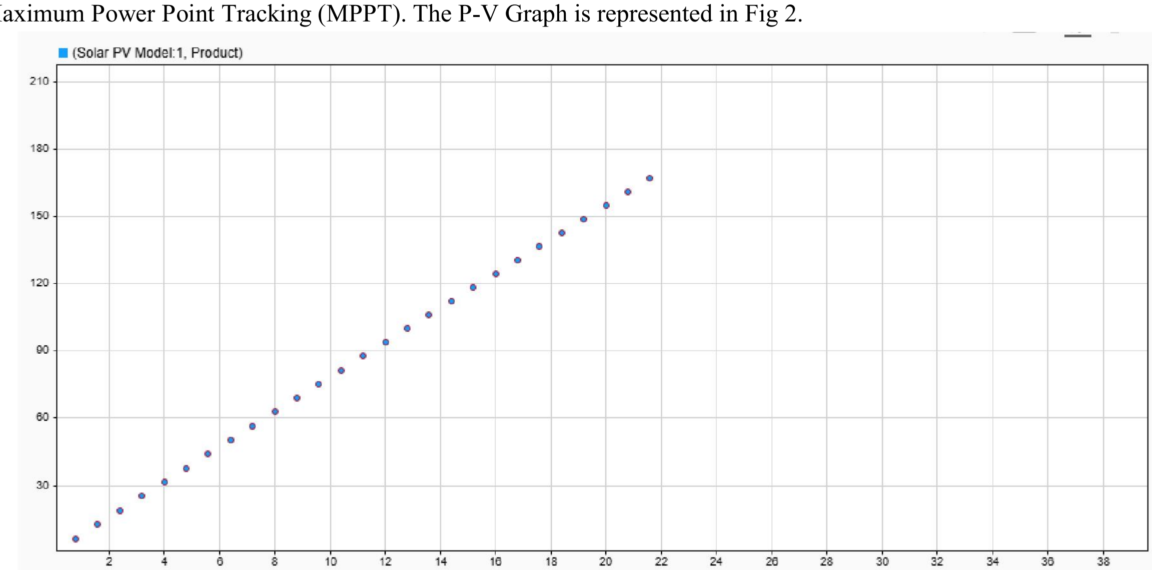

Fig 2 P-V Graph

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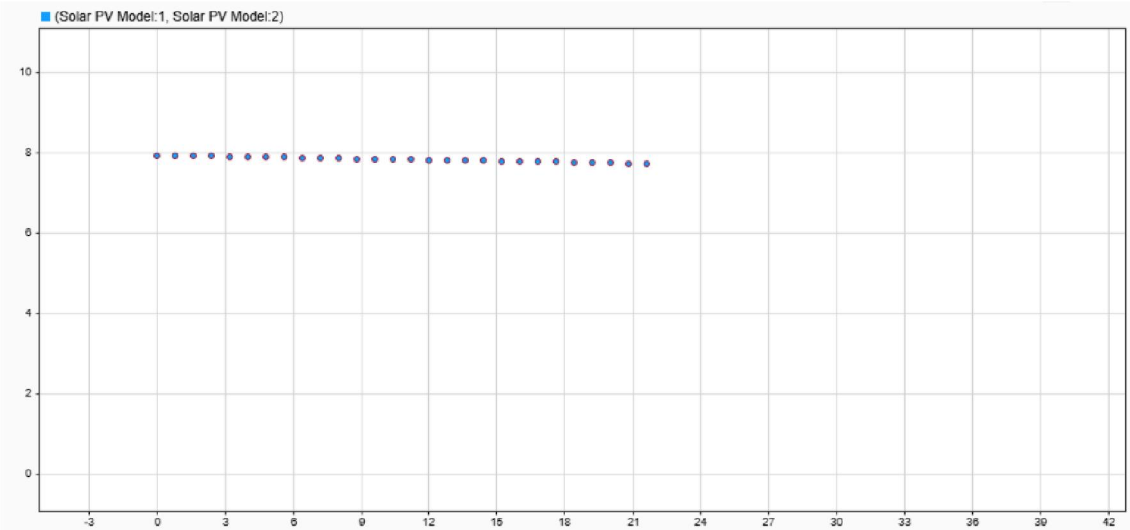

Fig 3 V-I Graph

The Voltage–Current (V–I) graph represents the electrical characteristics of the solar photovoltaic (PV) module under Standard Test Conditions (25°C and 1000 W/m²) as shown in Fig 3. The graph shows that the output current remains nearly constant at approximately 7.8–7.9 A as the voltage increases from 0 V to about 22 V. This behavior is typical of a PV module operating in the constant-current region before reaching the knee point of the I–V curve. The slight reduction in current with increasing voltage is due to the internal diode and resistive losses. The graph demonstrates stable current generation and efficient PV module operation under the given environmental conditions.

V. CONCLUSION

The MATLAB/Simulink-based Solar Photovoltaic (PV) model effectively demonstrates the electrical behavior of a PV module under Standard Test Conditions (25°C and 1000 W/m²). By incorporating temperature and solar irradiance as input parameters, the model accurately generates the output voltage, current, and power characteristics of the PV system. The simulated P–V graph shows a steady increase in power with increasing voltage, indicating operation toward the Maximum Power Point (MPP), while the V–I graph exhibits the characteristic nearly constant current region with a slight reduction due to internal diode and resistive losses. These results validate the expected performance of a photovoltaic module under standard operating conditions and highlight the influence of environmental parameters on PV output. Furthermore, the model provides a reliable platform for analyzing PV characteristics, evaluating system performance, and developing efficient Maximum Power Point Tracking (MPPT) algorithms. Overall, the proposed simulation serves as a valuable tool for the design, optimization, and performance assessment of solar photovoltaic energy systems.

REFERENCES

[1] Abidi H., Sidhom L., & Chihi I. (2023). Systematic literature review and benchmarking for photovoltaic MPPT techniques. Energies, 16, 8, 3509.

[2] Afroze, Shazia, R. Y. Udaykumar, and Anant Naik. "A systematic approach to grid-connected PV system." 2012 IEEE Fifth Power India Conference. IEEE, 2012.

[3] Aguila-Leon, J., Vargas-Salgado, C., Chiñas-Palacios, C., & Díaz-Bello, D. (2023). Solar photovoltaic Maximum Power Point Tracking controller optimization using Grey Wolf Optimizer: A performance comparison between bio-inspired and traditional algorithms. Expert Systems with Applications, 211, 118700.

ISSN: 2581-9429 Volume 6, Issue 2, July 2026 Impact Factor: 8.2

[4] Aguila-Leon, J., Vargas-Salgado, C., Chiñas-Palacios, C., & Díaz-Bello, D. (2023). Solar photovoltaic Maximum Power Point Tracking controller optimization using Grey Wolf Optimizer: A performance comparison between bio-inspired and traditional algorithms. Expert Systems with Applications, 211, 118700.

[5] Alshareef, M. J. (2022). An effective falcon optimization algorithm based MPPT under partial shaded photovoltaic systems. IEEE Access, 10, 131345-131360.

[6] Ben Mahmoud, Z., & Khedher, A. (2024). A Comprehensive Review on Space Vector Based-PWM Techniques for Common Mode Voltage Mitigation in Photovoltaic Multi-Level Inverters. Energies, 17(4), 916.

[7] Bennet, G. S. D., & Subramaniam Nachimuthu, D. (2024). Solar PV system with modified artificial rabbit optimization algorithm for MPPT. Electrical Engineering, 106(4), 4543-4559.

[8] Chen, Keng-Yuan, et al. "Low switching loss and harmonics PWM for three-phase grid-connected PV inverter." 2017 IEEE 3rd International Future Energy Electronics Conference and ECCE Asia (IFEEC 2017-ECCE Asia). IEEE, 2017.

[9] Chen, L., & Wang, X. (2019). Enhanced MPPT method based on ANN-assisted sequential Monte–Carlo and quickest change detection. IET Smart Grid, 2(4), 635-644.

[10] Chenchireddy, Kalagotla, and V. Jegathesan. "Multi-Carrier PWM Techniques Applied to Cascaded H-Bridge Inverter." 2022 International Conference on Electronics and Renewable Systems (ICEARS). IEEE, 2022.

[11] Chenchireddy, Kalagotla, et al. "Grid-Connected 3L-NPC Inverter with PI Controller Based on Space Vector Modulation." 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS). Vol. 1. IEEE, 2023.

[12] Chinmaya, K. A., & Singh, G. K. (2019). Experimental analysis of various space vector pulse width modulation (SVPWM) techniques for dual three-phase induction motor drive. International Transactions on Electrical Energy Systems, 29(1), e2678.

[13] Cui, Y., Yi, Z., Duan, J., Shi, D., & Wang, Z. (2019, February). A Rprop-neural-network-based PV maximum power point tracking algorithm with short-circuit current limitation. In 2019 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT) (pp. 1-5). IEEE.

[14] Dzung, Phan Quoc, et al. "The modified space vector PWM method for three-phase voltage source inverter with AC decoupling circuit." 2014 9th IEEE Conference on Industrial Electronics and Applications. IEEE, 2014.

[15] Farivar G. G., Manalastas W., Tafti H. D., Ceballos S., Sanchez-Ruiz A., Lovell E. C., ... & Pou J. (2022) Grid-connected energy storage systems: State-of-the-art and emerging technologies. Proceedings of the IEEE, 111, 4, 397-420.

[16] Figueiredo, S., & e Silva, R. N. A. L. (2021). Hybrid MPPT technique PSO-P&O applied to photovoltaic systems under uniform and partial shading conditions. IEEE Latin America Transactions, 19(10), 1610-1617.

[17] González-Castaño, C., Restrepo, C., Kouro, S., & Rodriguez, J. (2021). MPPT algorithm based on artificial bee colony for PV system. Ieee Access, 9, 43121-43133

[18] Gopinath, Anish, and M. R. Baiju. "Space vector PWM for multilevel inverters-a fractal approach." 2007 7th International Conference on Power Electronics and Drive Systems. IEEE, 2007.

[19] Gopinath, Anish, and M. R. Baiju. "Space vector PWM for multilevel inverters-a fractal approach." 2007 7th International Conference on Power Electronics and Drive Systems. IEEE, 2007.

[20] Halassa, E., Mazouz, L., Seghiour, A., Chouder, A., & Silvestre, S. (2023). Revolutionizing photovoltaic systems: an innovative approach to maximum power point tracking using enhanced dandelion optimizer in partial shading conditions. Energies, 16(9), 3617.

[21] Hamrouni, N., M. Jraidi, and A. Cherif. "New control strategy for a 2-stage grid-connected photovoltaic power system." Renewable Energy 33.10 (2008): 2212-2221.

[22] Han, Xiaonan, Xin Ai, and Yingyun Sun. "Research on large-scale dispatchable grid-connected PV systems." Journal of Modern Power Systems and Clean Energy 2.1 (2014): 69-76.

ISSN: 2581-9429 Volume 6, Issue 2, July 2026 Impact Factor: 8.2

[23] Harrison, A., Nfah, E. M., de Dieu Nguimfack Ndongmo, J., & Alombah, N. H. (2022). An Enhanced P&O MPPT Algorithm for PV Systems with Fast Dynamic and Steady-State Response under Real Irradiance and Temperature Conditions. International Journal of Photoenergy, 2022(1), 6009632.