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A Classical Approach for MPPT Extraction in Hybrid Energy Systems

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ABSTRACT- A novel approach for Maximum Power Point Tracking (MPPT) extraction using the Hill Climbing method in hybrid solar and wind energy systems. MPPT is essential for optimizing the energy harvesting efficiency of sustainable energy sources, the integration of multiple sources poses unique challenges. The proposed Hill Climbing algorithm is applied to both solar photovoltaic (PV) panels and wind turbines, enabling efficient tracking of the Maximum Power Points (MPPs) under varying environmental circumstances. This article investigates the performance of the Hill Climbing MPPT method through simulation and experimental validation in a hybrid energy system. The algorithm's adaptability to the dynamic nature of solar irradiance and wind speed is analyzed, demonstrating its capability to rapidly converge to the MPPs for both solar and wind components. The integration of Hill Climbing MPPT for both sources enhances the overall energy harvesting efficiency of the hybrid system. The Hill Climbing MPPT method offers a robust and unified solution for hybrid solar and wind energy systems, providing improved performance and simplicity of implementation. The findings contribute to advancing the optimization of renewable energy systems by addressing the challenges associated with the simultaneous utilization of solar and wind resources.

Keywords: Hill Climbing, Maximum Power Point Track, Solar, Wind

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1. INTRODUCTION

Solar and wind energy systems are crucial in advancing the shift to sustainable and clean energy solutions. Capturing energy from the sun and wind is vital for reducing environmental impact and meeting the increasing need for renewable energy sources. A key factor in enhancing the efficiency of solar and wind energy systems is the adoption of Maximum Power Point Tracking (MPPT) algorithms. These algorithms play an essential role in ensuring that solar panels and wind turbines perform at their optimal efficiency, by dynamically modifying their operating points to align with the Maximum Power Points (MPPs)[1].

1.1 Solar Energy

Solar energy systems convert sunlight into electricity through photovoltaic (PV) panels. These systems are widely deployed in residential, commercial, and utility-scale applications. The efficiency of solar panels is highly dependent on environmental factors such as solar irradiance and temperature. MPPT algorithms are essential in harnessing the maximum power from solar panels, by continuously adapting the operating voltage and current to locate the MPP, thereby enhancing the energy conversion efficiency[2].

A Solar Energy System with Maximum Power Point Tracking is designed to maximize the efficiency of electricity generation from solar photovoltaic (PV) panels. Solar panels exhibit a nonlinear relationship between their output power and operating conditions, such as solar irradiance and temperature. MPPT algorithms are utilized to dynamically modify the operating point of solar panels, guaranteeing their operation at the Maximum Power Point (MPP) amidst fluctuating environmental conditions. The choice of an MPPT algorithm significantly impacts the overall performance and energy yield of a solar energy system [3]. *Figure 1* depicts the key components and features of a solar energy system with MPPT.

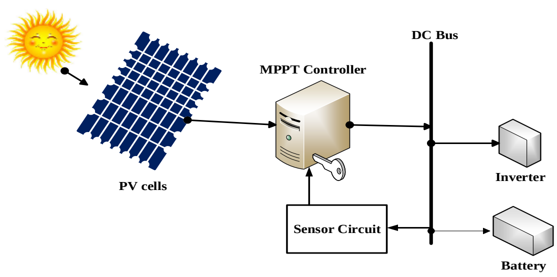

Figure 1. Representation of solar energy with MPPT Controller

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- **Solar Photovoltaic Panels**: Solar panels are the primary components responsible for converting sunlight into electricity. They consist of multiple solar cells interconnected to form a panel. The output of a solar panel is influenced by factors such as solar irradiance, temperature, and shading [4].

- **Inverter**: The direct current (DC) generated by solar panels needs to be converted into alternating current (AC) for use in most electrical applications. An inverter is a key component in a solar energy system that performs this conversion. Inverter systems often incorporate MPPT controllers to optimize the power output from the solar panels [5].

- **MPPT Controller**: The MPPT controller is the intelligence behind optimizing the solar panel's operating point. It continuously monitors the output of the solar panels and adjusts the electrical operating parameters (voltage or current) to maximize the power output [6].

- **Sensors and Monitoring System:** To effectively implement MPPT, solar energy systems are equipped with sensors to measure environmental parameters such as solar irradiance and temperature. These measurements provide critical input to the MPPT controller, allowing it to adapt the solar panel's operating point in real-time [7].

Finally, the MPPT technology in a solar energy system is essential for maximizing the energy harvest from solar panels. This optimization contributes to the economic viability and sustainability of solar power, making it a crucial aspect of modern solar energy installations [8].

1.2 Wind Energy
These are utilizing the kinetic energy of the wind to produce electricity through wind turbines. Wind conditions, including wind speed and direction, are highly variable, making it challenging to maintain optimal operating points for energy conversion. MPPT in wind energy systems involves adjusting the rotor speed or pitch angle to maximize power extraction at varying wind speeds. This ensures that the wind turbine operates efficiently and captures the maximum available wind energy [9].

A Wind Energy System with MPPT is designed to optimize the energy extraction from wind turbines by ensuring they operate at their MPP. Wind turbines, like solar panels, experience nonlinear power curves influenced by changing wind speeds. MPPT algorithms are employed to adjust the operating parameters of the wind turbine, maximizing power output and overall system efficiency[10]. *Figure 2* represents overview of the key components and features of a wind energy system with MPPT.

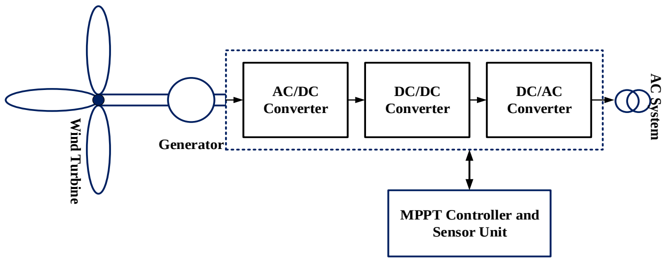

Figure 2. Block Diagram of wind energy system with MPPT Controller

- **Wind Turbine**: Wind turbines serve as the fundamental elements within a wind energy system, featuring rotor blades designed to harness kinetic energy and get the rotational mechanical energy. The efficiency and output power of a wind turbine are closely linked to wind speed, with the turbine's power curve displaying a peak output at a certain rotational speed [11].

- **Generator and Power Electronics**: The mechanical energy captured by the wind turbine's rotor blades is converted into electrical energy by a generator. The generator output is in the form of variable frequency and voltage AC power. Power electronics, including inverters and converters, are often used to condition the generated power and match it to the electrical grid or the load requirements [12].

- **MPPT Controller**: The MPPT controller for wind energy systems continuously monitors the wind turbine's performance and adjusts the rotor speed or pitch angle to maintain operation at the MPP. Various MPPT algorithms can be employed. The goal is to adapt the turbine's operating point to maximize power extraction at different wind speeds [13].

- **Wind Speed Sensors**: To effectively implement MPPT, wind energy systems are equipped with wind speed sensors. These sensors provide real-time information about the wind conditions, allowing the MPPT controller to adjust the turbine's operating parameters accordingly [14].

- **Yaw System**: Wind turbines are often mounted on a yaw system, allowing them to turn and face into the wind. The yaw system ensures that the rotor blades are properly aligned with the wind direction, optimizing energy capture. Some advanced systems may incorporate MPPT algorithms that consider the wind direction in addition to wind speed [15].

Therefore, MPPT technology plays a major role in optimizing the performance of wind systems. By adapting the operating points of wind turbines to changing wind conditions, MPPT algorithms contribute to increased energy yield, making wind power more economically viable and sustainable [16].

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1.3 Integration of Solar and Wind

The primary objective of MPPT in both solar and wind energy systems is to enhance energy harvesting efficiency. By continually adjusting the operating parameters to match the varying environmental conditions, MPPT algorithms enable these systems to operate closer to their peak performance. This optimization is crucial for maximizing the electricity output, improving the return on investment, and making renewable energy systems more economically viable[17].

Combining solar and wind energy sources with MPPT focuses on enhancing the performance of both solar panels and wind turbines for optimal power output under different environmental situations. Key to this process, efficient MPPT algorithms are pivotal in adjusting the operating points of these varied energy sources to accurately follow their individual Maximum Power Points (MPPs). *Figure 3* depicts the integration of solar and wind energy sources[18]

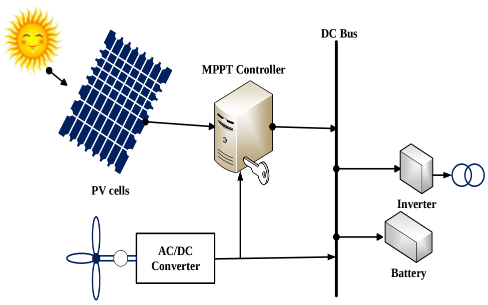

Figure 3. Block diagram Representation of Hybrid Energy System

2. PROPOSED TOPOLOGY

The Hill Climbing method is a popular MPPT algorithm used in both solar and wind energy systems to optimize power extraction by adjusting the operating points of solar panels and wind turbines. The Hill Climbing MPPT method offers a practical and effective solution for optimizing both solar and wind energy systems, providing real-time adjustments to operating points for maximum power extraction.[19]

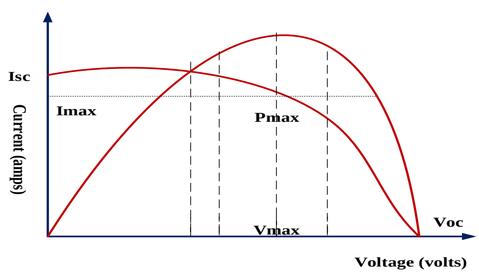

Figure 4.V-I characteristics

Within solar energy systems, the Hill Climbing MPPT algorithm is tasked with dynamically fine-tuning the operating voltage and/or current of solar panels to locate the MPP. This algorithm introduces minor, incremental adjustments to the operating parameters (voltage or current) and monitors the resultant changes in power output. Following each adjustment, it evaluates the impact on power output, comparing pre- and post-perturbation levels. An increase in power prompts the algorithm to persist in its chosen adjustment direction; a decrease, conversely, signals a need to reverse course. Through a process of iterative refinement, adjusting the operational parameters toward the direction that yields the highest power output, the algorithm methodically zeros in on the MPP. This ongoing adjustment process is conducted in real-time, ensuring the system's responsiveness to varying environmental conditions and optimizing the energy extraction efficiency [20]-[21].

In wind energy systems, the Hill Climbing MPPT algorithm adjusts the rotor speed or pitch angle of the wind turbine to find the MPP. Similar to the solar context, the algorithm makes small incremental changes in rotor speed or pitch angle and observes the resulting change in output. The algorithm compares the output before and after the perturbation and decides whether to continue in the same direction or change direction based on the power response. Through iterative adjustments, the algorithm converges to the MPP for the wind turbine. The dynamic nature of wind conditions requires real-time adaptation to maintain optimal performance. Hill Climbing in wind systems relies on real-time monitoring of wind speed and other environmental factors. The algorithm ensures that the wind turbine operates at its maximum efficiency under varying wind conditions.[20-22]

2.1 Flow Chart of Proposed Technique [21]

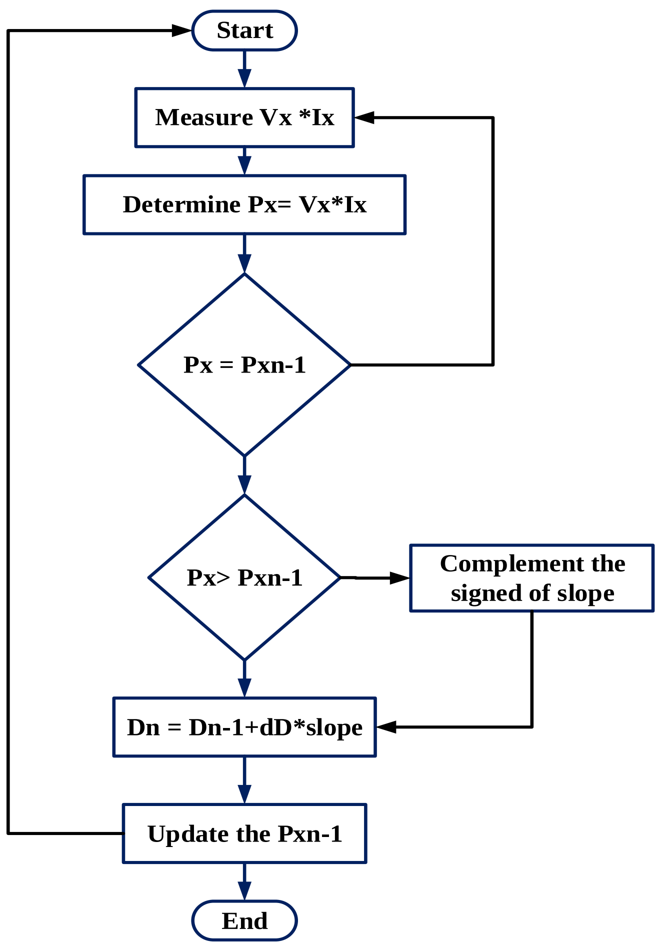

Figure 5. Flow Chart for Proposed Topology

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2.2 Estimation of V_{mpp} and I_{mpp} [24] [25]

$$\text{Let} \quad Pmpp = V\,mpp * Impp \tag{1}$$

Differentiate both sides with respect to *Ipv* and equate to *zero*

$$\frac{dPmpp}{dIpv} = \frac{d(Vmpp*Impp)}{dIpv} \tag{2}$$

$$\frac{dV}{dIpv} = -\frac{Vmpp}{Impp} \tag{3}$$

Let consider

$$\frac{Vt}{It} = -\frac{Vmpp}{Impp} \tag{4}$$

Then

$$\frac{Vmpp}{Impp} = -\frac{Vt}{(Isc+Io-Impp)} \tag{5}$$

Here

$$It = Isc + Io - Impp \tag{6}$$

Consider Isc= short circuit current and Io = open circuit current
Now

$$Vmpp = -\frac{Vt*Impp}{(Isc+Io-Impp)} \tag{7}$$

$$Impp = -\frac{Vmpp*(Isc+Io-Impp)}{Vt} \tag{8}$$

$$Impp\left(1+\frac{1}{Vt}\right) = -\frac{Vmpp*(Isc+Io)}{Vt} \tag{9}$$

$$Impp\left(\frac{1+Vt}{Vt}\right) = -\frac{Vmpp*(Isc+Io-Impp)}{Vt} \tag{10}$$

$$Impp = -\frac{Vmpp*(Isc+Io-Impp)}{1+Vt} \tag{11}$$

3. RESULTS AND DISCUSSION

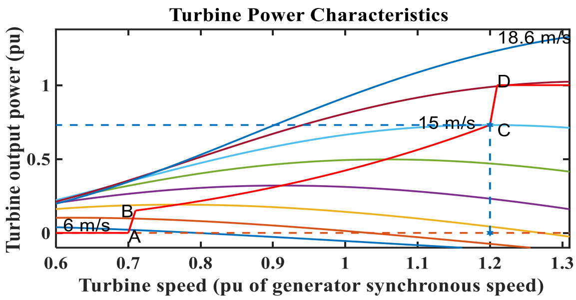

Figure 6. Turbine power characteristics

Figure 6 depicts turbine power to speed characteristics; here maximum turbine power will get at C point as mentioned.

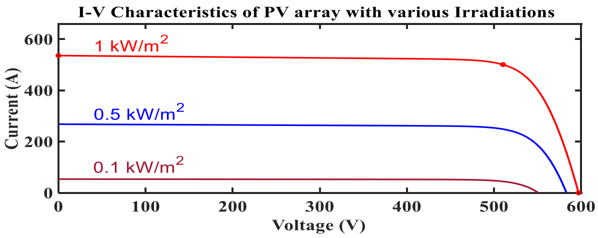

Figure 7. current Vs Voltage Characteristics of solar system

Figure 7-8 represents current to voltage, power to voltage characteristics at various irradiations. In proposed technique Sun power-SPR- 415E-WHT-D PV array has been considered.

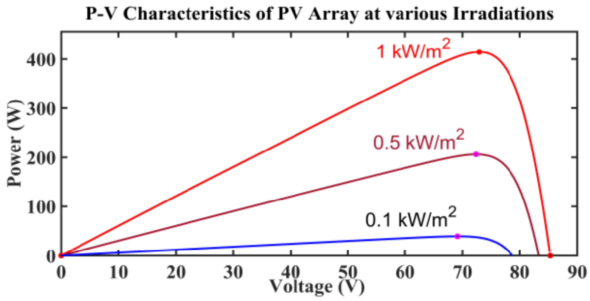

Figure 8. Power Vs Voltage Characteristics of solar system

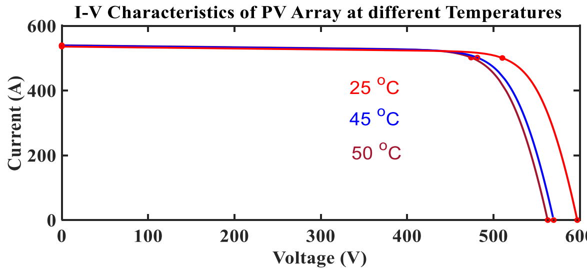

Figure 9. Current Vs Voltage Characteristics of solar system

Figure 9-10 depicts current to voltage, power to voltage characteristics at different temperatures.

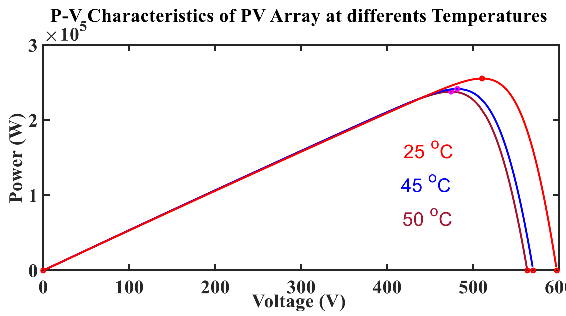

Figure 10. Power Vs voltage Characteristics of solar system

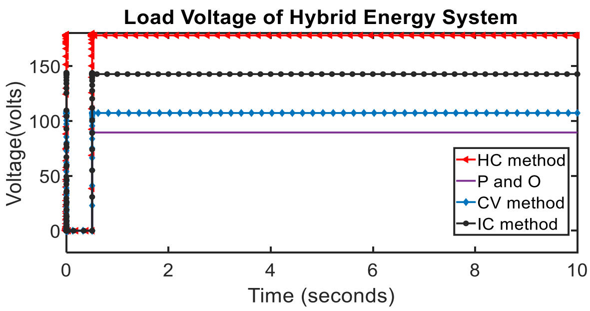

Figure 11. Load Voltage of Hybrid Energy System

Figure 11 represents dc Load bus voltage in hybrid energy system, various methods have been considered. Based on the methods proposed technique has got maximum voltage at 0.5 sec with effective results.

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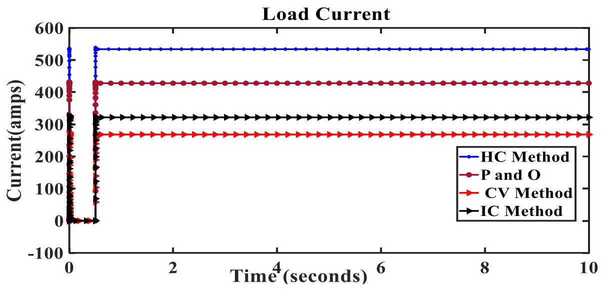

Figure 12. Load Current of Hybrid Energy System

Figure 12 depicts load current in hybrid energy system with various conventional topologies. Here HC method gives efficient results.

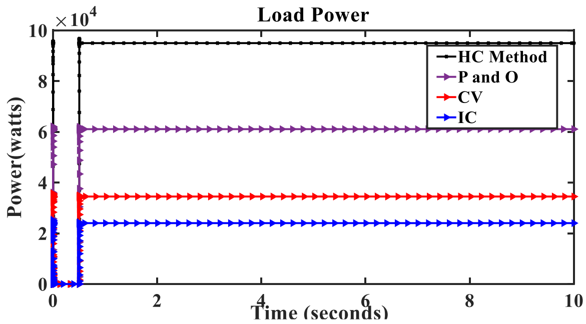

Figure 13. Load Power of Hybrid Energy System

Figure 13 depicts load power in hybrid energy system with different classical methods. In which proposed technique got maximum power in effective manner.

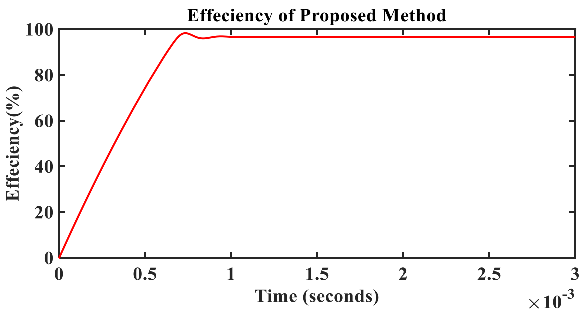

Figure 14. Efficiency of proposed method of Hybrid Energy System

Figure 14 depicts efficiency of proposed method.in which Tracking efficiency got 96.64 when compare with the above four methods, which means excellent efficiency.

Table 1 Represents comprehensive analysis of various parameters with different techniques at 1000w/m^2 irradiation and 15m/s wind speed.

Table 1. Comprehensive Analysis of Various Topologies

Method	Voltage (volts)	Current(amps)	Power(watts)
P and O - solar	160.3	481	7.712*10^4
CV	142.7	428	6107*10^4
IC	125	374	4.686*10^4
HC- Hybrid	177.87	533.76	9.52*10^4

Table 2. Parameters required in Hybrid System

Sl.No.	Parameter
1	Sun Power SPR-415E-WHT-D Solar Panel
2	7-Module string
3	88 Parallel Strings
4	45^{o}C Temperature
5	1000 Irradiance
6	38m blade radius
7	15m/s wind speed
8	3 blades
9	4 m/s cut-in speed
10	3 rad/s rated speed

4. CONCLUSION

Among various MPPT algorithms, the Hill Climbing method is commonly employed for its simplicity and effectiveness. In both solar and wind energy systems, the Hill Climbing MPPT algorithm iteratively adjusts the operating points to approach the MPP. The algorithm compares the instantaneous power output with small perturbations in operating parameters and moves towards the direction of increasing power, ultimately converging to the MPP. The integration of MPPT algorithms, particularly utilizing the Hill Climbing method, is crucial for optimizing the performance of solar and wind energy systems. These systems contribute significantly to the global shift towards sustainable energy, and efficient MPPT ensures that they operate at their maximum potential under varying environmental conditions.

REFERENCES

[1] H. Alnuman, A. Armghan, A. Kumar, E. T. Alanazi, and A. Sahbani, “Solar PV system fed improved power quality converter with digital proportional resonant controller,” *Comput. Electr. Eng.*, vol. 114, p. 109086, 2024.

[2] N. F. Claude Bertin, K. Martin, and W. Patrice, “A comprehensive assessment of MPPT algorithms to optimal power extraction of a PV panel,” *J. Sol. Energy Res.*, vol. 4, no. 3, pp. 172–179, 2019.

[3] G. Dileep and S. N. Singh, “Application of soft computing techniques for maximum power point tracking of SPV system,” *Sol. Energy*, vol. 141, pp. 182–202, Jan. 2017, doi: 10.1016/j.solener.2016.11.034.

[4] L. Abualigah *et al.*, “Wind, Solar, and Photovoltaic Renewable Energy Systems with and without Energy Storage Optimization: A Survey of Advanced Machine Learning and Deep Learning Techniques,” *Energies*, vol. 15, no. 2, Art. no. 2, Jan. 2022, doi: 10.3390/en15020578.

[5] E. Assareh, S. S. M. Asl, M. Ahmadinejad, M. Parvaz, and M. Ghodrat, “Optimization of a solar energy system integrating cooling, hot water, and power units in Australian cities: A climate-based analysis and cost-efficiency investigation,” *Int. J. Hydrog. Energy*, vol. 49, pp. 353–375, 2024.

[6] F. Gutiérrez-Martín, J. A. Díaz-López, A. Caravaca, and A. J. Dos Santos-García, “Modeling and simulation of integrated solar PV - hydrogen systems,” *Int. J. Hydrog. Energy*, Jun. 2023, doi: 10.1016/j.ijhydene.2023.05.179.

[7] C. H. Hussaian Basha and C. Rani, “Performance Analysis of MPPT Techniques for Dynamic Irradiation Condition of Solar PV,” *Int. J. Fuzzy Syst.*, vol. 22, no. 8, pp. 2577–2598, Nov. 2020, doi: 10.1007/s40815-020-00974-y.

[8] C. Hussaian Basha, M. Palati, C. Dhanamjayulu, S. M. Muyeen, and P. Venkatareddy, “A novel on design and implementation of hybrid MPPT controllers for solar PV systems under various partial shading conditions,” *Sci. Rep.*, vol. 14, no. 1, p. 1609, 2024.

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Research Article | Volume 12, Issue 3 | Pages 940-945 | e-ISSN: 2347-470X

[9] Z. Ishrat, A. K. Gupta, and S. Nayak, "A comprehensive review of MPPT techniques based on ML applicable for maximum power in solar power systems," *J. Renew. Energy Environ.*, vol. 11, no. 1, pp. 28–37, 2024.

[10] N. Khanam, B. H. Khan, and T. Imtiaz, "Maximum power extraction of solar PV system using meta-heuristic MPPT techniques: a comparative study," in *2019 International Conference on Electrical, Electronics and Computer Engineering (UPCON)*, IEEE, 2019, pp. 1–6. Accessed: Dec. 15, 2023. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/8980060/

[11] M. Kumar, S. Sen, S. Kumar, and J. Samantaray, "An Adaptive Fuzzy Controller-Based Distributed Voltage Control Strategy for a Remote Microgrid System with Solar Energy and Battery Support," *IEEE Trans. Ind. Appl.*, 2024, Accessed: Jan. 27, 2024. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/10382643/

[12] A. Mehmood, J. Ren, and L. Zhang, "Achieving energy sustainability by using solar PV: System modelling and comprehensive techno-economic-environmental analysis," *Energy Strategy Rev.*, vol. 49, p. 101126, Sep. 2023, doi: 10.1016/j.esr.2023.101126.

[13] V. L. Mishra, Y. K. Chauhan, and K. S. Verma, "A critical review on advanced reconfigured models and metaheuristics-based MPPT to address complex shadings of solar array," *Energy Convers. Manag.*, vol. 269, p. 116099, 2022.

[14] F. F. Muhammadsharif *et al.*, "Brent's algorithm based new computational approach for accurate determination of single-diode model parameters to simulate solar cells and modules," *Sol. Energy*, vol. 193, pp. 782–798, Nov. 2019, doi: 10.1016/j.solener.2019.09.096.

[15] Namburi Nireekshana, Tanvi H Nerlekar, P. N. Kumar, and M. M. Bajaber, "An Innovative Solar Based Robotic Floor Cleaner," May 2023, doi: 10.5281/ZENODO.7918621.

[16] Namburi Nireekshana, M. Anil Goud, R. Bhavani Shankar, and G. Nitin Sai Chandra, "Solar Powered Multipurpose Agriculture Robot," May 2023, doi: 10.5281/ZENODO.7940166.

[17] R. K. Pachauri, V. Sharma, A. Kumar, Shashikant, A. A. Khan, and P. Sharma, "Conventional and AI-Based MPPT Techniques for Solar Photovoltaic System-Based Power Generation: Constraints and Future Perception," in *Clean and Renewable Energy Production*, 1st ed., S. Mondal, A. Kumar, R. K. Pachauri, A. K. Mondal, V. K. Singh, and A. K. Sharma, Eds., Wiley, 2024, pp. 355–374. doi: 10.1002/9781394174805.ch15.

[18] A. Rahman, L. C. Saikia, and N. Sinha, "Automatic generation control of an interconnected two-area hybrid thermal system considering dish-stirling solar thermal and wind turbine system," *Renew. Energy*, vol. 105, pp. 41–54, 2017.

[19] Podder, A. K., Roy, N. K., & Pota, H. R. (2019). MPPT methods for solar PV systems: a critical review based on tracking nature. IET Renewable Power Generation, 13(10), 1615–1632. https://doi.org/10.1049/iet-rpg.2018.5946.

[20] Saxena, A., Kumar, R., Amir, M., & Muyeen, S. (2024). Maximum power extraction from solar PV systems using intelligent based soft computing strategies: A critical review and comprehensive performance analysis. Heliyon, 10(2), e22417. https://doi.org/10.1016/j.heliyon.2023.e22417.

[21] Ali, A., Almutairi, K., Malik, M. Z., Irshad, K., Tirth, V., Algarni, S., Zahir, M. H., Islam, S., Shafiullah, M., & Shukla, N. K. (2020). Review of Online and Soft Computing Maximum Power Point Tracking Techniques under Non-Uniform Solar Irradiation Conditions. Energies, 13(12), 3256. https://doi.org/10.3390/en13123256.

[22] N. Nireekshana, R. Ramachandran, and G. V. Narayana, "A New Soft Computing Fuzzy Logic Frequency Regulation Scheme for Two Area Hybrid Power Systems," *Int. J. Electr. Electron. Res.*, vol. 11, no. 3, pp. 705–710, Aug. 2023, doi: 10.37391/IJEER.110310.