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Optimization of Solar PV Array PerformanceUsing Fuzzy Logic MPPT In MATLAB

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***Abstract*—** The use of solar energy via photovoltaic (PV) cells is a major factor in the generation of sustainable energy, because photovoltaic cells directly convert solar radiation into electric energy without harming the atmosphere, they are extremely important in the production of solar energy. Panel efficiency can be increased by using the right DC-DC converters in conjunction with an extremely efficient Maximum Point of Power Transmission (MPPT) algorithm that pulls out the peak envelope results. The performance evaluation of photovoltaic array was carried out by use of the MATLAB SIMULINK toolkit. The outcomes of the simulation indicate that the Incremental Conductance (IC) method quickly finds the peak performance point when the sudden changes in radiant flux occur; it also shows faster convergence and better accuracy than the P&O algorithm. The intended controller for Fuzzy Logic is designed in order to maximise the authority output of PV array by accurately tracking the peak performance point under varied solar radiant flux and temperature circumstances. The controller employs a Fuzzy Logic based algorithm that uses the solar irradiance and voltage error as inputs to determine appropriate duty cycle for converter.

Index Terms— Finite Energy Point Monitoring, Controller for Fuzzy Logic, Photovoltaic Cell, MATLAB SIMULINK

INTRODUCTION

Fuzzy logic based MPPT controllers have emerged as a promising alternative, offering improved performance and a capability to nonlinear and complex systems like solar PV arrays [1]. By incorporating expert knowledge and linguistic rules; Fuzzy Logic controllers can effectively handle then non- linearity and uncertainties inherited in Photovoltaic (PV) systems, leading to faster and more accurate tracking of Peak Power Point Maximum (MPP). This work aims to develop and construct a Fuzzy Logic-based MPPT [2] controller for a polarizing array using MATLAB. The purposed controller will be designed to maximise the PV array's ability to harvest energy by continuously modifying that of the DC-DC to align the converter with the source resistivity, match its duty cycle to the load resistivity [3].

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The performance of Fuzzy Logic based peak performance controller will be evaluated through simulations under various environmental conditions and compared with traditional MPPT algorithms. The successful implementation of an efficient and robust Fuzzy Logic based peak performance controller can significantly perk up the overall efficiency and energy yield solar flat plate systems, contributing to the widespread adoption of energy produced by natural resources, sustainable energy solutions [4].

Direct reverse replica is a more complex model that considers the belongings of both series and shunt resistances in the solar cell. It is a more accurate representation of the I-V characteristics of solar cell [5], but it requires more computational resources and is more complex to implement. In turn to command point of maximal power, which is affected by the nonlinear properties of the photovoltaic board and is focused to constant variation in ecological circumstances like temperature and solar radiation [6]—this study compares the troubling discoveries equipped hybrid controller. The ongoing inefficiency of solar power systems is a major problem with current peak performance technology for astral energy [7]. This occurs because nonlinear fluctuations prevent the organization from operating to maximum efficiency. In order to perk up the MPPT controller's ability to adjust to nonlinear parameter changes, there has been an organizer created and compare to the distressing way [8]. The simulation study includes a PV array model with altering illumination and warmth state of affairs. The results for simulation will be analyzed to assess the effectiveness and efficiency for peak performance regulator base on fuzzy logic in tracking peak performance [9] point and improving power output. The effectiveness of a Fuzzy Logic-based regulator vs. traditional P&O (Perturb and Observe) technique will also be compared in this study, providing insights into the potential benefits of using nonlinear feedback of MPPT in solar flat plate array [10].

PHOTOVOLTAIC CELL

A P-N Intersection, created in slim semiconductor material flake or sheet, is the building block of solar cells. When light is applied, energy-containing photons higher than the semiconductor's band gap energy are taken in, which results in the production of a large number of electron-hole pairs [11]. As a result, the P-N junction facilitates the exchange of beam power keen on electrical force. The radiation intensity of the incident directly relates to the size of the current generated by photons. In terms of an electrical circuit, the simplest description a current source for lunar unit that is coupled [12] in equivalent by means of diode. Several cells (usually 36 or 72) are connected to create a photovoltaic (PV) module in categorize to make available required amount of energy produced. The photovoltaic (PV) cell is analyzed by mathematical modelling [13]. This analysis is based on monocrystalline technology, which is recognized for having higher efficiency than other commercially available technologies. The single diode model is a simple representation of a lunar cell which considers cell as existing basis in series through diode [14]. It a widely used model for simulating the behaviour of solar cell under different operating systems. There is an imbalance in electrical charge between the frontal and dorsal surfaces of the solar

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photovoltaic cell due to the movement of electrons [15], which are negatively charged, towards the front surface of the cell. This imbalance therefore produces a voltage potential that is similar to a battery's terminals. Electricity flows through the circuit when these conductors are connected to an external load, such a battery, in an electrical circuit [16]. A single cell's diameters can range from 0.5 inches to about 4.0 inches across. However, a single cell can only generate 1 or 2 Watts, which is adequate for small-scale uses like powering wristwatches or calculators [17]. These cells are electrically connected inside a weather-resistant, enclosed solar panel (sometimes called a module).

PV panels come in different sizes and have varying capacities for producing electricity. The surface area or the number of cells in a photovoltaic panel determines how much electricity the panel can produce [18]. PV arrays, which can consist of as few as two panels or as many as hundreds, are groups of PV panels that are joined together. The total amount of electricity produced by a PV array is mostly dependent on the number of PV panels [19] that are integrated into the array. Direct current (DC) electricity, which may be used to power devices that run on DC electricity and charge batteries, is produced by photovoltaic cells. Alternating current (AC) is the most common type of energy used in transmission and distribution networks.

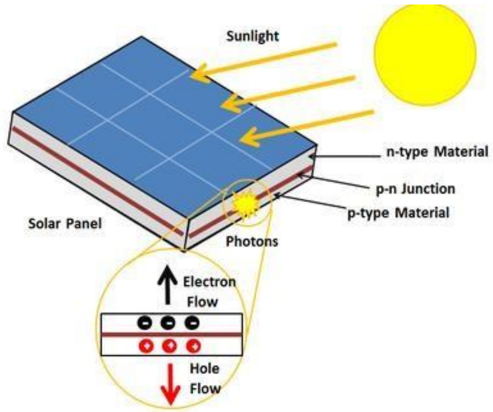

Fig: Photovoltaic Cell

PV CELL EQUIVALENT CIRCUIT

The photovoltaic (PV) cell, a fundamental P-N junction, is the essential part of a PV conversion device. Above illustration shows plan of photovoltaic cell by way of a single diode configuration [20]. This model includes a diode (D), a resistance in series (R_s) that represents the resistance within current flow, a shunt resistance (R_{sh}), and the photocurrent production (photo-current).

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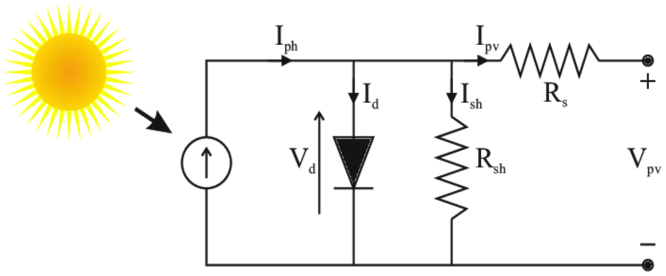

Fig; Equivalent circuit of PV cell

The stellar unit and PN junction diode's physics characteristics may be used to get the mathematical expression for the circuit above, which is commonly stated by the equations (1) below:-

$$- Io\ [e^{\frac{q(Vpv+IpvRse)}{}} -1]-(Vpv + IpvRse/R\ \ )$$

The current photo is I_{ph}
Repeal diffusion current of the diode is I_O
Electron charge is represented by "q" which is (1.602×10-19 C)The voltage across the diode is V pv.
Boltzmann's constant, K, (1.381×10-23 J/K)In Kelvin, T is the junction temperature.
N is the diode's idealist factor.
R_{se} is the diode's series resistance.
The diode's shunt resistance is denoted by R_{sh}.

The equivalent circuit can be used to solve the operating voltage and current of the cell [21], although the equation may not have a general analytical solution and may require numerical methods to solve. The parameters of the equivalent circuit, such as the photo generated current, diode idealistic factor and shunt resistance and can be used to describe the cell's performance under different operating conditions [22].

In summary, corresponding track of PV cell is theoretical model that simplifies the electrical characteristics of the device. It consists of an ideal current generator, diode and load as well as components that represent series and shunt resistance.

FEATURES OF PHOTOVOLTAIC CELL

The Solar I-V Characteristic Cell Curve gives a detailed explanation of the efficiency of solar energy conversion of exacting solarising unit, or group by illustrating its current and voltage (I-V) characteristics. Determining the operational efficacy and solar efficiency of a solar cell or panel requires an understanding of its electrical I-V characteristics, specifically its maximum power point (P max) [23].

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A simple way to summarize the major electrical character of a photovoltaic unit is to look at the connection between wattage and voltage formed in distinctive lunar unit I-V curve. While the voltage (V) drops as the solar cell's temperature increases, wattage is affected by the amount of lunar energy (insulation) that the cell receives.

Solar cells generate power using direct current (DC) and power is the result of multiplying voltage by current [24]. Consequently, association among current and voltage in a photovoltaic device can be represented by building I-V curves of stellar cells. The function of a lunar cell or module is visually represented by its curve, which captures affiliation flanked by wattage and energy at particular temperature and radiant flux levels. The information provided by these curves is crucial for configuring a stellar structure to run like efficiently as possible lock to the peak performance spot [25].

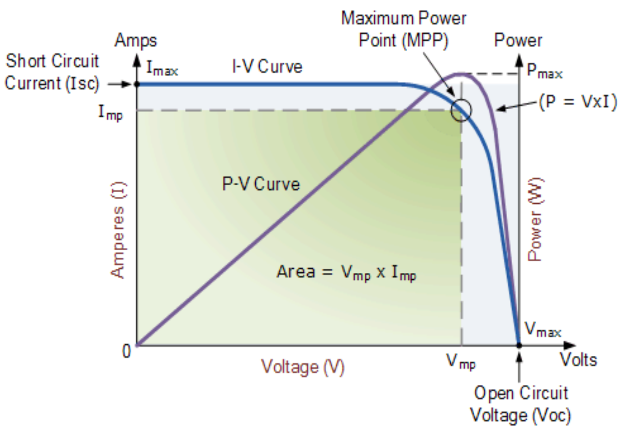

Fig: Characteristics graph of PV cell

Specific electrical behaviors can be seen in the wattage-voltage character of a usual silicon material photovoltaic (PV) unit in service below standard situation are shown in the above image. An individual solar cells or panel's energy is designed as result of its output electrical energy and current (I×V) [26]. The power curve for a particular radiation level is obtained by performing a methodical multiplication across all electrical energies; commencing short-circuits to open-circuit circumstances. To keep array operating at peak point, a process called Perturb plus Adjust, or "dithering," is used. This technique entails varying the current drawn on a regular basis and monitoring the power output that results.

TRACKING MAXIMUM POWER POINT [MPPT]

Maximum Power Point Tracking, or MPPT for short, is a technology extensively worn in solar inverters and indict controllers. It is essential for effectively managing the interaction between solar panels and the utility grid or battery storage system [27]. Its main purpose is to increase solar energy use under various environmental circumstances by keeping the array operating at the ideal voltage threshold. Because MPPT-enabled solar battery charge controllers have the ability to monitor and control the voltage levels between the solar panels

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and the battery units [28], they are the suggested answer when it comes to solar energy systems that incorporate energy storage solutions. The system ensures that the load characteristic is modified adaptively to function at the point of maximum power (MPP). There are two ways to get the most command out of flat plate: electrical tracking and mechanical tracking. Electrical tracking uses I-V arch to settle on peak performance [29], while mechanical tracking includes rotating the PV panel to accommodate seasonal and monthly fluctuations. Peak Power Outage is organized to provide best possible command transmission to stack, batteries, plus motors—as well as to the power grid in the event of an off-grid situation—tracking is a vital module of modern power system [30].

MPPT TECHNIQUES

Photovoltaic systems employ strategies for Peak performance point to optimize solarising array clout output by constantly monitoring the highest clout peak, Many tactics are used to locate the point at which power output peaks [31], some of the most widely used ones being discussed below:

1. The Perturb and Observe (P&O) approach.
2. Fuzzy Logic.
3. DC-DC Converter.
4. INC stands for incremental conductance.
5. FOSV, or voltage across a partial open circuit.
6. Current with Fractional Short Circuit (FSCC).

The complexity, implementation costs, and tracking time of the aim of highest clout all influence algorithm selection. This study uses a robust controller and a distressing observation approach to track the Peak performance point [32].

THE PERTURB AND OBSERVE (P&O) APPROACH

The perturbation and observation approach is one of the methods used in renewable energy systems the most frequently. It involves disquieting PV array's electrical energy [33], current, and observing resulting power. The disturbance proceeds in the same direction with increasing power, and in the opposite direction with decreasing power. In solar energy applications Perturb and Observe is often used in Peak performance algorithms for solarising system. These algorithms continuously adjust the operating circumstances of lunar panel to make sure they run at their maximum control productivity apart from altering ecological conditions like shading [34], temperature variations or fluctuations in solar irradiance. The algorithm that is being considered introduces a small inaccuracy into the mechanism, which yields a change in the module's power. If this modification produces affirmative shift in command, the riot continues in that route. Following the Peak Performance Point, after which close by is a rule outage occasion, causing the perturbation to reverse. When the algorithm reaches equilibrium, it exhibits oscillations around the maximum value [35].

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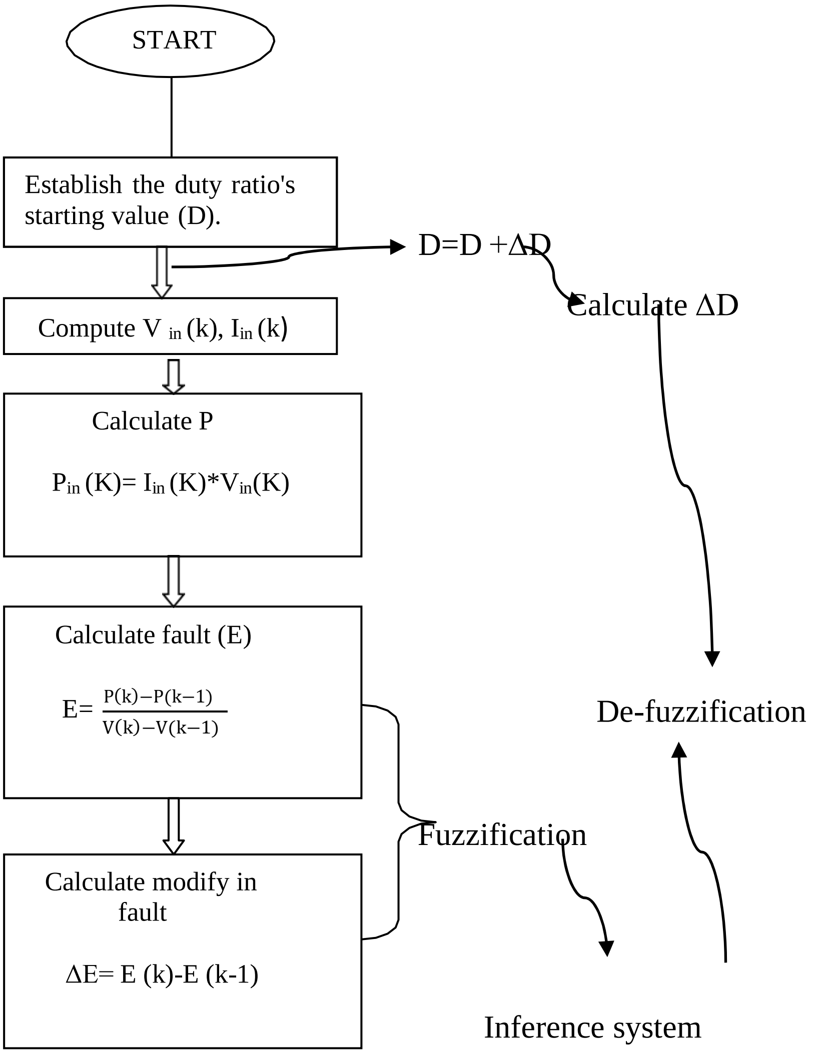

Fig: P&O MPPT Flowchart

From the above flowchart, the fuzzification and de fuzzification parts respectively constitute the Fuzzy set. The above flowchart typically involves following steps;

1. Firstly, we initialize the operational electrical energy for lunar cell.
2. Measure clout outputs of V& I respectively.
3. Calculate the error obtained in power outputs.
4. In the event that the new power output exceeds the prior power output, then continue in same direction.
5. It the new power obtained is less than previous power output, then reverse the direction.
6. At last, repeat the steps until maximum power is reached.

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DC-DC CONVERTER

Converters are used to transform specific level of direct current voltage into a different level. The voltage required for various electronic components like ICs and MOSFET can exhibit significant variation, thus necessitating the provision of appropriate voltage for each component. In the context of switch mode, a switching regulator is responsible for delivering a voltage output that is less than the initial voltage, whereas a switching regulator is designed to make available voltage that is superior to original level [36]. DC-DC converters are radio band clout alteration circuits that produce regulated DC voltages via transformers and capacitors while reducing switching noise through the use of inductors and high pitch switch techniques. Even when input voltages and output currents fluctuate, closed feedback loops keep the voltage output constant. They are typically smaller and far more efficient than linear regulators [37], operating at 90% efficiency. Their complexity and noise are drawbacks. Typically, switch mode are used to control solar module's output voltage and current. Numerous converters with unique benefits and drawbacks can be found in the literature. We employ a boost DC-DC converter in this paper. To fully satisfy the most clout transfer requirements, to equal the pack impedance with the inner impedance of the solar cause, a converter is required.

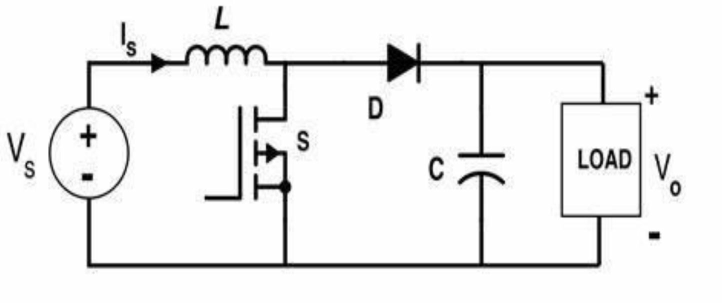

Fig: DC-DC Converter

The following formula used to determine the inductor value based on the circuit diagram above;

$$L_{min} = \frac{D(1-D)R}{2f}$$

FUZZY LOGIC CONTROLLER

One kind of control system that makes use of fuzzy logic is a fuzzy logic controller, which is derived from fuzzy sets, to analyze analog input values in terms of degrees of truth rather than strict true or false values. Fuzzy Logic Controllers are designed to handle complex, ill-defined problems efficiently, especially in situations where human operators can effectively control systems without detailed knowledge of their underlying dynamics. Fuzzy logic controllers are employed extensively in engineering processes recently because of heuristic character, effortlessness, usefulness, other variable's deliberation for together linear, non-linear stricture fluctuation of organization [38]. Fuzzy systems are made up of knowledge-based rule systems; the knowledge of base, which consists primarily of If-Then rules, makes

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up FLC. Fuzzy Logic is used to minimize electrical energy vacillation once Peak performance is documented and to attain with minimal overshoot, the MPP operation voltage point more rapidly. The control intention is to monitor utmost authority, which will subsequently result in the PV panel operating effectively. Variables that reflect the system's dynamic performance should be selected for the controller's input while designing the FLC.

. The key components and concepts related to Fuzzy Logic Controllers are as under:-

- Fuzzy Logic Base
- Control System Design
- Architecture of FLC
- Advantages of Fuzzy Control
- Implementation of Fuzzy Logic

Controller for Fuzzy Logic

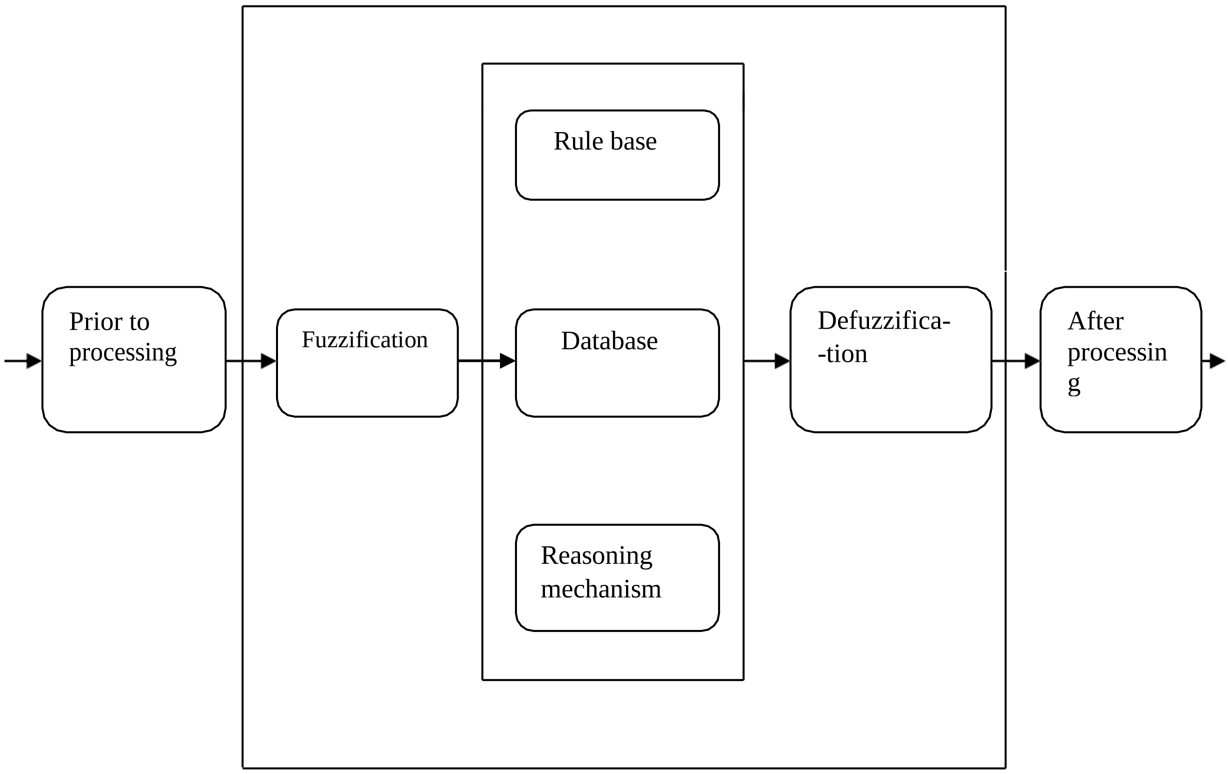

Fig: A basic fuzzy logic controller block diagram

Controller composes of following parameters, which are as under:

Fuzzification
Inference
systemDe-
fuzzification

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Fuzzification

Fuzzification is the conversion of sharp, precise input data into fuzzy sets or fuzzy variables. In other words, it involves quantifying the degree to which an input belongs to various linguistic categories or fuzzy sets. Using a subset known as the membership function, arithmetical put in mercurials are computed or rehabilitated keen on linguistic mercurials during the fuzzification stage [39]. The terms "change in power" and "change in voltage" are fuzzy inputs that are created using six fuzzy variables: PB (Positive Big), PS (Positive Small), NB (Negative Big), NS (Negative Small), and Zero (ZE). These fuzzy values of voltage and power variations are translated using variables. The suggested system's input variables are changes in power and voltage, and the production of controller is a shift in function. Each variable's association functions are affected by variations in voltage,

power, and duty cycle. The primary purpose of fuzzification is to represent the vagueness and uncertainty inherent in real-world data or human knowledge. By converting crisp inputs into fuzzy sets, it enables the application of fuzzy logic techniques which are well suited for handling imprecise and incomplete information [40].

Inference system

The Inference system in Fuzzy Logic plays a crucial role in making decisions based on set of laws and participation data. In context of research paper focusing on the mamdani method of Fuzzy Inference can be beneficial. The Mamdani method is worn in fuzzy models owed to aptitude and make available understandable results with a clear structure, making it intuitive and explainable. This method involves acquiring fuzzy sets by captivating the least amount significance, modifying the state, and applying operator OR to the output [41]. A collection of fuzzy control rules is gathered using the fuzzy rule algorithm in a certain order. These rules, which are founded on in-depth understanding of the system they are controlling, are used to regulate a system so that it meets the required performance standard. The scheme—which is related to the max-min work—is foundation for the fuzzy inference.

Three components make up a fuzzy logic controller's inference system:-

Basis for rules: - It comprises of several If-Then rules that are necessary for the controller to function properly. The antecedent and consequence of a rule are referred to as the if and then, respectively. These guidelines may be regarded of as analogous responses produced by the human thought process. The controller operates the rules by using the linguistic input variables that are obtained after fuzzification [42].

Database: - Every membership that is user-defined function contains the terms to be used in set of laws.

Logic method: - Basically, it interprets set of laws and produces the desired outcome based on specific rules and conditions. The table below shows how the rule base specifies the specifications for how the participation and productivity variables are supposed to relate to

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one another.

ΔVpv*[o/p]	ΔVpv [I /p]					
ΔPpv [I /p]		NB	NS	ZE	PS	PB
	NB	PS	PB	NB	NB	NS
	NS	PS	PS	NS	NS	NS
	ZE	ZE	ZE	ZE	ZE	ZE
	PS	NS	NS	PS	PS	PS
	PB	NS	NB	PB	PB	PS

Fig: Rules Implemented In Fuzzy Logic System

In the above table we get to know the variables which are being employed in Fuzzy Logic System, where eachof the variable having its own significance, which are as;

Positive big
(PB) Positive
small (PS)
Negative big
(NB)

Negative small
(NS)Zero (ZE)

De-fuzzification

De-fuzzification is a process commonly used in Fuzzy Logic systems to convert fuzzy sets (which represent linguistic terms or concepts) into crisp values that can be easily understood and used for decision-making or control purposes. In Fuzzy Logic, lingual terms are often represented by set [43], which express the extent to which an element belongs to a set. A set is input for the defuzzification method, and the result is sole figure that must be functional to the organization. The system requires a non-fuzzy control output value in order to produce the preferred end production, necessitating the need for a defuzzification stage. While there are several defuzzification techniques available today, the centric and bisector techniques are the most often used ones. The defuzzification process in the suggested design uses the centric defuzzification method [44].

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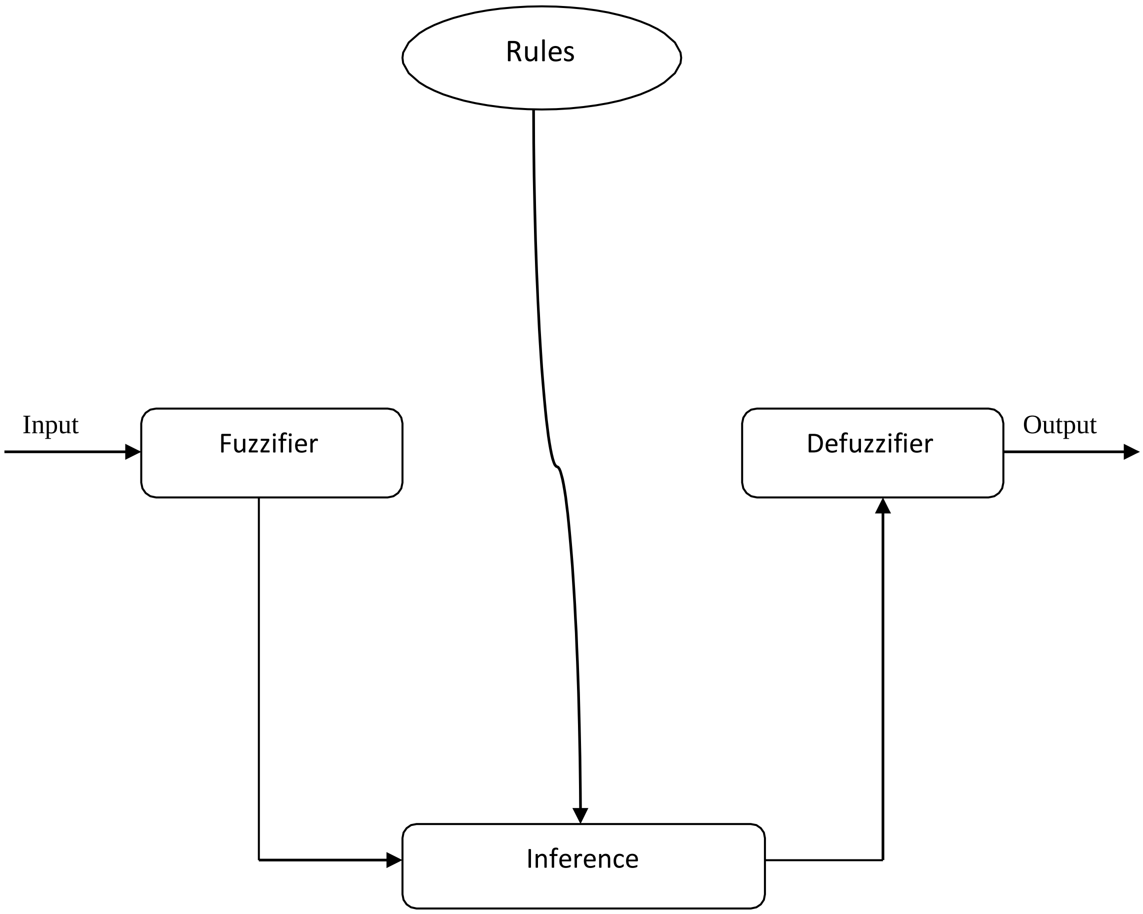

Fig: Flowchart for Defuzzification

The whole architecture of a illustrates a fuzzy logic system above diagram. The fuzzy rules that specify the evaluation are applied after all of the input variable values have been converted into the corresponding language variable values. Once more, the outcome is a linguistic value. This language outcome is converted into a numerical value via the defuzzification process. It begins with input fuzzy sets, which represent linguistic variables or terms (such as “low”, “medium”, and “high”) that describe the input data. It then utilizes fuzzy inference rules to make decisions based on input fuzzy sets [45]. These rules determine the fuzzy output set based on the combination of input sets and specified logic relationships. Block defuzzer converts the aggregated fuzzy output sets into the crisp, non-fuzzy value.

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MATLAB/SIMULINK Fuzzy Logic Based Model with and without MPPT

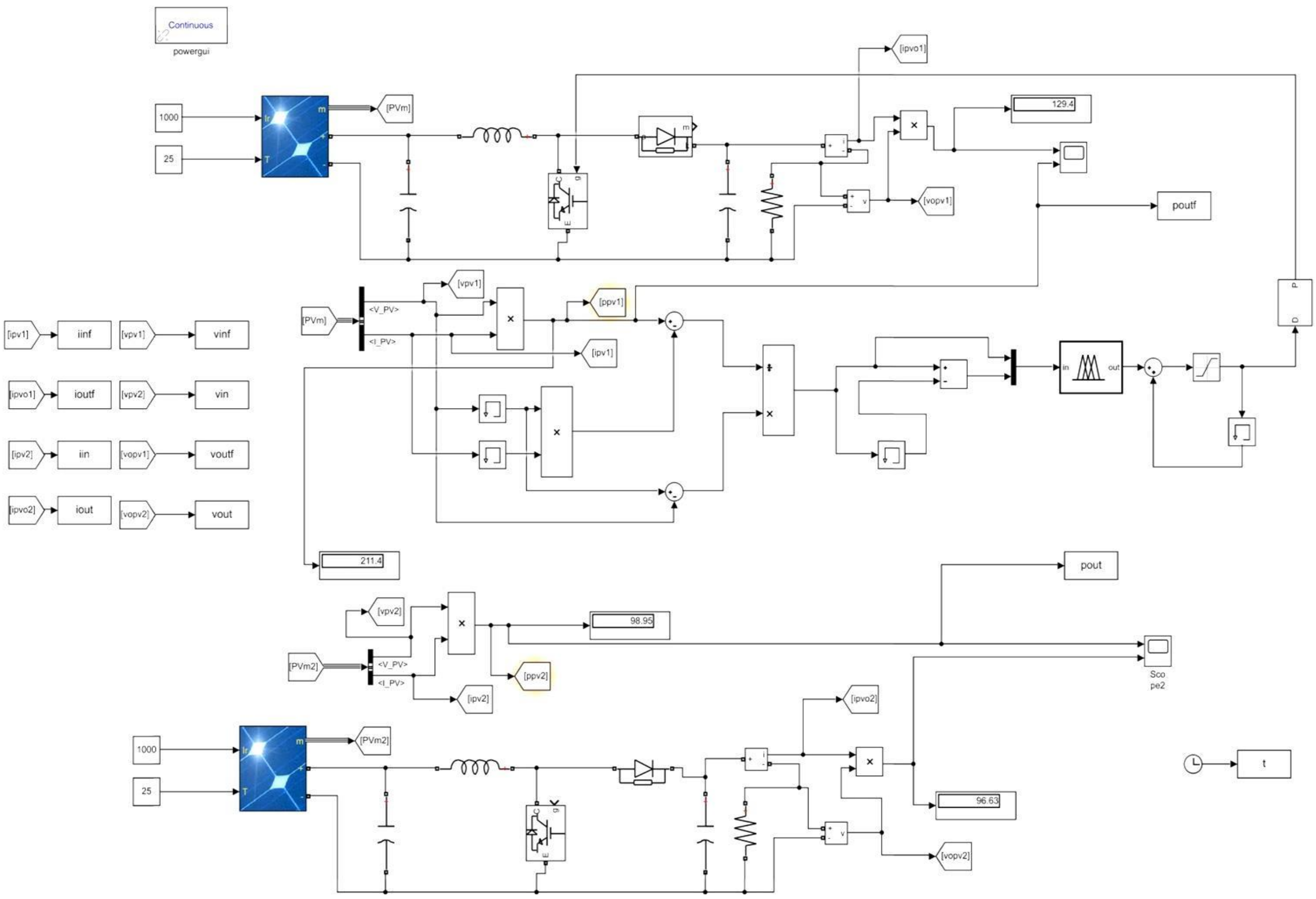

Fig: MATLAB/SIMULINK MODEL OF FUZZY LOGIC WITH AND WITHOUT MPPT

In context of MATLAB simulation, Fuzzy Logic is utilized both with and without MPPT in simulation of PV systems.

Integrating Fuzzy Logic controllers to dynamically track and maintain the MPP of a PV system for enhanced efficiency comes in the case of Fuzzy Logic with Peak performance. Utilizing Fuzzy Logic controllers in favour of intelligent scheme control and optimization based on input parameters comes in the case of Fuzzy Logic without MPPT.

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Simulation results

At hotness of 25ºC and irradiation of 1000 W/m², the production clout of the PV unit and converter using two distinct MPPT approaches is obtain in MATLAB/SIMULINK. The results of the simulation demonstrate the use of P&O approach and fuzzy logic in tracing utmost authority, as shown in the figures. The following figures display equivalent electrical energy variation in V_{MPP} and V_O for various converters.

1. The above graph shows us the relation between power and time with and without fuzzy logic controller using MATLAB/SIMULINK. As we can get from the graph that, power out with fuzzy is shown with blue shaded line while as power out without fuzzy can be seen in pinkish colour. The fluctuations can be seen in the power out with fuzzy controller.

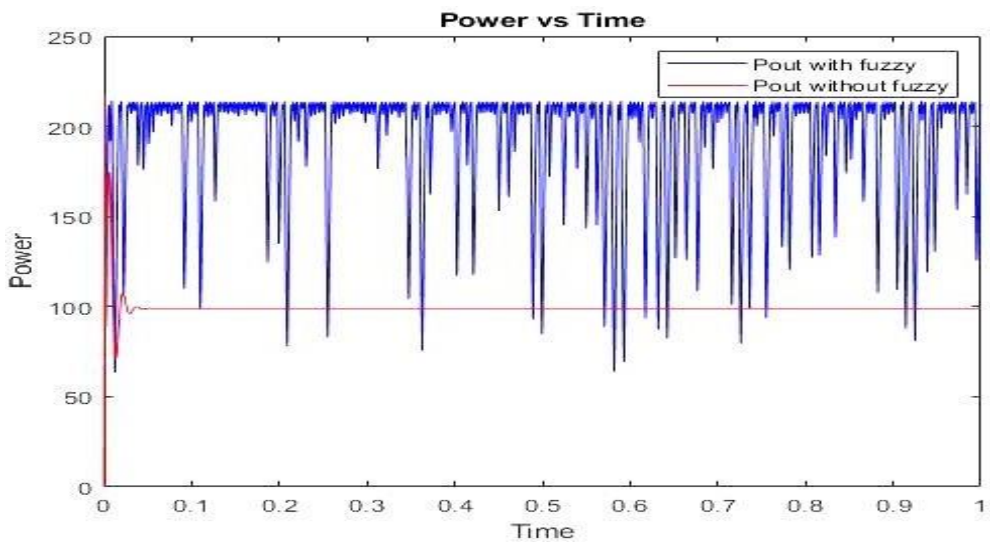

Fig.1: Power out with and without Fuzzy Logic Controller

From the above graph we can conclude that the fluctuations can be seen after every 0.1 seconds of Power Out (Pout) with Fuzzy Logic Controller and we get to know that Power Out (Pout) without Fuzzy Logic Controller gives us a constant power with respect to change in time after every 0.1 seconds of a new cycle.

2. The graph for the voltage versus time of the Voltage In (V_{in}) with Fuzzy and Voltage In (V_{in}) without Fuzzy, Voltage Out (V_{out}) with Fuzzy and Voltage Out (V_{out}) without Fuzzy can be seen in below graph.

The Output Voltage with Fuzzy Logic Controller gives us the more distorted result as compared to Output Voltage without Fuzzy, where we get the smooth result with at least zero distortion in its output.

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Similarly, the Input Voltage with Fuzzy Controller gives some fluctuations in the result and Input Voltage without Fuzzy gives us the same result as that of Output Voltage without Fuzzy Controller.

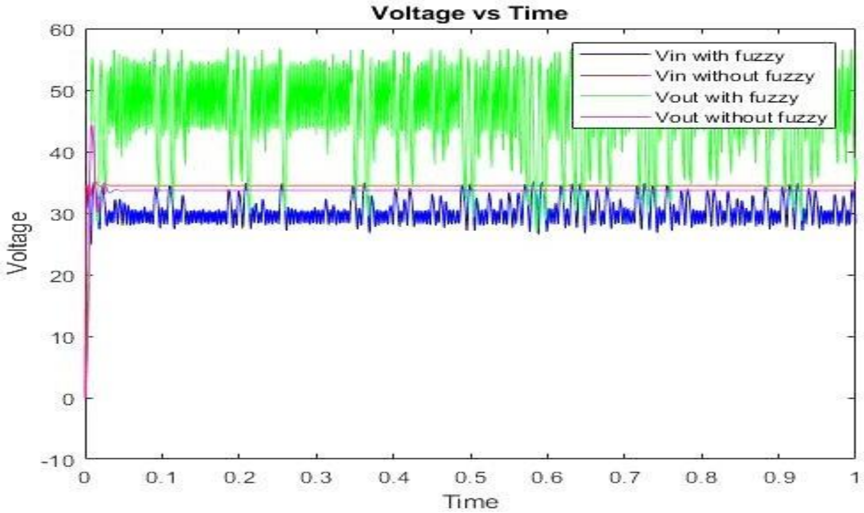

Fig.2 Input, Output Voltage with and without Fuzzy

3. The below Power Vs Voltage graph with Fuzzy Logic Controller shows an optimized performance where system is able to abstract the maximum power point efficiently. This is achieved through the intelligent decision-making capabilities of FLC's ensuring that system operates at optimal power point to minimize energy loss. On the other hand, in systems without FLC, the Power Vs Voltage graph may not exhibit same level of dynamic optimization and intelligent decision-making, potentially leading to suboptimal performance and lower energy efficiency.

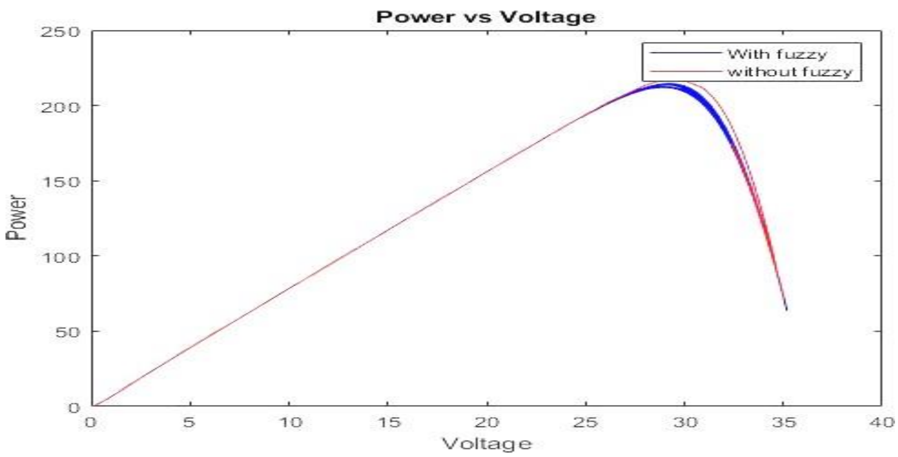

Fig.3: Maximum Power with and without Fuzzy

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4. The below shown graph gives us the result between Current and Time, that is Input Current with and without Fuzzy (I_{in}) and Output Current (I_{out}) with and without Fuzzy.

The result shows us that the Input Current (I_{in}) with Fuzzy has more fluctuations as compared to the input current without Fuzzy Logic Controller. On the other hand, the Output Current with Fuzzy Logic Controller has more distortion rate of the Output Current without Fuzzy Controller.

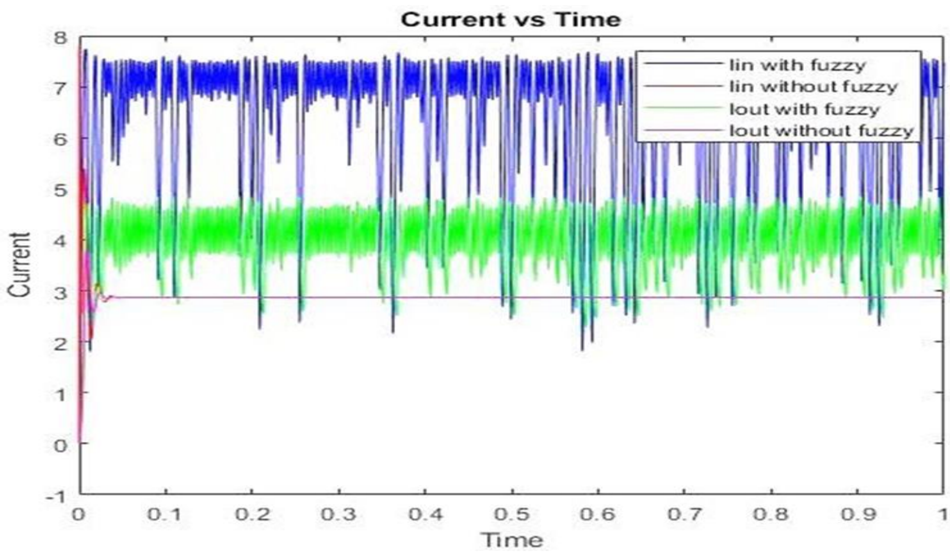

Fig.4: Input Output Current with and without Fuzzy

CONCLUSION

The utilize of fuzzy logic-based utmost energy position tracking algorithms for astral photovoltaic arrays is investigated in this study. Optimizing the PV array's energy extraction to the greatest extent possible under various temperature and irradiance circumstances is a major purpose. This work uses MATLAB/SIMULINK to derive the V-I and P-V distinctiveness of a photovoltaic component under 1000W/m^2 of energy and 25ºC of hotness. The study of the fuzzy logic organizer and P&O peak performance is finished, and the recreation outcome is displayed. The recreation grades show that the fuzzy-based MPPT follows authority of power incessantly with a lesser amount of vacillation and overrun than P&O MPPT process while having a faster tracking time. It is confirmed by the results that the fuzzy logic MPPT responds quickly. Our findings demonstrate that the fuzzy logic-based MPPT algorithm effectively tracks the maximum power point (MPP) of the PV array with reduced oscillations and overshoots compared to the P&O method, while achieving faster tracking response times. The simulation results validate that the fuzzy logic MPPT responds swiftly to changes in environmental conditions, thereby enhancing the overall energy extraction efficiency of the PV system.

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This research contributes to advancing the field of solar energy by proposing a robust MPPT technique that can adapt to real-time variations in solar irradiance and temperature conditions. The practical implementation of fuzzy logic controllers in MPPT systems offers significant improvements in performance and reliability, which are critical for maximizing the energy yield and economic viability of solar photovoltaic installations.

Future studies could explore further optimizations of the fuzzy logic-based MPPT algorithm across different climatic regions and under varying load conditions to assess its adaptability and robustness in diverse operational scenarios. Additionally, integrating advanced control strategies with fuzzy logic, such as neural networks or evolutionary algorithms, could potentially enhance the efficiency and stability of MPPT systems in solar PV applications.

In conclusion, the results affirm the efficacy of fuzzy logic-based MPPT in achieving superior energy extraction performance from solar PV arrays, underscoring its potential as a promising technology for optimizing renewable energy generation.

REFERENCES

1. Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed", 0- 7803-5772-8/00, IEEE, 2000, 1699-1702.
2. Dunia, James, and Bakari MM Mwinyiwiwa. "Performance Comparison between ĆUK and SEPIC Converters for Maximum Power Point Tracking Using Incremental Conductance Technique in Solar Power Applications." world academy of science, engineering and technology International Journal of Electrical, Computer, Electronics and Communication Engineering Vol: 7 No: 12, 2013.
3. Nasrudin Abd Rahim, Hew W0oi Ping and Jeyraj Selvaraj. "Photovoltaic Module Modelling using Simulink/Matlab." Procedia Environmental Sciences 17 (2013): 537-546.
4. Faranda, Roberto, and Sonia Leva. "Energy comparison of MPPT techniques for PV Systems." WSEAS transactions on power systems volume 3, no. 6, June 2008, pp. 446-455.
5. N.Ammasai Gounden, Sabitha Ann Peter, Himaja Nallandula and S.Krithiga. "Fuzzy logic controller with MPPT using linecommuted inverter for three-phase grid-connected photovoltaic systems", Renewable Energy (ELSEVIER Journal), vol.34, pp. 909- 915, July 2008.
6. H. Abu-Rub, A. Iqbal and Sk. M. Ahmed, "Adaptive neuro-fuzzy inference system-based maximum power point tracking of solar PV modules for fast varying solar radiations", International Journal of Sustainable Energy Vol.31, No.6, December 2012, 383-398.
7. Basil M. Hamed and Mohammed S. El-Moghany, "Fuzzy Controller Design Using FPGA for Photovoltaic Maximum Power Point Tracking", International Journal of Advanced Research in Artificial Intelligence, Vol.1, No3, 2012.

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

8. M.Zein Alabedin, E.F. El-Saadany, M.M.A. Salama, "Maximum Power Point Tracking for Photovoltaic System Using Fuzzy Logic and Artificial Neural Networks".
9. Trishan Esram, and Patrick L. Chapman, "Comparison of Photovoltaic Array Maximum PowerPoint Tracking Techniques" IEEE Transactions on Energy Conversion, 22 (2), 2007, 439-449.
10. S. Nima, R. K. Nima, and G. Agnehotri, "Matlab/simulink based study of photovoltaic cells/modules/array and their experimental verification," Int. J. Energy Environ., vol. 1, no. 3, pp. 487–500, 2010.
11. S. Simathi, L. Ashok Kemar, and P. Sureakha, Solar PV and Wind Energy Conversion Systems. 2015.
12. Kuey-Hsuang Chao and Jyun-Peng Chen, "A Maximum Power Point Tracking Method Based on Particle Swarm Optimization for Photovoltaic Module Arrays With Shadows," ICIC Express Lett., vol. 8, no. 1–5, pp. 626– 633, 2014.
13. T. Esrm and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Trans. energy Converters, vol. 22, no. 2, pp. 439–449, 2007.
14. Photovoltaic Cell Conversion Efficiency, U.S. Department of Energy, Retrieved, 19 May 2012.
15. M. Veerachary, et al., "Neural-Network Based Maximum Power Point Tracking of Coupled-Inductor InterleavedBoot Converter Supplied PV System Using Fuzzy Controller," IEEE Transactions on Industrial Electronics, vol/issue: 50(4), pp. 749-758, 2003.
16. A. A. Siddik and M. Shangeetha, "Implementation of Fuzzy Logic Controller in photovoltaic Power generation using Boost converter and Boost Inverter,"International Journal of Power Electronics and Drive System (IJPEDS), vol/issue: 2(3), pp. 249-256, 2012.
17. J. Kasera, et al, "Design of grid connected Photovoltaic System Employing Incremental Conductance MPPT Algorithm," Journal of Electrical Engineering.
18. M. D Singh and K. B Khanchandani, "Power Electronics," Tata Mcgraw Hill publishers, 2nd edition, pp. 135-670, 2011.
19. M. Ropp, J. Ginn, J. Stevens, W. Bower, and S. Gonzalez, "Simulation and experimental study of the impedance detection anti-islanding method in the single-inverter case," in Proc. 4th World Conf. Photovolt. Energy Convers., May 2006, pp. 2379–2382.
20. D. Hohm and M. Ropp, "Comparative study of maximum power point tracking algorithms," Prog. Photovolt., vol.11, pp. 47–62, Jan. 2003.
21. M.D Singh & K B Khanchandani (2011), "Power Electronics", Tata Mcgraw Hill publishers, Second edition, pp.135-670.
22. I. H. Altas and A.M. Sharaf, "A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment," IEEE, Clean Electrical Power, International Conference on Clean Electrical Power (ICCEP „07), June 14-16, 2007, Ischia, Italy.

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 *Revised: 15-05-2024* *Accepted: 28-06-2024*

23. S K Pillai , “A First Course on Electrical Drives”, New Age International Publishers, 2012, Third edition, pp. 3-54.
24. Zhang Jiyang, Li Da, Yang Ping, et al, "Analysis of the development trend of photovoltaic power generation,". Renewable energy, vol. 32, no. 2, pp. 127-132, 2014.
25. Ding Ming, Wang Weisheng, Wang Xiuli, et al, "Review of the impact of large-scale photovoltaic power generation on power system," China Journal of Electrical Engineering, vol. 34, no. 1, pp. 2-14, 2.
26. Zhang Jiyang, Li Da, Yang Ping, et al, "Analysis of the development trend of photovoltaic power generation," Renewable energy, vol. 32, no. 2, pp. 127-132, 20.
27. Ting-Chung Yu and Tang-Shiuan Chien, “Analysis and Simulation of Characteristics and Maximum Power Point Tracking for Photovoltaic Systems”, Proceedings of Power Electronics and Drive Systems Conference, pp. 1339 - 1344, Taipei, 2009.
28. D. P. Hohm and M. E. Ropp, “Comparative Study of Maximum Power Point Tracking Algorithms using an experimental, programmable, maximum power point tracking testbed”, Proceedings of Photovoltaic Specialists Conference, pp. 1699 - 1702, USA,2000.
29. Jancarle L. Dos Santos, Fernando L. M. Antunes, and Anis Chehab, “A Maximum Power Point Tracker for PV Systems Using a High-Performance Boost Converter”, Solar Energy, Issue 7, Vol. 80, pp. 772- 778, 2005.
30. Roberto Faranda, Sonia Leva, “Energy Comparison of MPPT techniques for PV Systems”, Wseas Transactions on Power System, Issue 6, Vol. 3, pp. 446- 455, June 2008.
31. Walker Geoff, “Evaluating MPPT Converter Topologies Using a MATLAB PV Model ” Journal of Electrical & Electronics Engineering, Vol. 21, No. 1, pp. 49-55, 2011.
32. Dunia, James, and Bakari MM Mwinyiwiwa. "Performance Comparison between ĆUK and SEPIC Converters for Maximum Power Point Tracking Using Incremental Conductance Technique in Solar Power Applications." world academy of science, engineering and technology International Journal of Electrical, Computer, Electronics and Communication Engineering Vol: 7 No: 12, 2013.
33. Nasrudin Abd Rahim, Hew Wooi Ping and Jeyraj Selvaraj. "Photovoltaic Module Modeling using Simulink/Matlab." Procedia Environmental Sciences 17 (2013): 537-546.
34. Raedani, Ronn, and Moin Hanif. "Design, testing and comparison of P&O, IC and VSSIR MPPT techniques." In Renewable Energy Research and Application (ICRERA), 2014 International Conference on, pp. 322-330. IEEE, 2014.
35. Ammasai Gounden, Sabitha Ann Peter, Himaja Nallandula and S.Krithiga. “Fuzzy logic controller with MPPT using linecommuted inverter for three-phase grid-connected photovoltaic systems”, Renewable Energy (ELSEVIER Journal), vol.34, pp. 909- 915, July 2008.

Power System Technology
ISSN:1000-3673

Received: 06-04-2024 *Revised: 15-05-2024* *Accepted: 28-06-2024*

36. H.Abu-Rub, A.Iqbal and Sk.M.Ahmed, "Adaptive neuro-fuzzy inference system-based maximum power point tracking of solar PV modules for fast varying solar radiations", International Journal of Sustainable Energy Vol.31, No.6, December 2012, 383-398.
37. M.A.S. Masoum, M.Sarvi, "A new fuzzy-based maximum power point tracker for photovoltaic applications", Iranian Journal of Electrical & Electronic Engineering, Vol.1, January 2005.
38. Basil M. Hamed and Mohammed S. El-Moghany, "Fuzzy Controller Design Using FPGA for Photovoltaic Maximum Power Point Tracking", International Journal of Advanced Research in Artificial Intelligence, Vol.1,No3, 2012.
39. M.Zein Alabedin, E.F. El-Saadany, M.M.A. Salama, "Maximum Power Point Tracking for Photovoltaic System Using Fuzzy Logic and Artificial Neural Networks".
40. Hussein, K.H, Murta, I, Hoshino,T., Osakada, M., "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions", IEEE Proceedings of Generation, Transmission and Distribution, vol. 142, No.1, 1995.
41. J.A.Jiang et Al.,"Maximum Power Tracking for Photovoltaic Power Systems," Tamkang Journal of Science and Engineering, Vol. 8, No. 2, pp. 147-153, 2005.
42. Y. Kuo, et Al., "Maximum power point tracking controller for photovoltaic energy conversion system", IEEE Trans. Ind. Electron., Vol.48, pp. 594-601, 2001.
43. Trishan Esram, and Patrick L. Chapman, "Comparison of Photovoltaic Array Maximum PowerPoint Tracking Techniques," IEEE Transactions on Energy Conversion, 22 (2), 2007, 439-449.
44. T. Esram, P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques", IEEE Trans. on Energy Conversion, vol. 22, no. 2, June 2007.
45. Nasrudin Abd Rahim, Hew Wooi Ping and Jeyraj Selvaraj. "Photovoltaic Module Modelling using SIMULINK/MATLAB." Procedia Environmental Sciences 17 (2013): 537-546.