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A REVIEW OF MAXIMUM TECHNIQUES

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Research Article

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Abstract: The kind of end-use energy consumption that is expanding the quickest in the globe is electricity. Global net power production is expected to increase by 2.3 percent annually on average until 2035. The fastest-growing source of new power production is renewable energy. Following the introduction of tracking regulations, the Indian solar PV market is enjoying its position in solar applications. The comparative analysis of maximum power point tracking (MPPT) methods is the main topic of this work. It has been examined using several MPPT techniques with the same objective of monitoring the maximum power under all operating conditions in order to maximize the output power of the PV system. The simplicity, convergence speed, digital or analog implementation, sensors needed, cost, range of efficacy, and other factors are taken into consideration while reviewing maximum power point tracking approaches in this study.

Keywords: MPPT, tracking methods, convergence rate, and analog or digital implementation.

INTRODUCTION

Since only 30–40% of the energy incident is transformed into electrical energy, a maximum power point tracking method is necessary to improve the solar panel's efficiency. Because photovoltaic (PV) energy is ubiquitous, freely available, environmentally friendly, and has lower operating and maintenance costs, it becomes a promising alternative in light of the growing demand for electricity, the limited supply, and the rising costs of conventional sources (such as coal and petroleum, etc.). As a result, there seems to be a rise in demand for both standalone and grid-connected PV generating systems [22], [27]. Consequently, an effective maximum power point tracking (MPPT) method is required, which is anticipated to monitor the MPP under all environmental circumstances and then compel the PV system to run at that MPP point.

MPP stands for PV's distinct operating point, which provides maximum power and the array's best efficiency. Temperature and sun insolation affect it, thus tracking methods must be used to keep an eye on it. The current source area and the voltage source region are the two regions that make up a solar cell's working characteristics, as shown in Fig. 1. The solar cell's internal impedance is high in the current source area, which is situated on the left side of the current-voltage curve. On the right side of the current-voltage curve is the voltage source area, which has a low internal impedance. The Maximum Power Transfer Theorem states that when the internal impedance of the source and the load are equal, the maximum power is transmitted to the load.

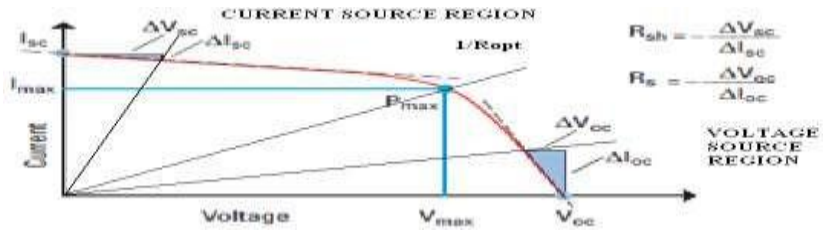


FIG 1: VOLTAGE-CURRENT & POWER-VOLTAGE CHARACTERISTICS

A tracker is put between the PV system and the load in order to determine the suitable MPP. It should be constructed with minimal volatility, quick reaction times, and high performance. Because the temperature and irradiance of the panel are stochastic and unexpected, they have an impact on the PV's efficiency. since of this, a balance of system (BOS) is required since it is not feasible to link the load directly to the PV to get the maximum power. This BOS is usually a DC-DC converter to change the load's characteristics. One benefit of this converter is that it can control the amount of power supplied to the load. The DC/DC converter is in charge of delivering the solar PV module's maximum power to the load. This serves as an adjustment to match source and load impedance. A dc-dc converter (step up or step down) is often used to perform MPPT. Although the MPP's position is unknown, it may be found using search algorithms or calculating models. The MPPT System Block Diagram is shown in Fig. 2.

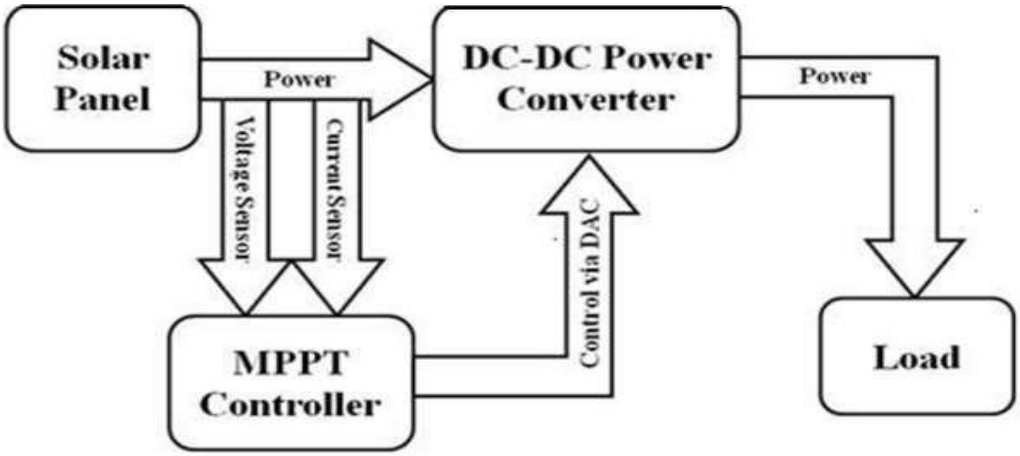


FIG 2: BLOCK DIAGRAM OF MPPT SYSTEM

An isolated load is obtained by feeding the voltage across the DC-DC converter. Duty Cycle provides the input-output voltage connection for converter conduction mode. Controller is employed in the process to correct for the parameter differences caused by temperature and irradiance variations. It enables the system to adjust to environmental changes.

I. LITERATURE REVIEW

The literature reports on a number of MPPT approaches and how they are implemented [3]–[38]. When choosing an MPPT approach for a certain application, researchers are often perplexed. Curve fitting, fractional short circuit current, fractional open circuit voltage, look-up tables, one cycle control, perturbation and observation, incremental conductance, and feedback techniques—including MPPT

techniques [22]–[38]—were, regrettably, the only methods available in this field until 2007. However, since then, numerous new MPPT techniques have been reported and illustrated in other papers [3]–[21], including fuzzy logic, artificial neural networks, adaptive perturbation and observation, estimated perturb and perturb, genetic algorithms, adaptive neuro fuzzy, and particle swarm optimization based MPPT.

A review including all successful and efficient MPPT approaches proposed before to 2007 and subsequent to 2013 must be prepared. The MPPT approaches are reviewed and compared based on their benefits, drawbacks, control variables, circuit types, algorithm complexity, degree of hardware implementation difficulty, and sorts of research and commercial applications.

Perturb & Observe (P&O) and Incremental Conductance (IC) are the most popular MPPT techniques due to their ease of use, shorter tracking times for the maximum power point, and other financial considerations. When MPP fluctuates consistently under abruptly changing weather circumstances (irradiation level), P&O interprets this as a shift in MPP caused by disturbance rather than irradiation, which sometimes results in incorrect MPP calculations [6]. However, as the approach uses two voltage and current samples to calculate MPP, this issue is resolved in the Incremental Conductance method [19]. Nevertheless, the algorithm's complexity is much higher than that of the previous one, which raises the cost of execution rather than increasing efficiency. Therefore, we must compromise between efficiency and ramification.

It has been noted that the converter also affects the system's efficiency. It is typically the lowest for a boost analysis, the highest for a buck analysis, and the lowest for a buck-boost analysis [11]. Equalization of output operating points in relation to force displacement of input operating points of the same operating system is assessed when many solar modules are connected in parallel. It is very efficient in both fixed and time-varying air circumstances and is relatively simple to execute [23]. The most popular MPPT techniques are Perturb & Observe (P&O) and Incremental Conductance because to their easy installation, quick tracking of the maximum power point, and other financial considerations. When MPP fluctuates consistently under abruptly changing weather circumstances (irradiation level), P&O interprets this as a shift in MPP caused by disturbance rather than irradiation, which sometimes results in incorrect MPP calculations [7]. However, the Incremental Conductance approach solves this issue since the algorithm uses two voltage and current samples to calculate MPP. Nevertheless, the algorithm's complexity is much higher than that of the previous one, which raises the cost of execution rather than increasing efficiency. Therefore, we must compromise between efficiency and ramification.

A high-precision sun tracking controller should be taken into consideration since the greatest quantity of solar energy that the collector can gather is correlated with the accuracy of monitoring the sun's location [28]. A number of strategies based on orientation and tilt motion control have been put forward in the past to enhance tracking systems for monitoring the sun's course [7], [21]. These strategies include tracking algorithms [13], [33–34], and mathematical models [35] to optimize the tilt and orientation angles of solar collectors using geographic latitude data [10]. Some methods based on motion control [12], [20], and signal processing utilizing data from electronic devices [13, 17] have been presented in the area of control engineering to automatically modify tilt and orientation angles in relation to the sun

position.

Some of the most important and well-known control schemes in solar applications have recently been introduced in the field of artificial intelligence. These include sun tracking systems that use fuzzy control based on light-sensors, ambient temperature, and electric load variations [5], fuzzy algorithms to connect household equipment on either the electrical grid or a photovoltaic panel [8], [9], [18], [19], [34], prediction [24], [25], [26], and estimation of current using solar radiation [15], and hybrid systems that combine solar energy with technology based on genetic algorithms [14]. Human knowledge has been interpreted in the same way as data from sensors and technical equipment, despite the existence of several ways based on intelligent processes. The initial network parameter setting may be chosen easily thanks to this structure's simplicity. Multivariate data might thus be included into the fuzzy inference system by adhering to IF-THEN criteria, which are akin to human sense.

However, there is human knowledge that has been produced over many years in physics and astronomy research [30], [31], and [32], which ought to be a potent tool-based knowledge. For instance, the benefit of fuzzy logic and neural network integration, known as neuro-fuzzy, stems from both fuzzy logic's human-like reasoning and neural networks' capacity for learning [16]. As a result, this plan implies that human knowledge might be included based not just on data from electronic devices but also on astronomical data from databases and scientific understanding gathered throughout time.

Three kinds of control methods are defined by the classification of MPPT approaches [3], [4] in the aforementioned assessed papers: probabilistic control, direct control, and indirect control. Without any prior knowledge of the PV panel characteristics, direct control techniques may directly seek MPP by accounting for the fluctuations of the PV panel operating points. Once again, they fall into two categories: modulation techniques and sampling techniques. To accomplish MPPT applications, two distinct control variables—such as voltage, current, solar irradiance, temperature, etc.—are often used. MPPT approaches may be divided into two categories, such as one-variable techniques and two-variable techniques, based on the variables that must be felt. Compared to current sensors, voltage sensors are simpler and less expensive to deploy. Analog and digital circuits are the two kinds of circuitry used in MPPT procedures. Certain applications, such solar cars, industries, and large-scale residential, need precise MPPT and cost is not a concern. However, a straightforward and affordable MPPT approach is required for various systems, such as modest home applications, irrigation water pumps, etc. Because precision and quick reaction are top goals in expensive applications, sophisticated and complicated circuitry is often used.

Given the aforementioned information, the evaluation supported the idea that intelligent or hybrid PV solutions based on fuzzy logic systems provide good performance, quick reactions, less overshoot, and fewer fluctuations for sudden changes in temperature and irradiance. Regarding Fuzzy

Since a precise PV model is not necessary, logic controllers and neuro-fuzzy based systems will be taken into consideration for further development. When creating a plan for the identification of shadowed photovoltaics, fuzzy logic offers an appealing framework. Given the absence of such unanimity, a fuzzy logic scheme's minimal modeling requirements and rapid prototyping speed are quite advantageous [4].

II. TECHNIQUES COMPARISON

S.N	TECHNIQUE USED	DESCRIPTION	METHOD	VARIABLE	CKT	TUNING	COST	HARDWARE
1	Curve Fitting	Characteristics based on mathematical equations or numerical approximations using third order polynomial with roots.	Incremental Conductance	Voltage	Digital	Yes	Inexp	Simple
2	Forced Short Circuit Current	Nonlinear characteristics of PV system is modeled using mathematical equations or numerical approximations for IMPP=KSCISC	Incremental Conductance	Voltage or Current	Analog and Digital	Yes	Inexp	Simple
3	Forced Open Circuit Voltage	In this technique, roots can be calculated from the empirical relationship shown as follows for VMPP=KOCVOC	Incremental Conductance	Voltage or Current	Digital	Yes	Inexp	Simple
4	Look Up Table	MPP of a PV system is calculated before hand for each probable environmental condition and stored in the memory device of MPPT's control system.	Incremental Conductance	Voltage or Current	Analog and Digital	Yes	Inexp	Simple
5	One Cycle Control	Nonlinear MPPT control technique. It involves the use of a single-stage inverter where the output current of the inverter can be adjusted according to the voltage of the PV array so as to extract the maximum power from it.	Sampling Method	Current	Analog and Digital	Yes	Inexp	Simple
6	Differenciation dV/dt	This technique determines MPP of a PV system on solving the following: dP/dt=d(IV)/dt=IdV/dt + VdI/dt=0	Sampling Method	Voltage or Current	Digital	Yes	Exp	Complex

7	Feedback Voltage or Current	This technique is used in the system which has no battery. Without a battery, a simple controller is needed to fix the panel voltage at a constant level. Hence, a simple MPPT controller can be applied to maintain duty cycle of converter.	Sampling Method	Voltage or Current	Digital	No	Exp	Complex
8	Feedback Power with Current	Similar to above technique with variation related to dP/dI equating 0 at MPP.	Sampling Method	Voltage or Current	Digital	No	Exp	Complex
9	Feedback Power with Voltage	Similar to above technique with variation related to dP/dV equating 0 at MPP.	Sampling Method	Voltage or Current	Analog and Digital	No	Exp	Complex
10	Perturb and Observe Hill Climbing	First PV voltage and current are measured power is calculated. A small perturbation of voltage or perturbation of duty cycle is done and then compared with previous power.	Sampling Method	Voltage or Current	Analog and Digital	No	Exp	Complex

11	Increment Conductnce	For a PV system, the derivative of panel output power with its voltage is expressed as dP/dt=d (IV)/dt=I + VdI/dV=0.It is zero at MPP, positive on the left and negative on the right of MPP.	Sampling Method	Voltage or Current	Digital	No	Exp	Complex
12	Forced Oscillation	Small-signal sinusoidal is injected into the switching frequency and comparing the ac component and the average value of the panel terminal voltage.	Modulation Method	Voltage or Current	Analog	Yes	Exp	Complex
13	Ripple Correction Control	When a PV array is connected to a power converter, the switching action of the converter imposes voltage and current ripple on the PV array. These ripples are used to determine MPP.	Modulation Method	Voltage or Current	Analog	Yes	Exp	Complex
14	Estimated Perturb Perturb	EPP technique is an extended P&O method. This technique has one estimate mode between two perturb modes for irradiance-changing conditions.	Sampling Method	Voltage or Current	Analog and Digital	No	Exp	Complex
15	Intelligent Techniques	Fuzzy Logic based Artificial Neural Network Based Particle swarm optimization based	Intelligent Method	Voltage or Current	Digital	Yes	Exp	Complex
16	Hybrid MPPT Techniques	P&O-ANN hybrid MPPT tracking is possible. For strengthening ANN based MPPT technique using Genetic Algorithm (GA). Adaptive Neuro-Fuzzy inference system (ANFIS).	Sampling Method	Voltage or Current	Digital	Yes	Exp	Medium

17	DMPPT Techniques	Distributed MPPT due to orientations of PV modules in array, shadowing effects, manufacturing tolerances, nonuniformity of temperature, uneven solar irradiation and air circulation, dust and spot dirtiness.	Intelligent Method	Voltage or Current	Digital	Yes	Exp	Complex

After surveying various Research works following limitations are highlighted:

(i) (i) Methods related to FOCV, FSCC, RCC, and LUT are described in [22–38] as being offline and unable to simultaneously control input and output impedances. Online systems only need to be built since indirect methods are based on pre-determined data.

(ii) (ii) The system must account for the efficiency loss caused by the DC-DC converter notwithstanding the significant efficiency gain via MPPT. Direct method systems are unable to simultaneously control input and output. Additionally, if the load is unable to use all of the power supplied, the MPPT terminates its initial duty, resulting in a trade-off between cost and efficiency [5], [6].

(iii) (iii) When implemented correctly, intelligent systems provide high performance, less fluctuations, and no overshoot. [3], [4]Either MPPT tracking algorithm using different techniques or Panel Rotation techniques have been identified [4]-[37]. To obtain maximum profit of standalone or grid connected PV system both need to be studied on a collective scale if MPPT efficiency needs to be improved given by:

$$\eta_{\mathrm{MPPT}} = \frac{P_{\mathrm{PV}}}{P_{\mathrm{mpp}}} \times 100$$

where P_{PV} refers to Power produced at output of PV Panel and P_{MPP} refers to Power produced at MPP.

(iv) Real-time PV simulator diagnostic is suggested by the worldwide PHOTON magazine. Distributed Maximum Power Point Tracking (DMPPT) is caused by a variety of factors, including different PV module orientations in arrays, cloud shadowing effects, manufacturing tolerances, nonuniform ambient temperature, uneven solar irradiation and air circulation, dust, and spot dirtiness (leaves, bird droppings), as examined in [9].

(v) Perovskites are a specific sort of crystalline material that must be stacked upon in solar cell configurations to increase absorption properties, reduce dirt, make installation less costly, and ensure efficient operation [37].

III. RESULT AND DISCUSSION

In the fig 3, 4 and 5, graph of Current Vs Voltage, Power Vs Voltage and Maximum Power Point are plotted using Simulink Modelling in MATLAB.

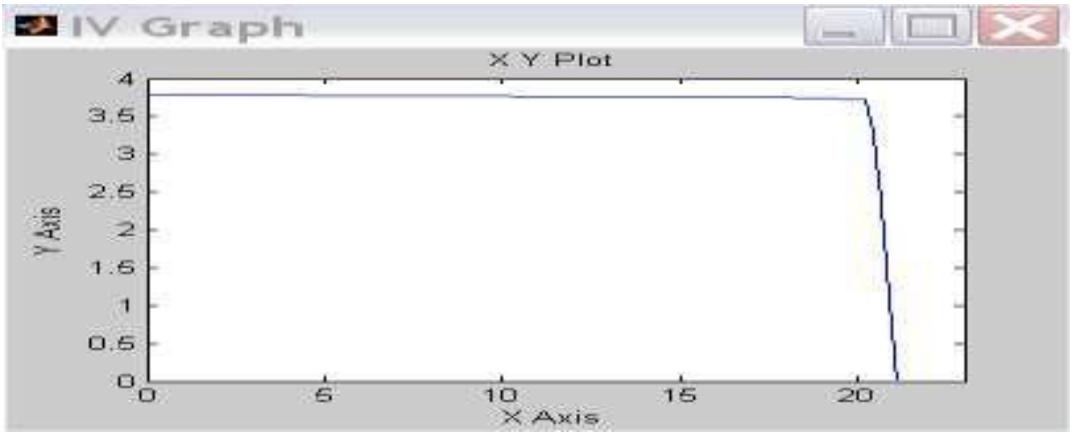


FIG 3: IV CHARACTERISTICS OF MPPT SYSTEM

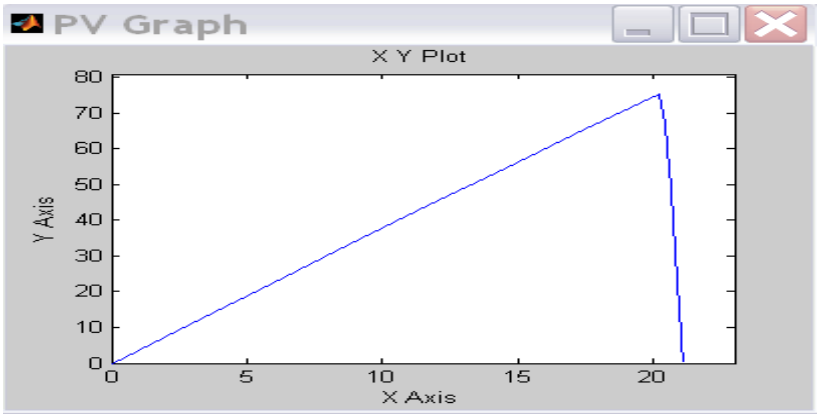


FIG 4: PV CHARACTERISTICS OF MPPT SYSTEM

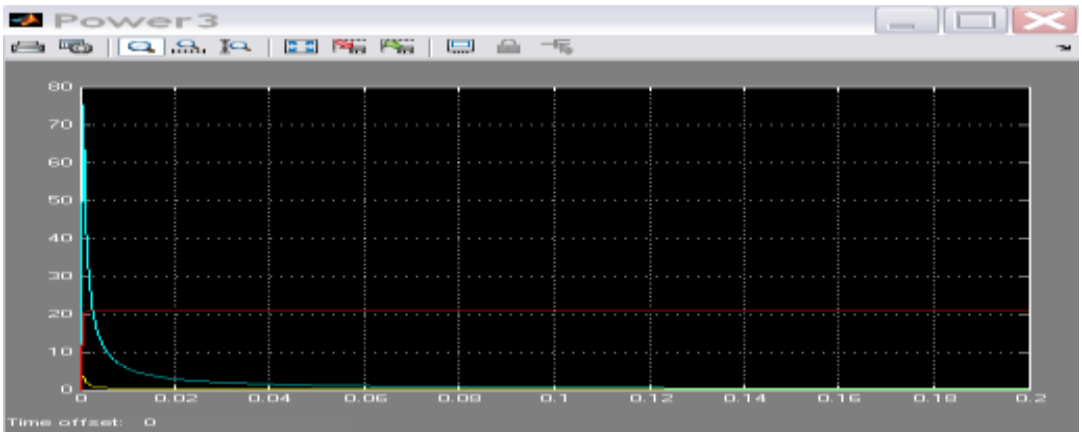


FIG 5: MPP DETERMINATION

CONCLUSION

As a consequence, the comparison and findings demonstrate that intelligent systems are more adaptable in controlling PV outputs.

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