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SURVEY OF MAXIMUM POWER POINT TRACKING TECHNIQUES IN SOLAR PV SYSTEM UNDER PARTIAL SHADING CONDITIONS

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ABSTRACT

Conventional energy sources such as thermal, diesel appliances, and nuclear are difficult to generate the electricity for the presence of greenhouse emission, maintenance problem. To overcome such problems, solar energy is one of the fastest growing renewable energy sources across the globe. In recent trends, solar power generation has tremendous growth. Solar energy offers various advantages such as contamination free, quiet in operation, long life, zero input energy cost, low maintenance. From the sunlight the light beams will be hit on a photovoltaic cell, it emitted the electrons from n-type to p-type layer and it will generate the power. Partial shading may takes place due to clouds, trees, dirt and dust in solar power generation systems. In partial shading, multiple peaks are followed in the PV characteristic curve. MPPT is a technique used to track the maximum power point of the PV source. MPPT can minimize the system cost and maximize the array efficiency. For tracking the GMPP, different types of algorithms and various techniques for MPPT are reported in various literatures. This paper reviews about the various MPPT algorithms of PV system based on partial shading conditions.

Keywords: PV panel, DC-DC converter, MPPT controller, battery, MATLAB software.

1. INTRODUCTION

Solar energy is the most readily available renewable energy sources. It is a non-polluting and maintenance free PV panels are used to convert the solar energy into electrical energy. Solar energy supplied by the sun in one hour is equal to the energy required by the human population in one year. Power generated by PV module depends upon the solar irradiation, cell temperature and load impedance. [1-5]. The demand of PV system installation has been increased over past few decades, technological improvement, lowered system costs, governmental initiatives, rising electricity bills.

With Jordan, the Solar has signed a first agreement to provide engineering, procurement and construction (EPC) services for 52.5 MW photovoltaic power plant. The company has also finalized a long-term operations and maintenance (O&M) contract for the project. In the Sivagangai district of Tamilnadu, India's first 5 MW of installed capacity solar power project was registered under the Clean Development Mechanism in 16 May 2011. According to the art of PV system, each PV cell is connected together to form a module and each module is combined together to form an array. The PV generation system has two major problems, low efficiency on energy, particularly under low irradiance conditions, electric power generated by solar array changes continuously with weather conditions and temperature variations. PV array has nonlinear current voltage characteristics and output power depends upon atmospheric conditions.

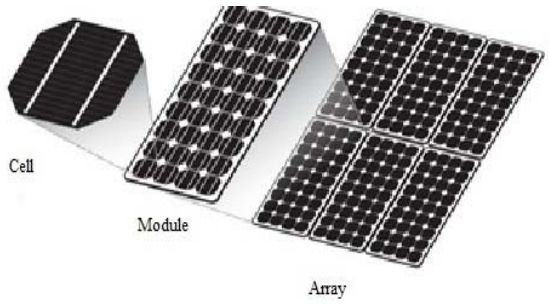

Figure-1. PV cell, module and array.

In general, there exists only one maximum power point on the P-V curve, it operates with maximum power efficiency, produces its maximum output power. In partial shading conditions, MPPT is an important concept for PV systems. A Dual tracking system includes a mechanical tracker and an electrical tracker MPPT, both controlled by two separate DSPs. The advantages and disadvantages of different techniques and also their performance were discussed in several literatures [5-7].The performance of MPPT techniques is compared on the basis of desirable features like difficulty, speed, hardware accomplishment, sensors required, cost, range of value and efficiency of the system The location of MPP is not identified, but can be calculated either through calculation models or by search algorithms [8-10]. This paper organized is as follows.

Section II provides about the characteristics of PV system. Section III presents about partial shading, Section IV reviews about DC-DC converter. Section V MPPT techniques are presented.

2. CHARACTERISTICS OF PV SYSTEM

The basic photovoltaic device is the Structure for PV modules. All modules contain cells. The group of

panels comprises the complete PV generating unit. A photovoltaic cell is a semiconductor p-n junction expose to light into electricity [11]. Single cells are connected in series or parallel combination to form a module to achieve certain voltage or current [12]. Photovoltaic cell is made from different types of semiconductors using manufacturing processes. Generally, mono crystalline and poly crystalline are used in commercial level. When light falls on the cell, it generates charge carriers that originate the electric current, if the cell is short-circuited. To draw the real model of a PV cell, it is necessary to take into the account, the losses due to leakage current in the diode. So, one resistor connected in series, its value will be low and another resistor will be connected in parallel, its value will be high [12], [13].

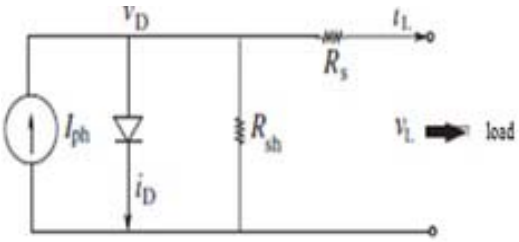

Figure-2. Equivalent circuit of Solar Panel.

The I-V characteristics of the solar panel equation are given by,

$$I = I_0\left[\exp\left(V + \frac{R_s I}{a V_t}\right) - 1\right] - V + R_s I / R_p$$
$$V_t = N_s KT/q$$
$$I_l = N_{ph} I_{ph}$$

Where, I_{ph} is the generated current in a PV module due to light, I_d is the Diode current, R_{sh} is the shunt resistance Rse is the series resistance, V_d is the diode voltage, I_l is the Light generated current of solar array, I_{pv} is the PV current, I_0 is the saturation current, A is the diode ideality factor, V_t is the thermal voltage related with the cells.

3. EFFECT OF PARTIAL SHADING

When one or more PV cells are shaded**,** bypass diodes are added in parallel for protection, prevent from the damage due to overheating, when cells are connected in series. Partial shading may occur due to environmental conditions, such as clouds, dirt and dust, trees and buildings. However, in power voltage characteristics curve also changes rapidly, multiple peaks are obtained. When the PSC occurs, the shaded PV cell act as a load instead of power flow, generating multiple peaks in the I-V characteristic curve and multiple peak values in the P-V curve. To prevent this problem, PV module is comprised of parallel connected bypass diodes [13]. In multiple peaks, one GMPP are obtained in the curve.

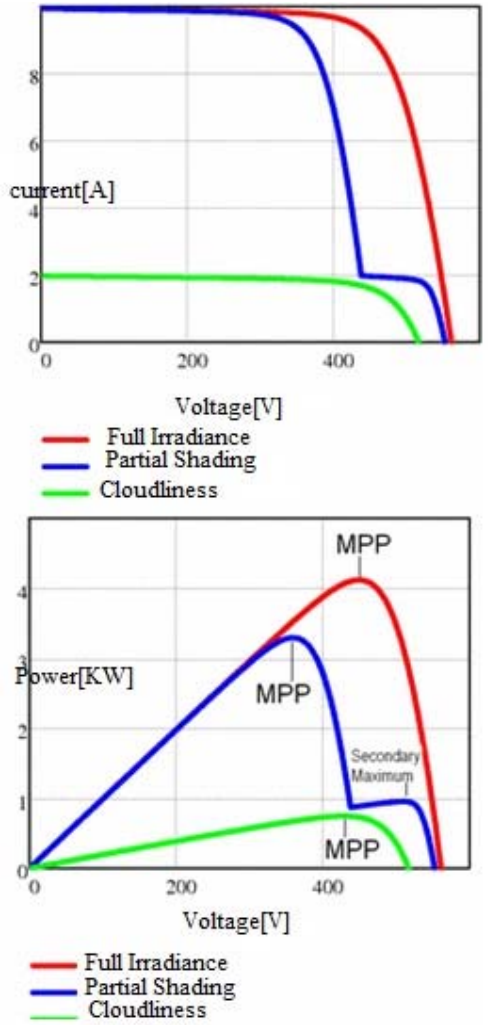

Figure-3. Characteristics of different irradiance conditions.

4. DC-DC CONVERTER

In the solar PV system, the obtained output is of DC which is unregulated in nature. Therefore, the unregulated output has been converted into regulated DC output by means of a converter called DC-DC Converter [14]. According to DC-DC converter, the unregulated DC voltage takes as input and converts the DC in to AC voltage. After the conversion process, the obtained voltage is transformed and rectified to desired DC output voltage. It is provided to regulate the constant output voltage under various operating conditions. Electrically, this converter can produce high power, light weight and noise free. The features of converters are

- Wide range of input voltage
- Over voltage protection.

The converter has two tasks, interface a PV model, grid and drive the operating point of the PV panel

to MPP. Converter classified into categories of application, types of switching and types of current modes [14]. DC-DC converter types are Non-isolated and Isolated. Isolation refers to the electrical barrier separating the input and output of the converter.

The main types of non-isolated DC-DC Converter are:

- Buck,
- Boost,
- Buck-boost,
- Cuk,
- SEPIC Converter.

In the buck converter, the output voltage will be less than that of input voltage. It can be used for connecting high module, voltage to low load. These converters can modulate the input voltage through PWM to generate the output voltage required to cause the panel to operate in MPP [15]. The step up converter, the output voltage is higher than that of input voltage magnitude. This converter used to connect high load and low module voltages. Many research workers developed the applications for Boost converter in PV systems. There are four different categories for low-cost and high efficiency boost converters [17].

- Coupled inductor
- Switched capacitor
- Inductor and Switched capacitor and
- Coupled inductor and switched capacitor.

The three phase system has three levels, boosting of MPPT control. Three level boost converters reduce diode reverse recovery losses and reduce the input filter size [15]. Several controlled voltage levels are needed with self-balancing and unidirectional current flow, such as PV systems. When applied to the MOSFET, boost converter balance the voltage. It avoids over voltage due to the leakage inductor [18]. In buck-boost converter, the output voltage magnitude may be higher or lower than the input voltage; it can be used in connecting nearly matched battery and module voltage. In Cuk converter performs like buck-boost converter. It is capable of stepping up or down input voltage with reverse polarity through the common terminal of input voltage [19-20]. In SEPIC Converter, the input current will be continuous and it draws the ripple free current from the PV panel. SEPIC Converter will use, when the battery voltage will be higher than the PV module voltage [19]. In front of the inverter, high step up converter will be required to improve power conversion efficiency and stable DC link to invert from the panel low voltage to a high voltage level. This converter achieves a high step up voltage conversion ratio; the leakage inductor energy of coupled inductor is recycled to load [20]. The converter has been built in two different ways, such as, to maximize the efficiency, the possibility of implementing MPPT, low price, reliability, flexible converter run with a wide range of input, output voltage and power [23].

The bidirectional Cuk converter used as the by-pass converter and a terminal Cuk converter was referred [24]. In bypass converter, performance can be evaluated, and efficiency will be better under partial shading conditions. Due to the additional power converter, cost of building the type of PV system will be higher than conventional ones using only by-pass diodes. When connected to a variable current source like a PV panel, behaviors will not be expected, but this converter designed to operate with constant voltage source [23]. For converting the low panel voltage in to high DC-link voltage with a high voltage conversion ratio is necessary, and this converter reduces the switching power losses by soft- switching operation of power devices [24]. High voltage gain interleaved boost converter [25] is a non-isolated boost converter, level up 24V DC input voltage to 130V DC output voltage. In long time operation, it gives better reliability and small size due to the simplicity of installation; switching devices can be controlled. Two-switch buck boost DC-DC Converter and low cost 8bit micro controller are referred [28]. This converter is more flexible and it can perform both step-up and step-down functions. It is able to bend through an entire voltage range of PV panel. In novel boost-half bridge micro inverter and repetitive current controller were explained [26].

The minimum use of semiconductor devices, circuit simplicity, and easy control was achieved. The boost half-bridge micro inverter possesses features of low cost and high reliability. In the boost-half-bridge dc-dc converter over the wide operation range, high efficiency (97.0%-98.2%) is obtained; current injected to the grid is regulated precisely and stiffly. The variable step size technique provides a fast tracking speed and high MPPT efficiency. In a low-cost, high efficiency current measurement technique using a resistor and bypass switch for PV power systems with MPPT control. Because of this technique, it can reduce the power loss significantly for feedback control systems using a DSP decreases the size and material cost. 80W prototype hardware has been implemented for PV MPPT verification of low power loss current measurement technique [27].

5. MPPT TECHNIQUES

The earliest MPPT method published in 1960s. There are different types of MPPT algorithm have been discussed in literature. It is broadly classified into two types.

- Conventional methods and
- Soft computing methods.

For conventional MPPT, the methods include incremental conductance, perturb and observe, hill combining, short circuit current, open circuit voltage, ripple correlation control, current sweep method. These methods are satisfied under uniform solar irradiance conditions. In normal condition, it is able to track

efficiently, but continuous oscillation around MPP, loss of power in a steady state condition. These techniques are failing to track GMPP and cannot capable of handling partial shading conditions. In soft computing method, the methods such as artificial neural network, fuzzy logic controller, particle swarm optimization, Ant-colony optimization and differential evolution. Recent approaches in software computing methods are cuckoo search and firefly algorithm. Compare with conventional MPPT, soft computing method able to track the GMPP in multiple peaks.

5.1. Incremental conductance method

This method appears to be the most popular one, due to medium complexity and good tracking performance. The fixed voltage step size for satisfying the tracking speed and maintain the MPP, but large values include oscillations around MPPs [33]. The array terminal voltage always adjusted to MPP voltage. This method changing conditions more rapidly than a Perturb and observes method (P and O). Like the P and O algorithm, it can produce oscillations in Output power. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to calculate the sign of the change in power with respect to voltage (dp/dV). It is derived by differentiating the PV array power with respect to voltage and setting the result equal to zero [34].

$$\frac{dp}{dv} = \frac{d(VI)}{dv} = I + \frac{VdI}{dv} = 0$$

$\Delta I/\Delta V = -I/V$ At MPP

$\Delta I/\Delta V > -I/V$ To the left of MPP

$\Delta I/\Delta V < -I/V$ To the right of MPP

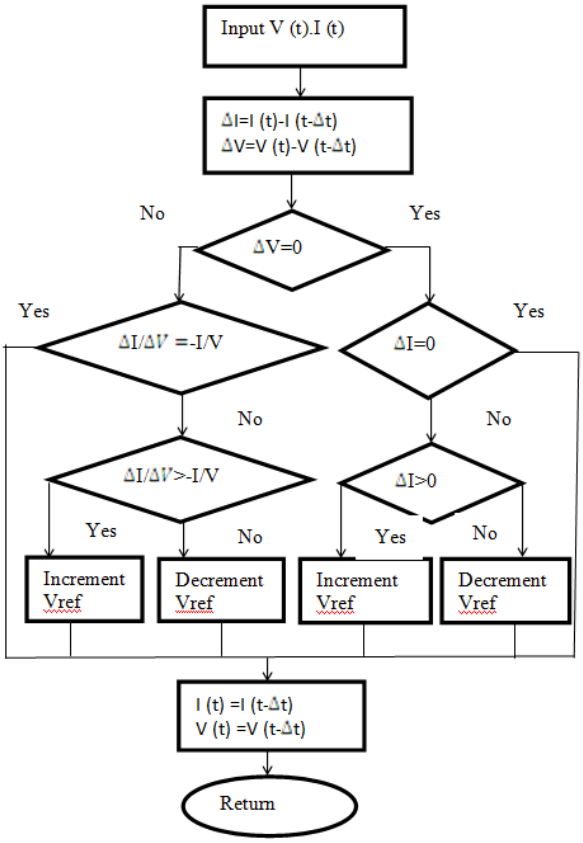

Figure-4. Flowchart for incremental conductance algorithm.

This method computes the maximum power point by comparison of the incremental conductance (I_Δ / V_Δ) to the array conductance (I / V). When these two are the same (I / V = I_Δ / V_Δ), the output voltage is the MPP voltage. The controller maintains the voltage until the irradiation changes and the process is repeated. In the change of well-known and widely accepted IC based on Nelder-mead optimization algorithm was to be investigated. It works accurately during uniform insolation when partial shading occurs. It uses NM in local and global search along with MPP condition from IC to know when it's reached MPP [35].

5.2. Fuzzy logic algorithm

It is one of the most popular control algorithm methods which are known by its multimode based variable control algorithm. It provides more accurate for MPPT problems, but it is more complicated in implementations [45]. It changes the duty cycle of the converter according to the voltage error input such that panel output voltage becomes equal to the voltage corresponding to maximum voltage. The fuzzy logic control algorithm is a Photovoltaic array dependent. It is based on the operator's experience, because it is followed by certain rules that are given by the operator. It helps to improve the response of a photovoltaic system. The main disadvantage of this

method is that the efficiency of the whole system which depends on the operator's performance and the precision of the rules.

Fuzzy logic control mainly consists of four stages, namely, Fuzzification, rule base, inference, defuzzification. First, we have to initialize the inputs to the Fuzzy logic controller. Fuzzy logic- based hill combining algorithm is introduced, where all the MPP's values are periodically stored in advanced micro controller and fuzzy logic is later implemented to track the GMMP. The use of fuzzy logic also involves the complicated fuzzification and defuzzification [46].

Compare with conventional nonlinear controllers, these methods will work with variable inputs, no need of an accurate mathematical model, handling nonlinearity and more robust. Compared with P&O algorithm, it is more complicated and possesses some advantages such as, better performance, good stability and fast response [47].

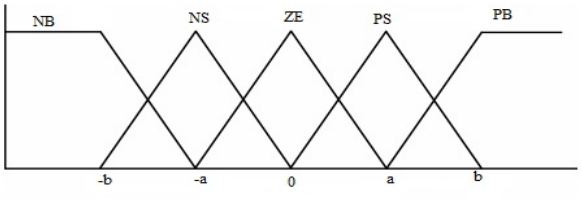

Figure-5. Membership function of fuzzy logic controller.

5.3. Neural networks

Artificial neural networks are a new emerging technology used to solve complex problems. It is used for the on-line estimation of the insolation dependent reference voltage, since MPP voltages are non-linearly associated with the solar insolation linear function approximation techniques are not suitable [48].

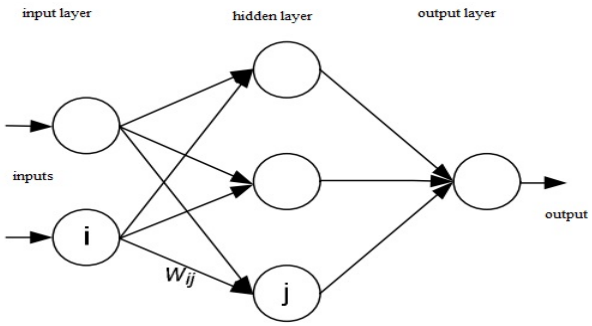

Figure-6. Artificial neural network.

ANN uses a feed forward neural network; the input of ANN consists of solar irradiance and cell temperature. The output voltage at maximum power point is calculated for different inputs. To estimate the maximum voltage to particular insolation, the offline ANN can be used. To introduce an ANN for MPPT, open circuit voltage worked as the only input to the ANNs originating from the solar panel [49]. The output of the ANN's is a signal which can be compared with the instantaneous voltage, in order to generate the control signal needed to drive the solar panel to MPP through a PI controller.

Advantages

- These methods do not require detailed information of the system.
- Without requiring extensive information about the PV parameters, ANN's can provide a sufficiently accurate MPPT. However, it must be well-known, that most PV arrays exhibit different output characteristics.

5.4. Cuckoo search algorithm

Cuckoo search is a nature inspired optimization algorithm based on the production strategy of cuckoo birds. Cuckoo lay their eggs and placed in other birds nest. The best nest with high quality of eggs will carry over to the next generation. The egg laid by cuckoo is discovered by host bird with a probability Pa € (0, 1) and number of available host nest is fixed. To mimic the shape and color of host bird is to increases its reproduction capability; some cuckoo species such as tapera are intelligent. Each egg in the nest represents the solution and cuckoo egg represents the new solution. Cuckoo destroys some of the host bird eggs to increase the chance of getting more food. Sometimes host birds discover the cuckoo's egg; completely abandon their nest to build a new nest. In general, searching for food, animals choose the directions that can be modeled by certain mathematical functions. The most common model is levy flight. Nest searching steps of cuckoo are characterized by levy flight. Levy flight is a random walk in a biased way with some random step size. Step consists of many steps, suitably long steps, long distance jumps. According to other algorithms, these long jumps many increase the efficiency of Cuckoo search. It requires 8multiplication, 6 additions, tuning two parameters only in this algorithm. It gives better performance and fast convergence tracking speed, Cuckoo search is particularly suitable to track GMPP for partial shading conditions [51].

5.5. Pseudo code for cuckoo search algorithm

Begin
Objective function;
Generate the initial population of host nest;
While (t< maximum generation or stop criteria)
Get a cuckoo randomly by levy flight
Evaluate its quality/fitness Fi,
Choose a nest among n (say, j) randomly
If ()
Replace j by the new solution
End
A fraction Pa of worst nest occurs;
Worst nest are abandoned and new nest is built;
Keep the best solutions;
Rank the solutions and find the best current;
End while
Post process of results and visualization;
End

5.6. Firefly algorithm

It is a population based optimization algorithm was introduced by Yang at Cambridge University. It is inspired by the movement of lightning bugs known as fireflies. The fundamental flashes of such fireflies are to attract mating partners and to attract potential prey. The following assumptions are, all fireflies are unisex. One firefly can be attracted to other firefly regardless of sex. The attraction between two fireflies is proportional to relative brightness. If there is no brighter one in the firefly colony, it moves towards brighter colony. For maximization problems, the brightness can be simply proportional to the value of functions. Firefly algorithm is superior to other methods in terms of tracking speed, convergence to track GMPP and possesses good tracking efficiency. The efficiency can be calculated by taking the ratio between output power and maximum power of the PV array under steady state conditions. The advantages of these methods, such as simple computational steps, faster convergence and implemented in low cost microcontroller [52].

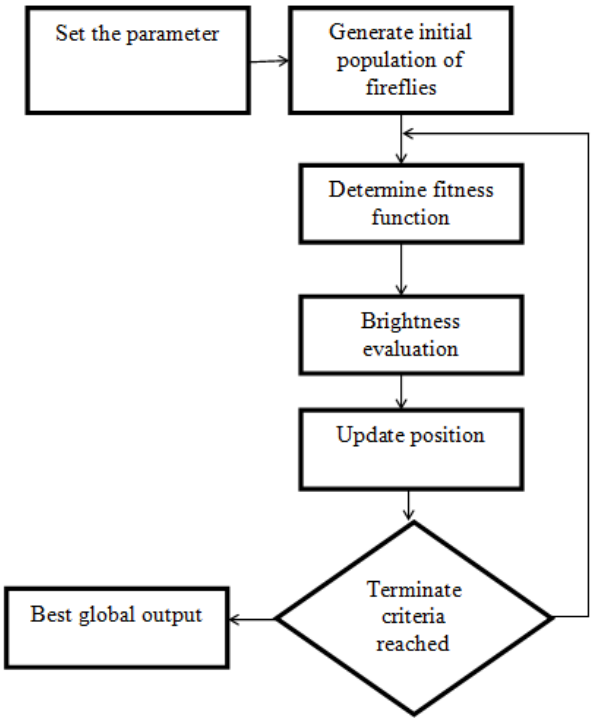

Figure-7. Flowchart for firefly algorithm.

6. COMPARION OF MPPT TECHNIQUES

Different MPPT techniques are compared in this paper on the basis of hardware requirement, sensors required, implementation cost, speed, accuracy.

The Table-1 represents the comparison of MPPT Techniques. MPPT is based on the load parameter method is better than other conventional algorithm in terms of tracking efficiency, and simplicity of hardware.

Table-1. Characteristics of mppt techniques.

MPPT techniques	Convergence speed	Sensed parameters	PV array dependent	Complexity	Periodic tuning	Ability to track GMPP	Sensitivity
IC	Varies	Voltage, current	Yes	Medium	No	Better	Moderate
Fuzzy logic controller	Moderate/low	Voltage, current	No	Complex	Yes	Poor	Moderate
Neural network	Moderate/low	Voltage, current	Yes	Complex	Yes	Poor	Moderate
Cuckoo search	Fast	Voltage, current	No	Simple	Yes	Very good	Moderate
Firefly	Fast	Voltage, current	No	Simple	Yes	Very good	Moderate

7. CONCLUSIONS

Solar energy is one of the most promising renewable energy sources, but it has certain limitations like high initial cost, low efficiency, etc. Many research projects help to improve PV system efficiency. This review paper concludes that the best type of converter for PV System is boost converter, which is of high switching frequency. Among various algorithm techniques, soft computing methods ensure better MPPT operation for any solar irradiation, cell temperature and different load conditions. This review article provides a detailed analysis of PV array characteristics on the basis of temperature and

insolation conditions. Analysis of the PV characteristics reveals the need of MPPT techniques to improve overall system efficiency. A lot of research projects are being done to improve efficiency of the PV system by extracting maximum power from the PV source.

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