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PV Application for DC-DC converter, Comparative Analysis of PV Panel Maximum Power Point (MPP) Tracking Techniques with fuzzy control

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Abstract – Now a days, mostly available energy sources in atmosphere is solar energy. Due to different atmospheric conditions the solar energy availability varies widely with ambient temperatures. Hence the PV system maximum power point (MPP) is not stable.Therefore, a maximum power point tracking (MPPT) controllers are needed to operate the PV at its MPP.To extract the efficient energy from PV array the maximum power point tracking (MPPT) algorithms are required.This paper focuses on dc-dc converter input source of solar energy, its investigation of various MPPT algorithms namely Perturb and Observe (P&O), Incremental Conductance (IC), Fuzzy Logic Control (FLC). These algorithms are compared on the basis of the tracking time, irradiance variation and operating point operations. The paper thus presents advantages, disadvantages and characteristics of different MPPT algorithms for PV applications.

***Keywords*–solar energy, dc-dc converter, Fuzzy logic controller, Maximum power point tracking, Perturb & observe, Photovoltaic systems.**

I. INTRODUCTION

The electrical energy demand is increasing day-by-day due to domestic and commercial applications. Today, the potential of generated electric power is very low and also majorly dependent on fossil fuels e.g. diesel, petrol and coal etc., but this generated power is not insufficient to meet the demand of required power. To fulfill the demand power, an interest is creating force to explore more sustainable and reliable energy sources for power generation such as PV system, wind turbine (WT), fuel cell (FC), bio-fuel etc.

Photovoltaic energy has increased interest in electrical power applications, since it is considered as abasically limitless and generally on hand energy resource. However, the output power induced in the photovoltaicmodules depends on solar irradiance and temperature of the solar cells. This makes the extraction ofmaximum power a complex task. The efficiency of the PV generation depends on maximum power extractionof PV system. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to trackthe maximum power point of the PV array[5]. The PV array has a single in service point that can supplymaximum power to the load. This point is called the maximum power point (MPP). The locus of this point hasa nonlinear distinction with solar irradiance and the cell temperature. Thus, in order to operate the PV arrayat its MPP, the PV system must contain a maximum power point tracking (MPPT) controller [1]-[3]. Many MPPTtechniques have been reported in the literature. The P&O method is an iterative algorithm to track the MPPby measuring the

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current and voltage of the PV module. This algorithm is easy to implement but the problemof oscillation of operating point around MPP is unavoidable as discussed in. INC method presented inis most widely used method. It tracks the MPP by comparing instantaneous conductance to the incrementalconductance. The INC method requires complex computations to acquire good accuracy under rapidlychanging weather conditions and the response time to reach MPP is also relatively long as discussed in.The[7] Perturbation and Observation (P&O) and Incremental conductance (INC) algorithms, which works satisfactorilywhen the irradiance varies very slowly but fails to track global MPP when irradiance changed.The above mentioned algorithms work satisfactorily only under uniform irradiance conditions in which PVcurve has a unique MPP. The fuzzy logic controllers have the advantages of robustness, simplicity in designand it does not need accurate mathematical model. The selection of parameters and membership function infuzzy logic[12] is not easy as it needs expert knowledge and experimentation.

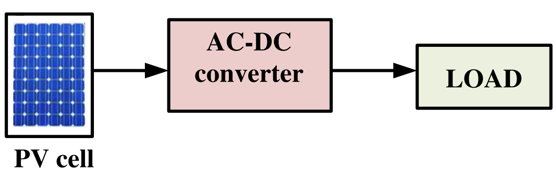

Fig.1 block diagram form PV cell integration with dc-dc converter

Most of these dc-dc converter ICs use either an internal or external synchronous rectifier. Their only magnetic component is usually an output inductor and thus less susceptible to generating electromagnetic interference. For the same power and voltage levels, it usually has lower cost and fewer components while requiring less pc-board area than an isolated dc-dc converter. For lower voltages non-isolated buck converters can be used.

There are five main types of converter in this non-isolating group they are

- Buck Converter
- Boost Converter
- Buck-Boost Converter
- Cuk Converter

This paper provides an overview of the most common MPPT approaches. From this, it is found that the perturbation and observation (P & O), incremental conductance (IC) and fuzzy logic controllers (FLC) algorithms are particularly popular approaches. For this reason, this paper presents a simulation study comparing the relative performance of thesethree techniques with respect to dynamic and steady state performance, and hence overall system efficiency.

II. PV SYSTEM MODEL

The PV system comprises of PV (Photo Voltaic) module, DC toDC converter, controllers and batteries as shown in Fig.1. ThePV module consists of many solar cells connected in series.The electrical equivalent circuit of solar cell is shows in Fig.2.Usually, for small system, batteries are connected directly asload, whereas for large systems, synchronized line inverters areused for direct interfacing with mains grid. In simple systems aswitching device is used to stop the charging when the batteryis fully charged. The sensing of full charge status is determinedby the battery voltage. To attain maximum efficiency, MPPTcharge controllers are used in PV system.

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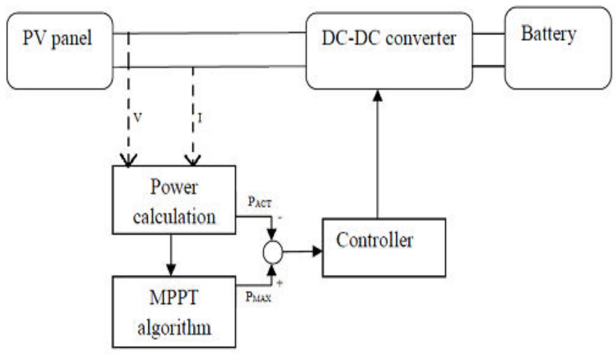

Fig.2. Block diagram of PV system

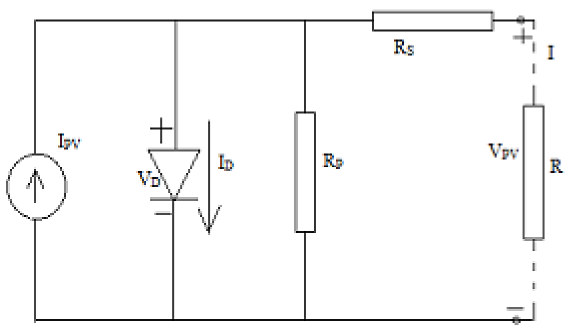

Fig.3. Equivalent Electrical circuit of Solar Cell

In the above figure and are the output voltage and current,is series resistance of the solar cell, it is equivalent tocontact resistance between silicon and metal contact, isparallel resistance which come in the appearance due tomanufacturing defect. In ideal condition and are zero andinfinite respectively. The output current is determined by the(1).

$$I = I_{PV} - I_o\,[exp((V + IR_S)/aV_T) - 1] - (V + IR_S)/Rp \quad (1)$$

In the above equation is the photocurrent produced byconstant current source, is reverse saturation current, is thediode quality factor (ideality factor), is temperatureequivalent voltage, and are the series and parallelequivalent resistance of the solar cell. This expression alsobetell the I-V characteristic of solar panel or solar cell, as in.

The output power of photovoltaic array mainly depends onsolar irradiance, panel temperature and the load impedance.The solar irradiance and temperature is subject to atmosphericchanges, and thus, is not fixed but unpredictable to a largeextent. The output power obtained varies depending on theabove factors. The output voltage and current must be fixed for higher efficiency. The solar PV system is not so popularbecause of its low efficiency and high cost. There are primarilythree factors that affect the efficiency of a PV system. Theseare the efficiencies of the solar PV panel, MPPT charge controlsystem and the inverter.

III. MPPT TRACKING METHODS

To obtain maximum power from PV module, variouselectrical and mechanical MPPT methods are proposed. Inmechanical methods, the orientation of the PV panel isadjusted with the pre-estimated angle throughout the day fortracking the sun direction manually. In electrical trackingmethod, the maximum power point (MPP) is tracked on P-Vcurve of the system by the help of power electronics interface.Conventional tracking methods use the sensed data of PVsystem such as voltage, current, temperature and solarirradiation to track the MPP.

A.P&O Based MPPT Method

In this method, the voltage of the PV system is considered as a reference signal. The aim of this MPPT[3] is to force the reference voltage of the PV system to

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maximum voltage (Vmpp), which causes the instantaneous PV voltage to track Vmpp. This is done by applying small and constant perturbations to the PV voltage a step-by-step. After each perturbation the variation in power (dP) is measured. A positive value of dP indicates that output power will approachMPP. So, a perturbation of positive sign is fed to the PV voltage in the next stage. On the other hand, if the value of dP is found negative, negative sign perturbation is applied. These steps are repeatedly performed until the MPP of the system is reached where dP is equal to zero or maximumcondition. The steps involved in this method are depicted withthe help of flowchart shown in Fig. 2.

Table.1. Summary of P& Oalgorithm

Perturbation	Change in power	Next perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

In this method (to find out thedirection of tracking correctly) a system is proposed in whichtracking of MPPT is based on the samples taken from each PVmodule individually and also collectively as an array, so as tooptimize power obtained from each PV module as well as thearray. The MPP is considered as moving target. Thus every PVmodule can chase the MPP automatically.

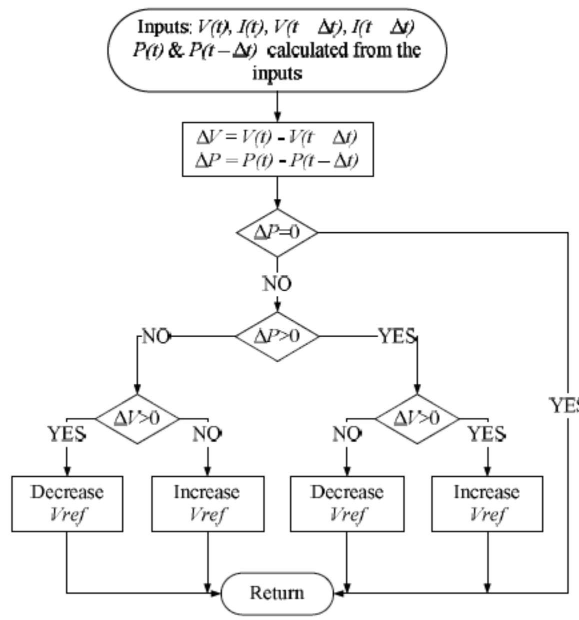

Fig.4. Perturbation and Observation algorithm

B. Incremental conductance

Another commonly cited MPPT algorithm is the incremental conductance (INC) algorithm. This scheme tracks the maximum power point by comparing the solar array incremental and instantaneous conductance, the function of this procedure is explained in the flowchart in Fig.3. The PV panel voltage and current are measured at fixed sampling intervals and fed to the controller to calculate the PV panel power. The PV panel incremental conductance is predictable by measuring miniature changes in array voltage and current. The PV panel instant conductance is calculated by dividing the array current by the voltage. Once these variables are updated, the method tracks the maximum power point by comparing the incremental and instant conductance of the solar array until the maximum power point (MPP) is reached, as illustrated in Fig.3. In conclusion, the

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null value of the slope of the PV array power versus voltage curve infrequently occurs.

In both P&O and IncCond. schemes, time taken to track theMPP depends on the size of the increment of the referencevoltage (V_{ref}). For fast tracking the large increment size is usedbut then the system will not operate exactly at the MPP and willoscillate about the MPP which means that the full efficiency ofthe system is never reached. The perturbation size problem issame in P&O and I.C. This can be solved by variable perturbation size, in which the first stage pushes theoperating point close to MPP and then uses IncCond. Forreaching at MPP exactly, but this algorithm requires complexand costly control circuit. The IncCond. algorithm has higherefficiency than P&O [4]in frequently changing irradiancecondition.

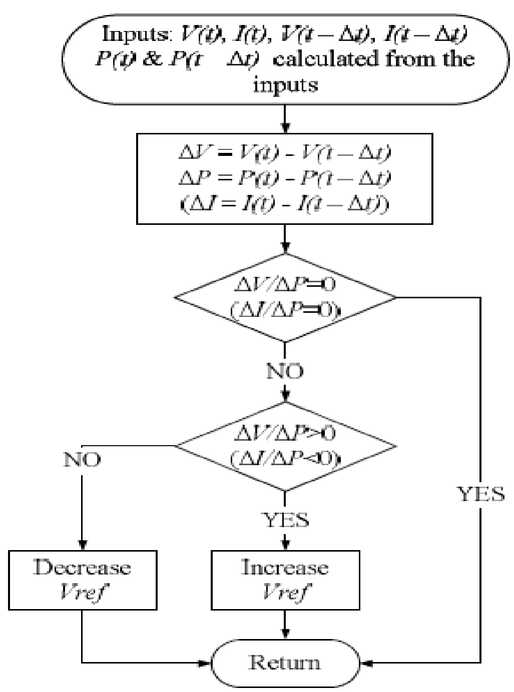

Fig.5.Incremental conductance algorithm

C. Fuzzy logic controller

Conventional methods of tracking the most favorable point of operation have shown their restrictions to sudden changes of climate and the load associated to the panel. Another encouraging tracker algorithm is fuzzy logic. The operation of this technique is explained in the block diagram shown in Fig.4. In this paper the fuzzy inference rule is carried out by using Mamdani's method and the defuzzification use the centre of gravity to compute the output of this FLC which is the duty cycle. FLC system has two inputs and one output. The two FLC input variables are the error E (k) and change of error ΔE (k) at sampled times k defined. Where P (k) and V (k) are the instant power and voltage of the photovoltaic system respectively E (k) is zero at the maximum power point of PV array.

The input E (k) shows if the operation point at the instant k is located on the left or on the right of the MPPT on the PV Characteristic while the input ΔE (k) expresses the moving direction of this point. The objective of designed FLC is to track maximum power irrespective of panel voltage variations. Accordingly FLC uses two input variables: change in PV array Power (ΔP_{in}) and change in PV array voltage (ΔV_{in}) corresponding to the two sampling time instants and determining duty cycle of converter.

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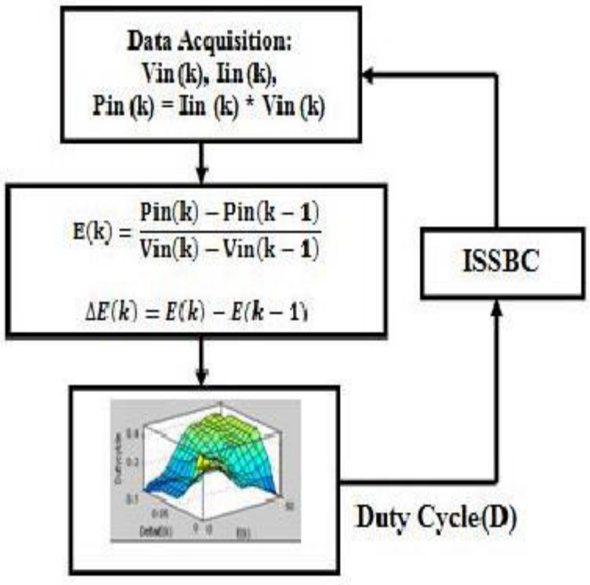

Fig.6.Fuzzy logic systems

IV.SIMULATION RESULTS

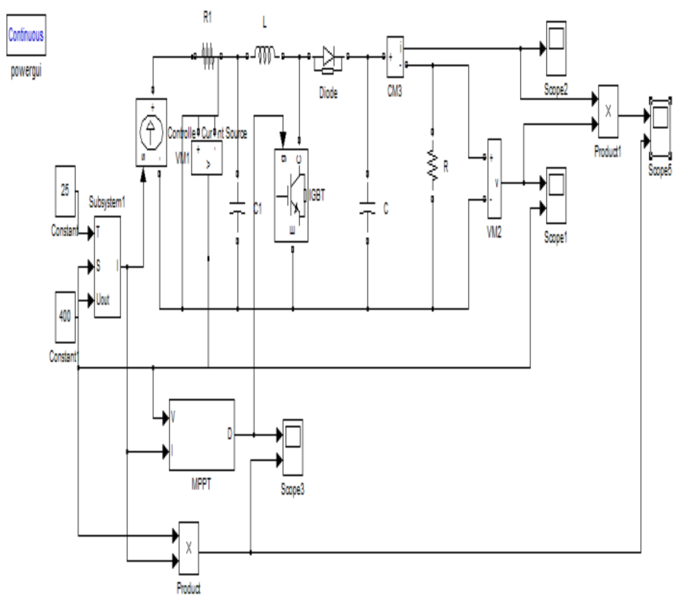

Fig.7PV cell with a boost converter with MPPT

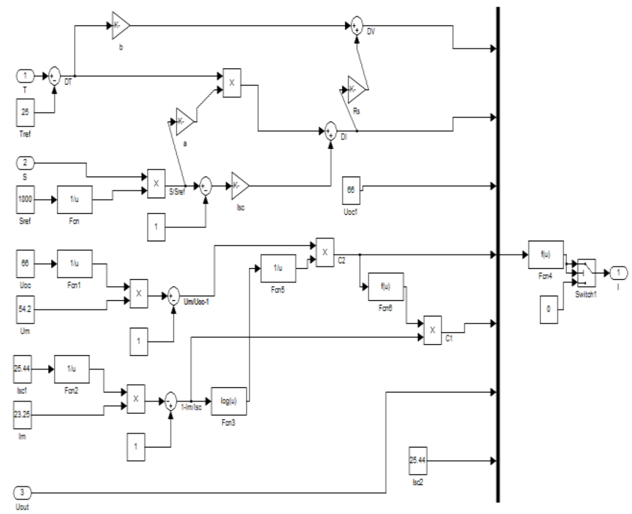

Fig.8Photovoltaic cell module

Fig.6 and 7 shows matlabsimulink designed diagrams for Boost Converter with MPPT and PV cell module. Here pv celled boost converter with MPPT was analyzed by three methods those are showed in below.

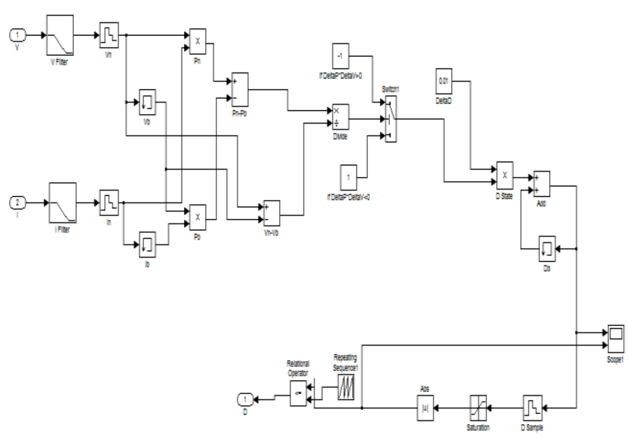

Fig.9Simulation for the Petrub and Observe (P&O) Method Sub-Circuit

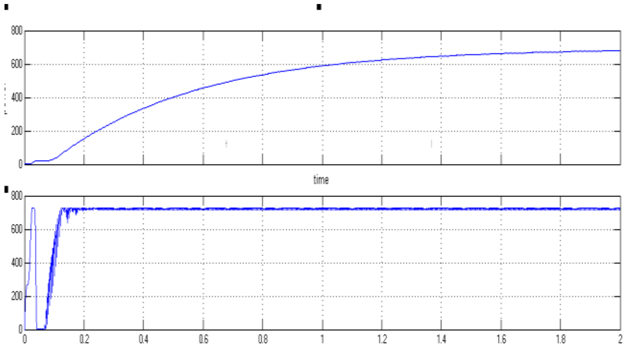

Fig.10Output Waveform for the Pertrub and Observe Method Implementation

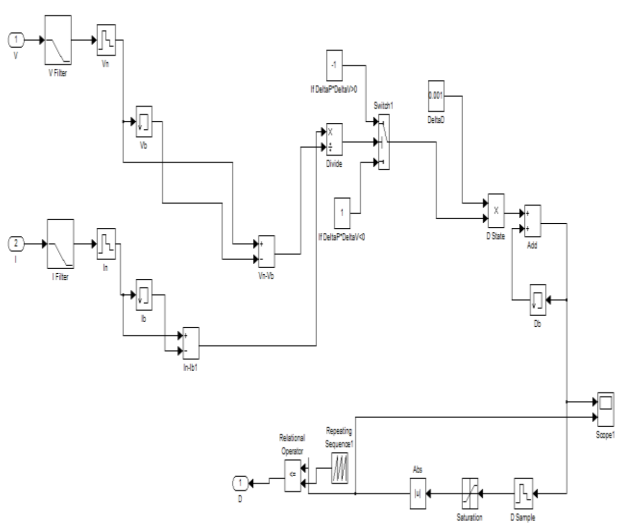

Fig.11Incremental conductance method sub circuit

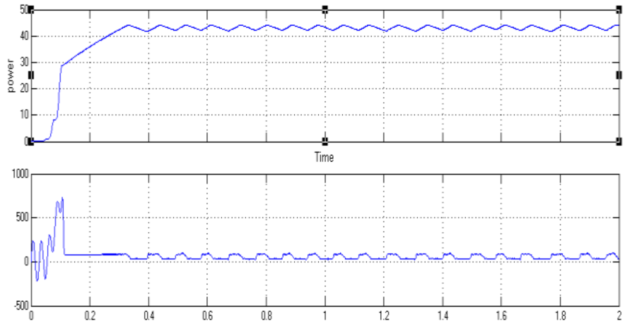

Fig.12 Output Waveforms for the Ic Algorithm Implementation

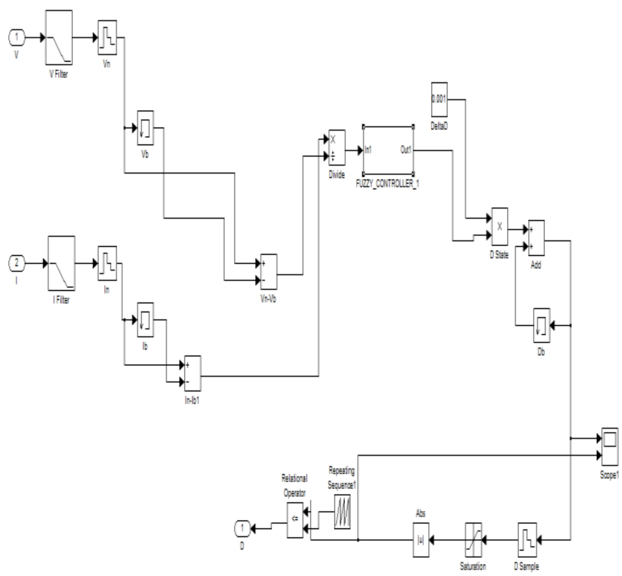

Fig.13Fuzzy Control Method Sub Circuit

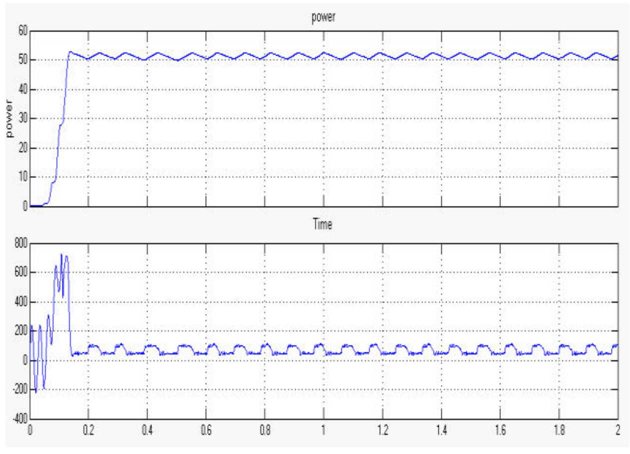

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Fig.14 Output Waveforms for Fuzzy Control Implementation

V. CONCLUSION

This paper presents an overview of dc-dc converter input PV panel voltage tracking MPPT methods, and considers their suitability in systems which experiencea wide range of operating conditions. The MPPTtechniques are discussed such as perturb & observe incrementalconductance and fuzzy logic control. Alldiscussed MPPT techniques are compared on the basis of complexity and cost. Out of these techniques, some are low in cost and complexitybut also has less efficiency and others are expensive but hasgood efficiency. The proposed fuzzy logic controlalgorithm shows high efficiency in this technique compared to other techniques.

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