ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

Investigation into Recent Developments in Maximum Power Point Tracking Technologies for Photovoltaic Systems

Manda Ranjith Kumar[1], Dr. K. Vijaya Kumar Reddy[2]

[1]Reaserch scholar, Centre for Energy Studies, University College of Engineering Hyderabad (JNTUHUCEH), Telangana, INDIA

[2]Professor of Mechanical Engineering, (JNTUHUCEH), Telangana, INDIA

Abstract

In electrical phenomenon photovoltaic (PV) system applications, it's important to style a system for operative of the solar cells (SCs) beneath best conditions and highest efficiency. Maximum power point (MPP) varies looking on the angle of daylight on the surface of the panel and cell temperature. Hence, the operative purpose of the load isn't invariably MPP of PV system. Therefore, so as to produce reliable energy to the load, PV systems area unit designed to incorporate quite the desired range of modules. The answer to the current downside is that change power converters area unit used, that's known as maximum power point tracker (MPPT). During this study, the varied aspects of those algorithms are analyzed intimately. Classifications, definitions, and basic equations of the foremost wide used MPPT technologies are given. Moreover, a comparison was created within the conclusion.

Introduction

Photovoltaic (PV) systems have a structure containing solar cells (SCs), connection, protection, and storage components and some additional elements depending on load characteristics. The most important element of these systems, the solar cells, also has distinctive features especially on the initial investment cost and the quality and quantity of other elements. Therefore, in the initial installation stage, it is very important to design for operating of SC under the best conditions and effectively. Switching power converters are used, that is called as maximum power point tracker (MPPT) for the solution of this problem. However, efficient use of a PV panel includes some problems for the following two main reasons.

Photovoltaic (PV) systems have a structure containing solar cells (SCs), connection, protection, and storage parts and a few extra components betting on load characteristics. The foremost necessary component of those systems, the solar cells, additionally has distinctive options particularly on the initial investment price and therefore the quality and amount of alternative components. Therefore, within the initial installation stage, it's important to design for in operation of SC below the most effective conditions and effectively. However, economical use of a PV panel includes some issues for the subsequent 2 main reasons.

(1) PV systems might embody some circuits to trace the movements of stepper motor or different devices. These mechanisms are known as the mechanical tracking systems and increase the quantity of created PV energy.

(2) For radiation and cell temperature values taken as examples, maximum power is made. Therefore, operation of the cell at this time is that the right possibility. This method is termed as electrical most outlet following or just MPPT.

Solar power

The tapping of solar energy owes its origins to the British astronomer John Herschel [5] who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar

photovoltaic cells [6] or with concentrating solar power plants.

The sound of alternative energy owes its origins to Brits physicist Herschel [5] World Health Organization magnificently used a star thermal collector box to cook food throughout associate degree expedition to Africa. Alternative energy may be used in 2 major ways in which. Firstly, the captured heat may be used as star thermal energy, with applications in area heating. Another different is that the conversion of incident radiation to voltage, that is that the most usable sort of energy. This may be achieved with the assistance of star electrical phenomenon cells [6] or with concentrating alternative energy plants.

Photovoltaic Cell and MPP

Figure 1 shows the equivalent circuit of solar cell. Electrical energy production of cell has been symbolized by current (I_{ph}) demanded from voltage-dependent current source. The amount of produced energy is proportional to solar radiation. Because the body of the solar cell semiconductor material is symbolized as a diode, output voltage of PV cell is shown as V_{pv}. Serial resistance (R_s) is equal to the sum of contact and semiconductor material's resistances. Parallel resistance (R_p) is taken as the sum of resistances between thin-film layers and around cells. In the investigations, it is determined that parallel resistance is too large compared with series resistance, and its effect can be neglected.

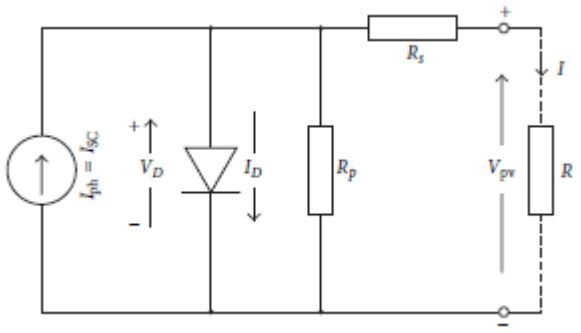

Fig 1: Equivalent electrical circuit of an SC

Classification of MPPT Algorithms

1) Perturb and observe (hill climbing method)

2) Incremental Conductance method

3) Fractional short circuit current

4) Fractional open circuit voltage

5) Neural networks

6) Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

Perturb & Observe

Perturb & Observe (P&O) is that the simplest technique, during this we have a tendency to use only one sensing element, that's the voltage sensing element, to sense the PV array voltage and then the price of implementation is a smaller amount and thus straightforward to implement. The time quality of this algorithmic rule terribly incredible less however, on reaching very getting ready to the MPP it doesn't stop at the MPP and keeps on distressing on each the directions. Once this happens the algorithmic rule has reached terribly getting ready to the MPP and that we will set associate degree acceptable error limit or will use a wait perform that winds up increasing the time quality of the algorithmic rule.

Incremental Conductance

Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. Once this instant electrical phenomenon equals the electrical phenomenon of the star then MPP is reached. Here we tend to measure sensing each the voltage and current at the same time. Therefore the error because of amendment in irradiance is eliminated. But the complexness and therefore the price of implementation will increase.

At MPP the slope of the PV curve is 0.

$$(dP/dV)_{MPP}=d\,(VI)/dV$$

$$0=I+VdI/dV_{MPP}$$

$$dI/dV_{MPP}=-\,I/V$$

Fractional open circuit voltage

Linear relationship between VMPP and V_{OC} of the PV array, below variable irradiance and temperature levels, has given rise to the incomplete V_{OC} technique.

$$V_{MPP}=k_1\,V_{oc}$$

Where k_1 may be a constant of proportion. Since k_1 depends on the characteristics of the PV array getting used, it always must be computed beforehand by trial and error deciding VMPP and V_{OC} for the particular PV array at totally different

irradiance and temperature levels. The issue k_1 has been reported to be between 0.69 and 0.76. Once k_1 is understood, VMPP will be computed with V_{OC} measured sporadically by momentarily motion down the ability device [15].

Fractional short circuit current

Fractional I_{SC} results from the fact that, under varying atmospheric conditions, I_{MPP} is approximately linearly related to the I_{SC} of the PV array.

$$I_{MPP} = k_2 I_{sc}$$

where k_2 is a proportionality constant. Just like in the fractional V_{OC} technique, k_2 has to be determined according to the PV array in use. The constant k_2 is generally found to be between 0.78 and 0.92. Measuring I_{SC} during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that ISC can be measured using a current sensor [15].

Fuzzy Logic Control

Microcontrollers have created victimization fuzzy logic management well-liked for MPPT over last decade. Fuzzy logic controllers have the benefits of operating with general inputs.

Neural Network

Another technique of implementing MPPT which are also well adapted for microcontrollers is neural networks. Neural networks commonly have three layers: input, hidden, and output layers. The number nodes in each layer vary and are user-dependent. The input variables can be PV array parameters like V_{OC} and I_{SC}, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP [15].

MPPT Techniques

There are several techniques to achieve the MPP, which differ in some aspects, such as online or offline methods, search techniques, artificial intelligence-based methods, and model- based or model-free methods.

Search techniques use system disturbances to find the maximum power point. The power output, resultant from this disturbance, is the parameter to define the MPP.

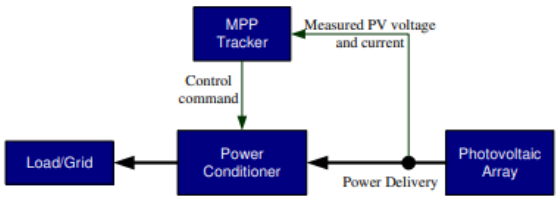

Fig. 1 Block diagram of the topology of maximum power point tracking in a photovoltaic power system.

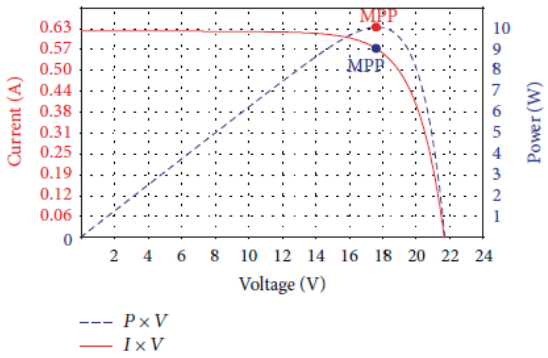

Figure 2: Maximum power point in $I \times V$ and $P \times V$ curves

PV Module

The operating principle of the silicon PV cell is the conversion of energy from the sun, of a specific wavelength (from 300 nm to 1100 nm), into current [22].The PV module is made of light sensitive semiconductor, which produces energy from solar radiation [4]. The circuit model of the PV module is shown in Figure 3. There are other models in the literature; however, the one used in this paper is simple and has satisfactory performance [11]. The incidence of light on the cell produces charge carriers that originate the photo generated current Iph. I

D is the reverse saturation current of the PN junction. The series (RS) and shunt (RP) resistances represent the sum of several structural resistances and the effect of the leakage current on the PN junction, which depends on the fabrication method of the PV cell [23].

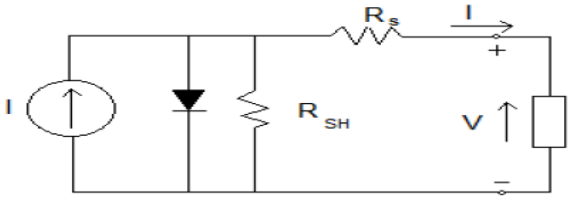

Figure 3: Single diode model of a PV cell

Standalone Photovoltaic System Components

Photovoltaic cell a solar cell or photoelectric cell could be a conductor that converts light-weight to voltage by electrical phenomenon result. If the energy of gauge boson of sunshine is bigger than the band gap then the negatron is emitted and also the flow of electrons creates current. But a solar cell is totally different from a photodiode. in an exceedingly photodiode light-weight falls on channel of the semiconductor junction and gets born-again into current or voltage signal however a solar cell is often forward biased.

Literature Review:

Studies show that a solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. There are different techniques for MPPT such as Perturb and Observe (hill climbing method), Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network Control etc. Among all the methods Perturb and observe (P&O) and Incremental conductance are most commonly used because of their simple implementation, lesser time to track the MPP and several other economic reasons. Under abruptly changing weather conditions (irradiance level) as MPP changes continuously, P&O takes it as a change in MPP due to perturbation rather than that of irradiance and sometimes ends up in calculating wrong MPP[11]. However this problem gets avoided in Incremental Conductance method as the algorithm takes two samples of voltage and current to calculate MPP. However, instead of higher efficiency the complexity of the algorithm is very high compared to the previous one and hence the cost of implementation increases. So we have to mitigate with a trade-off between complexity and efficiency.

Table 1: Characteristics of different MPPT techniques [9]

MPPT technique	Convergence speed	Implementation complexity	Periodic tuning	Sensed parameters	Efficiency (%)
Perturb & observe	Varies	Low	No	Voltage	81.5–85
Incremental conductance	Varies	Medium	No	Voltage, current	73–85
Fractional V_{oc}	Medium	Low	Yes	Voltage	93–96
Fractional I_{sc}	Medium	Medium	Yes	Current	88–89.9
Fuzzy logic control	Fast	High	Yes	Varies	>95
Neural network	Fast	High	Yes	Varies	99.8

MPPT Interfacing

The controlled voltage source and the current source inverter have been used to interface the modelled panel with the rest of the system and the boost converter which are built using the SimPower Systems module of MATLAB. The block diagram for the model shown in Figure 5.4is a simulation for the case where we obtain a varying voltage output. This model is used to highlight the difference between the power obtained on using an MPPT algorithm and the power obtained without using an MPPT algorithm.

To compare the power output in both the cases stated above, the model is equipped with manual switch as shown. When the switch is thrown to the left the circuit bypasses the MPPT algorithm and we obtain the desired power, voltage and current outputs through the respective scopes. Contrarily when the switch is thrown to the right, the embedded MPPT function block is included in the circuit and we obtain the desired outputs through the respective scopes.

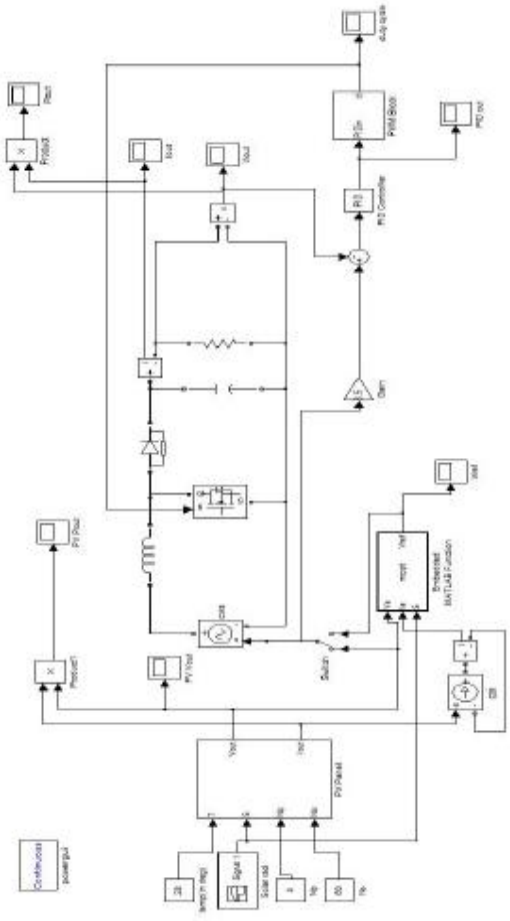

Fig 4: SIMULINK™ Model of MPPT system using P&O algorithm

PI Controller

The system additionally employs a PI controller. The task of the MPPT formula is simply to calculate the reference voltage V ref towards that the PV in operation voltage ought to move next for getting most power output. This method is continual sporadically with a slower rate of around 1-10samples per second. The external management loop is that the PI controller, that controls the input voltage of the device. The pulse dimension modulation is carried within the PWM block at a significantly quicker change frequency of one hundred kHz.

Results

Study Case I:

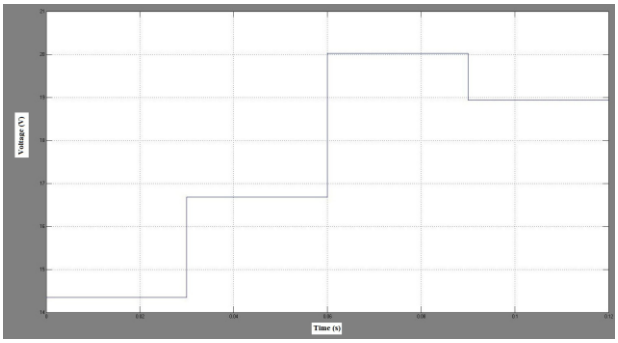

Fig 5: Plot of voltage O/P PV panel v/s time without MPPT

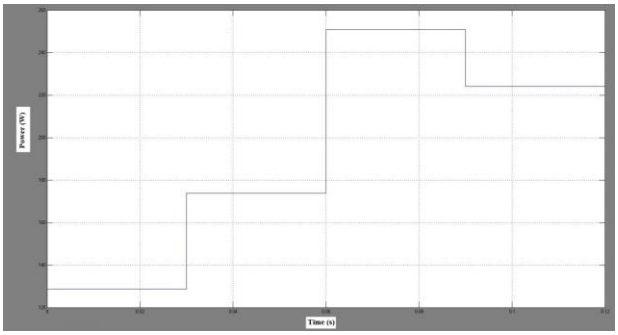

Fig 6 : Plot of Power O/P PV panel v/s time without MPPT

Study case II:

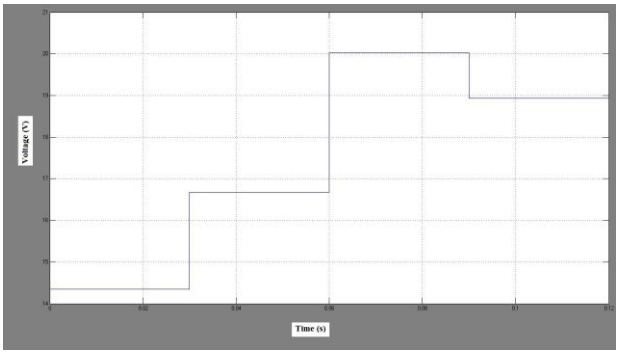

Fig 7: Graph shows voltage O/P PV panel v/s time with MPPT

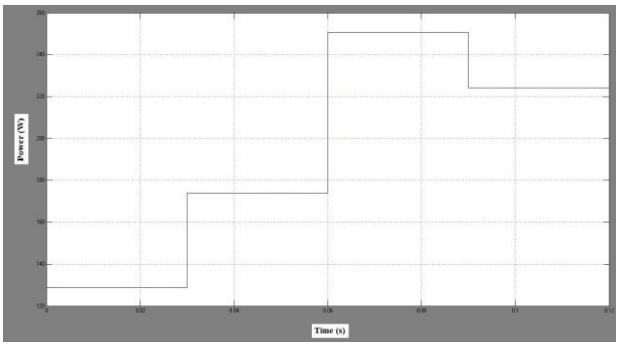

Fig 8: Graph shows power O/P PV panel v/s time with MPPT

Conclusion:

The model shown in Figure 4 was simulated using SIMULINK and MATLAB. The simulation was first run with the switch on no MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load side was around 95 Watts for a solar irradiation value of 85 Watts per sq. cm. It must be noted that the PV panel generated around 250 Watts power for this level of solar irradiation. Therefore, the conversion efficiency came out to be very low. The simulation was then run with the switch on MPPT mode. This included the MPPT block in the circuit and the PI controller was fed the V_{ref} as calculated by the P&O algorithm. Under the same irradiation conditions, the PV panel continued to generate around 250 Watts power. In this case, however, the power obtained at the load side was found to be around 215 Watts,thus increasing the conversion efficiency of the photovoltaic system as a whole. Therefore, it absolutely was seen that exploitation the Perturb & Observe MPPT technique exaggerated the potency of the electrical phenomenon system by roughly 124.8% from associate degree earlier output power of around 93 Watts to associate degree obtained output power of around 216 Watts.

References:

[1] J. Xu, L. Kang, C. Zhong, and B. Cao, "Photovoltaic power system with MPPT functionality for a small-size electric vehicle," International Journal of Photoenergy, vol. 2014, Article ID

460390, 9 pages, 2014.

[2] B. Subudhi and R. Pradhan, "A comparative study onmaximum power point tracking techniques for photovoltaic power systems," IEEE Transactions on Sustainable Energy, vol. 4, no. 1, pp.

89–98, 2013.

[3] H. Rezk and A. M. Eltamaly, "A comprehensive comparisonof different MPPT techniques for photovoltaic systems," Solar Energy, vol. 112, pp. 1–11, 2015.

[4] N. Onat, "Recent developments in maximum power point tracking technologies for photovoltaic systems," International Journal of Photoenergy, vol. 2010, Article ID 245316, 11 pages,

2010.

[5] M. H. Moradi, S. M. Reza Tousi, M. Nemati, N. Saadat Basir, and N. Shalavi, "A robust hybrid method for maximum power point tracking in photovoltaic systems," Solar Energy, vol. 94,

pp. 266–276, 2013.

[6] O. Wasynczuk, "Dynamic behavior of a class of photovoltaic power systems," IEEE Transactions on Power Apparatus and Systems, vol. 102, no. 9, pp. 3031–3037, 1983.

[7] S. K. Kollimalla and M. K. Mishra, "A Novel Adaptive P&O MPPT Algorithm Considering Sudden Changes in the Irradiance,"IEEE Transactions on Energy Conversion, vol. 29, no. 3,

pp. 602–610, 2014.

[8] M. A. S. Masoum and H. Dehbonei, "Design, constructionand testing of a voltage-based maximum power point tracker(VMPPT) for small satellite power supply," in Proceedings ofthe 13th Annual AIAA/USU Conference, Small Satellite, pp. 1–11, Logan,Utah, USA, 1999.

[9] D. Raveendhra, P. Joshi, and R. K. Verma, "Performanceand control system design for FPGA based CVMPPT boostconverter for remote SPV water pumping system applications,"in Proceedings of the Power and Energy Systems Conference:Towards Sustainable Energy (PESTSE '14), pp. 1–6, March 2014.