

DIFFERENT TECHNIQUES OF MULTIPLE POWER POINT TRACKING FOR PHOTOVOLTAIC SYSTEMS

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Abstract – Understanding in such way the maximum available power generated by the photovoltaic (PV) array varies with the weather is critical for improving system efficiency by encouraging the PV system to operate at that maximum power point (MPP). Therefore, to maintain optimum power functioning at all irradiance levels and temperatures, a Maximum Power Point Tracking (MPPT) system is necessary. MPPT methods have been developed and implemented in a number of studies. The accuracy, convergence speed, ease of hardware implementation, PV dependency, number of necessary sensors, which are significantly differ across these systems. The first technique to be introduced was a single MPPT technique. However, as it works independently, it was unable to achieve several of the required characteristics. Afterwards, the merger techniques of multiple MPPTs and the combination of both (single and multiple MPPTs' techniques) due to integrate the benefits of each algorithm while removing their limitations. Comparing and surveying MPPT algorithms in general took a significant amount of time. Despite this, there is a limited literature examining the combination techniques towards the multiple MPPT techniques and the single one. This paper presents the work and uses MATLAB/Simulink platform to simulate it. It is based on a study that contrasts single MPPT techniques with different combinations, namely the constant voltage (CV) method, the perturb and observe (P&O) method and the combination of both (CV+P&O), in order to validate MPPT's better performance.

Keywords: PV systems, MPP, MPPT Techniques, MPPT algorithms.

I. INTRODUCTION

Solar energy is becoming extremely attractive alternative energy source since it is abundant, renewable, clean, and ecologically benign. However, since its high initial cost, low conversion efficiency, and low reliability, its commercial viability and application were limited. In order to achieve the benefits of solar systems, increasing the dependability and efficiency of solar systems is an issue that must be solved. The electricity generated by photovoltaic (PV) systems is a function of numerous elements, including solar irradiation, ambient temperature, age, and so on, due to the intermittent nature of the source.

The ambient temperature and the PV exposed irradiance influence the current and voltage produced, and thus the power generated by the PV. Several studies of MPPT algorithms and techniques have been discussed and presented in the literature in order to set the converter duty cycle to a value that equalizes the resistance seen by the PV system to that of the load.

This paper presents a comparative study of three MPPT techniques (single, multiple, and their combinations) to evaluate their performance and validate in simulation that multiple MPPT techniques outperform any single one. The simulation on MATLAB/Simulink was used for the comparative study. The following is the way the paper is structured: Section 2 emphasizes the importance of implementing an MPPT system, whereas Section 3 discusses the single, multiple, and combination of both MPPTs' techniques used. This

section also introduces the implemented MATLAB model, as well as the results obtained and a detailed discussion of them. Section 4 summarized the performance of the MPPT techniques.

II. METHODS

As indicated in Fig. 1, the PV has two operational zones. The first zone, where point A is located, is referred to as the right-hand side (RHS). The voltage in the RHS is nearly constant while the current decreases; the power is directly proportional to the decreasing current and inversely proportional to the voltage. The second zone of the operation, where point B is located, is the left-hand side (LHS), in which the current is nearly fixed and the voltage is increasing; the power generated in this region increases as the voltage increases and the current drawn decreases [1][2][3].

The maximum power point (MPP) distinguishes these two zones by matching the PV resistance to the load resistance seen by the PV. Thus, if the operating point is in the LHS, it must be shifted to the right to reach MPP, whereas if it is in the RHS, it must be shifted to the left to reach MPP. The PV's resistance varies with irradiance and temperature, making it a variable resistor depending on weather conditions. This causes a mismatch between the fixed load resistance, which is directly powered by the PV, and the variable PV resistance, preventing maximum power transfer from the PV source to the load under different weather conditions.

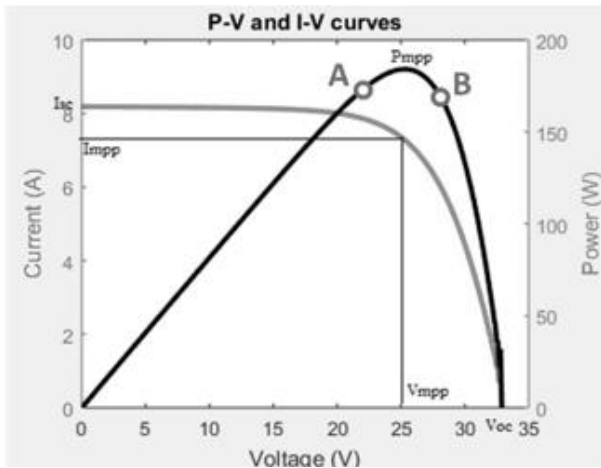


Fig. 1 I-V and P-V Characteristics of PV Module

A DC-DC converter is inserted between the PV system and the load to compensate for the mismatch between the load and the source resistances by varying the duty cycle of the DC-DC converter [4][5].

The PV module has one maximum power point for each combination of irradiance and temperature, and that point must be tracked in order to drive the system's operating point towards it and further increase the overall efficiency of the PV system.

References [6][7] discussed the offline methods, which measure voltage or current by disconnecting the system, such as the fractional open circuit voltage (FOCV) and fractional short circuit current (FSCC) methods, can be classified as MPPT techniques are presented. These methods are notable for their simplicity and rapid convergence speed, but also for their inaccuracy.

Instead, in references [8-11], online methods avoid the energy loss, which is associated with disconnecting the system by taking measurements online. Perturb and Observe (P&O) and Incremental Conductance (IC) are two simple online MPPTs that are more accurate in tracking the MPP and yet slower than offline methods.

Combining two MPPT methods proved very efficient in utilizing the benefits and mitigating the drawbacks of the individual components, necessitating the use of Hybrid MPPT techniques. For example, one of the offline methods can be combined with an online method to benefit from the former's fast speed and the latter's high accuracy. Furthermore, the PV dependency of Intelligent techniques can be reduced by combining them with another MPPT method [12-16].

III. RESULTS AND DISCUSSION

To investigate the performance of each MPPT technique algorithm, the model was built in MATLAB/Simulink platform, as shown in Fig. 2, and the PV parameters used are listed in Table 1. The switching frequency of the converter is 50kHz.

We consider the constant voltage (CV) method, the perturb and observe (P&O) method and the combination of both (CV+P&O). The limitation of this paper is not

discussing the ability of the MPPT techniques to track the Global Maximum Power Point (GMPP) under partial shading conditions.

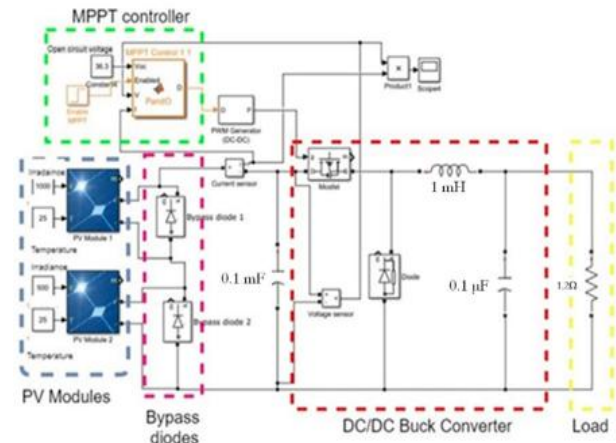


Fig. 2 MATLAB/Simulink Model of PV with MPPT

Table I
Parameters of PV System

PV specification	Ratings
Maximum Power, P_{MPP}	106.5W
Voltage at MPP, V_{MPP}	14.5V
Current at MPP, I_{MPP}	7.36A
Open Circuit Voltage, V_{OC}	18.15V
Short Circuit Current, I_{SC}	7.84A

Moreover, The CV method is combined with the P&O into a sequential combined MPPT algorithm to achieve a fast and accurate tracking system for the MPP of a PV system that is also PV independent and simple to implement. During the first stage, the MPP location is rapidly estimated using the CV algorithm by restricting the operating point to any two points A and B on either side of the MPP, as shown in Fig. 1. After estimating the MPP location, the P&O is in charge of driving the system's operating point as close to the actual MPP as possible.

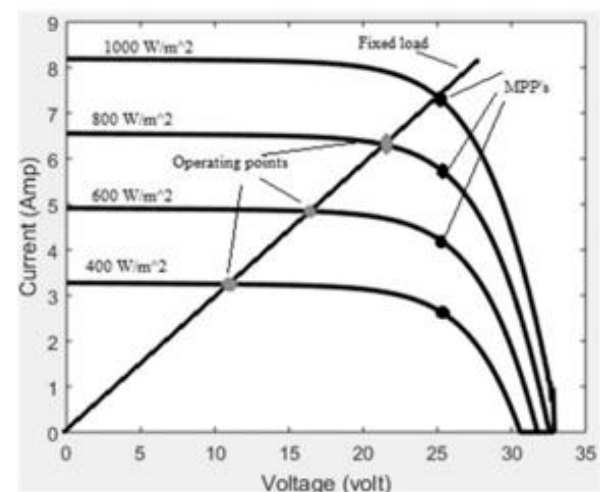


Fig. 3 I-V Curve with Different Irradiance Levels and The Location of MPP

Furthermore, using the CV method instead of offline techniques such as FOCV and FSCC as described in the literature eliminates the need to isolate the PV system from the load for measurements of the open circuit voltage or short circuit current.

To emphasize the importance of implementing a MPPT, Fig. 3 illustrates the system's operating point for different irradiance and temperature when directly connected to the load without MPPT. Due to the obvious mismatch between the source and load impedances, maximum power is not transferred from the source to the load. As the results, the poor efficiency, lower reliability, and significant power loss were occurred.

A DC-DC converter is introduced to perform the task of matching the source impedance with that of the load by adjusting its duty cycle using various algorithms and techniques. The overall system configuration, which includes the DC-DC converter and MPPT controller is shown in Fig. 4.

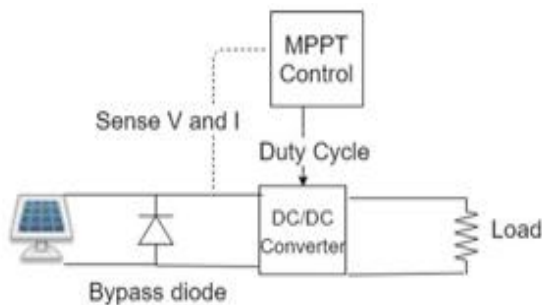


Fig. 4 PV System Configuration in MATLAB/Simulink

The ambient temperature and the PV exposed irradiance influence the current and voltage produced, and thus the power generated by the PV. Fig. 5 and Fig. 6 show the effects of temperature and irradiance on the I-V and P-V curves, respectively, where an increase in temperature reduces the voltage produced by the PV and an increase in irradiance is directly proportional to the current provided by the PV.

The CV method tracks the MPP of the PV system by simply setting a constant operating voltage for the PV to estimate the MPP under different weather conditions. It is noticeable that when the irradiance level is significantly lower, the power produced is decreased as well due to the decrease in current generated, whereas the voltage is only slightly affected by that change. As a result, changes in ambient temperature and irradiance have a minor effect on the voltage, which can be considered constant.

The CV method has gained popularity in low-budget PV systems due to its ease of hardware implementation, reduced number of sensors, stability, and fast estimation of the MPP location. Thus, for the implemented of MPPT techniques (CV, P&O, and CV+P&O), we can tabulate the performance for each technique and its combinations is the following Table 2.

Table II
MPPT Techniques Characteristics

Characteristics	MPPT Techniques		
	CV	P&O	CV+P&O
Speed level	High	Low	High
Accuracy level	Good	High	High
Acceptable level	Very Easy	Easy	Easy
Irradiance changes performance	Good	Good	High
Dynamic weather performance	Very Good	High	High
PV Dependency	Yes	No	Yes

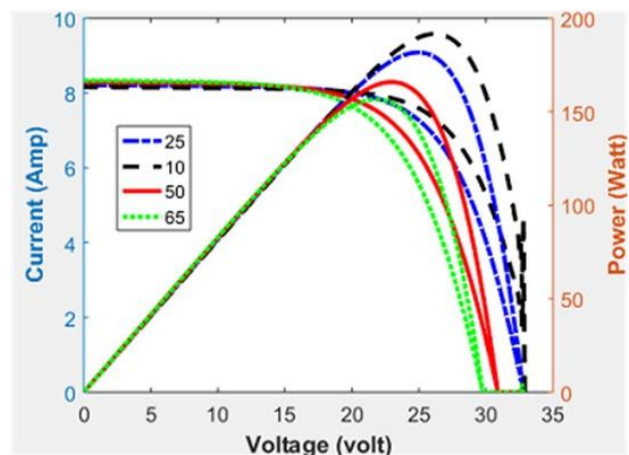


Fig. 5 Effects Temperature Change on P-V and I-V

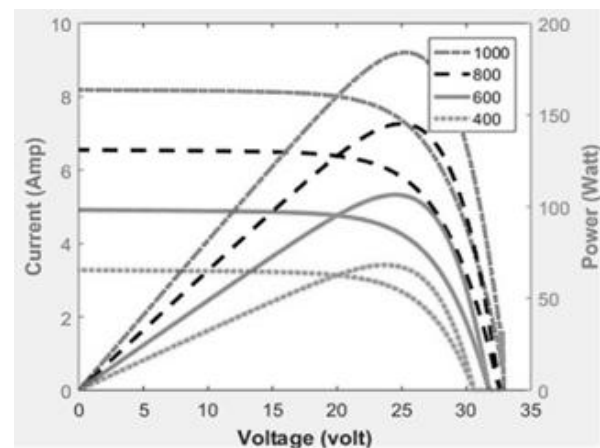


Fig. 6 Effects of Irradiance Change on P-V and I-V

IV. CONCLUSION

This paper discussed three different techniques of MPPTs for PV system and simulated those techniques in MATLAB/Simulink platform. These systems differ significantly in terms of accuracy, convergence speed, ease of hardware implementation, PV dependency, and the number of required sensors. A single MPPT technique was the first to be introduced. However, because it operates independently, it was unable to meet several of the requirements. Following that, the merger techniques of multiple MPPTs and the combination of

both (single and multiple MPPTs' techniques) were developed to integrate the benefits of each algorithm while removing their limitations. The CV and P&O methods, as well as a combination of both, were used. Based on the simulation results, we can conclude that the MPPT combination technique outperforms both when implemented separately. For further study, the authors will discuss the ability of the MPPT techniques to track the Global Maximum Power Point (GMPP) under partial shading conditions.

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