ANALIZA I POREĐENJE RAZLIČITIH METODA MPPT KOD PV SISTEMA NAPAJANJA

ANALYSIS AND COMPARISON OF DIFFERENT MPPT METHODS IN PV POWER SYSTEMS

Zoran STEVIĆ*[1], Miša STEVIĆ[2], Ilija RADOVANOVIĆ[3]
[1] School of Electrical Engineering - University of Belgrade, Technical Faculty Bor, University of Belgrade, CIK, Belgrade, Serbia
[2] Mikroelektronika, Belgrade
[3] School of Electrical Engineering - University of Belgrade, Innovation center of School of Electrical Engineering in Belgrade, Serbia

U radu su dati pregled stanja i uporedna analiza različitih metoda praćenja tačke maksimalne snage (MPPT – Maximum Power Point Tracking) PV sistema napajanja. Za date konfiguracije i uslove predložene su optimalni algoritmi.

Ključne reči: *MPPT; PV sistemi; uslovi delimičnog zasenčenja; procena efikasnosti*

The paper presents an overview of the state and comparative analysis of different methods of the maximum power point tracking (MPPT - Maximum Power Point Tracking) of the PV power system. Optimal algorithms have been proposed for the given configurations and conditions.

Key words: *MPPT; PV systems; partial shading conditions; performance evaluation*

1 Introduction

The voltage and current of the solar panel, ie its power, depend on several factors, the most important of which are the intensity of solar radiation and ambient temperature. Typical curves of current and power of the solar panel on its voltage are given in Fig. 1.

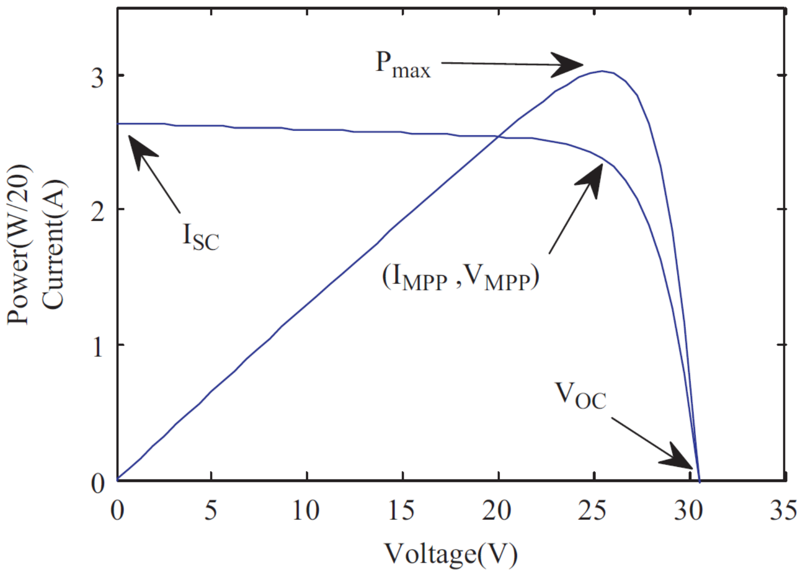

Figure 1. I–V and P–V characteristics of solar cell [1]

In the given operating conditions, there is still only one point at which the power of the solar panel is maximum. Considering the low degree of efficiency of solar panels and the existence of only one point of their maximum power under certain operating conditions, it is very important to obtain and monitor the maximum power from solar panels. In order to obtain the maximum power from

* Corresponding author, email: zstevic@tfbor.bg.ac.rs

them, the load must be constantly adjusted to their operating point, ie the load line of the load must intersect the point of maximum power of the solar panels. Therefore, it is necessary to insert a converter (DC / DC or DC / AC) between the solar panel and the load, which have the function of finding and monitoring the maximum power point of the solar panel, or adjusting the load to the operating conditions of the solar panel. The process of tracking the maximum power point of solar panels is called the MPPT (Maximum Power Point Tracking) procedure. MPPT algorithms also determine the operating point of the inverter.

Several different MPPT algorithms have been developed, such as: P&O (perturbation and observation), incremental conductance method, no-load voltage methods, solar panel short-circuit current methods, phase-logic method, neural network-based methods, etc. [1] .

The solar power system generally consists of three basic parts: a solar panel, a converter and a load. The MPPT procedure is impossible to perform without the existence of a converter between the solar panel and the load. There are many different topologies for both DC and AC solar power systems. In recent times, a voltage buck-boost converter is most commonly used. Depending on the value of the duty cycle of the control pulses, this inverter can either a lower or raise the voltage [2].

2 MPPT methods

MPPT algorithms can be evaluated by various criteria, such as complexity, number of required sensors, convergence rate (reaching the point of maximum power of the solar panel), adaptability to rapid changes in atmospheric conditions, price, efficiency, application in certain applications, implementation hardware, etc. .

2.1 Perturbation and observation algorithm (P&O)

The perturbation and observation algorithm is based on the perturbation of the DC-DC converter duty cycle and the perturbation of the DC line operating voltage between the photovoltaic module and the converter. The change in voltage is caused by the perturbation of the converter duty cycle. If there is an increase in power, the perturbation is maintained in the same direction, and if the power decreases, the direction of the next perturbation changes [3].

2.2 Incremental conductance algorithm

The incremental conductance algorithm modifies the voltage relative to the voltage corresponding to the point of maximum power. It is based on the incremental and instantaneous conductivity of the photovoltaic module. Figure 2 illustrates the principle of operation of this algorithm [3].

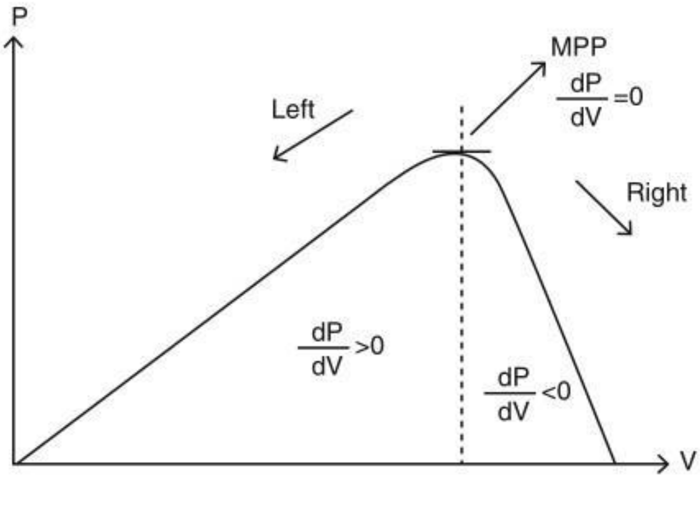

Figure 2. Illustration of the principle of operation of the incremental conductance algorithm [3]

At the point of maximum power, the slope of the voltage and power curve is equal to zero. To the left of the point of maximum power is positive, and to the right of it is negative. The speed of reaching the maximum power depends on the size of the increment, but this speed is higher in relation to the perturbation and observation algorithm [4]. Negative features of this method are the possibility of faulty monitoring the conditions of rapid changes in atmospheric parameters and setpoints oscillations around the point of maximum power.

2.3 Idle fractional voltage algorithm

The no-load fractional voltage algorithm is based on an almost linear relationship between the no-load voltage and the voltage at the point of maximum power of the photovoltaic module, through variable values of temperature and radiation [5]:

$$V_{MPP} \approx k_1 V_{OC}$$

The coefficient of proportionality depends on the type of photovoltaic module and needs to be determined. Most often, its value ranges from 0.71 to 0.78 [3]. This method works by periodically measuring the no-load voltage, which requires a short-term shutdown of the converter. To avoid this, an unloaded pilot cell is installed, from which the no-load voltage is determined. After that, the closed voltage on the converter asymptotically reaches the appropriate voltage. The pilot cell should represent the characteristics of the photovoltaic module. Linearity is an approximation, so that in reality work is never achieved at the point of maximum power, but for certain applications and situations the accuracy is satisfactory. The good side of this method is the cheap implementation. However, in cases of partial illumination of the module, several local maximums of the voltage-power curve appear, so that the coefficient is not valid in this case, so this method cannot be applied. The problem also arises if the atmospheric conditions on the implemented pilot cell are different from the conditions on the photovoltaic module [3-5].

2.4 Fractional short circuit current

Just like in the fractional open circuit voltage method, there is a relationship, under varying atmospheric conditions, between the short circuit current *ISC* and the MPP current, *IMPP*, as is shown by:

$$I_{MPP} \approx k_2 I_{SC}$$

The coefficient of proportionality k_2 has to be determined according to each PV array, as in the previous method happened with k_1. The constant k_2 is between 0.78 and 0.92.

2.5 Extremum Seeking Control method (ESC)

ESC is a robust and adaptive control techniques for non linear dynamic uncertain systems. It is based on theories namely averaging theory, adaptive control and singular perturbation techniques. The objective of ESC is to rapidly reach the MPP despite uncertainties and disturbances on the PV panel and the load. The reference current is perturbed by a sinusoidal modulation. The power got at the output of the PV system is high pass filtered, to get only effect of the perturbation.

2.6 Artificial neural network (ANN)

ANN is a representation of interconnected artificial neurons (nodes), similar to the structure of the biological brain. In general ANN consists of three layers: input, hidden and output. A simple configuration of ANN to identify MPP in PV is illustrated in Fig. 3. The irradiance, temperature, Voc, and Isc are normally used as input layer, while the output may be in the form of voltage, duty cycle or current depending. In each layer the numbers of nodes are defined by the user and varied based on the requirement [2].

2.7 Comparison of MPPT methods

Each of these methods has its advantages and disadvantages. That is why we are constantly working on modifying the standard methods and setting up new ones, and often resort to hybrid methods. Table 1 shows the basic characteristics for the most commonly used methods, so that the optimal method can be chosen according to the circumstances.

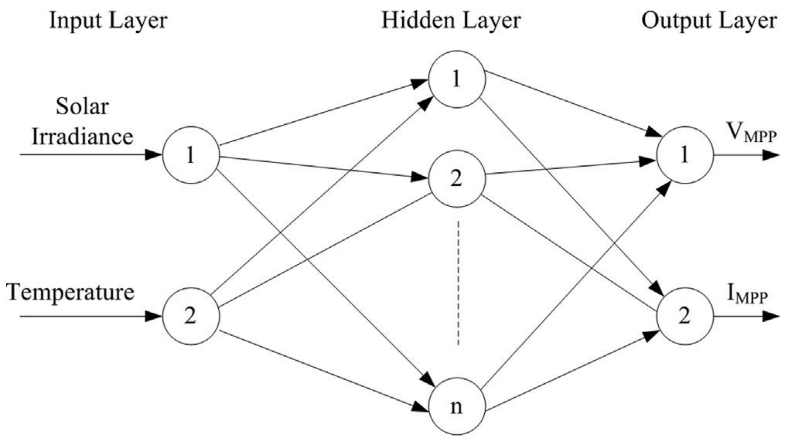

Figure 3. A typical ANN structure for MPPT [2]

Table 1. Comparison of MPPT methods

MPPT method	*Complexity*	*Convergence speed*	*Sensed parameters*	*Efficiency*
Open circuit voltage	Low	Medium	Voltage	Low (86%)
Short circuit current	Medium	Medium	current	Low (89%)
Artificial neural networks	High	Fast	Depends	High (98%)
Fuzzy logic	High	Fast	Depends	High
P&O (fixed perturbation size)	Low	Low	Voltage and current	Low
P&O (variable perturbation size)	Medium	Fast	Voltage and current	High (96%)
ESC	Medium	Fast	Voltage and current	High (97%)
IncCond	Medium	Depends	Voltage and current	High

3 Conclusion

The advantages and disadvantages of the most commonly used MPPT methods are discussed, including ease of implementation, costs as well as all hardware requirements. The requirements are often conflicting, so it is always necessary to find the optimal solution. In addition to the developed optimization methods, the experience and creativity of the designer are also required. In further research, special attention will be paid to the integration of microprocessor control MPPT and related electronics, the application of embedded systems and IoT.

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5 Literature

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