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Performance Evaluation of Maximum Power Point Tracking Principle for PV Systems

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Abstract

According to numerous use of the fossil fuel, the reserves of petroleum significantly and quickly reduced, and will be exhausted in a few decades. Maximum Power Point Tracking is a method used frequently with wind turbines and photovoltaic solar systems to exploit the power extraction under all climatic conditions. Although solar power is mostly covered, the principle applies normally to sources with variable power. Photovoltaic solar schemes exist in many diverse structures with regard to their relationship to inverter systems, battery banks, external grids and other electrical loads. Irrespective of the ultimate destination of solar power, though the central problem addressed by Maximum Power Point Tracking is that the efficiency of power transfer from the solar cell mainly depends on both the quantity of sunlight falling on the solar panels and the electrical characteristics of load. The deterministic procedure of Incremental Conductance algorithm is more complicated than the other two algorithms. The main objective of this paper is to make a research and compare the performance of various Maximum Power Point Tracking algorithms in a photovoltaic system (Perturbation and Observation, Incremental Conductance and Hill Climbing algorithms). Perturbation and Observation Maximum Power Point Tracking algorithm holds fast dynamic-response and well-regulated Photovoltaic output voltage than Hill Climbing Algorithm.

Keywords

Maximum Power Point Tracking, Perturbation and Observation Algorithm, Incremental Conductance Algorithm, Hill Climbing Algorithm.

I. Introduction

In Taiwan, ninety-five percentage of the needed energy resources is imported from foreign countries. Since the crisis of energy depletion will not occur in a small period of time, though the researchers and scientists have done a lot of researches for the expansion of alternative energy sources. Solar energy is one of the alternative clean energy sources which are paid close attention by the humans. Taiwan is situated in the subtropical region and possesses outstanding sunshine conditions. It is very appropriate for Taiwan to develop photovoltaic power generation [1]. Nevertheless, in addition to the exceptional geographical conditions it is very imperative to have an effective and appropriate Maximum Power Point Tracking (MPPT) algorithm for the photovoltaic system. If there is a decent irradiance condition, the photovoltaic system can produce maximum power resourcefully while an effective MPPT algorithm is used with the system. Inverter efficiencies characteristically declared are calculated as the fraction of Alternating Current (AC) output divided by the Direct Current (DC) input power. Inverter constructors and system installers assume that the inverters are generally working at the Maximum Power Point (MPP) of the I-V curve of the PV array.

In practice, there are number of issues which cause the actual operating point to vary from the true MPP [2]. For instance, devices that use search algorithms to find the MPP have to move continually around this optimal point thus operating the array off of MPP for some period of time. Search algorithms use finite-time and voltage or current steps that may reason for some error. These MPPT inexactitudes conspire to lessen the conversion efficiency of the PV array and therefore the complete system (figure1). MPPT

performance is significant to system designers who are ensuring a certain system performance and need to know all of the system losses, as well as to system operators who want to safeguard that their system is operating per its specifications. Thus an inverter or separate MPPT certification should comprise MPPT performance [3]. MPPT performance is significant to system designers who are guaranteeing a certain system performance and essential to know all of the system losses as well as to system operators who want to safeguard that their system is operating as per its specifications. Thus an inverter or distinct MPPT certification should include MPPT performance. A lot of MPPT algorithms have been developed by the researchers and industry delegates all over the globe [4]. They are voltage feedback method, perturbation and observation method, linear approximation method, incremental conductance method, hill climbing method, actual measurement method, fuzzy control method and so on.

Hua, J. Lin and C. Shen used DSP chips to implement the function of MPPT in order that the output of solar modules can approach its extreme power by continuous perturbing and observing. In the research work proposed by Fangrui Liu, Yong Kang, Yu Zhang and Shanxu Duan, the response speed and applicability of the perturbation and observation, and hill climbing methods are compared for the grid connected system. Furthermore, C. C. Hua, J. R. Lin and W. Xiao advance the efficiency of the perturbation and observation and hill climbing methods in their researches. The requirements of implementing supreme performance of a photovoltaic system are not only good weather conditions, but also with the suitable MPPT method [5].

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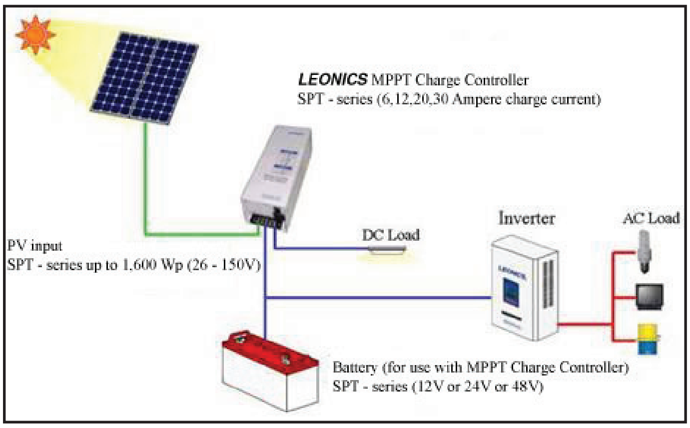

Fig. 1: The Principle of Maximum Power Point Tracking

The purpose of this paper is to study and compare advantages, shortcomings and execution efficiency for three power-feedback type MPPT methods including Perturbation and Observation (P&O), Incremental Conductance (INC) and Hill Climbing (HC) methods [6].

II. Available Maximum Power Point Tracking Algorithms

Perturbation and Observation Method (P&O) method is the most commonly used algorithm to track the maximum power due to its modest arrangement and fewer essential parameters. This technique finds the maximum power point of PV modules by means of iteratively perturbing, observing and comparing the power generated by the PV components. It is extensively applied to the maximum power point tracker of the photovoltaic system for its structures of simplicity and convenience. The essential parameters of the power-feedback type MPPT algorithms are only the voltage and the current of PV modules [7].

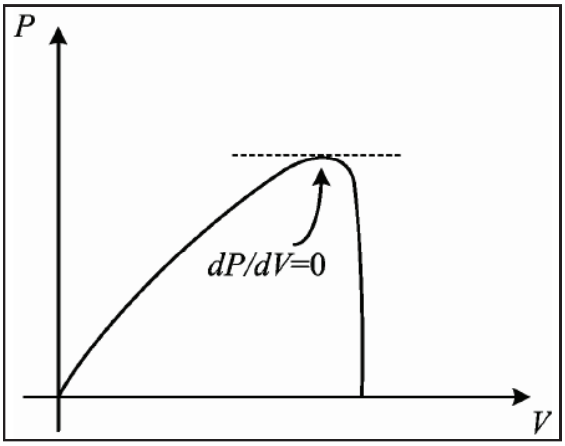

Fig. 2: Relationship between the terminal voltage and output power generated by a PV module.

Shown in figure 2 is the general relationship between the terminal voltage and the output power generated by a PV segment. It can be perceived that irrespective of the magnitude of sun irradiance and terminal voltage of PV modules, the maximum power point is attained while the condition dP/dV = 0 is accomplished. The slope (dP/dV) of the power can be calculated by the successive output voltages and output currents. In this algorithm, operating voltage of the PV module is perturbed and the resulting changes in power is observed. If the change is positive, then it is imagined that it has moved the operating point closer to the MPP. Consequently, further voltage perturbations in the similar direction must move the operating point towards the MPP. If the change is negative, the operating point has moved away from the MPP and the direction of perturbation must be reversed to move back towards the MPP. Fundamentally, three MPPT algorithms have been discussed in this paper to achieve the condition (dP/dV=0) to find the maximum power point of the PV modules. The difference among the selected three MPPT algorithms is the method used to meet the needed condition. In a fixed period of time, the load of the PV system is accustomed in order to adjust the terminal voltage and output power of the PV modules. The disparities of the output voltage and power before and after the changes are then observed and then compared to be the reference for increasing or decreasing the load in the subsequent step.

If the perturbation in this time results in better output power of PV modules than that before the variation, the output voltage of PV modules will be varied towards the same direction. Else, if the output power of PV modules is less than that before variation, it specifies that the varying direction in the next step should be altered. The maximum output power point of a PV system can be found by using these iterative perturbation, observation and assessment steps. The advantages of the P&O method are its unassuming structure, informal implementation and less essential parameters. The inadequacies of the P&O method can be summarized: (a) The power tracked by the P&O method will oscillate and perturb up and down near to the maximum power point. The magnitude of oscillations is determined by the magnitude of disparities of the output voltage. (2) There is a miscalculation phenomenon for the P&O method when weather conditions changes rapidly.

The theory of the incremental conductance method is to regulate the variation direction of the terminal voltage for the PV modules by gauging and associating the incremental conductance and the instantaneous conductance of the PV modules. If the value of incremental conductance is equal to that of the instantaneous conductance, it characterizes that the maximum power point is found. The elementary schematic diagram of the incremental conductance method is portrayed in figure 3. When the operating behaviour of PV modules is within the constant current area, the output power is relational to the terminal voltage [8]. That means the output power increases linearly with the increasing terminal voltage of PV modules (slope of the power curve is positive, $dP/dV > 0$). When the operating point of PV modules passes through the maximum power point, then its operating behaviour is similar to the constant voltage.

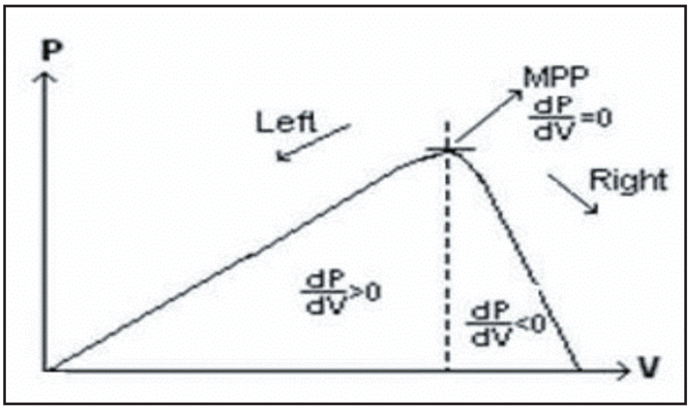

Fig. 3: Schematic Diagram of the Incremental Conductance Method

Therefore, the output power decreases linearly with the increasing terminal voltage of PV modules (slope of the power curve is negative, $dP/dV < 0$). When the operating point of PV modules is exactly on the maximum power point, the slope of the power curve is generally zero ($dP/dV = 0$). It can be perceived that the weather conditions does not change and the operating point is located on the maximum power point when $dV = 0$ and $dI = 0$. If $dV = 0$ but $dI > 0$, it characterizes that the sun irradiance increases and the voltage of the maximum power point rises. Temporarily, the maximum power point tracker has to raise the operating voltage of PV modules so as to track the maximum power point. On the contrary, the sun irradiance decreases and the voltage of maximum power point reduces if $dI < 0$ [9]. At this time the maximum power point tracker necessities to decrease the operating voltage of PV modules. Also, when the voltage and current of PV modules change during a voltage perturbation and $dI/dV > -I/V$ ($dP/dV > 0$), the operating voltage of PV modules is located on the left hand side of the maximum power point in the P-V diagram and has to be elevated in order to track the maximum power point. If $dI/dV < -I/V$ ($dP/dV < 0$), the operating voltage of PV modules will be located on the right hand side of the maximum power point in the P-V diagram and has to be condensed so as to track the maximum power point.

The main advantage of incremental conductance method, which is larger to those of the other two MPPT algorithms is that it can compute and find the exact perturbation direction for the operating voltage of PV modules. In theory, when the maximum power point is found by the judgment conditions ($dI/dV = -I/V$ and $dI = 0$) of the incremental conductance method, it can evade the perturbation phenomenon near the maximum power point which is typically happened for the other two MPPT algorithms. The value of operating voltage is then fixed. Though, it specifies that the perturbation phenomenon is still happened near the maximum power point under stable weather conditions after doing some trials. This is due to the reason that the probability of meeting condition $dI/dV = -I/V$ is tremendously small.

The elementary operating theory of the hill climbing method is similar to that of the P&O method. Both methods use the condition that $P(n)$ is greater than $P(n-1)$ or not to make the decision. As described in preceding section, the P&O method uses the condition dP/dV to regulate whether the maximum power point has been found or not. Though, the hill climbing method uses the condition dP/dD to judge. In most of the applications, DC-DC converters and DC-AC inverters are usually employed as the power interface devices between PV modules and the loads. The hill climbing technique uses the duty cycle (D) of these switching mode power interface devices as the judging parameter when the mission of the maximum power point tracking is implemented. When the condition $dP/dD = 0$ is proficient, it characterizes that the maximum power point has been tracked. The duty cycle in every sampling period is determined by the assessment of the power at present time and previous time. If the incremental power $dP > 0$, the duty cycle should be augmented in order to make $dD > 0$. If $dP < 0$, the duty cycle is then condensed to make $dD < 0$. The benefits of the hill climbing method are comparable to those of the P&O method which are unpretentious structure and fewer required parameters. The inadequacies of hill climbing method are described below. Figure 4 portrays the *P-D* curve diagram of PV modules when the power interface device is DC-DC buck converter. If the preliminary operating point of the PV system is situated on the left side of the maximum power point, then the duty cycle has to be uninterruptedly increased on the basis of the judgment procedure of the hill climbing method in order to track maximum power point. When the operating point of the PV system is positioned on the right side of the maximum power point, the duty cycle should be unceasingly reduced to return back to the maximum power point. Nevertheless, if the operating point wants to move toward the maximum power point ($DP>0$) the incremental duty cycle should be greater than zero ($dD >0$) conferring to the judgment procedure of the hill climbing method. This will reason for the operating point to move beyond away from the maximum power point. Consequently, the misjudgement of tracking direction may occur under this kind of condition. For the hill climbing method, this misjudgement is a fatal weak-point.

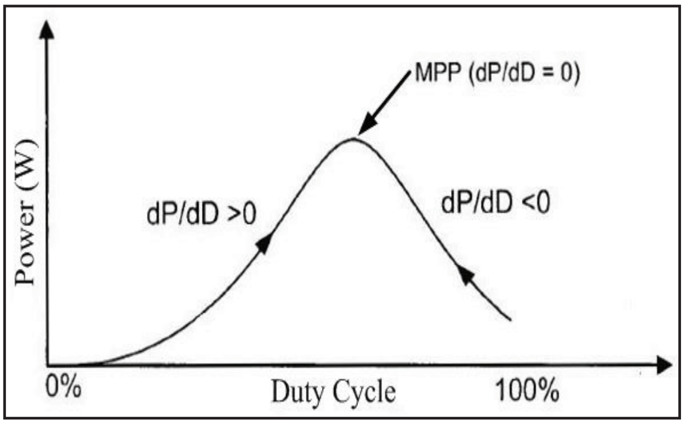

Fig. 4: P-D curve diagram of PV modules

III. Conclusion

The chief objective of this paper is to make a research and compare the performance of various Maximum Power Point Tracking algorithms in a PV system mainly the Perturbation and Observation, the Incremental Conductance and Hill Climbing algorithms. Perturbation and Observation Maximum Power Point Tracking algorithm holds fast dynamic-response and well-regulated PV output voltage than Hill Climbing Algorithm. The deterministic process of Incremental Conductance algorithm is more intricate than the other two algorithms. P&O algorithm has well-regulated PV output voltage than hill climbing algorithm. However, perturbation magnitude of the hill climbing method will be receiving slighter under the condition of having analogous oscillations of PV output voltage. This reasons to a longer simulation elapsed time for the hill climbing method to track the maximum power point. Therefore, P&O algorithm possesses quicker dynamic response than hill climbing algorithm. Also, the tracking elapsed time of the incremental conductance method is lengthier than the other two methods due to its complex judgment procedure in every perturbing period. The incremental conductance method has compensations of exact perturbing and tracking direction, and steady maximum power operating voltage. Nevertheless, the other two methods have the possibility of misjudgement for shaping the perturbing and tracking direction.

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Author Profile

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