Comparing Different MPPT Techniques for PV Systems

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Abstract— **Currently, one of the most efficient and cleanest forms of renewable energy source for effective power generation is Photovoltaic (PV) source. But tracking the sun energy with the solar panels for effective utilization of its energy is a major challenge to researchers. This paper proposes a detailed comparative survey of several maximum power tracking techniques convergence speed, ease of implementation, efficiency, and cost of implementation.**

Keywords- MPPT, Buck-Boost, NPC-VSI, Micro- Grid.

INTRODUCTION

Solar power is an important and valuable tendency inthe global market, as it answers the need for producing energy without harming the environment. The major problem with solar panel technology is that the efficiencies for solar power systems are still poor and the costs per kilo-watt-hour (kwh) are not competitive, in most cases, to compete with petroleum energy sources. Solar panels themselves are quite inefficient (approximately 30%) in their ability to convert sunlight to energy. However, the charge controllers and other devices that make up the solar power system are also somewhat inefficient and costly. The MPPT is an DC/DC converter that is connected between the PV solar cells (panels) and the battery or inverter. The MPPT is used to control (increase ordecrease) power output under the required conditions of thesystem and determines the operating point that will deliver that maximum amount of power available to the batteries. If a version of theMPPT can accurately track the always-changing operating point where the power is at its maximum, then the efficiency ofthe solar cell will be increased. An introduction of the most popular and basic MPPT techniques such as P&O method, IC method, CV and FOCV methods, their comparison is done and discusses the advantages and disadvantages of each one.

1. BASIC MPPT TECHNIQUES

For each PV system, there is a singular operating point labelled as MPP in I-V and V-P curves for each temperature and irradiation condition. The maximum power point (MPP) changes its position with any change in atmospheric conditions. Because of that, the tracing system was designed to keep tracking MPP, and because of that they are a necessary part of the PV system. The controller changes the resistance seen by the panel, and forces the panel to operate closer to MPP.

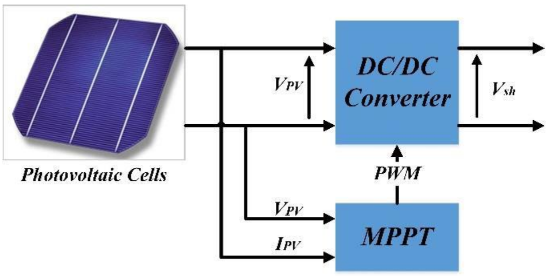

Figure 1: Block diagram of PV system

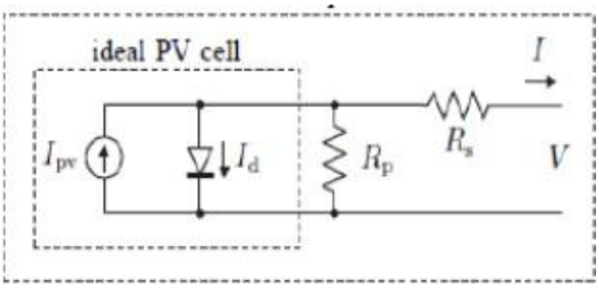

Figure 2: Equivalent Circuit of PV cell with R_S and R_P

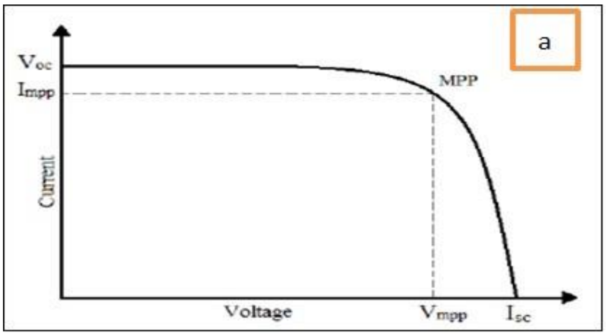

Figure 3: (a) I-V Characteristics

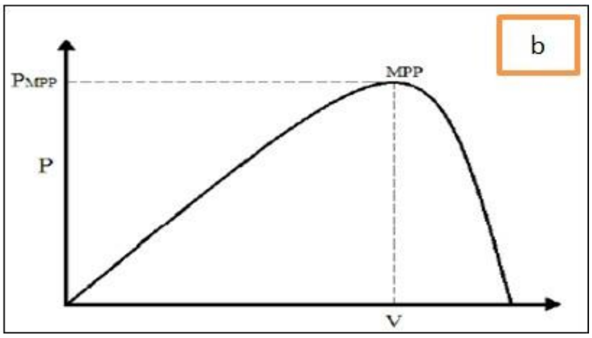

Figure 3: (b) P-V Characteristics

1.1 Perturbation and Observation (P&O) Method

Perturbation and Observation method has been widely used due to its ease of implementation P&O algorithm will force the PV system to approach to the maximum power point by increasing or decreasing the PV panel-output voltage. Based on the simple mathematical condition ($dP/dV = 0$), when the PV array operates to the left area of the MPP curve, the output power will be increased due to the increase in voltage and output power decreases on increasing voltage when the sameoperates to the right area of the MPP Curve. Hence if $dP/dV > 0$, the system keeps the disturbance, and if $dP/dV < 0$, the disturbance should be reversed. The process repeats until theoperating point is across to the maximum power point, whereP and V are power and voltage at output of PV module respectively.

The P&O algorithm method gives a good operation provided the solar radiation does not deviate too quickly. The classic Perturb and observe (P&O) method has poor efficiency at steady state and low irradiation, the operating point oscillates aroundthe MPP voltage (usually fluctuates lightly) but never reaches exactly the MPP.

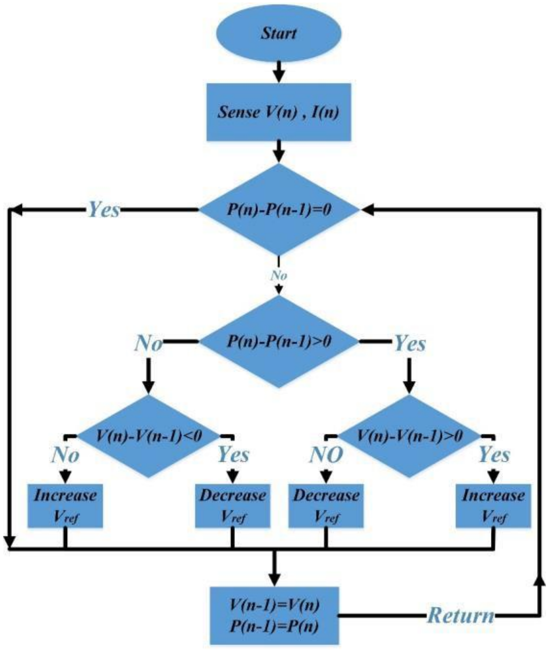

Figure 4: Perturbation and observation method flowchart

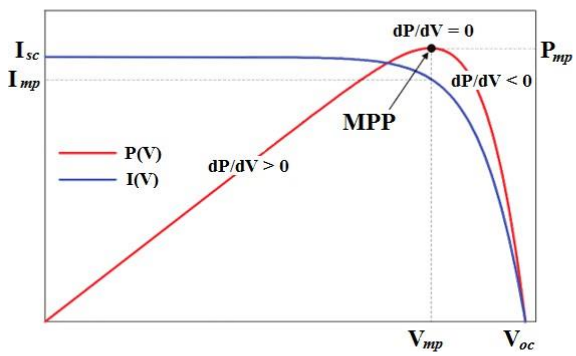

Figure 5: V-I characteristic of Perturbation and Observationmethod technique of PV system

1.2 Incremental Conductance (IC) Method

The method of Incremental Conductance works when the dP/dV =0, because the derivative of the power of the PV module is equal tozero at the MPP, the positive results off the left area of the MPP curve and negative results on the right of the MPP curve. Table 1 show the mathematical relations for

$\frac{dp}{dV} = 0$	At MPP
$\frac{dp}{dV} > 0$	Left Area of MPP
$\frac{dp}{dV} < 0$	Right Area of MPP

Table 1. Mathematical properties of Incremental Conductance

Incremental Conductance technique. The maximum power point of PVsystem can be tracked by comparing the I/V to ΔI/ΔV. where I/V: Instantaneous conductance and ΔI/ΔV: Incremental conductance.

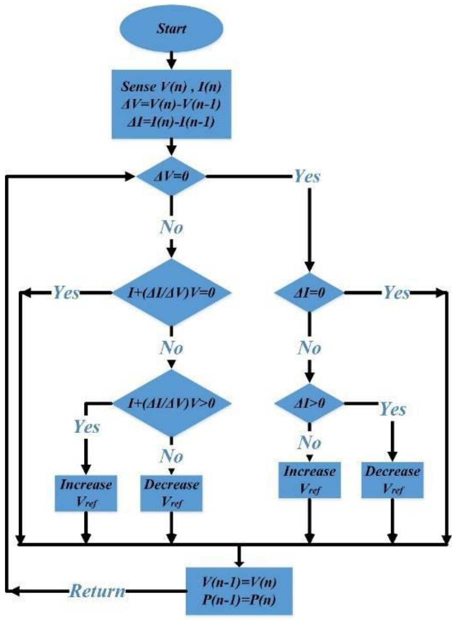

Figure 6: Incremental Conductance method flowchart

$Vref$ is the reference voltage of the PV array operation. When the MPP is achieved at that moment, $Vref$ must be equal to Vmpp. When it happens, the system keeps the output voltage at MPP until a change in it occur or the change in atmospheric conditions. Thus, the decision of decreasing or increasing $Vref$ by IC algorithm is to always reach the new MPP.
The advantage of this technique is its ability to track more accurately in extremely variable weather conditions and less oscillating behavior around the MPP compared to the Perturbation and Observation technique. The disadvantage of this algorithm is the complexity of the hardware to implement it.

1.3 Constant Voltage (CV) Method

The constant voltage (CV) algorithm is one of the simplest algorithm of MPPT algorithms. The operating point of thePV system is fixed close to the maximum power point (MPP) by setting the output voltage of solar to conform to the continuous reference voltage (V*ref*). The V*ref* is regulated to the same value of the voltage at the maximum power point (V*mpp*) of the characteristic PV array. For this technique, the panel variations in irradiation and temperature are not substantial and the constant reference voltage (V*ref*) is antecedent regulated to achieve performance closely to the MPP. Because of that, in practice, this method may never exactly find the MPP. The CV method requires data collection before to demonstrate a constant voltage reference,and this may vary from place to place.

1.4 Fractional Open-Circuit Voltage (FOCV)Method

In the FOCVM, the MPP voltage can be calculated from themathematical relationship shown in Equation

$$V_{mpp} \approx K_{oc} \cdot V_{oc}$$

The constant value K_{oc} usually changes between 0.78 and 0.92, andcan be calculated by analyzing the PV system at a broad range of solar temperatures and radiations. In this method, the PV system isopen-circuited at load end for a fraction of a second and is measured, then the voltage calculated using the equation 3. The sample is taken repeatedly every few seconds and the output value is updated. The advantage of this method is its simplicity to implement. On the otherhand, the drawback is that the true MPP may be never reached.

1.5 Fuzzy logic controller method

Advances in microelectronic technology permitted to the fuzzy logic control to become the most significant and fruitful application for fuzzy logic theory. Fuzzy logic controllers, based on fuzzy logic, provides a mathematical tool for converting linguistic control rules in the form of (IF-THEN) statements into an automatic control strategy. The tow inputs of the FLC are the error *E* and, also, the associated change of error *CE*.

$$E(k) = \frac{P(k) - P(k-1)}{V(k) - V(k-1)}$$

$$CE(k) = E(k) - E(k-1)$$

Where *P(k)* and *V(k)* refers to the output power and voltageof PV panel at the sampling instant *k*. *gE* and *gCD* are the inputs scaling factors, and *gdD* is the Defuzzification gain While *dD* denotes the output of the fuzzy process.
The fuzzy logic controller consists of three functional blocks: fuzzification, Fuzzy rules and inference engine, andfinally Defuzzification.

Fuzzification

The fuzzy process requires that each variable used indescribing the control rules, has to be expressed in terms of fuzzy set notations with linguistic labels.

Fuzzy rules and inference engine

The kernel of fuzzy logic controller is the fuzzy inference system. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. Themapping then provides a basis from which decisions can be made. The proposed Mamdani-type inference system endeavors to force the error function (*E*) to zero. Two cases are to consider:
First case: *E* is positive; working point is on the left of the MPP. If the change of error *CE* is positive, then the working point converges toward the MPP. If *CE* is negative, the inverse that occurs.
Second case: *E* is negative; working point is, therefore, on the right of the MPP. In this case if *CE* is positive,working point moves away of the MPP and vice versa if *CE* is negative.

Defuzzification

The process of Defuzzification calculates the crisp output of the FLC. It describes the mapping from a space of fuzzy logic statement, corresponding to the inferred output, into a non-fuzzy control action. In this paper the center of gravity DE fuzzifier, which is the most common one, is adopted.

Conclusion

This paperprovides a clear explanation of the basic MPPT methods with an introduction to the most basic and common MPPT techniques for instance Perturbation and Observation, IC, Constant Voltage and Fractional Open-Circuit Voltage and Fuzzy logic. Correct implementation and design of MPPT techniques highly improves the efficiency of the energy conversion process andprevents energy loss due to variations in environmental conditions and intelligent methods such as Fuzzy shows better performance.

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