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COMPARISON OF PHOTOVOLTAIC ARRAY MAXIMUM POWER POINT TRACKING (MPPT) TECHNIQUES AND DC-DC CONVERTER

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Abstract: Maximum power point trackers (MPPTs) play an important role in photovoltaic (PV) power systems because they maximize the power output from a PV system for a given set of conditions, and therefore maximize the array efficiency. Thus, an MPPT can minimize the overall system cost. MPPTs find and maintain operation at the maximum power point, using an MPPT algorithm. Many such algorithms have been proposed. However, one particular algorithm, the perturb-and-observe (P&O) method Incremental Conductance (IncCond), claimed by many in the literature to be inferior to others, continues to be by far the most widely used method in commercial PV MPPTs. Part of the reason for this is that the published comparisons between methods gives a good idea about its function and application. This paper provides such a comparison and DC-DC converter used in solar PV MPPT systems. MPPT algorithm performance is quantified through the MPPT efficiency. In this work, It is found that the P&O method and IncCond method, when properly optimized, can have MPPT efficiencies well in excess of 97%, and is highly competitive against other MPPT algorithms considering easy implementation.
Keywords: Photovoltaic (PV), Maximum Power Point Tracking (MPPT), DC-DC Converter, P&O(Perturb and Observe), IncCond(Incremental conductance).

I. INTRODUCTION

Global warming and energy policies have become a hot topic on the international agenda in the last years. Developed countries are trying to reduce their greenhouse gas emissions. In this context, photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases. In their lifetime, which is around 25 years, PV panels produce more energy than that for their manufacturing. Also they can be installed in places with no other use, such as roofs and deserts, or they can produce electricity for remote locations, where there is no electricity network Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation. Instead, improving the tracking of the maximum power point (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price. MPPT algorithms are necessary because PV arrays have a non linear voltage-current characteristic with a unique point where the power produced is maximum [6][10]. This point depends on the temperature of the panels and on the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore irradiation can change rapidly due to changing atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained. In the past years numerous MPPT algorithms have been published [1][2][10]. They differ in many aspects such as complexity, sensors required, cost or efficiency. However, it is pointless to use a more expensive or more complicated method if with a simpler and less expensive one similar results can be obtained. This is the reason why some of the proposed techniques are not used. The objective of this paper is firstly to review different MPPT algorithms. Then the most popular, perturb and observe (P&O)[7], incremental conductance (InCond)[3][6][7][9], neural network and fuzzy logic control (FLC)[4] are analyzed in depth. After that, improvements to the P&O and the InCond algorithms are suggested to succeed in the MPP tracking under conditions of changing irradiance[7][10]. This paper can be interesting to looking for a deeper knowledge in MPP tracking or those looking for an introduction to PV power generation, because it includes a review of the general concepts related to PV power generation.

II. MAXIMUM POWER POINT TRACKING (MPPT)

As was previously explained, MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array[2][4][6]. Over the past decades many methods to find the MPP have been developed and published. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. Among these techniques, the P&O and the InCond algorithms are the most common[7][9]. These techniques have the advantage of an easy implementation but they also have drawbacks, as will be shown later. Other techniques based on different principles are fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc. Most of these methods yield a local maximum and some, like the fractional open circuit voltage or short circuit current, give an approximated MPP, not the exact one. In normal conditions the V-P curve has only one maximum, so it is not a problem. However, if the PV array is partially shaded, there are multiple maxima in these curves[6][9]. In order to relieve this problem, some algorithms have been implemented as in. In the next section the most popular MPPT techniques are discussed. Below shown is block diagram of MPPT system.

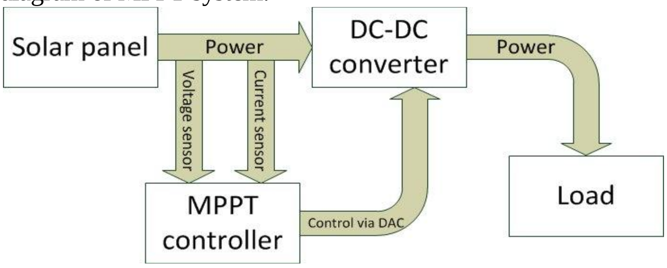

Figure 1.MPPT block diagram.

A. Perturb and Observe (P&O)

The P&O algorithm is also called "hill-climbing", but both names refer to the same algorithm depending on how it is implemented. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter. In the case of the Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of the DC link between the PV array and the power converter, so both names refer to the same technique[7]. In this method, the sign of the last perturbation and the sign of the last increment in the power are used to decide what the next perturbation should be. As it can be seen in Figure 2, on the left of the MPP incrementing the voltage increases the power whereas on the right decrementing the voltage increases the power

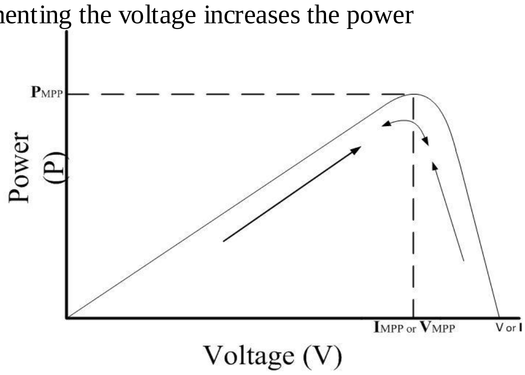

Figure 2.P-V characteristics

If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction[7]. Based on these facts, the algorithm is implemented. The process is repeated until the MPP is reached. Then the operating point oscillates around the MPP. This problem is common also to the InCond method, as was mention earlier. A scheme of the algorithm is shown in the figure 2.

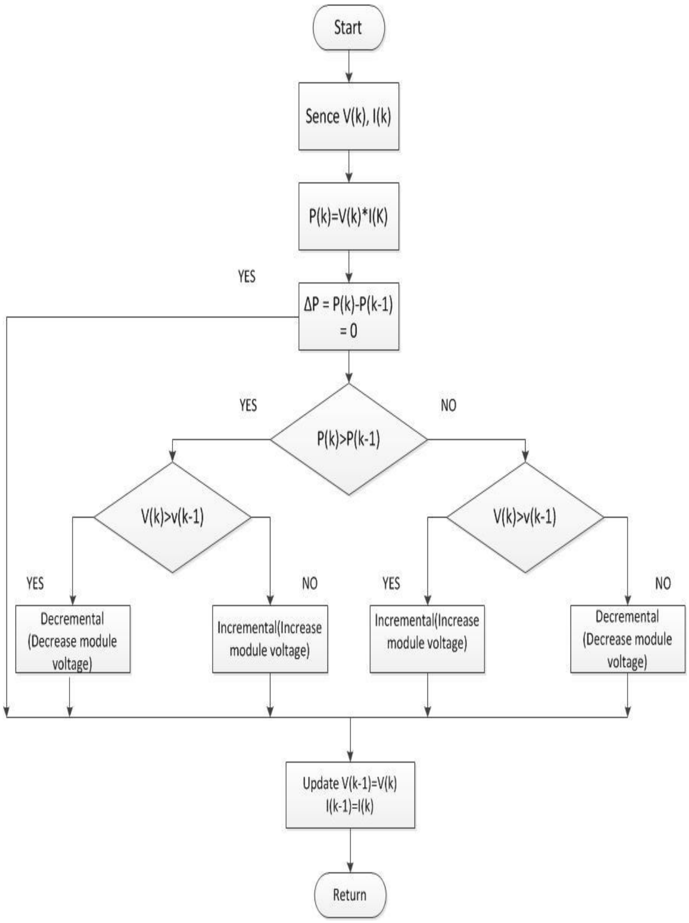

Figure 3.Perturb and Observe (P&O) flowchart

B. Incremental Conductance (IncCond)

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IncCond method. The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right[3][6][10], it can be written as.

$\frac{dI}{dV} = -\frac{I}{V}\ or\ \frac{dP}{dV} = 0$ At MPP

$\frac{dI}{dV} > -\frac{I}{V}$ or $\frac{dP}{dV} > 0$ Left of MPP

$\frac{dI}{dV} < -\frac{I}{V}$ or $\frac{dP}{dV} < 0$ Right of MPP

By comparing the increment of the power vs. the increment of the voltage (current) between two consecutives samples, the change in the MPP voltage can be determined.

A scheme of the algorithm is shown in figure below.

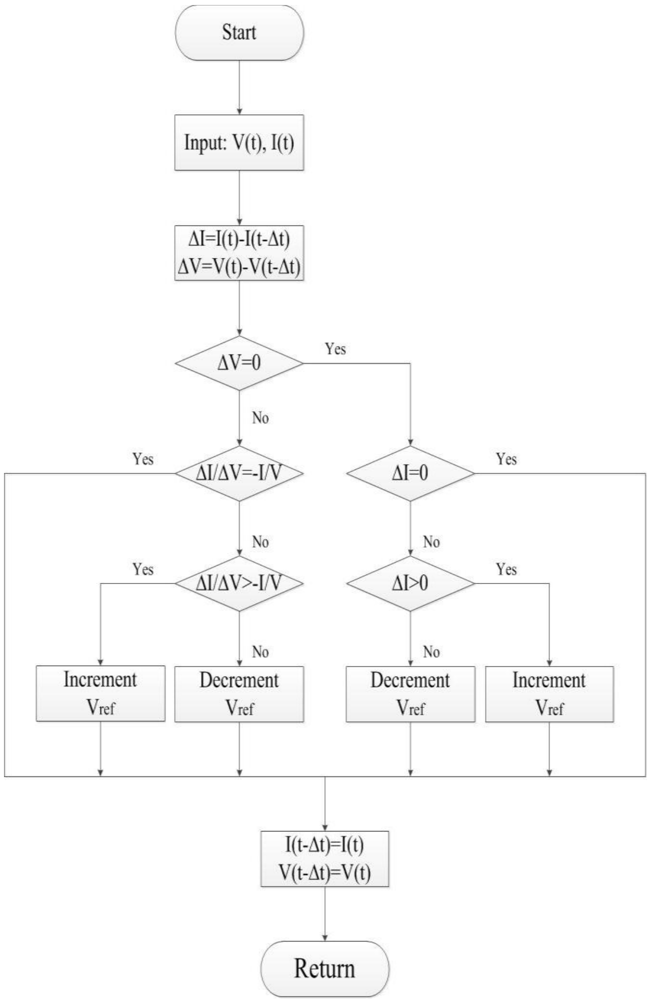

Figure 4.IncCond Flowchart

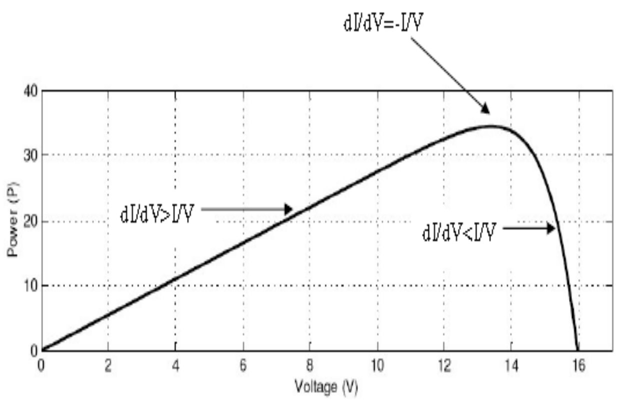

Figure 5.P-V characteristics of IncCond.

The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP[3][7], shown in Figure 5. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to P&O.

Comparison of P&O and INC Algorithm

- Unlike P&O, Incremental Conductance algorithm is able to track a MPP in rapidly changing environment.
- However Incremental Conductance algorithm has increased susceptibility to noise and has increased complexity compared to P&O.
- In INC Power loss occurs since it oscillates around MPP like P&O.
- Tracking step size is value has significant effect on effectiveness of MPPT.
- When tracking step is chosen correctly, P&O will give performance equivalent to INC.
- P&O is a very popular and widely accepted MPPT algorithm and simpler to implement than INC.

C. Fuzzy logic

MPPT method Based on artificial intelligence have become prevailed in recent years as compared to conventional methods because of good and fast response under rapid variation in temperature and solar radiation. The fuzzy logic based MPPT method does not require the exact model of PV system for design. In most of the literature, fuzzy logic based MPPT method has been proposed with two input and one output. The two input variable are change in error ΔE(k), given by.

$E(k)=\Delta I/\Delta V+I/V$

$\Delta E(k) = E(k) – E(k-1)$

Where, I is output current from PV array, ΔI is I(k)-I(k-1); V is output voltage from array, ΔV is V(k)-V(k-1). The fuzzy inference can be carried out by one of the various available methods and the defuzzification can be done using centre of gravity method to compute the output (duty cycle).

D. Neural networks

Another MPPT method well adapted to microcontrollers is Neural Networks. They came along with Fuzzy Logic and both are part of the so called “Soft Computing The simplest example of a Neural Network (NN) has three layers called the input layer, hidden layer and output layer[4], as shown in Figure 6. More complicated NN’s are built adding more hidden layers. The number of layers and the number of nodes in each layer as well as the function used in each layer vary and depend on the user knowledge. The input variables can be parameters of the PV array such as VOC and ISC, atmospheric data as irradiation and temperature or a combination of these[4]. The output is usually one or more reference signals like the duty cycle or the DC-link reference voltage.

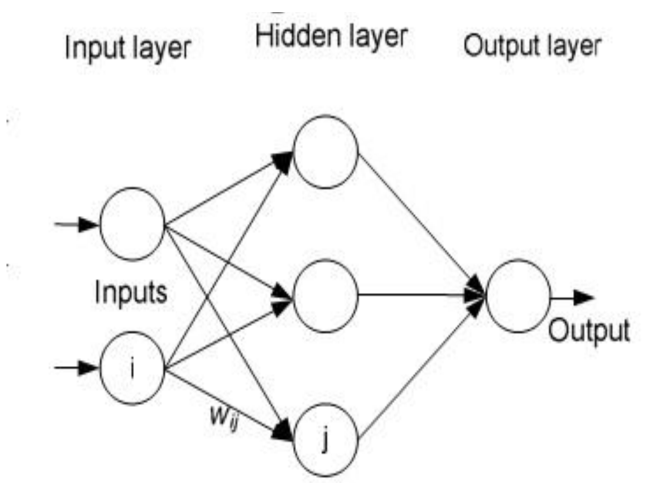

Figure 6. Neural Network

The performance of the NN depends on the functions used by the hidden layer and how well the neural network has been trained. The links between the nodes are all weighted. In Figure 16 the weight between the nodes *i* and *j* is labelled as w_{ij}. The weights are adjusted in the training process. To execute this training process, data of the patterns between inputs and outputs of the neural network are recorded over a lengthy period of time, so that the MPP can be tracked accurately[4]. The main disadvantage of this MPPT technique is the fact that the data needed for the training process has to be specifically acquired for every PV array and location, as the characteristics of the PV array vary depending on the model and the atmospheric conditions depend on the location. These characteristics also change with time, so the neural network has to be periodically trained. Implementation of this method is complex.

III. COMPARISON OF DIFFERENT METHODS.

MPPT method	True MPP	Implementation Complexity	Speed	PV Array dependent	Analog or Digital	Periodic tuning	Efficiency.
P&O	Yes	Low	Varies	No	Both	No	Low
IncCon	Yes	Medium	Varies	No	Digital	No	High
Fuzzy Logic	Yes	High	Fast	Yes	Digital	Yes	High
Neural network	Yes	High	Fast	Yes	Digital	Yes	High
Other Conventional Methods	No	Low	Slow	Yes	Both	No	Low

Table showing comparison of different methods

IV. DC-DC CONVERTERS.

A. Buck converter

The buck converter can be found as the step down converter in many literatures. This gives a hint of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio $M = V_O/V_i$ varies with the duty ratio D of the switch[8].

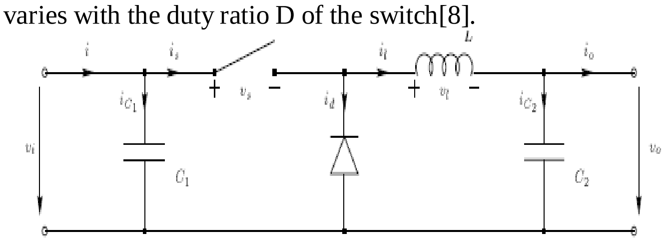

Figure 7.Buck Converter circuit.

B. Boost Converter.

The boost converter is also known as the step-up converter. The name implies its typically application of converting a low input-voltage to a high out-put voltage, essentially functioning like a reversed buck converter[2][5][8][10].

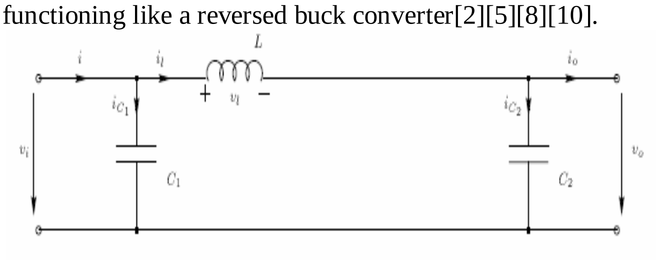

Figure 8.Boost Converter circuit.

C. Cuk Converter.

The Cuk converter uses capacitive energy transfer and analysis is based on current balance of the capacitor. Cuk converter will responsible to inverter the output signal from positive to negative or vice versa[3][8].

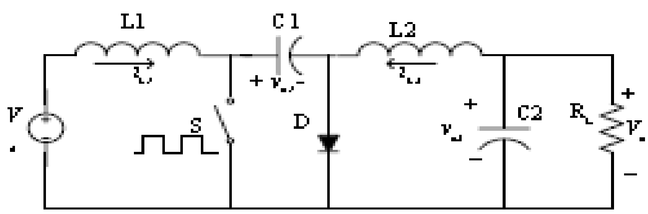

Figure 9.Cuk converter circuit.

V. CONCLUSION

This paper has presented a basic of MPPT and comparison of different MPPT techniques like P&O, IncCond, Fuzzy Logic, Neural Network and more. This paper mainly focuses on MPPT methods and on three DC-DC converters. Here this paper deals to say that P&O and IncCond are best suitable in many applications then all other methods due to their easy implementation comparing with fuzzy logic and neural network. P&O method gives good results in changing atmospheric condition also. DC-DC converters are shown which can be used in MPPT system accordance with application.

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