Perturb and Observe (P&O) and Incremental Conductance (INC) MPPT Algorithms for PV Panels

H. Mohssine, M. Kourchi, H. Bouhouch F. Debbagh

Abstract— ***In this work we present a study on the comparison between two MPPT algorithms: Perturb and Observe (P&O) and Incremental Conductance (INC). We base our approach on the difference between computed results using an adapter bloc Buck DC-DC converter. The MPPT algorithms are combined with it to complete the PV simulation system. We show that the MPPT control with both P & O and INC keeps the system power operating point at its maximum. For this purpose the conventional P&O, the converter input reference voltage is perturbed in fixed steps until the maximum power is reached. However, depending on the step size, the system operating point will oscillate around the MPP resulting in a loss of energy.***

Keywords— ***Photovoltaic (PV), Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), Incremental Conductance (INC).***

I. INTRODUCTION

Renewable energy is commonly called green energy are used in a first step to power satellites in space and since 1970 in terrestrial applications. Photovoltaic cells are used to generate electricity from solar energy useful in remote applications, such as pumping water in remote areas. With lower costs, they become as competitive energy widely used in several technology. The advancement of photovoltaic technology therefore rises with advances on the other technological fields. However, the photovoltaic industry is not able to solve all our current problems and to substitute traditional energy sectors. Indeed, the recovered energy is too low and the cost is still higher than other sectors. Under the normal weather conditions, the photovoltaic generator can operate over a wide range of voltage and current. But it cannot provide a maximum of power for the particular values of current and voltage. Indeed the characteristic I (V) of the generator depends on climatic parameters as temperature and illumination. These natural variations cause a significant change in the maximum power point. To remedy this problem, we often put between the generator and the load a controlled static converters witch search instantly the maximum power point. The search for maximum power point tracking (MPPT) is practical and effective method for understanding photovoltaic systems. Several techniques have been developed for a long time.

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These techniques are different from each other by their complexity, the required number of sensors, the convergence speed, cost, and performance and application area. [1]. Optimal exploitation of electric power available at the terminals of the PV generator can help to reduce the overall system cost.

II. MODELING OF GPV

Modeling of a photovoltaic generator is based on the fact finding a suitable equivalent electrical circuit. Many mathematical models have been developed by researchers. A non-linear nature of the curves I -V results from the semiconductor junctions which form the basis of their constitution. Indeed, the excitement of the P-V by two input parameters (G & T) can give a current-voltage as response. The photovoltaic panel can be modulated by a power generator. In the following, we will present our GPV by the single diode model as showing in Fig.1.

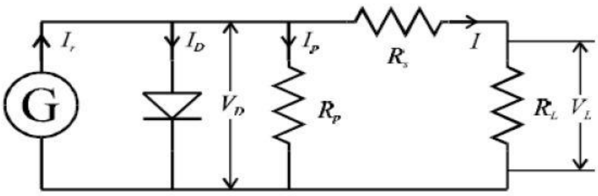

Fig. 1. GPV single diode model

This model offers a good compromise between simplicity and accuracy [1], and has been used by several authors in previous works, sometimes with reducing the numbers of equations from model but always with the basic structure composed of a current source and a parallel diode [1], [2]–[3]. The simplicity of the single-diode model with the method for adjusting the parameters and the improvements proposed in this paper make this model perfect for power electronics designers who are looking for an easy and effective model for the simulation of PV devices with power converters. Some authors [4] have proposed more sophisticated models that present better accuracy and serve for different purposes. The equivalent circuit of a solar cell can be modeled with connecting current source in parallel to a diode. The current generator is such that its output is directly proportional to the sunlight. The (I-V) characteristics of the cell are given by:

$$I = I_r - Io\left(e^{\frac{q(V_L+IR_s)}{kT}} - 1\right) - \frac{V_L + IR_s}{R}$$

Where:

I: Solar cell current (A)
I_P: Light generated current (A
I_o: Diode saturation current (A)
q: Electron charge (1.6×10^{-19} C)
K: Boltzmann constant (1.38×10^{-23} J/K)
T: Cell temperature in Kelvin (K)
V_L: solar cell output voltage (V)
R_S: Solar cell series resistance (Ω)
R_p: Solar cell shunt resistance (Ω)

III. MPPT TECHNIQUES

MPPT is an adaptive system used to control a static converter between the load and the PV panel. This converter is designed to fit every time the apparent impedance of the load to the impedance of PV field corresponding to the maximum power point. This method is based on the use of a search algorithm of maximum power of the photovoltaic panel curve. In recent years the method of the Maximum Power Point Tracking MPPT has been widely studied and analyzed. These techniques differ in many aspects such as used algorithms and convergence speed.

III.1. Perturb and Observe (P&O) algorithm

This Algorithm is among the most common techniques and easily programmed and provided quite satisfactory results with their convergence. The concept of this technique is based on observation of PV array output power and its perturbation by changing the voltage of PV array cells. The algorithm increments or decrements continuously the reference voltage based on the previous value of power until reaches the MPP [4, 5]. When dP/dV > 0 and the operating voltage of PV array is perturbed in a specific direction, it known that perturbation moves the operating point of PV array to the MPP. P&O method will then continue to perturb the PV voltage in the same direction. When dP/dV <0, the perturbation moves the operating point of PV array away from the MPP and the P&O method reverses the direction of the perturbation .

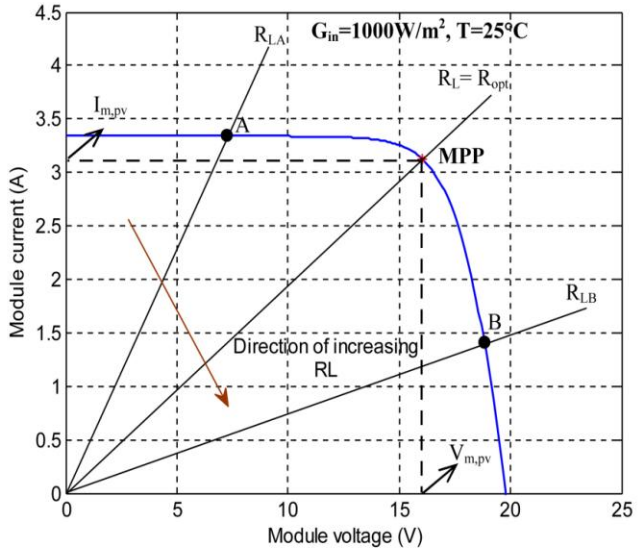

Fig. 2. The current-voltage characteristic.

We can also describe this algorithm as perturbation near the operating point of the PV generator by increasing or decreasing a control parameter by a small amount (step size) and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise the system is perturbed in the opposite direction. The number of perturbations made by the MPPT algorithm per second is known as the perturbation frequency or the MPPT frequency [4].

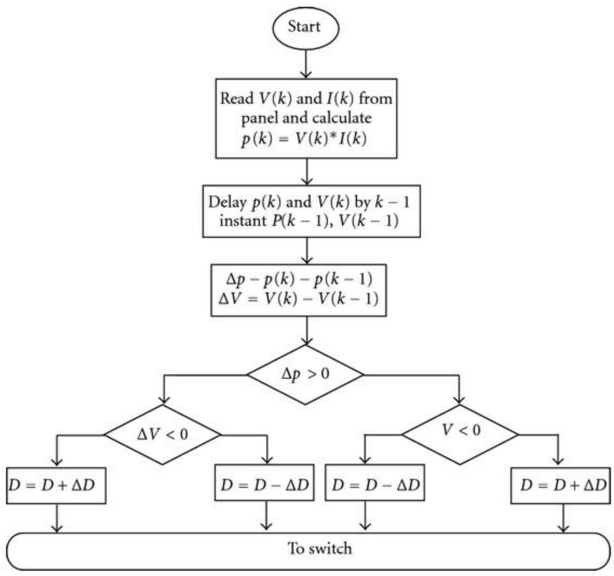

Fig. 3. P & O MPPT algorithm

III.2. Incremental Conductance (INC) algorithm.

MPPT algorithm is a method used in photovoltaic strings to optimize the power in the adaptation block (DC / DC). It allows to maximizing the output power panels with the calculation of the load resistance at which maximum power is tracking. This operate function is done before applying the change to the DC-to-AC converters. The basis for this approach is based on the derivative of function theory as shown in the following equation:

$$\frac{dP}{dV} = I + V\frac{dI}{dV}$$

The power is optimized where the current-voltage (I.V) derivative curve is equal but with signs opposed to the I/V (PV array conductance) ratio:

$$-\frac{I}{V} = \frac{dI}{dV}$$

MPPT uses various control circuits and logic approaches to track the maximum power point of the panel to set the optimum strength to extract the point of proper operation.

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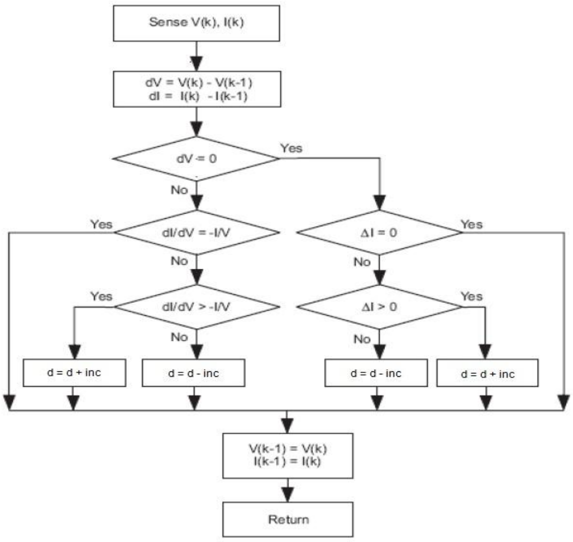

Fig. 4. INC MPPT algorithm

The Simulink model that we used in our design to characterize PV system is shown schematically in Fig.5. Photovoltaic solar panel connected to a resistive load through a Buck DC-DC converter with a variant subsystem MPPT control that allow to choose between these two algorithms MPPT: P & O and incremental conductance.

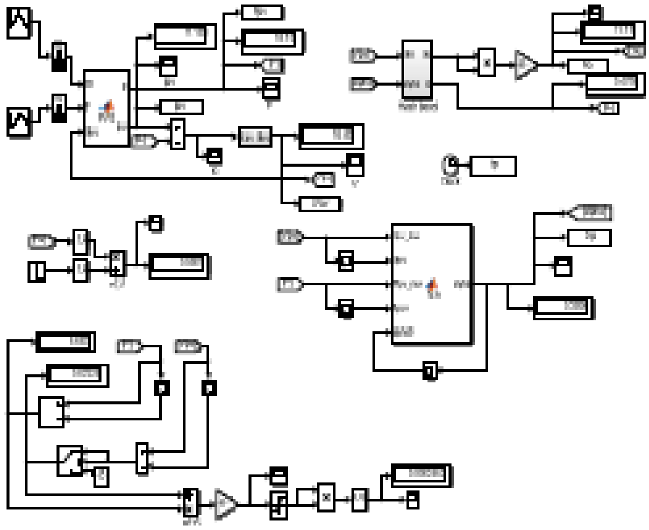

Fig. 5. The Simulink model

The P&O and incremental conductance algorithms using the step variation of irradiance at temperature of 25°C are investigated in order to show both the variation of the out power with solar illumination and the tracking maximum point. The simulation result are presented in Fig.6.

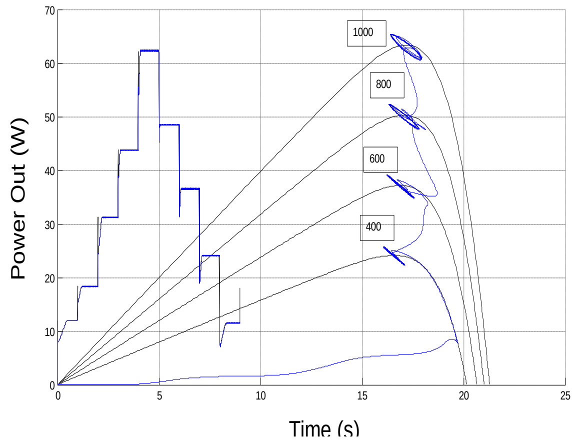

Fig. 6. Tracking Maximum with P & O algorithm.

The results show the tracking maximum point for five levels of solar illumination (1000, 800, 600 and 400) w/m^2 and at temperature cell 25 C employing a P & O MPPT algorithm. The results show that at irradiance (400W/m^2) we can observe that the system makes a lot of time to get the maximum power. It should be noted that the conditions under which the technical P & O used in our model is highly depending on the location of the operating point. The system starts with a step size, but begins to decrease until it reaches the operating point of the MPP. The main difficulty of this technique is to determine the appropriate factor by which the step size should be changed. This technique is also depending on the configuration of the photovoltaic system. A rapid change of the irradiance level shows that the system tried to get the maximum power in a few time less than the start (400) w/m^2. During this operation we won both times in tracking maximum as well as energy (19%): compared to the PV output rated power (600) w/m^2. The system continues in the same way until reach the illumination 1000 w/m^2 we get up to 19 % of the P_{out} value. [6] It should be noted that difference between the output power of the panel and that provided in the load remains within the limits of 3%. These losses are probably attributed to switching losses and by conduction in the MOSFET, and the diode in the various components of MPPT control. Although this technique results present many oscillations around maximum point, but it remains one among the methods that reached the maximum point rapidly [7]

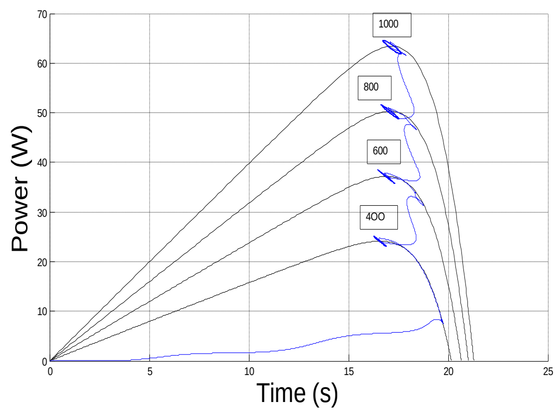

Fig. 7. Tracking Maximum with Inc algorithm

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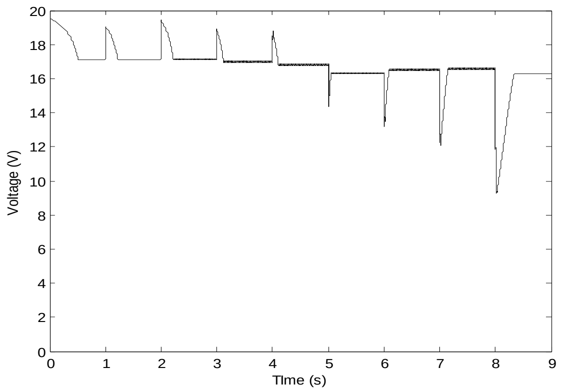

Fig. 8. Voltage vs Time with Inc algorithm

As seen in Fig.7 we present the simulation result of incremental conductance MPPT algorithms for various levels of irradiance 1000,800,600 and 400 W/m2 from the Irradiance at temperature levels of PV Panel sources of 25°C. From these figures it can be seen that incremental conductance algorithm is also better than P&O algorithm at change of irradiance variations but P&O can reach first the MPP faster than INC for rapid change of irradiance. These results depend on the coefficient on step of perturbation. Many oscillations around maximum power point which are due to instability of the system as can be seen clearly in Figure 8.

IV. CONCLUSION

In this work we compare two MPPT algorithms Perturb and Observe (P&O) and Incremental Conductance (INC) in order to get the maximum power point. We base our approach on the difference between simulation results found using an adapter bloc Buck DC-DC converter. The results obtained show the many oscillations around MPP independently of changes in the operating solar illumination. It should be noted that difference between the output power intensity lost in the two algorithms within the limits of 3%. These losses are probably attributed to switching losses and by conduction in the MOSFET, and the diode in the various components of MPPT control. Both algorithms provide efficient use of high energy up to 97% depending on weather conditions. The yield is slightly lower than the rapidly changing irradiance due to the loss of energy during periods of confusion and recovery. We can conclude that the P & O algorithm may reach first the MPP than INC for rapid change of irradiance.

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