Integrating a P&O through a Variable Steps Fuzzy Logic Control for a Photovoltaic System to Track the Maximum Power Point

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***Abstract* — Based on the characteristics of solar cells, such modules have the ability to convert the sun irradiance into electricity. Although this is possible however it has a major drawback in terms of its low power extraction efficiency, the overall cost of the modules, and the interruption of service. The Perturb and Observe (P&O) technique was analyzed in this paper and a variable step adaptive fuzzy logic controller was applied to minimize the oscillation around the maximum power point and to apply an automatic step control to respond to the changes of the dynamic weather parameters in terms of temperature and irradiance.**

Keywords — fuzzy control, perturb algorithm, maximum power point

I. Introduction

Today, the world is facing a reduction of nonrenewable energy resources. Renewable energy is attracting multi nations and investments in this domain is growing and this is due to the green energy, free of pollution and the minimal maintenance required to produce a non-polluted energy source.

The use of photovoltaic systems that perform the conversion of solar energy into electricity has been implemented in wide spectrums with the aid of a tracking systems algorithms to extract the maximum power point (MPP) by utilizing a maximum power point tracking algorithm (MPPT) to extract the full power of those systems. Knowing that the dynamic changes in the environmental factors of irradiance and temperature makes the extraction of maximum power more complex [1].

In addition of the nonlinear characteristics of such systems, in this article we will present and analyze one of the several algorithms available in detecting and tracking the maximum power point through the use of a maximum point tracking algorithm (MPPT) known as the Perturb and Observe (P&O) algorithm [2].

As known from a (P-V) curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. The optimum operating point changes with the solar irradiation, and cell temperature. Therefore, on line tracking of the maximum power point of a PV array is an essential part of any successful PV system. A variety of maximum power point tracking (MPPT) methods are developed. The methods vary in implementation complexity, sensed parameters, and required number of sensors, convergence speed, and cost.

It is well known that photovoltaic systems are affected by factors that reduce their efficiency such as (i) changes on irradiation, (ii) changes on cells temperature, (iii) impedance variations at the system output, (iv) partial shading on the photovoltaic panel.

II. Objectives

The main focus in this research is to analyze the issues affecting the P&O from tracking efficiently the MPP and to adapt an intelligent fuzzy controller to use an automatic step size perturbation to get the most efficient and accurate results in tracking the MPP and guiding the operating point in moving in the right direction toward that point (MPP). The accuracy of tracking the MPP will be illustrated and examined as well.

Tracking accuracy of determining and implemented the MPP has played an essential factor in determining the efficiency of a photovoltaic system. Over the past and recent years, proposals are conducted in applying more control systems such as the Fuzzy Logic and Model predictive control and integrate them in the process of detecting the MPPT in a faster manner regardless of the dynamic weather conditions to ultimately getting a better and accurate results in regards of the extraction of the MPP. This will lead to more efficient photovoltaic system.

III. Methodology

In this section the modeling of the solar panel will be examined. Photovoltaic cell is the device that can convert the sun light into electricity using the photovoltaic effect. The incidence of light on the cell is generates charge carrier that generate an electric current if the cell is short-circuited [3]. Basically, the PV phenomenon is prescribed as the absorption of solar radiation, the generation and transport of free carriers at the p–n junction, and the collection of these electric charges at the terminals of the photovoltaic device [4]. The commonly accepted solar cell model is a one diode model, which is shown in Fig. 1. Such a photovoltaic cell model is a nonlinear system and can be represented as a current source model. The I-V characteristics of a photovoltaic cell is similar to diodes characteristic. This is represented by a set of equations [5].

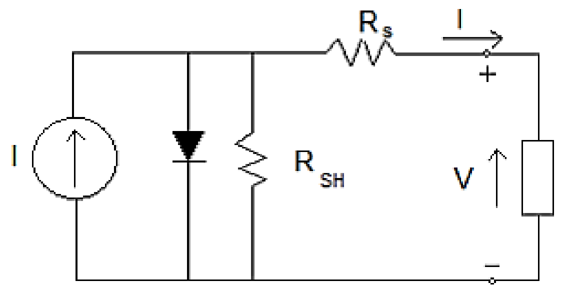

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Fig. 1. Circuit diagram of photovoltaic system

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (Rsh) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array is [6,7,8]:

$$I = Isc - Id \qquad (1)$$

$$Id = Io\,(e^{qVd/kT} - 1) \qquad (2)$$

Where;
I_o is the reverse saturation current of the diode
q is the electron charge
k is the Boltzmann constant ($k = 1.38*10^{-19}$ J/K)
T is the junction temperature in Kelvin (K)

From the equation (1) and (2);

$$I = Isc - Io(e^{qVd/kT} - 1) \qquad (3)$$

Using suitable approximation,

$$I = ISc - Io(e^{q\left(\frac{V+IRs}{nkT}\right)} - 1) \qquad (4)$$

Where;
I is the photovoltaic cell current
V is the PV cell voltage
n is the ideality factor.

The characteristic of photovoltaic arrays can be mathematically described as:

$$I = Ipv\left\{\exp\left(\frac{q(Vo+IRs)}{aNsKT}\right) - 1\right\} - Vo + \frac{IR}{Rsh} \qquad (5)$$

Equation (5) have a wide application in theoretical analysis of photovoltaic cell.

So we can approximately see (Vo+IoRs)/Rsh equal to zero. For the purpose of efficiency and stability, a maximum power point tracker (MPPT) is a power electronic DC-DC converter inserted between the photovoltaic array and its load. That would ensure the photovoltaic array will always works at its maximum power point as the temperature, insolation and load vary.

IV. RESULTS AND DISCUSSION

P&O technique is considered as one of the easiest algorithms used to implement and simple to design. Its operation depends on periodic perturbation on the PV terminal voltage module and after that it compares the current power value at the PV output to that of a previous perturbation. As a result, and due to the perturbation, the operating point that needs to be moved in the direction of the maximum power point will continuously oscillate around the MPP but will never reach it to extract the maximum power of a PV system. Fig. 4 explains the MPP tracking procedure of the P&O technique.

The P&O with its simplified implementation it uses a voltage sensor, to sense the PV array voltage. By applying this technique this algorithm, tries to apply a fixed perturbation steps to reach the MPP however it will oscillate around it and this will result in not getting or extracting the maximum power out of a PV station due to applying fixed voltage steps. Further to that this algorithm does not adjust the perturbation steps in accordance to the dynamic rapid changes of whether the irradiation or temperature factors. To overcome this issue an adaptive Fuzzy logic controller agent can be integrated to apply a variable step size perturbation and to automatically change the steps based on the changes of the irradiance and temperature factors. The flow chart of the P&O algorithm is shown in Fig 2.

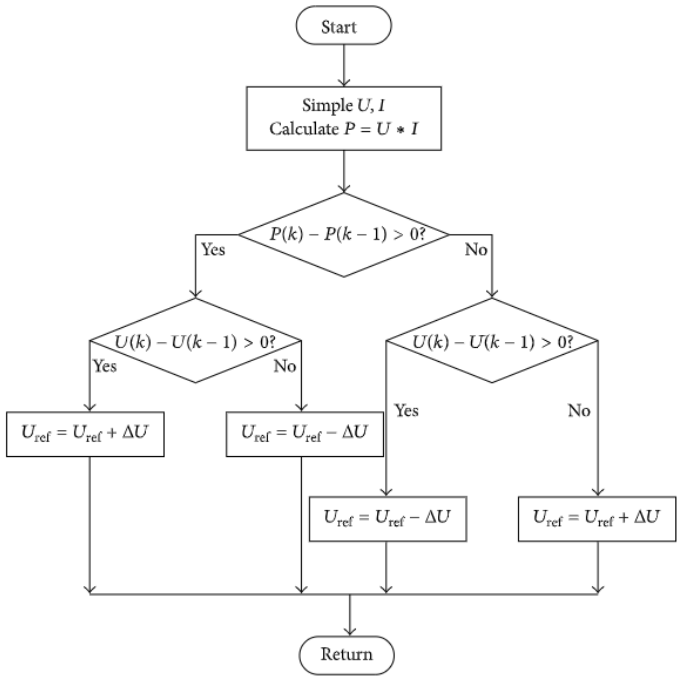

Fig. 2. Perturb and observe algorithm (P&O)

In the below simulation we set the P&O to extract the maximum power using an adaptive fuzzy P&O. Based on the results obtained we can verify that as the FLC was applied the oscillations were less and the tracking speed of determining the maximum power point was achieved as compared to the selection of P&O solely where it was evident that the oscillation affected the module in gaining stable power as shown in fig. 3.

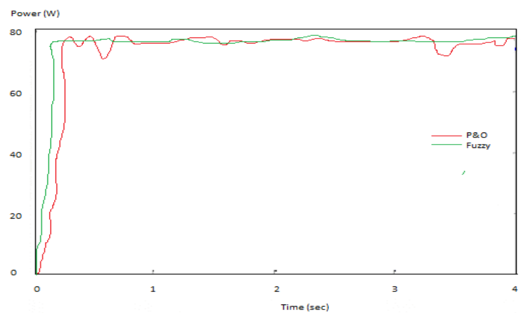

Fig. 3. Simulation results of Adaptive Fuzzy P&O

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V. Conclusion

To reach and detect the maximum power point of a PV module a tracking algorithm shall be implemented. In this paper the P&O we addressed as one of the simplest algorithms that can detect the MPP from a PV module. The analysis of discussing its weak points revealed that due to the use of fixed step size perturbations the algorithm will guide the operating point to reach the MPP however it will oscillate around it and that will cause inefficient extraction of power.As a result of this fact a fuzzy logic controller agent was used to overcome the issues encountered with the use of P&O.

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