Power Tracking Photovoltaic System Tied to Single-Phase Grid

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Abstract*– *The photovoltaic system is one of the sustainable renewable resource pillars that have attracted researchers' interest in recent years. Since the ambient conditions change over time with an increase or decrease in temperature and radiation, the productive strength of the system is affected. Since the effectiveness of this system is low due to these changes, a Maximum Power Point Tracking (MPPT) technique should be used to enhance the overall system. MPPT is a programmable control innovation used to achieve the best possible pool of energy. This paper presents the Maximum Power Point Tracking algorithm in a PV system under variable irradiance and temperature. The perturb and observe (P & O) method for MPPT is proposed. The proposed technique gives faster integration with the largest strength, which will make the overall system more efficient. The overall system is simulated using MATALB/SIMULINK POWER LIB in meanwhile a practical protype for overall system is implemented. Both results show that the proposed system expected goals are achieved successfully.

Keywords- Maximum Power Point Tracking (MPPT), Maximum Power (MP) Perturb and Observe (P&O).

I. Introduction

Electricity is the backbone of modern industries and a base tool in our modern life. Because of the increasing in the energy demand and the pressure on traditional energy resources with unfavorable effect on environment, the generation of electricity has been looking forward to explores on new different energy resources [1]. Photovoltaic (PV) renewable energy resource is one of this new resources of energy which is environmentally friendly and available for free. It generates electrical power without any emissions of gases and it does not make any noise when it operates. Furthermore, it can be simply designed and does not requires a lot of maintenance [2]. The raise of efficiency in PV cells can be done by developing the used materials on it beside improving the PV system in energy management [3].

Maximum power point tracing (MPPT) control is a strategy that is usually applied with PV systems in order to increase the expected output from it [4]. MPPT is not a mechanistic tracking system that moves the modules physically to make them directly pointed to the sun. MPPT is fully electronic system which varies the electrical operational point of modules that makes the modules able to deliver highest available power [5]. The scientific analysis used a great deal to make a better income of PV by applying a lot of planning methods for MPPT as Perturb and Observe (P&O) that is commonly used practically as it could be easily applied. This method determine the operating point of the PV system at maximum power point (MPP) [6]. P&O method is organized based on the monitoring of a characteristic power – voltage (P-V) curve and the uniqueness of power with respect to concerning voltage in the PV system [7]. There is some method that are more professionally than P&O but they will be more expensive [8]. The location of the array MPP on the I-V curve could not be determined easily. So that it must be known by calculation models or through algorithmic search [9].

There is a lot of MPPT methods that can be used today like P&O, Practical Swarm Optimizer, Neural Network, Cuckoo Search Algorithm and Fuzzy logic control. P&O method is the commonly used, as it is inexpensive and has a simple algorithm. The disadvantages of this method is that it has low stability, low efficiency and low speed for fluctuations that are varying in short time. Practical Swarm Optimizer (PSO) is one of the new technologies which characterized by it is very fast speed, very stable and have a very high efficiency but the disadvantage of this method that it has an expensive cost. Neural Network is characterized by it is high efficiency, very fast speed and stability while the disadvantage of this method is it is high cost. Cuckoo Search Algorithm (CSA) is a new methodology that has a high efficiency, fast speed and a good stability but it is main disadvantage that it has a high cost. At the end of this comparison there is Fuzzy Logic Control method which has a very fast speed, high efficiency and high stability while it is disadvantage is that it has an expensive cost [10].

This paper will present a section on P&O method strategy. It will also present sections on the description of the whole PV system and its operation including the I-V characteristics of the used PV system, arithmetical modeling of PV, MPPT P&O technique and finally the results of operation of the PV system.

II. Description of Whole System and Operation

The block diagram in Fig. 1, describes the connection of the PV system with a PV array of maximum power up to 250 W (Trina Solar TSM-250PA05.08).

A. PV Module I-V Characteristics

Table 1 present the parameters of the PV module that will be applied to perform the I-V characteristics of the PV system.

TABLE 1
ELECTRICAL PERFORMANCE OF PV MODULE

Parameters	Values
Voltage at MPP (Vmp)	31 V
Current at MPP (Imp)	8.06 A
Power at MPP (Pmp)	250 W
Open circuit voltage (Voc)	37.6 V
Short circuit current (Isc)	8.55 A
Efficiency	17 %
Temperature coefficient of Voc	-0.35%/C
Temperature coefficient of Isc	0.06%/C

Fig. 2, presents the I-V and P-V characteristics of the PV module that were given in Table 1. It operates at irradiance 1000 W/m^2 and module temperature 25°C and Fig. 3, describes the P-V and I-V characteristics at different temperature and different irradiance.

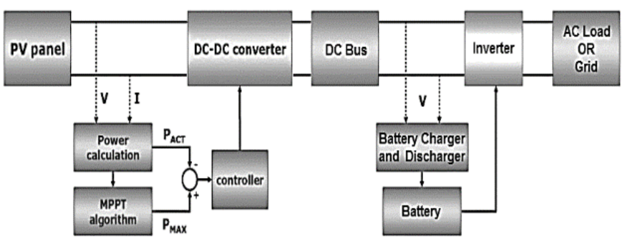

Fig. 1. PV module block diagram

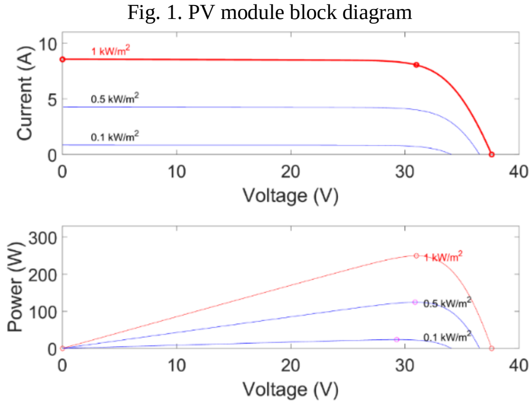

Fig. 2. I-V & P-V module at 25°C

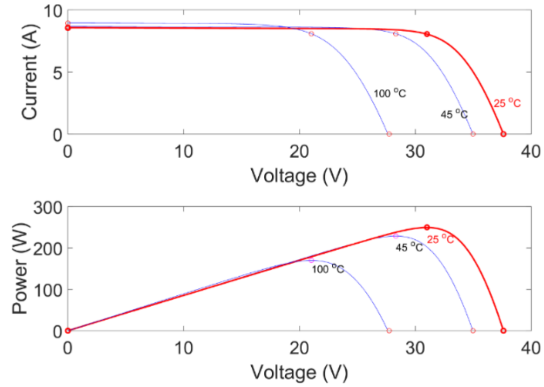

Fig. 3. I-V & P-V module at different temperatures and different irradiance

III. Mathematical Modeling of PV

To examine a PV system performance, a PV model must be firstly created. Fig. 4, describes an equivalent simplified model of a cell.

This model can be presented as a current source linked in parallel with single diode model (SDM) and the represented losses in the circuit which are shunt resistor (RS) connected in parallel and series resistor (RP) connected in series with the circuit, these losses appear due to reflection of the sun light rays on the surface of the PV cell and absorption of photons without the production of holes or free electrons [1].

The following is the mathematical equation for the produced current of the cell affected by losses Equation (1):

$$i_{PV} = I_{ph} - i_d - i_{sh} \quad (1)$$

Where i_{pv} is the output current of the PV (A), I_{ph} is the generated photo current (A), i_d is the current of the diode (A) and i_{sh} is the leakage current (A). diode current in Equation (2) expressed as:

$$i_d = I_{sat.}(e^{\frac{v_d}{a \times v_T}} - 1) \quad (2)$$

Where Isat is the saturation diode current (A), vd id the voltage of the diode (V), ɑ is the ideality diode factor, vT is the voltage of temperature (V). The photo generated current (Iph) in Equation (3) is:

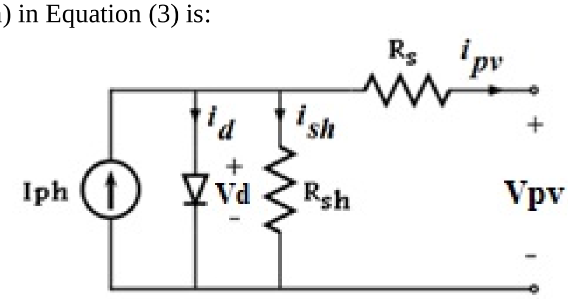

Fig. 4. Equivalent circuit of PV cell

$$I_{ph} = [I_{ph.ref} + K_0(T - T_{ref})]\frac{G}{G_{ref}} \quad (3)$$

Where $I_{ph.ref}$ is the generated photo current at saturated (A), Ko is the coefficient of short circuit of temperature, T is the temperature of the cell (K), T_{ref} is the temperature reference (at 298°K), G is solar radiation (W/m^2), Gref solar radiation reference (at 1000 W/m^2). The Equation (4) of the dark current saturation (I_{sat}) is:

$$I_{sat} = I_{sat.ref}\left(\frac{T}{T_{ref}}\right)^3 e^{\frac{e.E_g}{K_b.a.V_T}}\left(\frac{1}{T_{ref}}-\frac{1}{T}\right) \qquad (4)$$

Where E_g is the band gap energy, $I_{sat.ref}$ is the dark saturation at saturation. By substituting the above equations i_{pv} can be calculated [4].

IV. Perturb and Observe Method

There is a lot of techniques for MPPT control system. Perturb and observe (P&O) technique is commonly used to perform MPPT control [12]. The aim of the MPPT is to withdraw the largest output power from the PV module. The MPPT analysis the PV module output, then choose the preferable power point than can be generated to direct current (DC-DC) converter by the PV module as shown in Fig. 5. [13].

The P&O algorithm is frequently utilized in commercial products and services as the foundation for the majority of the literature is more complex algorithms [14]. It is commonly used in practical operations, as it has a simplicity of implementation and for it is low cost [15]. P&O obtains the reference voltage (V_{ref}) by perturbing the operational voltage (V) point and observing the power deviation in order to derive the next progression direction [16]. As a result, if the PV's working voltage is perturbed in a direction that is forward and the power consumed from it increases, the point of working has the advance toward the MPP, so that the working voltage (V) should be perturbed in that direction as well. Another factor to

consider is that if the power drawn from the PV decreases, the working point has animated away from the MPP, requiring the working voltage perturbation to be reversed [10]. Fig. 6, illustrates the P&O method flowchart.

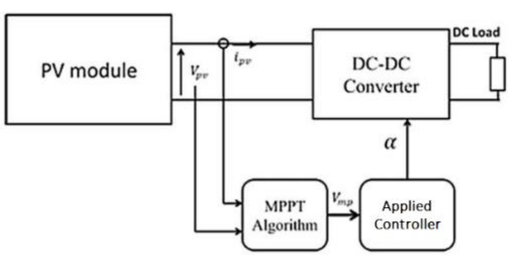

Fig. 5. Full PV system using MPPT block diagram connection

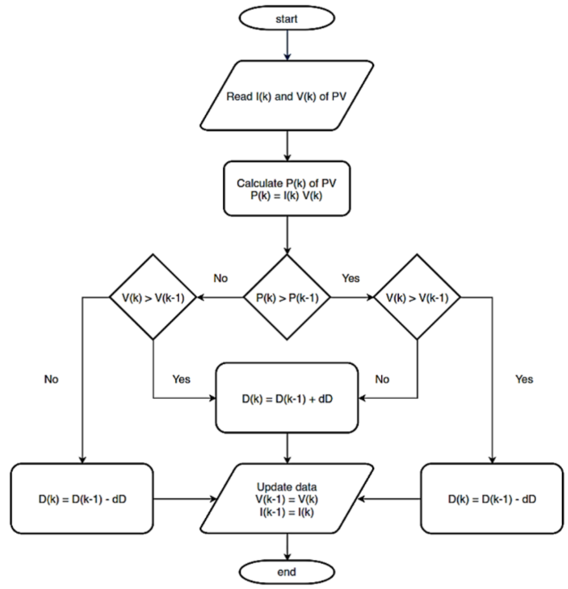

Fig. 6. P&O method flowchart

The actual drawbacks of the P&O method are deviations from the MPP when rapidly changing atmospherically conditions, such as mists [10].

V. Results

In this section simulation and practical results are illustrated.

A. Simulation Results

The system consists of PV aray, Grid Inverter that is controlled by P&O, AC load and Grid. The system is done using MATLAB/SIMULINK POWER LIB.

Fig. 7 shows the output waveforms of the PV-fed inverter connected to maximum power point tracking (MPPT) using the P&O method of maximum power detection.

Fig. 8 shows the grid voltage and the current that feeds it from the PV and its inverter or comes from the grid to feed the load, when its power is greater than that of the PV.

Fig. 9 shows the output waveforms of the grid voltage and current. The changes in current is due to the entery of different loads by time.

Fig. 10 shows the output waveforms of the PV, grid and power consumed in the load. From time 0 sec to 0.5 sec, the direction of current from the inverter connected to the grid PV is to the grid where there is no load connected. From 0.5s to 1, the load power is less than that of the PV, so it can be fed by the PV without any coming from the grid. From 1 to 2 seconds, the load power is greater than the PV power, so the load is fed from the PV and the grid.

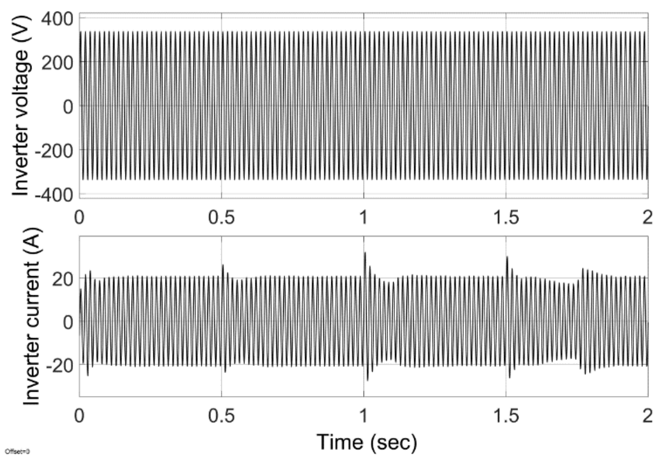

Fig. 7. Output waveforms of voltage and current of the PV-fed inverter with P&O MPPT

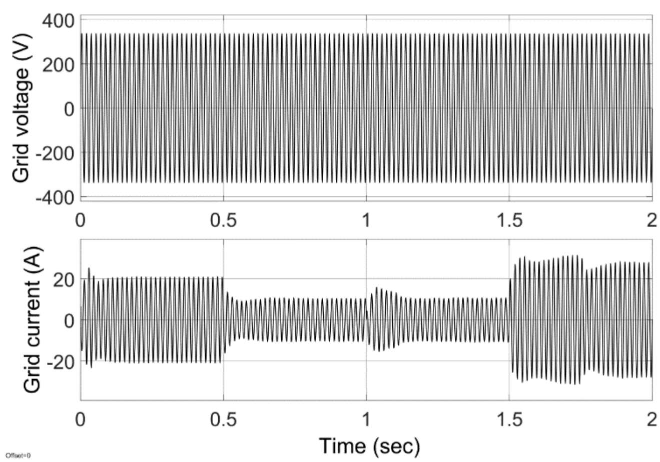

Fig. 8. Output waveforms of voltage and current of the grid

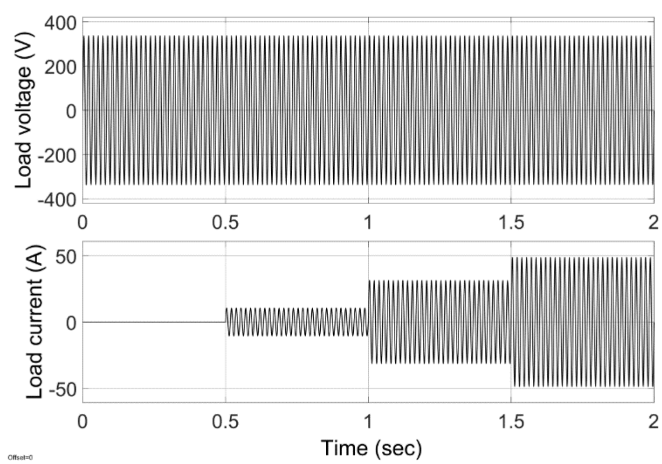

Fig. 9. Output waveforms of voltage and current of the Load

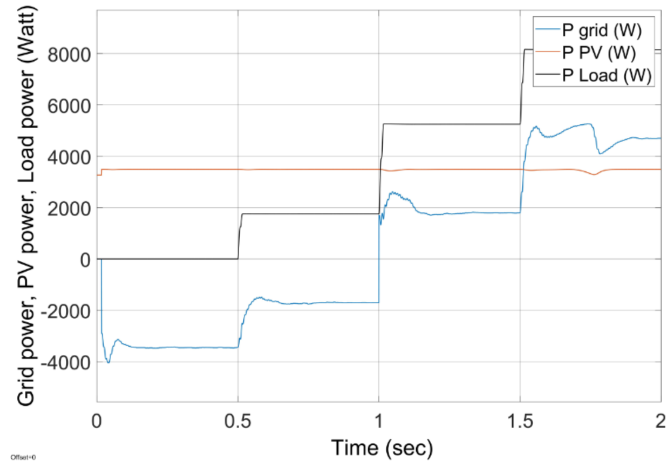

Fig. 10 shows the output waveforms of the PV, grid and power consumed in the load

As shown from the above figures, P&O successfully tracks the MPP of the PV system even under irradiance change situations with an average efficiency of 96%. Also, the grid voltage and current are pure sinusoidal wave.

Both the grid and the PV system supply power to the load. While in other situation when the PV system power is larger than that of the load and the grid. PV system supply power for both.

B. Practical Results

The practical system consists of two PV panels connected to an MPPT using the P&O method for charging two batters of 12V and 90A connected in series and a 1.5 kVA inverter of 24V DC inlet and a 220 ACV outlet for feeding the AC load.

Fig. 11, shows the output waveform of voltage coming from the PV panels that oscillate at MPP because of P&O MPPT operation. The battery was approximately charged at 70%, the maximum output power of the PV panels during the test was 130 W and output voltage 30 V.

Fig. 12, shows the voltage waveform coming from the batteries that are connected to the PV panels that oscillate because of P&O operation. The volt of the batteries during this test was equal to 27 V and the full charge voltage of this batteries is equal to 28.5 V.

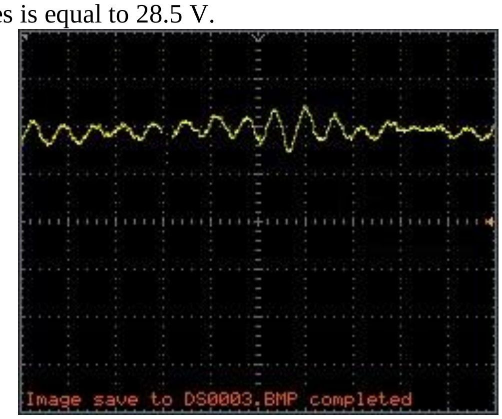

Fig. 11. Output voltage of PV panels under P&O MPPT

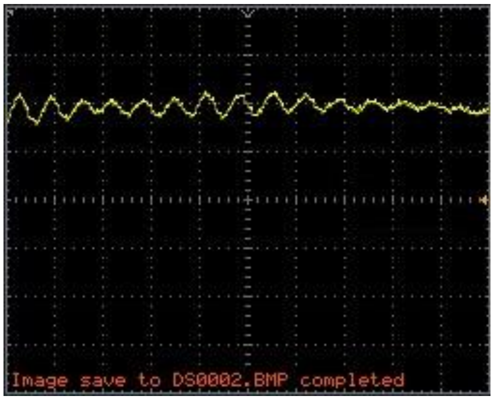

Fig. 12. Voltage of batteries under P&O MPPT

VI. Conclusion

Good MPPT control helps improve system output and reduce losses. The proposed P&O method used in this paper for the MPPT system. It has the advantages of low cost, simplicity in construction, easy maintenance with moderate efficiency which makes it popular in use. The initial premise of this method is to adjust the turbulence amplitude for the actual operating states. Numerical simulation was used to validate this methodology, which considered the experimentally identified and characterized PV panels. In recent work, the P&O approach is implemented by setting constraints on temperature, power change, and boundary conditions. In the proposed MPPT controller, it receives the temperature variation corresponding to the change in power as input and generates the duty cycle in line with the change in the input variables.

Simulation and practical results show that P&O tracks the MPP of the PV system with an average efficiency of 96%. Furthermore, the proposed power system is following the load needs. If the load power needs are sufficient to be supplied from the PV system, the power is transferred from the PV system to the load and the extra-power is transported to the single-phase grid. If not the difference between the power that the PV system can offer, and the load needs is supplied from the single-phase grid.

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