The Performances of Use and Non-Use Maximum Power Point Tracking for Photovoltaic Systems

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Abstract—**Solar arrays are nonlinear devices, and as a result the output current-voltage are dependent on their bias point. Power can be optimized by biasing the PV cell's voltage at the maximum power point (MPP). The PV array is affected by solar irradiation, cell temperature, age, loading condition, and other conditions. These variations are also having nonlinear responses, which need to control with the help of buck boost converter to ensure that maximum power output is transferred to the load. This paper summarizes some of important applications of the MPPT. A comparison between direct and indirect connected to resistive load with MPPT in terms of PV total energy. The MPPT algorithm, which is based on the perturb and observe method) plays an important function that is developed in MATLAB Simulation, and the outputs are observed. It includes module BP SX 150S for a solar photovoltaic. This module approximately provides a maximum power of 150 W.**

Index Terms: **Maximum power point tracking (MPPT); photovoltaic (PV)Solar; Perturb and observe; Optimization**

I. INTRODUCTION

Photovoltaic energy, has gained a lot of attention in recent years because it is environmentally friendly and sustainable compared to traditional energy sources. Good examples include large-scale grid-connected wind turbines, solar water heating, and off-grid stand-alone PV systems [1]. It is estimated that the PV electricity will contribute with 7% of the world electricity needs by the year 2030, and this will increase to reach 25% by the year 2050 [2]. The main piece of a solar cell is that it generates electricity from solar through the solar photovoltaic module, each solar cell made from silicon cells. Although each cell outputs a relatively low voltage, if many of them are connected in series. In a typical module, there can be up to 72 solar cells, producing an open circuit voltage of about 40V. Although the price for such cells is decreasing, making use of a solar cell module still requires extensive economic investment. Thus, it is necessary to get as much energy as possible from such a system. At a certain temperature and insolation, PV cells given maximum power at one specific point so-called the maximum power point (MPP).

The MPP locations are changing in different range, depending on insolation intensity and PV array temperature. Also, shading conditions are affect the MPP. Furthermore, the load electrical characteristics may also effect. Thus, to achieve operation at the MPP should be matching network required point tracking network (MPPT), by means of switched mode
DC-DC converters. A lot of ways to control MPP tracking, the most generally used ones are the 'Perturb and Observe'. The duty cycle of the converter will be controlled, so that the source will send maximum power to the load. Solar powers have been used for deferent applications, such as feed the grid network, charge a battery, and working as standalone PV for feeding pumps. There is a great and urgent need to supply drinking water. Remote water pumping systems where no utility systems are available, PV generator will be very gifted key, where it's can feed the system directly from the sun by solar cells. Different types of motors drive water pumps. AC and DC, however, an AC motor need an inverter to convert DC output power from PV to AC power, which is generally isn't cheap. In other hand, DC motors can be directly coupled with a PV module or array. And they are highly efficient. PV systems are highly reliable and are often chosen because they offer the lowest life-cycle cost, especially for applications requiring less than 10KW, where grid electricity is not available [3]. If the water source is 1/3 mile (app. 0.53Km) or more from the power line, PV is a favorable economic choice [4]. This paper proposes a method to provides theoretical studies of photovoltaics (PV) and its modeling techniques. It also investigates in detail the maximum power point tracker (MPPT), a power electronic device that significantly increases the system efficiency. At last, it presents MATLAB simulations of the system and makes comparisons with a system without MPPT.

II. FUNDAMENTALS OF SOLAR PHOTOVOLTAIC CELL

An ideal PV cell is simulated by MATLAB using the simplest equivalent circuit model is a current source in parallel with a diode as shown in Figure (1). The solar array is a nonlinear device and its electric power fluctuates depending on the solar radiation value and temperature. The output of the current source is directly

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proportional to the light falling on the cell. The diode determines the I-V characteristics of the cell [5].

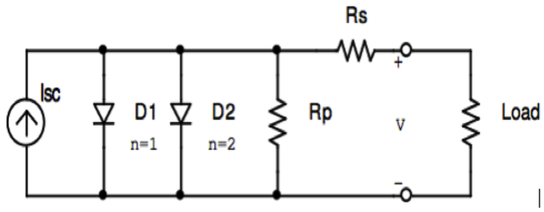

Figure. 1. Equivalent Eircuit of PV Cell

The output current (I) from the PV cell is found by applying the Kirchhoff's current.

$$I = I_{sc} - I_d \dots\dots\dots\dots\dots\dots\dots (1)$$

The diode current Id is given by the Shockley's diode equation.

$$I_d = I_0 \left(e^{\frac{qv}{kT}} - 1\right) \dots\dots\dots\dots\dots (2)$$

Where: Io is the reverse saturation current of diode (A); q is
the electron charge1.602 x10^{19} C^o ;V is the voltage across the
PV cell (V); k is the Boltzmann's constant (1.38 x10^{23} J/K);
T is the junction temperature in Kelvin (K).

Combining the diode equation with the equation of the output current of the PV cell.

$$I = I_{sc} - I_0 \left(e^{\frac{qv}{kT}} - 1\right) \dots\dots\dots (3)$$

Using the equation (1.3), let I = 0 (no output current) and solve for Io.

$$0 = I_{sc} - I_0 \left(e^{\frac{qv}{kT}} - 1\right) \dots\dots\dots (4)$$

$$I_{sc} = I_0 \left(e^{\frac{qv}{kT}} - 1\right) \dots\dots\dots\dots\dots (5)$$

$$I_0 = \frac{I_{sc}}{\left(e^{\frac{qv}{kT}} - 1\right)} \dots\dots\dots\dots\dots\dots (6)$$

To a very good approximation, the photon-generated current, which is equal to Isc, is directly proportional to the irradiance, the intensity of illumination, to PV cell [6].

Thus, if the value, Isc, is known from the datasheet, under the standard test condition, $G_0 = 1000(W/m^2)$, at the air mass (AM) = 1.5, then the photon generated current at any other irradiance, G(W/m2), is given by.

$$I_{sc} * I_G = \frac{G}{G_0} * \frac{I_{sc}}{I_{G_0}} \dots\dots\dots\dots (7)$$

Where (I_G, I_{G_0}) are the currents at irradiance (G, G_0) respectively.

$$I = I_{sc} - I_0 \left(e^{\frac{q(v+IR_s)}{nkT}} - 1\right) - \frac{(v + IR_s)}{R_p} \dots\dots (8)$$

Where n is known as the "ideality factor"; however, it takes a value between one and two; Figure (2) shows the effect of the varying ideality factor.

The characteristics at several module temperatures simulated with the MATLAB model for BP SX 150S PV module. Data points covered on the plots are taken from the I-V curves published on the manufacturer's datasheet [6].

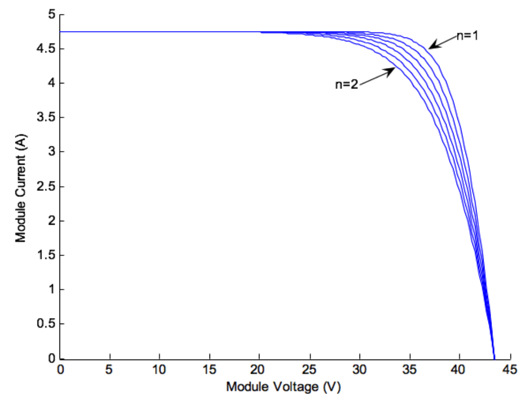

Figure. 2. Effect of Diode Ideally Factors (1KW/m2, 25C^o)

The I-V characteristic and the power respect to voltage and current curve of different solar array are represented in figures (3), (4), (5).

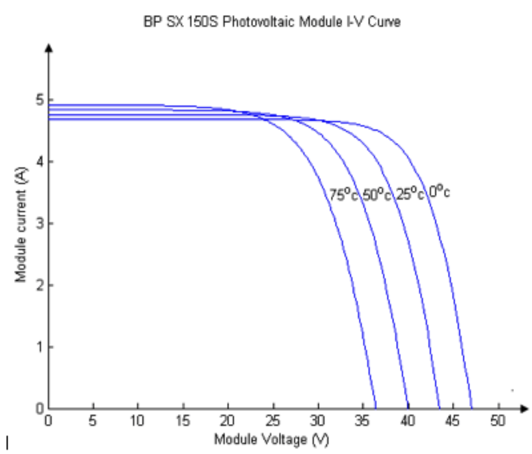

Figure. 3. I-V Curves at Various Temperatures

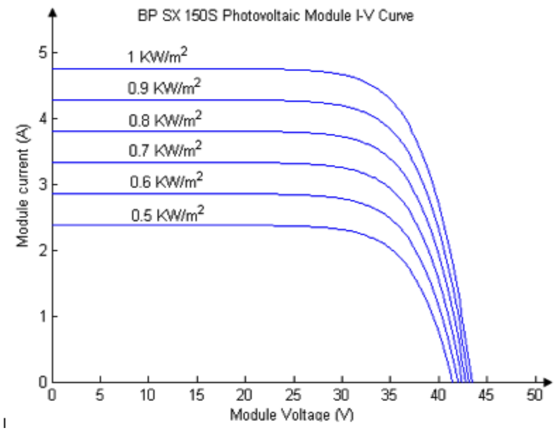

Figure. 4. I-V Curves at Various Sun Radiations

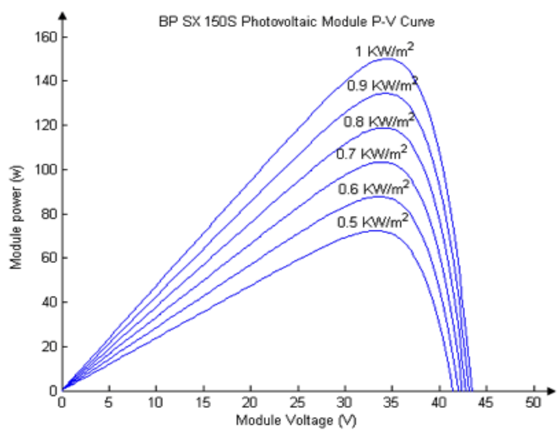

Figure. 5. Power Curves at Various Temperatures

III. MATLAB SIMULATION BP SX150S PV

BP Solar BP SX 150S PV module is chosen for a MATLAB simulation model. The module is made of 72 multi crystalline silicon solar cells in series and provides 150W of nominal maximum power. Table (1) shows its electrical specification of BP SX 150s provide from the datasheet [9].

Table1.The Characteristics Date of BP SX150S

Electrical Characteristics	BP SX 150s
Max. Power (Pmax)	150 W
Voltage at Pmax (Vmax)	34.5 V
Current at Pmax (Imax)	4.35 A
Warranted minimum Pmax	140 W
Short-circuit current (Isc)	4.75 A
Open-circuit voltage (Voc)	43.5 V
Temperature Coenff. Of Isc	$(0.065\pm \mathbf{0.05})\%\ \mathbf{C0}$
Temperature Coenff. Of Voc	$-(160+\mathbf{20})\mathbf{mv\ C0}$
Temperature Coenff. Of P	$-(0.5\pm \mathbf{0.05})\%\ \mathbf{C0}$
NOCT	$47\pm \mathbf{2\ C0}$
Max. system voltage	600

IV. MAXIMUM POWER POINT TRACKING ALGORITHMS

The Perturb & Observe (P&O) algorithm, also known as the “hill climbing” method, is very popular and the most commonly used in practice because of its simple structure and the few measured parameters which are required [5]. The Perturb & Observe algorithm is based on the constant measuring of the PV current and voltage and calculation of its power output while the operating point is moving in order to reach the maximum power. In this algorithm the operating voltage of the PV module is perturbed by a small increment, and the resulting change of power, ΔP, is observed. As shown in figure (6), if theΔP, is positive, then it is supposed that it has moved the operating point closer to the MPP. Thus, further voltage perturbations in the same direction should move the operating point toward the MPP. If the ΔP is negative, the operating point has moved away from the MPP, and the direction of perturbation should be reversed to move back toward the MPP.

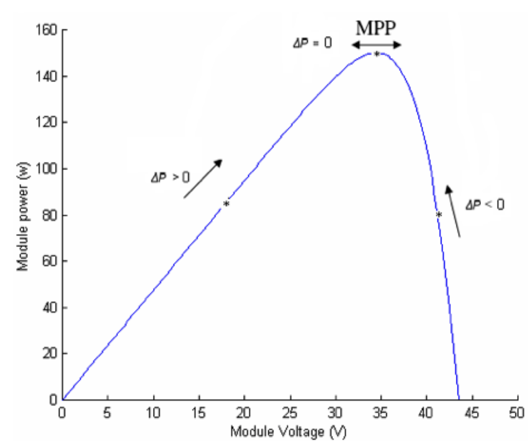

Figure. 6. Power vs. Voltage for BP SX 150S PV

When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation a small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple. The flowchart of this algorithm is given in Figure (7).

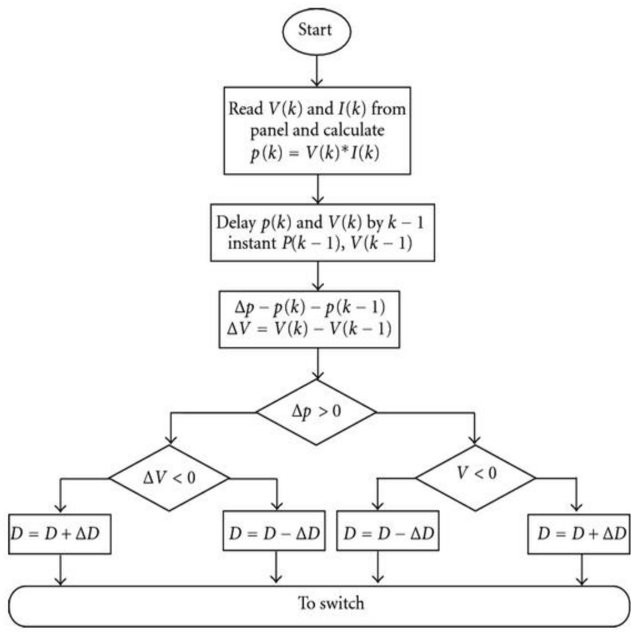

Figure. 7. Flowchart of the P&O Algorithm [4].

V. DIRECT AND NON-DIRECT OF MPPT COUPLED WITH RESISTIVE LOADS

The MPPT with a resistive load is implemented in MATLAB simulation as seen in Figure (8.a), (8.b). The simulation results in Table (2), have shown that, the simulation with MPPT, the total electric energy produced during a 12-hour period is constant. On the other hand, the direct connection shows that the total electric energy is changing through different resistive loads. The results show that the system without MPPT has poor efficiency (31.60 %) because of mismatching between the PV module and the resistive load. On the other hand, it shows that the system with MPPT can utilize more than 97 % of the capacity.

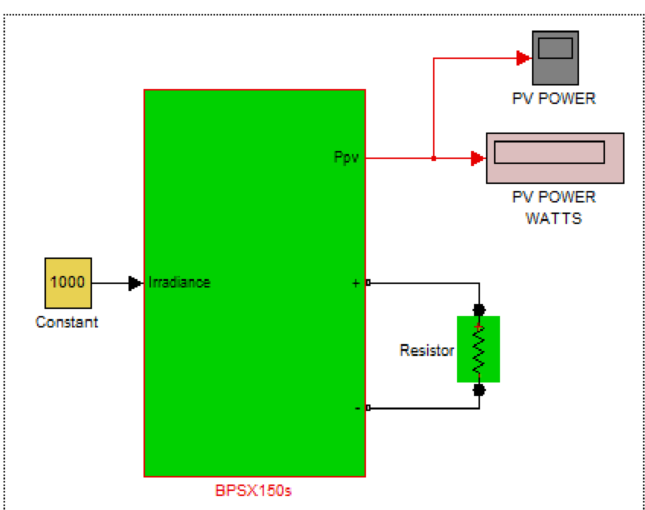

Figure. 8-a BP-SX150S Simulation Without MPPT to Load

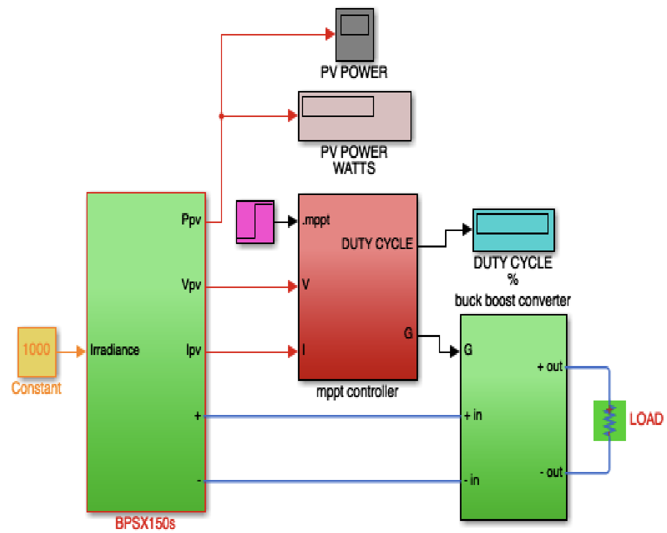

Figure. 9-b BP-SX150S Simulation with MPPT to Load

Table 2. The Result Energy Production of PV Module

Resistive loads	The module power (w) without MPPT	The module power (w) with MPPT
4	90.16	149.1
6	132.4	149.1
8	149	149.1
10	139	149.1
12	124.6	149.1
14	111.6	149.1
16	100.3	149.1

VI. .CONCLUSION

This paper presents a study of maximum power point tracking (MPPT) for photovoltaic (PV) systems and its different applications for different loads. The modeling of the PV module based on a simplified version of the two-diode model achieves good matching with data sheet information. The MPPT ensure impedance matching between the PV generator and the load for maximum power transfer by controlling the duty cycle of the DC-DC converter. MPPT algorithms is simulated to achieve maximum power transfer; the Perturbation and Observation (P&O) algorithm. The P&O algorithm shows better performance in terms of efficiency.

A small improvement of efficiency could bring substantial savings if the system design is large. The comparative study of the PV system with resistive load with MPPT vs. direct- coupled system shows that the PV system without MPPT has poor efficiency because of mismatching between the PV module and the load. On the other hand, it shows that the system with MPPT can utilize more than 97% of PV theoretical capacity. However, MPPT has some limitations; one of its main drawbacks is that there is no regulation on the output while it is tracking a maximum power point. It cannot regulate both input and output at the same time. If the application requires a constant voltage, it must employ batteries to maintain the voltage constant. In addition to that, if the value of the load resistance changes the duty cycle of the converter changes even if the input is the same; this means that the design of the converter must satisfy the specifications of the source and the load at the same time. Thus, it is very important to select the appropriate size of the load, so that the full capacity of the PV module and array is utilized.

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BIOGRAPHIES

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