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## Mathematical Modeling and Controller for PV System by Using MPPT Algorithm

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*In this research, the study theory of system includes the use of an important source of renewable energy sources (solar source) and linking this system with an electrical load. The world is witnessing a significant rise in fossil fuel prices since the ending of the 20th century and now, this rise in price increases with the decrease in inventory day after day. Therefore, it turned that the field of attention to researchers of power generation to expand in non-conventional energy sources (new and renewable energy sources).*

*New and renewable energy is inexhaustible in use because they rely on renewable natural resources. The mathematical model is an important part of the detailed study for PV systems. As well as study models for photovoltaic systems via the MATLAB/Simulink, this programming environment contains many models for renewable systems intended to perform simulation and analysis.*

*Solar cells system needs to apply the MPPT algorithm due to the instability of external circumstances such as solar radiation and temperature.*

*At a constant temperature of 25 °C, as the radiation level increases, the current and voltage of the module increase, this leads to an increase in output power. At a constant radiation level of 100 W/m<sup>2</sup>, as the module temperature increases, the current increases and the voltage decreases, this causes the output power to decrease. The maximum power is reached at 17 V and 3.5 A by the MPPT method. The Perturb and Observe algorithm is used to achieve maximum power.*

**Keywords:** PV module, MPPT algorithm, voltage source multilevel inverter, mathematical modeling.

### Introduction

Solar panel generation becoming and more main as a renewable power foundation as it offers many advantages over other sources such as not being polluting, incurring no energy costs, requiring small preservation and emitting no sound. PV panel still has comparatively low change efficiency, so, controlling Maximum power point tracking (MPPT) for a solar panel is important in a photovoltaic system [1]. The amount of energy generated by a photovoltaic panel depends on the panel voltage used [2]. The PV Maximum Power Point (MPP) depends on the climatic rays and temperature. From the  $PVV-I$  and  $V-P$  characteristic curves, the unique duty point at which the maximum possible power is generated can be determined. In MPPT, the photovoltaic system operates at maximum efficiency. Therefore, several algorithms have been developed to determine MPPT [3, 4]. Others have used a new three-point weighting method that avoids the problem of fluctuations in the perturbation and observation algorithm that is

often used to track the maximum power point, solar energy that can be gained by with a photovoltaic panel is able to change sunshine to electricity, the price of PV unit is still expensive and greatest power point of power is easily changed by surroundings factors such as solar rays, temperature, load, etc. In addition, to get solar energy as much as potential form PV module, the process of maximum power point PV module must be controlled because the alteration efficiency of the PV module is very low [5]. PV array needs sturdiness control concerning parameter variation due to non-linear characteristics. Forwarded a study and implementation of real-time Estimate - Perturb-Perturb algorithm for max power point tracking control in the photovoltaic system [6]. The MP and O algorithm recover the P and O algorithm at the cost of speed reply to changes of irradiance. In a new system, named the Estimate - Perturb-Perturb algorithm was forwarded through the authors, which displayed a good performance. Perturbation - Observation and  $PID$  controllers are used in this work to

improve the *PV* panel performance and tracking the maximum power under the weather conditions such as radiation and temperature [7-9]. A comparison between simulation and experimental results according to the Perturbation - Observation algorithm as well as the *PID* controller algorithm was performed [10].

**Mathematical sample of PV panel**

The solar cell is the constitutive element of *PV* arrays, it is essentially a *p-n* semiconductor connection shown in Figure 1. The *V-I* special equation 1 gives equation of a solar array [11].

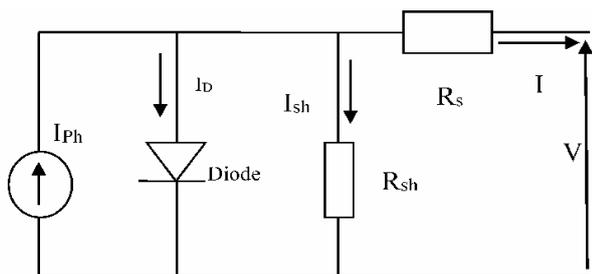


Fig. 1. *PV* mathematical model of the *PV* panel

$$I = I_{sc} - I_0 \left[ \exp \left\{ \frac{q(V + R_s I)}{nkT_k} \right\} - 1 \right] - \frac{V + R_s I}{R_{sh}}, \quad (1)$$

where *V*, *I* - current and voltage for output *PV* panel; *R<sub>s</sub>*, *R<sub>sh</sub>* - resistance of the panel in series and parallel; *q* - electronic charge; *I<sub>sc</sub>* - light generated current; *I<sub>0</sub>* - reverse diffusion current; *n* - factor for dimensionless; *k* - Boltzmann constant; *T<sub>k</sub>* - temperature in Kelvin.

The cell parameters are shown in the table 1 [12, 13].

Table 1. Photovoltaic panel parameters [14]

Panel number	1
Dimension (cm)	158×8.08×4
Maximum power (w)	200
Open circuit voltage (v)	45.62
Maximum circuit voltage (v)	37.26
Maximum circuit current (A)	5.37
Wight (Kg)	15.5
Short circuit current (A)	5.66

**Perturbation and Observation (P&O) Algorithm**

This algorithm is based on producing a slight perturbation by the system; the perturbation causes a change in the solar module power [15]. If the power is increased, the perturbation must be kept on in that direction, otherwise, reverse the perturbation direction [16, 17]. The power of the panel

starts decreasing after reaching the peak value for a certain period that is why the perturbation reverses its direction. At steady-state case, the system oscillates about the peak power point. When the power reaches the peak value, the power variation will be small [18-20]. The flowchart of the P&O algorithm of the maximum power tracking is shown in figure 2, where *V(n)*, *I(n)* and *P(n)* - are the current-voltage, current and power of the *PV* panel respectively [21].

**Simulink of the Photovoltaic system**

Photovoltaic array connected to a 25 kV network through a DC-to-DC boost converter and a 3-phase 3-level voltage converter. Maximum Power Point Tracking (MPPT) is realized in the boost converter using a Simulink model using the technic of the neural network technique [22].

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*PV* array delivering a maximum power of (100 kW) at (1000 W/m<sup>2</sup>) sun irradiance and Average model of voltage source converter. The voltage source converter 500-260 V (DC-AC) and keeps the unity power factor [23].

Figure 3 shows a Simulink diagram of a proposed system that uses a solar panel and a buck DC-DC converter controlled by an MPPT controller. The system is used to produce three output voltages and currents.

**Results and Discussion**

The proposed *PV* module was Simulink by using dialogue box from block Libraries in MATLAB. The results are as follows:

- Figure 4 shows the *I - V*, *P - V* and *P - I* characteristics for different values of solar irradiation (400, 700 and 1000 W/m<sup>2</sup>) at constant temperature (25 °C), when the irradiation increases, the power and current increase as shown in fig. 4, *a*, *b* respectively.

- Figure 5 shows the *I - V*, *P - V* and *P - I* characteristics for different values of temperature (25, 35 and 45 °C) at constant irradiation (1000 W/m<sup>2</sup>) Here, when the operating temperature increases, the power and output voltage decreases as shown in Figure 5, *a*, *b*. The value of power is 60 W at temperature 25 °C, and decreases when the temperature increases.

- From the *PV* characteristics, we can observe that there is a point at which the power output is maximum, which gives the maximum efficiency. In the Standard Test Conditions, it was found that the proposed *PV* Emulator produces the maximum power at 60W with voltage 17 V and current 3.8 A with increasing irradiation at a constant temperature. For comparison, according to the datasheet, at

Standard Test Conditions, the MSX-60 solar module produces the maximum power 60 W with the voltage at the maximum power of 17.1 V and current of 3.5 A.

• Figure 6, *a, b* shows the continuous level of the  $V_{pn}$  and  $I_{pn}$  values respectively, that is fed to MPPT controller to produce the switching signal of the required duty cycle as shown in Figure. 6, *c* to control the DC-DC buck converter to achieve maximum efficiency. The output of MPPT is

a signal for two operating conditions, the duty Interval ( $T_{on}$ ) and the freewheeling mode ( $T_{off}$ ). However, these MPPT pulses more convenient for regulating the output voltages of the Buck DC-DC converter.

For this proposed design, the module formed by connecting 36 PV cells in series. The output voltage can be calculated by multiplying the cell voltage by the number of the cells, while the total current is equal to the cell current (Fig. 7).

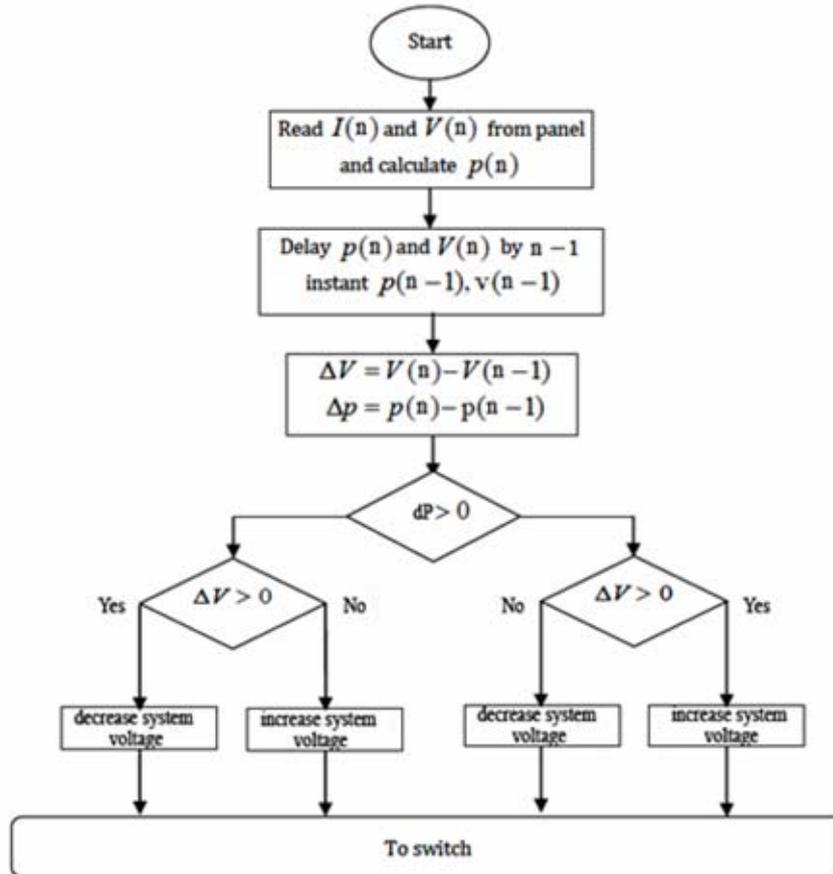


Fig. 2. The block diagram of the algorithm “Perturbation and observation” method

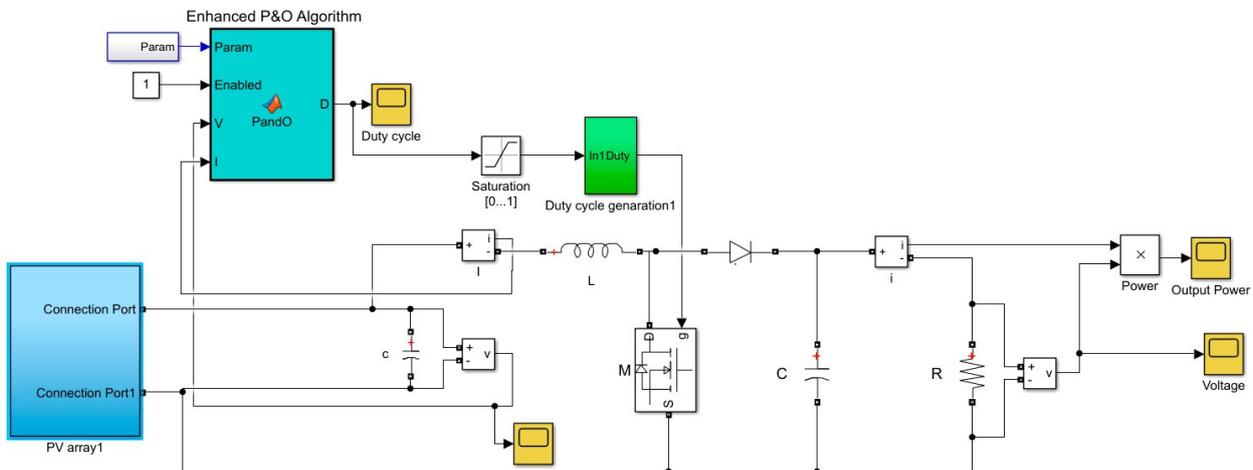


Fig. 3. Model of solar PV emulator utilizing buck converter

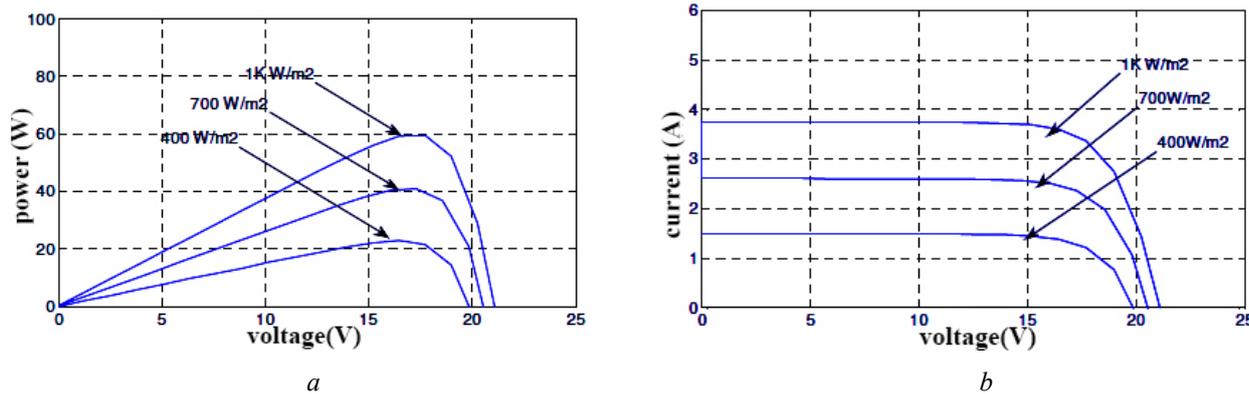


Fig. 4.  $P - V(a)$ ,  $I - V(b)$  characteristics at  $T = 25\text{ }^\circ\text{C}$

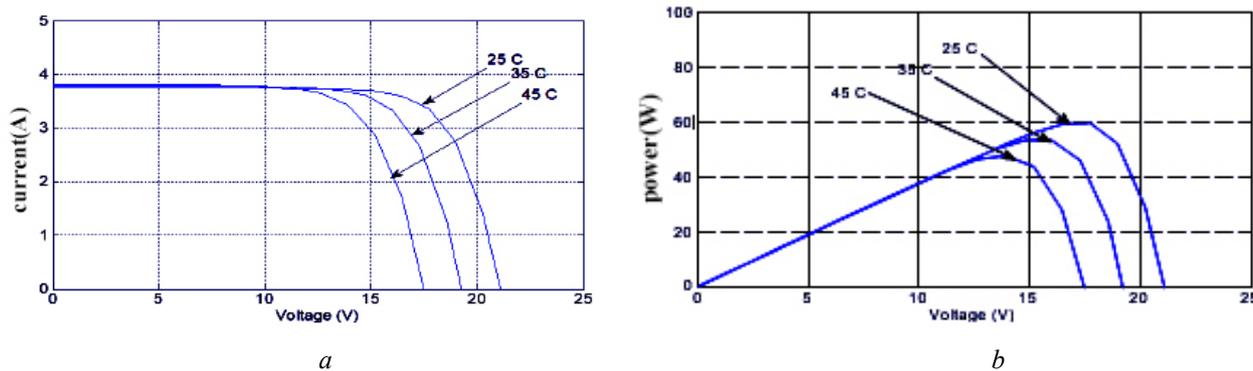


Fig. 5.  $I - V(a)$ ,  $P - V(b)$  characteristics at  $S = 1000\text{ W/m}^2$

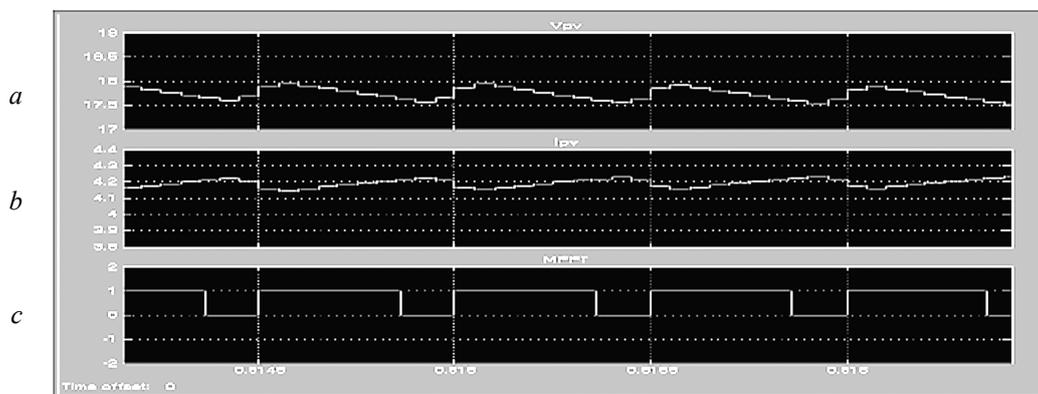


Fig. 6.  $V_{pn}$ ,  $I_{pn}$  and MPPT switching waveforms

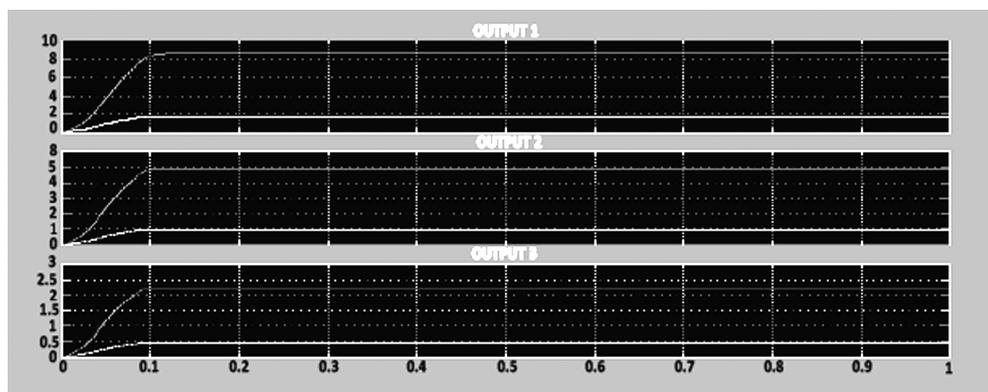


Fig. 7. Simulink results for output currents and voltages

Figure 7 shows the simulated waveforms of three output voltages and currents, here approximate values of the first output voltage of circuit is 9 V and current is 2 A, the second output voltage is about 5 V and current is about 1 A, and the third output voltage is about 2.2 V and current is about 0.5 A.

### Conclusions

A Matlab/Simulink model for the PV solar panel with Multiple Outputs DC-DC Converter controlling by MPPT Technique was developed and presented in this paper. The PV system module is design depending on the circuit equations of solar cell model. The electrical characteristics ( $P - V$ ,  $I - V$  and  $P - I$  curves) are achieved for the solar module that explains its dependence on the solar radiation and atmospheric temperature. When temperature remains constant at 25 °C, and the radiation increases, the current and voltage of the cell model increase, this leads to an increase in the output power. In addition, when the radiation level keeps constant at 100 W/m<sup>2</sup> and the cell temperature increases, the current increases, but the voltage decreases, this leads to reduce in output power.

The maximum power achieved at voltage 17 V and current 3.5 A with MPPT technique. The Perturb and Observe algorithm is used for achieve Maximum Power Point. The regulator outputs of buck converter controlling by the signal feds from MPPT controller are achieved successively.

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### Математическое моделирование и контроллер для фотоэлектрической системы с использованием алгоритма MPPT

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*Теория системного исследования включает использование важного источника возобновляемой энергии – солнечной радиации – и связывает эту систему с электрической нагрузкой. В мире наблюдается значительный рост цен на ископаемое топливо; с конца 20-го века и до настоящего времени эта тенденция продолжается, при этом запасы традиционного органического топлива постоянно сокращаются. В связи с этим внимание исследователей в области выработки электроэнергии сосредоточено на вопросе расширения использования нетрадиционных источников энергии (альтернативных и возобновляемых видов энергии).*

*Новая альтернативная энергетика является неисчерпаемой в использовании, потому что она полагается на возобновляемые природные ресурсы. В данном исследовании представлено подробное описание использования фотоэлектрических преобразователей и систем с различными типами солнечных элементов. Математическая модель является важной частью подробного исследования фотоэлектрических систем. Исследование модели фотоэлектрических систем выполнено в MATLAB/Simulink.*

*При математическом моделировании систем солнечных модулей использован алгоритм MPPT из-за неустойчивости внешних условий, таких как солнечное излучение и температура.*

*При постоянной температуре 25 °С, при увеличении излучения ток и напряжение модуля увеличиваются, что приводит к увеличению выходной мощности. При постоянном уровне излучения 100 Вт/м<sup>2</sup>, при повышении температуры модуля ток увеличивается, а напряжение уменьшается, это приводит к уменьшению выходной мощности. Максимальная мощность достигается при напряжении 17 В и токе 3,5 А по методу MPPT. Для достижения максимальной мощности используется алгоритм Perturband Observe.*

**Ключевые слова:** фотоэлектрический модуль, алгоритм MPPT, многоуровневый инвертор источника напряжения, математическое моделирование.

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