Maximum Power Point Tracking Of Photovolatic System

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ABSTRACT: The main purpose of this paper is to develop a photovoltaic simulation system with maximum power point tracking (MPPT) function using Mat lab/Simulink software in order to simulate and evaluate the behaviours of the real photovoltaic systems. A model of the most important component in the photovoltaic system, the solar module, is the first to have been established. The characteristics of the established solar module model were simulated. After that, a model of a photovoltaic system with maximum power point tracker, which was developed by DC-DC buck converter established and simulated and the model of the photovoltaic system that was built in this paper can track the maximum power point of the system successfully and accurately under arbitrary temperature and irradiance conditions. This work presents a boost converter controlled by P&O technique for the maximum power point tracking of the photovoltaic panel.

I. INTRODUCTION

As reported in the literature, the amount of traditional energy such as petroleum and coal has been gradually becoming insufficient to meet demands. The problem of a looming energy crisis has stimulated rapid development of the renewable energy to accommodate requirements worldwide as economies continue to grow and develop. In all kinds of renewable energy technologies, photovoltaic technology is one of the best renewable energy technologies because it won't produce noise, air pollution or greenhouse gases.

Most of the photovoltaic simulation systems proposed in literature [1]–[4] were established using hardware and software to perform and simulate the operation of equipment in the system such as solar modules, maximum power point trackers, PWM controllers, DC-DC converters, and so on. Yusof *et.al,* [1] proposed a solar cell model that simulated the maximum power and I-V curve diagram of the proposed model using C language. However, it is hard to connect the proposed solar cell model to the other equipment in the photovoltaic system model. Hua *et.al,* [3] used DSP to implement their proposed MPPT controller, which controls the DC/DC converter in the photovoltaic system. Hussein *et.al,* [4] also used hardware to implement an incremental conductance algorithm to track the maximum power. The main distinguishing feature of this paper is to establish a model for the photovoltaic system with maximum power point tracking function that solely uses software simulation. This simulation system could predict and evaluate the behaviours of a real photovoltaic system without using any hardware equipment.

This paper includes 5 sections. The rest of this paper is organized as follows. Section 2 introduces the characteristics of solar modules and shows the relationship of current and voltage for the solar modules along with the variations of irradiance and temperature.

Section 3 interprets the modelling of the DC-DC boost converter.

Section 4 shows the simulation results of the proposed photovoltaic simulation system, and the last section is the conclusion of this paper.

II. CHARACTERISTICS OF A SOLAR MODULE

The basic structure of solar cells is to use a p-type semiconductor with a small quantity of boron atoms as the substrate. Phosphorous atoms are then added to the substrate using high-temperature diffusion method in order to form the p-n junction. In the p-n junction, holes and electrons will be rearranged to form a potential barrier in order to prevent the motion of electrical charges.

When the p-n structure is irradiated by sunlight, the energy supplied by photons will excite the electrons in the structure to produce mobile hole-electron pairs. These electrical charges are separated by the potential barrier at the p-n junction. The electrons will move towards the n-type semiconductor and the holes will move towards the p-type semiconductor at the same time. If the n-type and p-type semiconductors of a solar cell are connected with an external circuit at this moment, the electrons in the n-type semiconductor will move to the other side through the external circuit to recombine with the holes in the p-type semiconductor. The above phenomenon shows how currents of the external circuit generate. Because the output voltage of a solar cell is extremely low (about 0.5–0.7V), solar cells have to be connected in series and in parallel in practical applications first in order to obtain a higher terminal voltage.

After connection, solar cells have to be strengthened by a supported substrate and covered by tempered glass to comprise the solar module (Fig. 1).

After this, solar modules can be connected in series and in parallel to create a solar array according to capacity demands. At present solar modules are combined with architecture, such as walls and rooftops, in order to achieve the broadest development. Each solar cell can be represented as a structure consisting of a photocurrent source, diode and resistors.

The equivalent circuit of the PV cell is shown in Fig. 1 [5-6]. PV cells are grouped in larger units called PV panels which are further interconnected in a parallel-series configuration to form PV arrays. To simulate the array, cell model parameters are properly multiplied by number of cells.
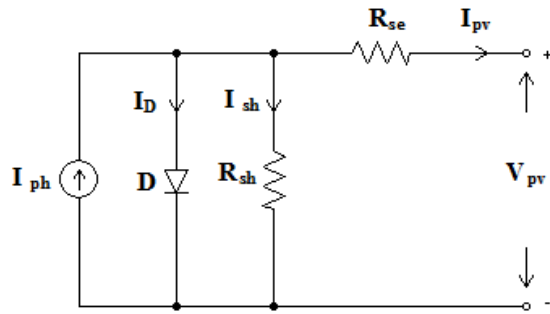
Fig. 1. Equivalent circuit of SPV panel.

The model equations are given from (1) to (5).

$$I = n_p I_{ph} - n_p I_{rs} \left[\exp\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1 \right] \quad \text{...(1)}$$

$$I_{rs} = I_r \left[\frac{T}{T_r}\right]^3 \exp\left(\frac{qE_G}{KA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right) \quad \text{... (2)}$$

$$E_G = E_0(0) - \frac{\alpha T^2}{T + \beta} \quad \text{... (3)}$$

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{S}{100} \quad \text{... (4)}$$

$$P = IV = n_p I_{ph} V\left[\left(\frac{q}{KTA} * \frac{V}{n_s}\right) - 1\right] \quad \text{... (5)}$$

Where,
I - PV array output current;
V - PV array output voltage;
n_s- Number of cells in series
n_p- Number of cells in parallel;
q - Charge of an electron;
K- Boltzmann's constant;
A -p-n junction ideality factor;
T- Cell temperature (K);
I_{rs}-Cell reverse saturation current.

The current to voltage characteristic of a solar array is non-linear, which makes it difficult to determine the MPP.

The Figure below gives the characteristic I-V and P-V curve for fixed level of solar irradiation and temperature.
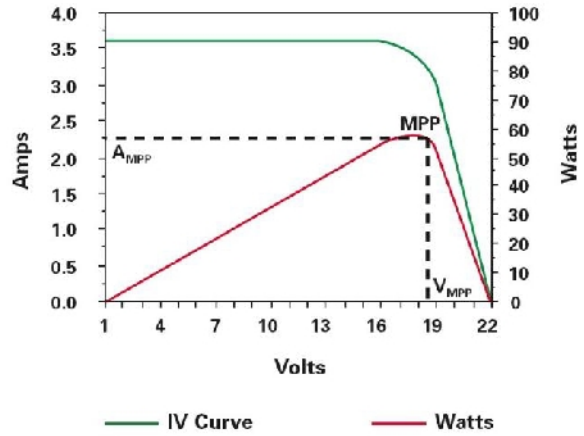

Fig. 2. I-V and PV curve characteristics.

The IV and PV curves for various irradiance but a fixed temperature (25C) is shown below in Figure (3) & (4).The characteristic I-V curve tells that there are two regions in the curve: one is the current source region and another is the voltage source region. In the voltage source region (in the right side of the curve), the internal impedance is low and in the current source region (in the left side of the curve), the impedance is high. Irradiance temperature plays an important role in predicting the I-V characteristic, and effects of both factors have to be considered while designing the PV system. Whereas the irradiance affects the output, temperature mainly affects the terminal voltage. The Fig. (5) & (6) gives the simulated I-V and P-V characteristic for various temperatures at a fixed irradiance at 100mW/m2 [4].
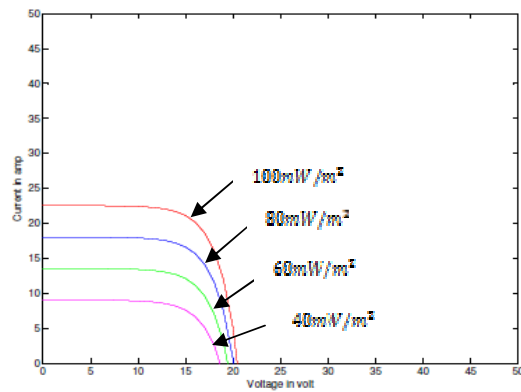

Fig. 3. I-V characteristic of a solar array for a fixed temperature (T=25^0C) but varying irradiance.
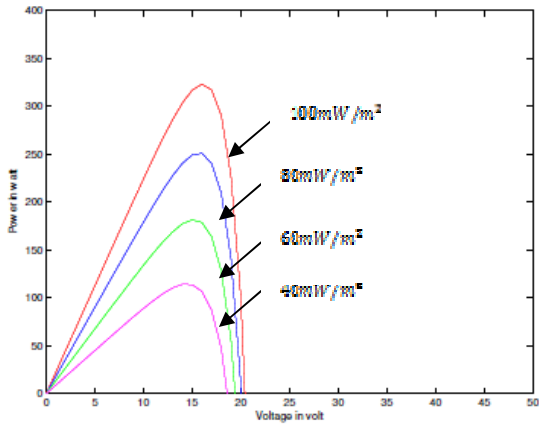
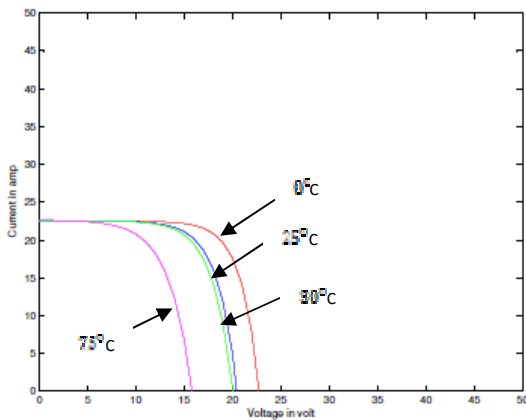**Fig. 4.** P-V characteristic of a solar array for a fixed temperature (T=25⁰C) but varying irradiance.

Fig. 5. I-V Characteristic of a PV array under a fixed irradiance(S=100mW/m²) but varying temperatures.

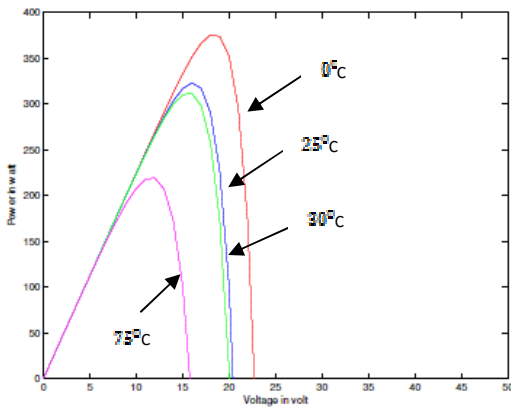**Fig. 6.** P-V Characteristic of a PV array under a fixed irradiance (S=100mW/m²) but varying temperatures.

From the I-V, we observe that the short circuit current increases with increase in irradiance at a fixed temperature. Moreover, from the I-V and P-V curves at a fixed irradiance, it is observed that the open circuit voltage decreases with increase in temperature.

The voltage-current and voltage-power characteristics at STC [S = 100m W/m2, T = 25C] are shown in Fig. 2 which is obtained by simulating the equations (1) to (5) through MATLAB M-file coding.

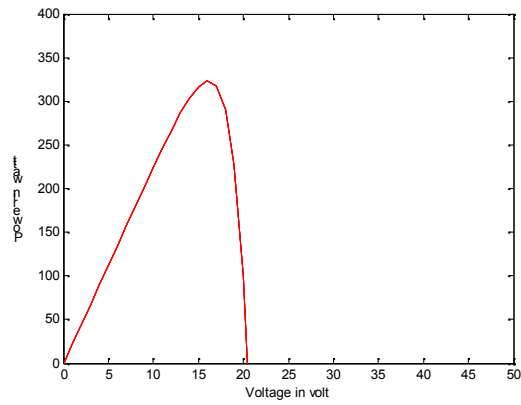**Fig. 7.** Simulated characteristics of SPV panel.

The PV panel specifications are: I_{sc}=23.5A, V_{oc}=20.25, P_{max}=37.08W, V_{max}=16.54 and I_{max}=22.6A.

III. SIMULATION OF MPPT SYSTEM

A. *Design of Power Circuit*
The Buck converter interfaces PV panel and the load. The design equations of the Buck converter are presented from (6) to (8).

The voltage ratio of the Buck Converter is given as, Conversion ratio,

$$M_V \equiv \frac{V_O}{V_S} = D \qquad \text{... (6)}$$

The inductor and capacitor is designed based on the following equations to operate converter in Continuous Current Mode (CCM).

$$L_b = \frac{(1-D)R}{2f} \qquad \text{... (7)}$$

$$C_{min} = \frac{(1-D)V_O}{8V_r Lf^2} \qquad \text{... (8)}$$

The SIMULINK diagram of the buck converter is shown in Fig. 8.The design parameters used in simulation are L=25µH, C = 25µF and f_s = 100 kHz.

IV. MATLAB MODEL AND SIMULATION RESULTS

The PV array has been interfaced with the boost converter using controlled current source with MPPT function as shown in the circuit diagram below.
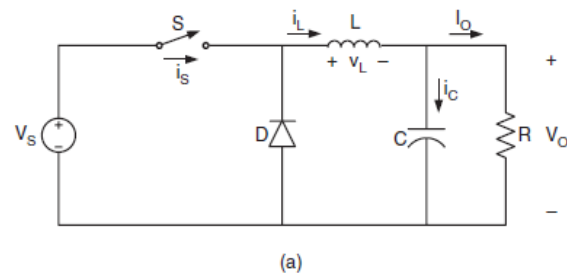

(a)

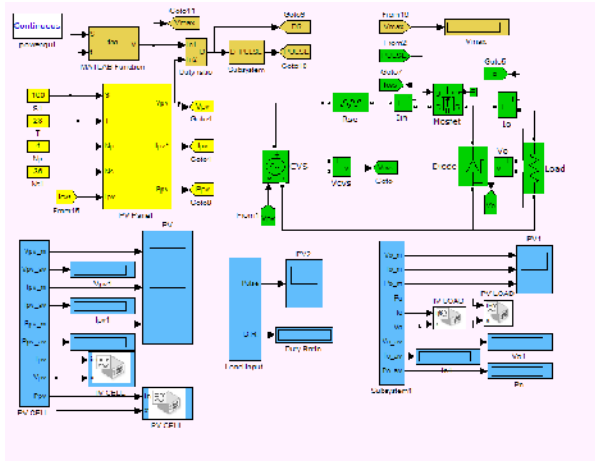**Fig. 8.** Schematic of Buck Converter.

Fig. 9. The complete simulink circuit model showing the coupling of PV array with the buck converter.
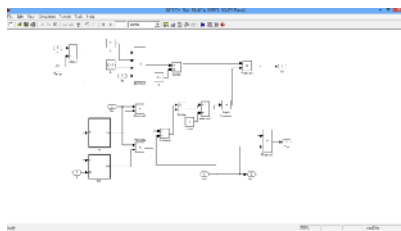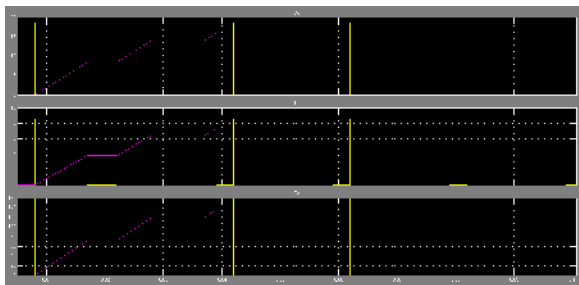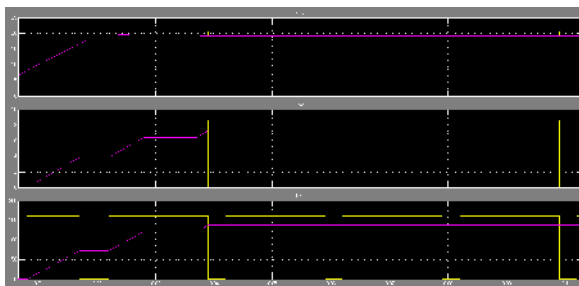

Fig. 10. The subsystem of PV panel.

(a)

(b)

Fig. 11. Output waveforms of (a) load side (b) PV panel.

The interfacing of the PV array with the buck converter has been achieved using a constant voltage source.
From Fig. 3, we observed that by increasing the solar radiation at constant temperature the voltage and current output from PV array also increases.

Hence at higher insulation we can get our required level voltage.

From Fig. (4), we observed that by increasing the solar insulation level, the power output from PV array increases

From Fig. (5), we observed that by increasing the temperature level at constant irradiance, the voltage output from PV array decreases but current output increases slightly with respect to voltage and, hence the power output from PV array decreases.

From Fig. 11, we observed the value of output voltage, current and power of PV panel and load.

V. CONCLUSION

The main purpose of this paper is to establish a model for a photovoltaic system with maximum power point tracking function completely through the use of software techniques. A model of a solar module was first established and then combined with an MPPT algorithm, and a DC-DC converter, in order to set up a complete photovoltaic simulation system. MPPT is an important process for the PV system to deliver maximum power to the load and also to increase the efficiency. A DC-DC converter is included in the system between the load and the source to achieve maximum power transfer between the source and the load.

By changing the duty cycle of the converter for each weather condition (temperature and radiation), the impedance matching can be reached using MPPT.

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