JJMIE

Volume 13, Number 1, May. 2019
ISSN 1995-6665
Pages 21 - 25

Jordan Journal of Mechanical and Industrial Engineering

Using Matlab for Simulating Real-World Photovoltaic System

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Received 10 December. 2018

Abstract

This paper presents an advanced simulation for real-world photovoltaic system which includes a kind of simulation that consists of a control panel and a solar system. This interactive and flexible control panel controls the whole simulation parameters including the location and panel's parameters. The user will be capable to insert two sets of data, the panels and location data. For the panels, the user can choose data from a predefined set of panels as well as the user can add or remove panels from the list, or the user can enter any data to do test. The location data as well can be chosen automatically or manually by the user. Finally, the simulation output will give a message indicating the results in addition to three output figures; current-voltage curve, power-voltage curve, efficiency-temperature curve.

Keywords: Photovoltaic, Solar system, I-V curve, P-V curve, Efficiency, Fluidics, Simulation , MATLAB, SIMULINK, Panel, Module;

1. Introduction

The primary source of energy on the planet Earth is the radiant energy from the Sun. Solar cells which function as electronic device that directly convert sunlight into electricity are used in this research. Solar cell which transforms the radiated sun energy into electrical energy can be used for almost every application now in our daily lifeSolar cells have different types such as Monocrystalline, polycrystalline, thin film and plastic solar cells; they come with different specifications as well. This diversity caused confusion to the researchers. The reason lies in the huge number of parameters that must be taken into consideration when deciding to study solar panels such as the variation of temperature from time to time in different times of the day and year, the changing of radiation over the day or seasons and much more. All these factors affect the output power produced from the panels. As a result, there must be a way that connects all these factors together which can be applied on different types of panels resulting in choosing the proper type of panels for the parameters chosen [1,2,3,4].

This work established a new way of combining the real-world parameters in addition to solar cell parameters. The design contains two fundamental blocks: the solar system and control panel. The control panel is the main fundamental component of the design, its features comes in its flexible interface which permits the user to choose from a predefined data or simply enter his own. Solar radiation, temperature of any geographical area can be chosen from the database or can be manually entered by the user. In addition, the user can choose from a wide variety of solar cell manufacturers. This design is presented for any user that would like to study solar energy without any concerns, by entering the location parameters, the user can apply different solar panels type and compare the results then choose the most suitable type of solar panels that fits his needs.

2. Modeling Photovoltaic Systems.

Different methods can be applied for building photovoltaic systems [3,7,11 13], some use photovoltaic equations and others use Artificial Intelligence. . Here the simulation of photovoltaic model will be built using MATLAB m-files and SIMULINK by using the photovoltaic equations in an efficient and accurate way. The simulation results can be displayed using the feature of linking the m-files with SIMULINK. Furthermore, the use of m-files can give the researcher the ability to modify his design in such a way that can satisfy the needs of his work.

As explained earlier, the design contains two fundamental blocks

- Solar System
- Control Panel

2.1. Solar System.

The model should be accurate and reliable when implementing the equivalent circuit of the solar. The single diode method has been used. The equivalent electrical circuit of the model is shown in figure 1.

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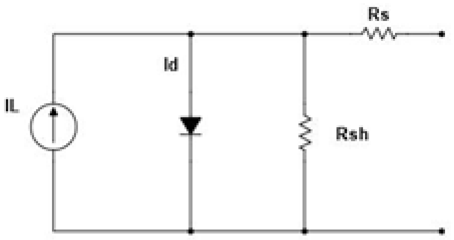

Figure 1. Single diode method equivalent circuit

The solar system is the brain of this model. Its main function is transforming the equations of solar cell into SIMULINK as shown in figure 2. In addition, it applies the data inserted in the control panel to perform the simulation.

Note that in the equations below we will suppress the effect of (Rsh) [1-11].

The Internal photon current (Iph) depends on the value of irradiance (G), as shown in equation 1:

$$I_{ph} = I_{SC} + K_I(T - T_{ref})\left(\frac{G}{100}\right) \quad (1)$$

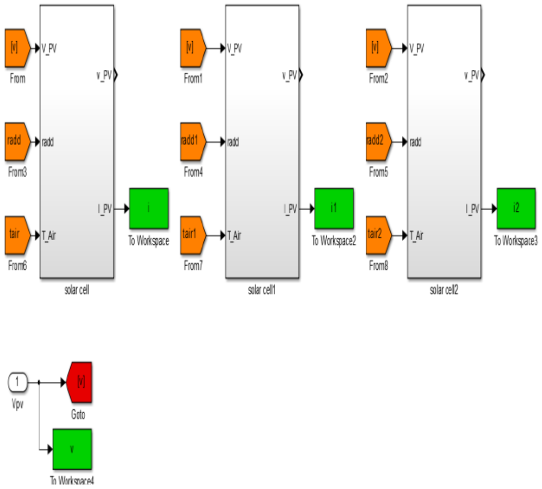

Figure 2. Overview of solar system block

Table 1. Reference table for internal photon current equation

Symbol	Definition	Unit
I_{ph}	Photon current	Amperes
I_{sc}	Short circuit current	Amperes
K_I	Short circuit temperature coefficient	Ampere/Kelvin
T	Temperature of the cell	Kelvin
T_{ref}	Standard temperature	Kelvin
G	Irradiance	Watt/m^2

When the irradiance increases, the number of carriers will in-crease in the semiconductor material, this will increase the output current produced from each cell in the panel. The out-put current produced from the cell can be calculated using Kirchhoff's current law:

$$I = I_{ph} - I_d \quad (2)$$

Where I_d is the diode current measured in Amperes, and it is determined by the following formula:

$$I_d = I_0 \exp\left(\frac{qv}{e^{A}KT} - 1\right) \quad (3)$$

The I0 is the reverse saturation current measured in Amperes.We can calculate the reverse saturation current using:

$$I_0 = \frac{I_{SC}}{\exp\left(\frac{qv}{e^{A}KT} - 1\right)} \quad (4)$$

The saturation current Ist is calculated by equation 5

$$I_{st} = I_{rs}\left(\frac{T_c^3}{T_{ref}}\right) \cdot \exp\left(\frac{qE_g\left(\frac{1}{T_{ref}} - \frac{1}{T_c}\right)}{K \cdot A}\right) \quad (5)$$

The bandgap energy EG is measured with electronvoltsev.The output current can be calculated using the following equation:

$$I = N_p \cdot I_{ph} - N_p \cdot I_0 \exp\left(\frac{q(V_{pv} - I_{pv}R_s)}{N_s \cdot A \cdot K \cdot T}\right) - 1 \quad (6)$$

Table 2. Reference table for output current equation

Symbol	Definition	Unit
Np	Solar cell connected in parallel	panel
Io	Saturation current	Amperes
Q	Electron charge	Columb
Vpv	Output voltage	Volt
Ipv	Output current	Amperes
Ns	Series connected cells	UnitWatt/m2
A	Ideality factor	-
K	Boltzmann constant	Kgs−2K−1

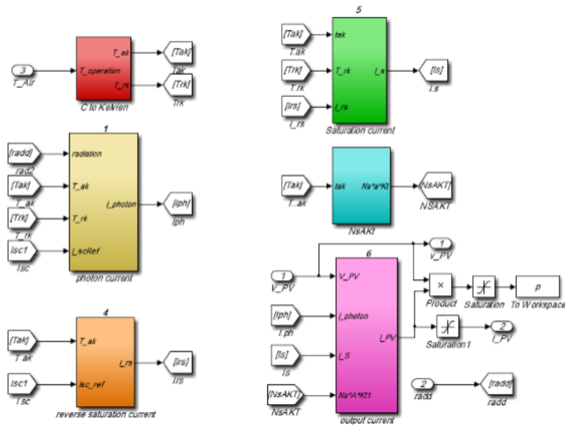

Figure 3. Implementation of equations 1 to 6 using SIMULINK

According to figure 2, there are three solar panels found in the proposed system such that they are used for comparison between different temperature or radiation when location is fixed. Figure 3 shows the implementation of equations 1 to 6 using SIMULINK.

2.2. Control Panel.

The control panel is the heart of the proposed system. It is used for controlling through entering the Cell's location and external parameters (temperature and radiation).

The flexible interface distinguishes our model, it makes the control process and external parameters of the solar cell and choosing the location more flexible and easier because it can directly send the entered data to the proper destinations in the equations. The control panel allows the user to enter his own data manually or he can simply choose the date and time for the location he wants to perform the calculations on it. In our model we already programmed the location parameters of Amman- Jordan. The program automatically uses the data from a predefined Excel sheet containing the data such as radiation and temperature with respect to time for all periods of the year. In addition, the control panel has a section specified to the solar cell parameters like Noc,Voc and Isc and here the user can input his own parameters or simply choose from different manufacturers' datasheets which are already saved in the control panel. Figure 4 shows the control panel layout.

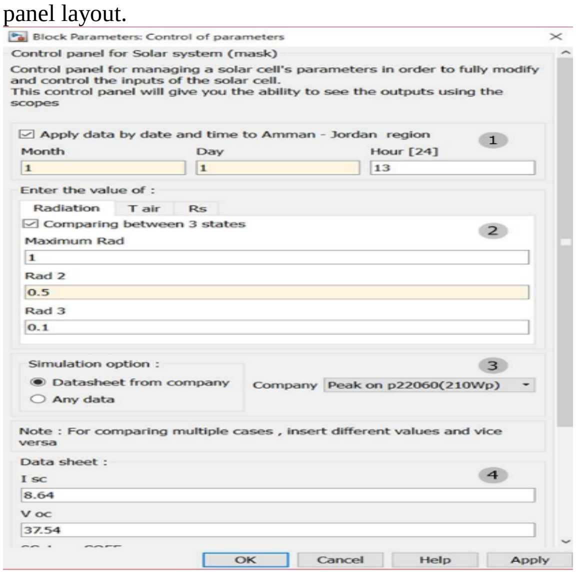

Figure 4. Control panel Layout

2.3. Date and Time Parameters.

As mentioned before, there are a lot of parameters affect the output power produced from the solar cell which differ simultaneously with time and date for any location. The proposed model takes into consideration this issue, you can choose the date and time for a specific location using a predefined Excel sheet and here the model already programmed for Amman-Jordan. An example made to the Queen Alia International Airport region, in Amman-Jordan.

The flexible operation with MATLAB and SIMULINK gave us the opportunity to integrate between them. The model automatically brings the temperature and radiation data for the location from a predefined Excel file according to the entered date and time. This feature gives any user the ability to compare the production of solar panels in different parts of the day and different parts of the year. The user can simply find the perfect time which can obtain the maximum power production.

2.4. Operating Parameters.

This section permits the user to either manually enter his own operating parameters or automatically from a predefined Excel sheet that contains all the parameters for the specified location. In addition, the user will have the capability to compare between three states of temperature, radiation and series resistance.

2.5. Simulation Options.

This section permits the user to choose between two simulation options:

- Data sheet from company
- Any data

When selecting data sheet from company, the user will choose from predefined data sheets programmed in the proposed model. The user can add/remove any data sheet to/from the list.

On the other hand, when selecting any data, the user will manually enter his own parameters for the solar panel.

2.6. Data sheet.

This section contains the solar panel parameters such as Isc,Voc,NOCT,Ns,Np,Length and Width.

Simulating the Model After entering all parameters, the user can observe the results in two ways. At first, a compact message will appear containing all the information, such as location, time, radiation, temperature, and maximum power generated by the panel. The second is a screen with five graphs containing the Current-Voltage curves (I-V), Power-Voltage curves(P-V), Efficiency-Temperature curve, P-V I-V curve and zoom in figure for the P-V curve as seen in figure 5.

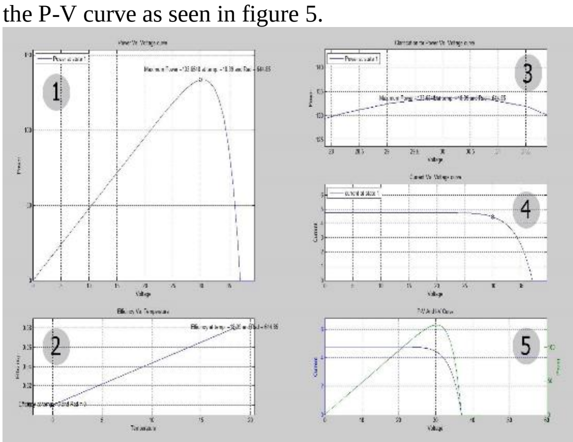

Figure 5. Solar Panel Curves

In figure 5, power and voltage, efficiency and temperature, zoom in for power and voltage, currents and voltage and P-V.

I-V in the first, second, third, fourth and fifth curves respectively.

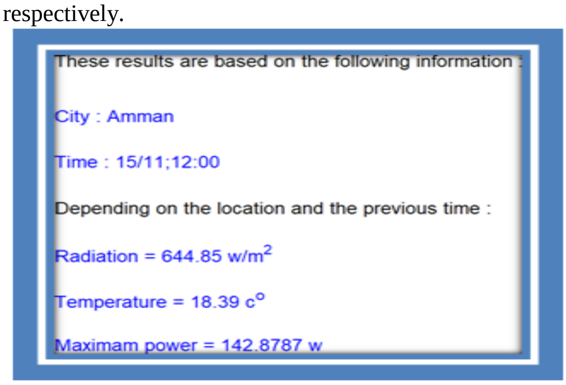

Figure 6. Simulation compact message

Figure 6 shows the compact message after the simulation.

If the user wants to compare between different operating conditions, the results can be observed in figure 7. Note that

the points marked (o) in the figures above represent the maximum power point (MPP). We can calculate the maximum power using:

$$P_{max} = I_{max} \cdot V_{max} \quad (7)$$

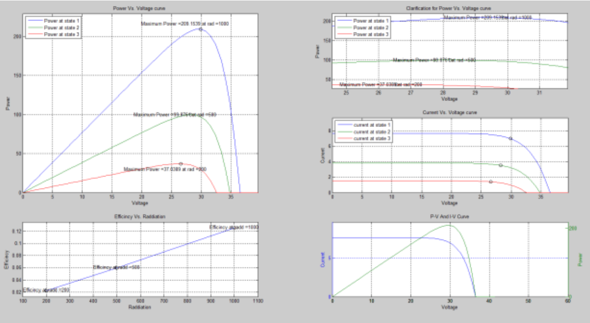

Figure 7. Comparing between different operating conditions

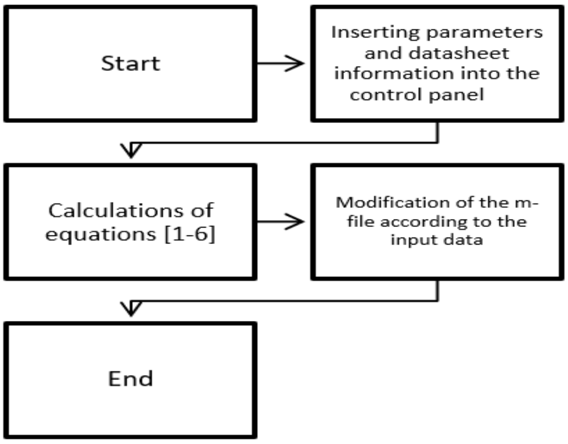

Figure 8. Flow chart for simulation

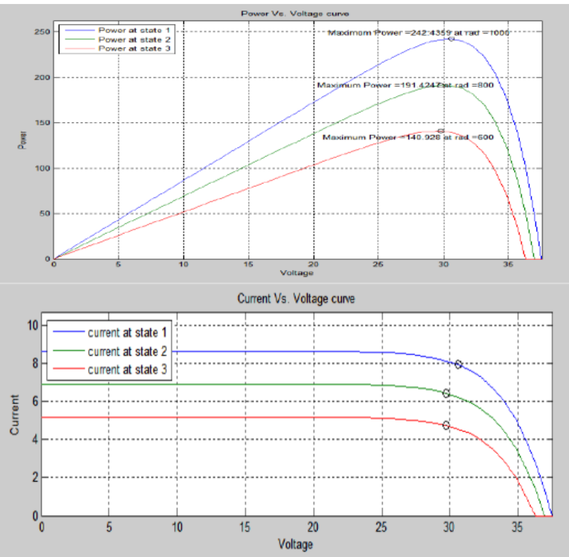

Fig. 9. I-V and P-V characteristics with Varying Radiation

Figure 9. shows the I-V and P-V characteristics when changing radiation.

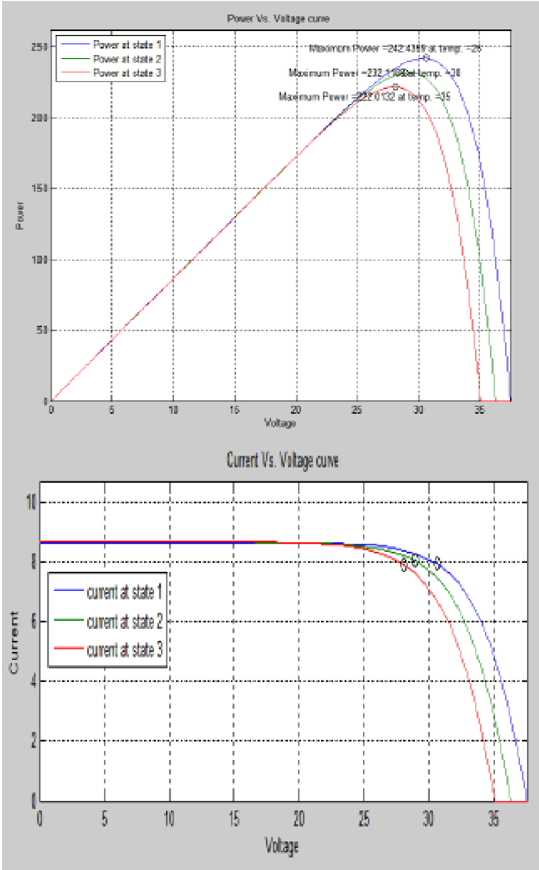

Figure 10. I-V and P-V characteristics with Varying Radiation

Figure 10 shows the I-V and P-V characteristics when changing temperature.

3. Case Study for Queen Alia International Airport.

This section provides a case study for Queen Alia International Airport Amman-Jordan. This is Jordan's main and largest airport located in Zizya 30 Km south of the capital city, Amman. This strategic place covers a large area as it is located in an open region in which the radiation of sun can fulfil the borders of the airport. The location parameters were obtained using Polo software, which is a software used for simulating photovoltaic systems. . The data obtained, such as radiation and temperature with respect to time will be entered to the control panel as an Excel sheet. Two types of solar panels will be tested.

As we can see from table III, we took the middle of each odd month (the 15th day of each odd month) as a reference in addition for midday (12 O'clock) for comparison. The output power differs from Jan 15th to November 15th. By observing the maximum power, it occurs when the radiation at maximum levels which is in July. Furthermore, we can compare between two different manufacturers, so the user can choose the type of solar panels which produce the maximum power.

Table 3. Comparison between different types of solar panels for Queen Alia International Airport area

Radiation	Temperature,Kelven	P22060(210W) module	SPR-210-BLK (210W) module
591.87	5.64	125.39	141.02
763.63	9.84	163.06	179.8
855.1	17.39	180.9	193.1
988.46	27.89	204.86	210.64
936.37	28.89	192.65	197.81
644.85	18.39	133.65	142.87

4. Conclusion

This paper provides a new systematic approach for controlling and modeling a solar system using control panel. The proposed method implemented a photovoltaic system in a flexible design. The main part of the system was the control panel which establishes a connection between location and solar panel parameters. The connection established in two ways, the first is to obtain data from a predefined Excel sheet which contains the radiation and temperature data with respect to time, also the user can change the location parameters using the predefined Excel sheet. Second, the user can manually input his data into the control panel. The control panel permits the user to enter and control different output characteristics in a simplified and easy way. In addition, for connecting the m-files with Simulink. I-V and P-V characteristics are plotted with varying parameters like short-circuit current and open circuit voltage. The relation between efficiency and varying conditions like temperature and radiation are presented and how they affect the total performance of the system. Finally, there are several methods for simulating photovoltaic systems starting from cells and ending with arrays, some of these methods include the single diode model as implemented in the research, others include MATLAB coding such as model presented in work [13] while the newest methods implement AI. The current when compared to others showed the flexibility and accuracy.

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