

Photovoltaic Lunar Cell Materials — Design, Manufacturing and Simulation

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Abstract

Solar cells provide clean energy around the world. However, in some area the solar power is limited by weather conditions. The search for more powerful and energy-efficient systems has led to an increasingly broad field of research. This paper proposed a new technology to build low-energy collectors - lunar cells. We have introduced a multi-disciplinary collection framework that represents this diverse research area; and provide an opportunity to link previous researches from multiple specializations, such as engineering, renewable energy, and chemistry.

Keywords: Renewable energy, lunar cell, multi-disciplinary collection

Introduction

As the society develops, human needs more and more energy to build the industry and maintain the normal life. Energy is a significant issue that plays a fundamental role in economic growth and industrialization all over the world. The crisis of fossil fuels and oil prices due to increasing the energy demand faces the world to exploit solar energy. Solar energy inexhaustible, effective, unpolluted, and cost-free source [1]. Other energy like wind energy, nuclear energy, and bioenergy also contribute to the renewable energy resource.

[2] introduced a way to collect and convert wind energy to electricity. Photovoltaic module is one of substitutes for conventional energy source that gaining more concern because it has a large potential to supply energy demand such as electricity, heating, and cooling in all aspects. Mainly, PV module is a collection of silicon cells (semiconductor) that convert directly solar radiation into DC electricity. Silicon cell can be recognized into three types according to the kind of crystal. These types are mono crystalline, poly- crystalline and thin amorphous [3].

Iraq receives an enormous amount of solar radiation due to location near the Sun Belt. It receives solar radiation with an average of (6.5-7) kilowatt-hour per square meter. During the year, the period of sunshine ranges from 2800 to 3300 hours. This privilege gives Iraq the possibility to exploit solar energy widely and used it to provide the load demands in national grid, which represent a challenge [4]

Solar panels are great — they provide your household with clean, renewable energy and cut down your electricity bills. They do have one flaw, though — they only work during the day. Yet, now that you think about it, couldn't the moon do the exact same thing as the sun? Isn't it possible to power your home at night with lunar energy?

Unfortunately, so far, we don't have that kind of technology. But let's explore in more depth how lunar panels work and why the moon can't power them. If you don't know anything about solar panels, their ability to convert the sun's rays into electricity may seem like magic. But of

course, it's nothing like that — just a bit of science and technical ingenuity. So, let's unravel the mystery of lunar panels!

But why is all that necessary? Well, because these opposite charges create an electric field at the junction of the two silicon layers. Once sunlight hits the panel, it knocks some of the electrons free, and then the electric field pushes them out of the silicon junction.

Now, these free electrons comprise the power that you receive from the panels. However, before they become usable, they have to pass through conductive metal plates that collect and transfer them to wires. Then, you can use this energy to cook a meal, warm up water, or simply store it for later!

As their name alone suggests, solar panels need sunlight to work. In fact, photons, tiny light particles from the sun's rays, are the main ingredient that causes electrons to run free. Thus, if there are no photons, there's no solar energy.

Now, as you know, the moon doesn't produce any light on its own. In fact, that silver like glow you see at night is simply the sun's reflection. And while the full moon may be able to light up your way, it's nowhere nearly as bright or powerful as the sun during the day. In addition, the moon doesn't generate its own photons. Thus, its light intensity is far lower.

As a result of all that, moonlight can't power up solar panels and create lunar energy. There simply isn't enough light, nor are its photons powerful enough. And even if the panels could collect lunar energy, it would take too long to have enough to power a home. All in all, at least for now, your solar panels will have to remain dormant at night.

But even though you can't use your solar panels at night, you will certainly have lots of benefits from them during the day. After only a month, you'll notice a huge difference in your electricity bills, and you could even earn some money! On top of that, you'll have a constant source of clean energy that is immune to blackouts and power cuts. All that if you simply install a solar panel!

And who could do it better than Atlantic Key Energy? As experts in this field, we'll help you convert to renewable energy sources in no time. Maybe you can't power your home at night with lunar energy yet, but you certainly can make a difference for our planet!

First, you should know that solar panels aren't just large metallic boards — they are made of numerous tiny photovoltaic cells. These cells contain two slices of silicon infused by materials with opposite charges. For instance, phosphorus, with its negative charge, is added to the top silicon layer, while the bottom one receives a dose of positively charged boron.

Related Work

Pern [4] studied the effect of encapsulation materials, processing and testing of PV panel. It was concluded that the various type of encapsulation materials provides various performance. Further, lamination quality and reliability of PV panel dependence on encapsulation manner and processing factors. Mahajan and Bhole [5] presented a Simulink model by using MATLAB software to describe current – voltage and power – voltage characteristics of PV panel. It was observed that the output power from the panel increased by increasing the solar radiation while reduced when cell temperature increased. Jiang et al. [6] developed a mathematical and a simulation model to predict the output behaviour of the PV panel under different weather conditions. They found that the simulation model was simple, accurate and used to design and simulate PV module with any converter and controller.

Jadallah et al. [7] presented a simulation model for PV cells by using a computer program in MATLAB software to study the effect of different parameters such as solar irradiance, diode ideality factor and dark saturation current. The results showed that the output power increased by increasing the solar irradiance and ideality factor but Decreased when dark saturation current and operating cell temperature increased. Bellini et al. [8] improved a mathematical model based on data sheet manufacture parameters only. They reported that the output electrical (open circuit voltage and short circuit current) parameters varies from the parameters provided by data sheet due to the change in electrical output of PV module during the years. Islam et al. [9] studied the influence of environmental conditions, shunt resistance and series resistance on the performance of PV panel. by using MATLAB/Simulink environment. It was observed that adopted model could be used for any rated size of PV module.

Gao et al. [10] designed game theory algorithm for robust control systems and developed MATLAB/ Simulink model for PV panel and array. The simulation model taken into consideration the effect of climatic and physical parameters. Abd El-Basit et al. [11] presented a simulation model by using MATLAB/ Simulink to verify (I-V) and (P-V) characteristic of PV module under different operating conditions. It was found that the electrical efficiency reduced by increasing cell temperature and the increase in solar radiation leads to increase in current and series resistance. Khezzar et al. [12] improved four parameters model to simulate PV module to study (I-V) characteristic under various conditions.

Park et al. [13] proposed a novel modelling algorithm for simulating any kind of PV cell material (Cr-Si, Thin film, tandem) to predict (I-V) characteristic of PV cell. It was observed that this modelling gave

accurate results with minimal error, do not required long time to estimate the five parameters and suitable for any kind of solar cell.

To collect lunar energy, this paper focuses on fabrication process of glass-to-glass PV module with various packing factor to generate electrical power and enhance thermal gain. Further, simulink module to predict the output characteristic of the module. The main phases of PV module are soldering of the electrical connection between cells and encapsulation through the lamination process. The PV module will be undergone several tests such as pull test and visual inspection before the measuring process.

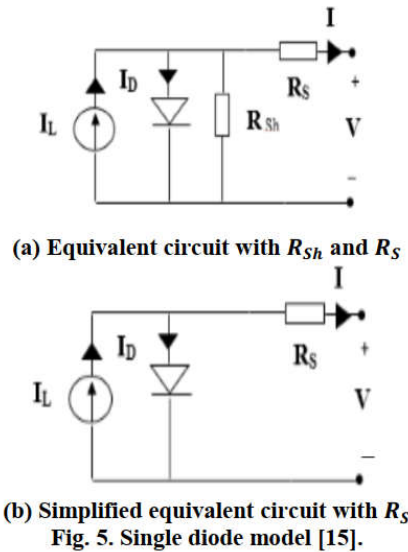
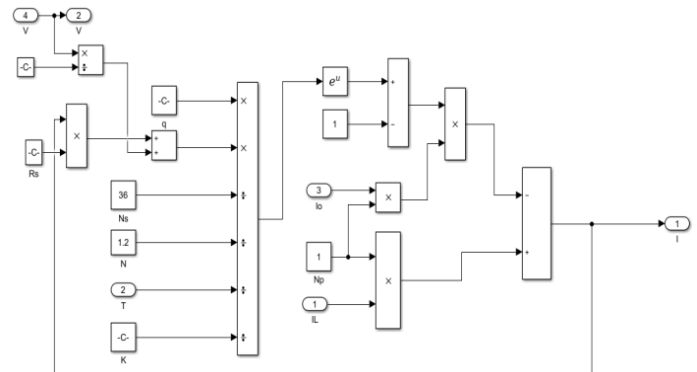


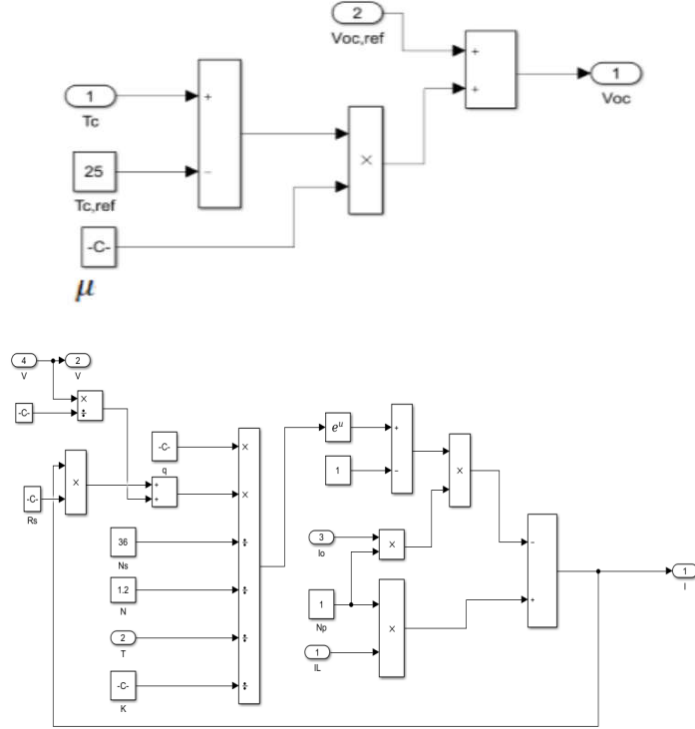
Fig. 5. Single diode model [15].

Design

Figure 1(a) shows the adopted design of the PV module. The basic step upon, which the proposed design is the setting of the range of electrical efficiency of mono crystalline PV module, is started from 10% to 15%. The significant parameters which affected the proposed design are cell efficiency, number of cells, area of cell, area of module and packing factor. In this study, the packing factor is 0.63. All the data used for evaluating packing factor are illustrated in Table 1. The layers of PV module are solar cells, Ethylene vinyl acetate (EVA), and glass cover as shown in Fig. 1(b). In the future scope, this PV module will be employed in hybrid photovoltaic thermal system to enhance electrical and thermal performance at the same time.

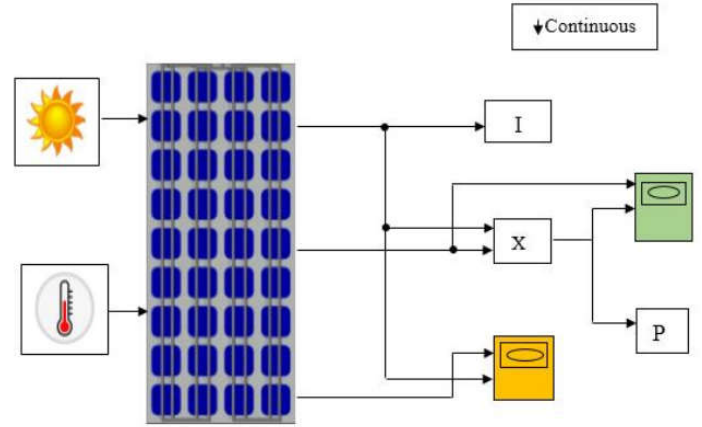


Photovoltaic module is a group of solar cells electrically connected in series to increase the voltage or in parallel to increase the current. Fabrication process of PV module is started by putting a wood template of width 30 mm between each of two cells as shown in Fig. 2(a). After that the ribbon are manually weld on the solar cells. The manner of welding is from top face (negative) to back face (positive) that which form the strips of PV module as shown in Fig. (b).



Testing process of PV module occur on five steps. The first step is before soldering process and the others after the soldering process. Firstly, solar cell must be tested to know output power and cell efficiency at STC. The cell can be tested by cell tester, which is shown in Fig. 3(a). The results of the test of one solar cells that which form PV module was found 17.37 % as presented in Fig. 3(b). The second step is to check soldering durability of ribbon by using Pull tester, as shown in Fig. 3(c). The cell is subjected to an applied force of 125 g, the results of pull test is accepted. The results of pull test for proposed design is 150 g. The third step is visual inspection. Array of cells is placed on lightening table as shown in Fig. 3(d), which is easily to seek the defects or misalignment of the strips and the results of this inspections was found reasonable.

Finally, after covering cells array with second EVA and glass layers PV module enter laminator machine to get final product, electrical characteristic of PV module is tested at STC, the tested results were obtained as shown in Fig. 3(f). PV module in final look is shown in Fig. 4.



Hence, the end of strips was connected electrically to form the final electrical circuit. The output voltage is measured by digital multi meter as shown in Fig. 3(e).

Manufacturing

The most important parameter that effect on the proposed design is the packing factor (PF), which represent the ratio of the solar cells occupied by the module area. Mainly, it depends on the area of cell, number of solar cells and module area. The relationship of (PF) can be represented as below [14]

$$P_f = \frac{n^c}{v_c}$$

Cell efficiency (η_c) represents maximum power of lunar cell to the solar irradiance receiving by lunar cell.

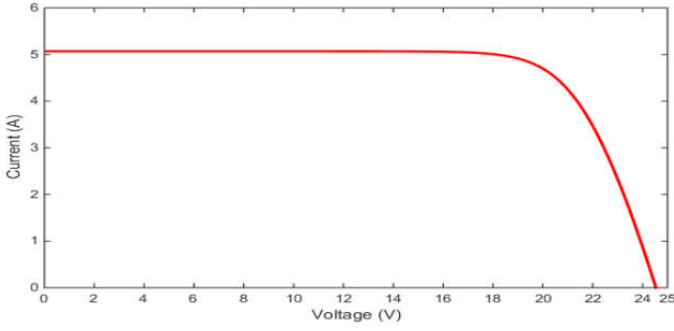
$$n_f = \frac{Aq^c}{t_c}$$

Module efficiency is the product of cell efficiency by packing factor, thus module efficiency will be less than cell efficiency

$$n_m = c * n_f$$

Equivalent circuit of PV cell is based on single diode model. This model includes current source (current generated by the sun light), a diode, series resistance and shunt resistance as shown in Figs. 5 [15]. In general, five parameters (I_L , I_D , R_S , R_{sh} , a) must be evaluated to describe current-voltage characteristics of PV module as shown in Fig. 5(a). These parameters are function of two environmental conditions (solar radiation and temperature).

The value of series resistance is very small, which represent the resistance of silicon cell while shunt resistance value is large which referred to the leakage current through parallel resistor. Shunt resistance can be neglected to simplify equivalent circuit. The four parameters model (I_L , I_D , R_S , a) is more practical model used to predict photovoltaic panel behavior.



An equation of output current of PV module can be obtained by applying Kirchhoff's current law at the equivalent circuit provided in Fig. 5(b) [16].

$$I_l = I_D - I$$

Mainly, diode current is proportional to the saturation current as in Eq. (2).

$$I_D = I_o \left(e^{\frac{A+I}{B}} - 1 \right)$$

$$B = V_t a$$

where B is the product of thermal voltage to ideality factor.

Cell temperature and solar irradiance effect on the following parameters:

$$V_T = \frac{T_c k}{q}$$

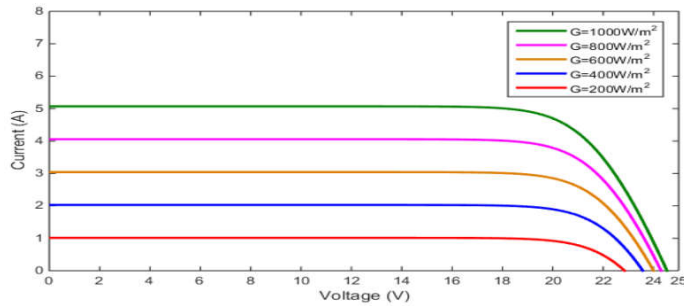
Thermal voltage of diode is exclusive depend on cell temperature, (V_T) is given by the equation (4). Saturation current of diode varies with cell temperature, which is defined as below [17].

$$I_o = I_{o,ref} \left(\frac{T_c}{T_{c,ref}} \right)^3 e^{\frac{qk}{\alpha} \left(1 - \frac{T_c}{T_{c,ref}} \right)}$$

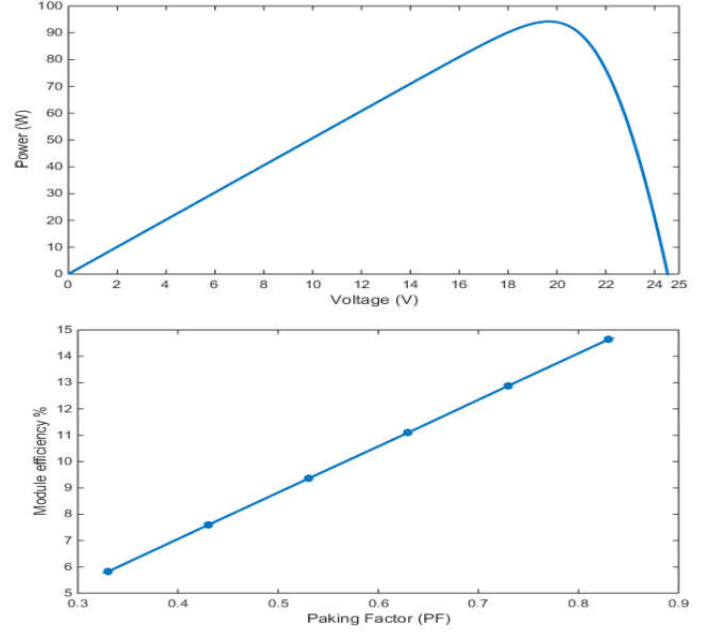
where saturation current of diode can be approximately obtained as:

$$I_{o,ref} = \frac{I_{sc}}{e^{\frac{V_{oc}}{B}} - 1}$$

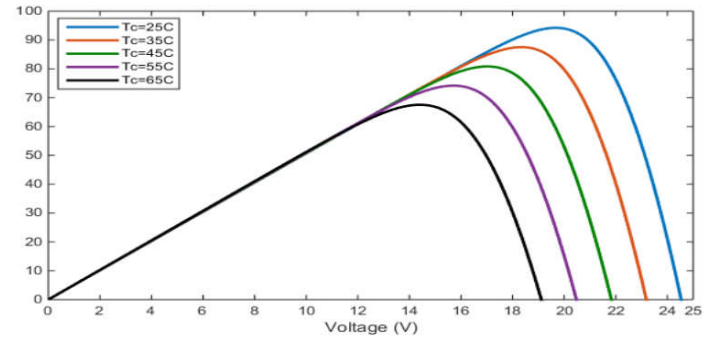
Current generated by the sun light is depend on both solar radiation and Cell temperature.



Lunar cells are electrically connected in series or in parallel to rise the voltage and current. When the cells connected in series, the voltages of each cell are added up while the current is the same as the cells one. As cells are connected in parallel the current of each cell are added up while the voltage is the same as the cells one.



Saturation current and output current formula of PV module containing several cells are presented as [17].



Simulation

Based on the mathematical equation of PV module, a model is simulated by using MATLAB /Simulink environment. This model taken in to account the effect of solar radiation and cell temperature on the output characteristic. Electrical parameters of PV module (Tabark Ha, 94.2 W) at STC used in Simulation model as illustrated in Table 2.

Simulink block for current generated by the sun light (I_L) as given in equation (10) is illustrated in Fig. 6. Open circuit voltage (V_{OC}), which is given in equation (11). It was simulated via the block diagram shown in Fig. 7.

Saturation current of diode described by equation (8). Is simulated in the block diagram shown in Fig. 8. Final Simulink block for output current of PV module (I) as written in equation (13) is shown in Fig. 9. Simulink model of PV module was represented by block diagram as shown in Fig. 10.

Results

The effect of packing factor on the design are shown in Fig. 11. Packing factor value varies from 0.33 to 0.83 based on the present design. It was observed that at packing factor equal 0.63. Module efficiency is kept on an acceptable efficiency 11.1%. As the value of packing factor is lowered, module do not remain in range of mono crystalline PV module efficiency. The reduction in module efficiency resulting from uncovered total module area with cells will be compensated as a heat gain for PVT system.

Power –voltage and current – voltage characteristics of the proposed PV module at STC are simulated using MATLAB/Simulink Software are shown in Figs. 12 and 13. It is found that simulation results of open circuit voltage and short circuit current and maximum power are 24.52 V, 5.07 A, 94.2 W, respectively. Simulation curves and data sheet of PV module are in a good closeness. The percentage error between simulated results and data sheet parameters for open circuit voltage, short circuit current and maximum power are 0.041%, 0%, 0%, respectively. Figures 14 and 15 reveal the effect of various solar radiation at constant cell temperature 25 °C on I-V and P-V characteristics of PV module. It was noticed that the current increased linearly with the increase of solar radiation, but the voltage increased nonlinearly which lead to an increase in output power. The influence of different cell temperature at constant solar radiation 1000 W/m² on P-V and I-V characteristics are presented in Figs. 16 and 17, respectively. It was observed that increasing cell temperature lead to a linearly decrease in voltage while the current increased slightly which lead to reduce the power generated of PV module.

Conclusions

PV cells and thermal lunar collectors are hybridized in PV/T systems to improve the electrical and thermal efficiencies as well. Although the air-based PV/T system has an efficiency lower than that of the water-based PV/T system, it may be considered as a promising design concept because of its simplicity in manufacturing. Design and fabrication of PV module (glass to glass) with packing factor 0.63 was achieved to be compatible with the climate of Iraq. Alternating the packing factor from standard value only module conducts a compensation between electricity productivity and heat production in summer and winter seasons. The increase in solar radiation has a favorable effect on the output current, while the increasing in operating cell temperature reducing output voltage of PV panel. The simulation results show a good closeness with manufactures data sheet

End Matter

Author Contributions and Notes

Jack and Jeslin designed research, Jeslin performed research, Jack. wrote software, Robert analyzed data; and Robert and Jack. wrote the paper. The authors declare no conflict of interest.

Acknowledgment

The authors express their deepest thanks and gratitude to the staff of Al-Mansour State Company at the Ministry of Industry and Minerals in Iraq for providing the effort, advice and knowledge during the entire period of this work, particularly, Ammar, N.; Saleh, W.; and Kamel, D. This is an example of a subheading This is normal text after the subheading.

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