Volume 4, Issue 12, pp. 51-53, 2020.
International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

Solar Panel Efficiency of Photovoltaic Cells

Fitria Hidayanti, Shaprizal Ibrahim
Engineering Physics Department, Universitas Nasional, Jakarta 12520, Indonesia
Email: fitriahidayanti @ gmail.com

***Abstract*— *Photovoltaic cells have been a major breakthrough invention in the field of energy science. Since the working principles to convert solar energy into electricity discovered, we gradually able to develop solar panel and thus use it as an alternative energy source, from the scale of the solar field to the ones that are used in residential buildings. Another problem that challenged engineers & scientists as the development of solar panel technology arose is efficiency: How can we extract as much solar energy as possible even from the low intensity of the sunlight exposure or other technical problems.*

***Keywords*— *Solar panel, photovoltaic cell, solar energy, alternative energy, solar panel efficiency, clean energy.*

I. Introduction

Solar panel which came from photovoltaic cells, a device that can harvest electricity from solar radiation, has been a major breakthrough invention in the field of energy science. We used to think if it's possible to harvest electricity from the solar energy back then. But with the discoveries of Compton effect by Albert Einstein, and other supporting theories about converting solar energy into electricity, and, with the continuous development of the semiconductor technologies, we were able to realize that particular concept to real life. We were finally able to convert solar radiation into electricity [1, 2].

But, despite the advantages of solar energy, we knew that solar energy had not been a major source of our daily needs of energy. We still use it as an alternative source of energy. There are several reasons regarding this. First, of course, the cost of implementing the energy source. The solar panel still tends to be expensive for the majority of people for its instalments and maintenance. People still tend to think why should they use solar panel if they can have another cheaper option for their daily needs of energy. Another reason that cannot be avoided is solar panel efficiency: the rate of how much photon energy from solar radiation that can be converted into electricity. Without continuous maintenance, the electricity that can be harvested from the solar panel will decline [3, 4].

The efficiency and power output of a solar panel module decrease at the peak of sunlight. This happens due to energy loss as heat energy [5]. The electrical yield of the solar panel is mainly affected by optical and thermal losses which caused by reflection and temperature variations [2]. Thus, when we talk about solar panel efficiency, we talk about minimizing that loss of energy problem as heat. There are several methods in decreasing heat of solar panel, which then will increase the solar panel efficiency. Those are water-cooling technique, coating technique, multi-concept cooling technique, etcetera. This paper will try to dig deeper on that topic on how to increase solar panel efficiency by reducing its heat loss. This paper will also be discussing how to extract maximum energy from a solar panel by adjusting its inclination angle to the horizontal plane.

II. Study Literature

A. Solar Energy

Amount of energy in the form of heat and radiations called solar energy. It's radiant light and heat from the sun that is a natural source of energy. Solar energy basically is heat, light, and electromagnetic energy produced by nuclear reaction inside the core of the sun and thus radiated through space. The large magnitude of solar power available makes the highly appealing source of electricity. 30% (approx.) solar radiation is back to space while the rest is absorbed by ocean, clouds and landmasses.

B. Working Principles of Solar Energy

Photovoltaic cells convert sunlight to DC electricity. Charge controller works as controller of the power from PV module, which reverses back to solar panel avoiding the panel damage. Battery system acts as storage of electric power (DC) and is used when sunlight is not available. This system then connected to an inverter which then converts DC electricity into Alternating Current (AC).

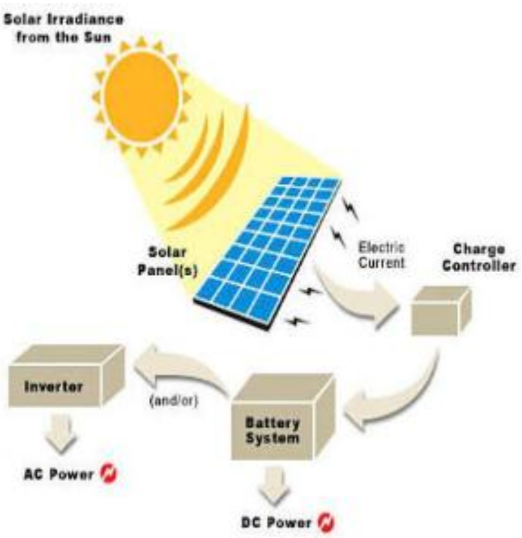

Fig. 1. Working Principles of Solar Panel [4]

International Journal of Scientific Engineering and Science
Volume 4, Issue 12, pp. 51-53, 2020. ISSN (Online): 2456-7361

C. Modelling of PV Panel

1. Solar cell

The cells convert solar energy directly into electricity. It consists of various kinds of semiconductor materials. It has two types: positive charge and negative charge. This cell technology is used to design solar cells with low cost as well as high conversion efficiency. When the cell absorbed photons from sunlight, electrons are excited from silicon atoms and are drawn off by a grid of metal conductors, pressure a flow of direct electric current.

2. PV module

A PV module consists of solar cell circuits sealed in an environmentally protective layer. PV modules are the building blocks of PV system. Generally, the power produced by a PV module varies from 60W to 170W. Usually, a number of PV modules are arranged in series and parallel to meet the amount of energy needed.

3. Solar panel

Solar panel includes one or more PV modules assembled as a pre-wind, field installable unit. In this panel, PV cell is arranged in series connections. Solar panels are made up of individual PV cells connected together.

4. Photovoltaic array

PV array contains of several PV cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module, whereas the parallel connection is responsible for increasing the current in the array. PV array generates a maximum of 180 watts power in full daylight. The larger total surface area of the array, the more electricity will be produced.

To sum up this section, here is an image that shows the differences between each component:

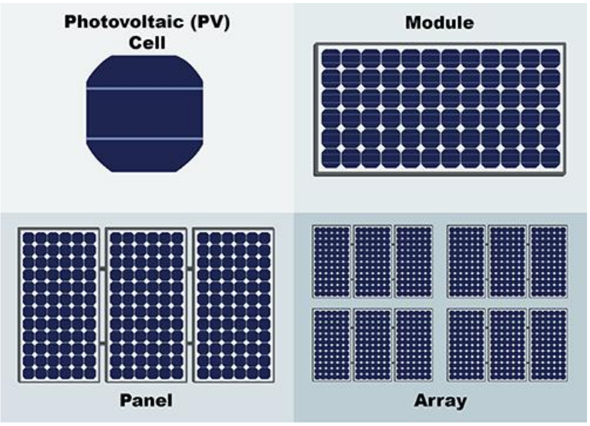

Fig. 2. PV Components Build up [2]

D. PV Module Efficiency

The temperature of a PV module, as well as the ambient temperature, affects a photovoltaic module efficiency and this is mainly because the module voltage and current depend on temperature. The photovoltaic module maximum power as expressed in Sethietal (2012) and Dubeyetal (2013) is

$$Pmp = Vmp \cdot Imp = Voc \cdot Isc \cdot FF \quad (1)$$

Where the PV module maximum power expressed as Pmp, the maximum voltage expressed as Vmp, maximum current as Imp, fill factor as FF, while Voc and Isc stand for open-circuit voltage and short circuit current, respectively. As the module temperature increases, the Isc rises a little bit while the fill factor and Voc reduce in magnitude. The efficiency of a PV cell as in Chikate and Sadawarte (2015) is the ratio of energy output obtained from the PV cell divided by the energy input provided by the sun as represented in Eq.(2).

$$\eta = Eout / Ein \quad (2)$$

The PV module efficiency can also take the form of Equation 3.

$$\eta = Pmax/E \cdot A \quad (3)$$

Where Pmax is the maximum power, E is the solar irradiance under STC (W/m^2) and A is the surface area of the module in m^2.

The efficiency of a solar cell can also be expressed using the relation in Kaldellisetal (2014) as

$$\eta pv = \eta rT [1 - \beta (Tpv - TrT)] \quad (4)$$

Where the efficiency of the PV cell is represented by ηpv, ηrT is the PV module efficiency at the reference temperature, which is usually 25˚C, Tpv is the temperature of the PV module cell, β represents the temperature coefficient of power and TrT is the reference temperature of the PV module or module cell [3].

E. Effect of Heat on PV Module

PV module exposed to sunlight, the temperature of the module increases. Also, heat generation started to occur in the process. When this heat reaches a point where the output of the PV module drops, overheating becomes obvious. This overheat process is one of the major challenges, which against PV module’s smooth operation. It is because of exposure to solar radiation and high-level ambient temperatures more than what is required. The overheating decreases the efficiency as well as the power output of the module. The efficiency, as well as the output power, reduces substantially as temperature rises, the extent of the reduction is a function of the material used to fabricate the solar cell.

In order to find a solution to this challenge of overheating and loss of valuable energy as heat, cooling of PV modules is required.

F. Increasing PV Efficiency

A lot of research has already done in the past and several others are ongoing on ways to tackle overheating problem. Heat energy can be lost from a Photovoltaic module through conduction, radiation and convection. Two major cooling techniques can be identified, namely Passive cooling, which requires natural means for heat removal without energy consumption and active cooling where energy consumption is needed for heat removal (GrubišićČaboetal.,2016).

Besides of passive and active cooling, we can also do the panel coating technique to overcome the overheating and thus increase solar panel efficiency. Another method that can be done but has nothing to do with the cooling mechanism is that we can adjust the inclination angle of the solar panel.

III. DISCUSSION

As we already talked in the previous chapter, there are several techniques that we can do in order to increase PV

International Journal of Scientific Engineering and Science
Volume 4, Issue 12, pp. 51-53, 2020. ISSN (Online): 2456-7361

efficiency. The first one is a cooling technique to overcome the overheating. The second one is the coating technique. And the third one is adjusting the inclination angle of the PV to get the maximum exposure to the sunlight. We will go deeper into those three techniques in this chapter.

A. Water-Cooling Techniques

Concentrating photovoltaics is used to integrate the extraction of light and thermal energy. The cooling water system provides effective cooling by circulating cold water to remove heat from the PV systems. The use of a water circulation cooling system improves photovoltaic power systems 2% to 15% and increases the efficiency of electricity production of photovoltaic 2.29% - 3.37%. Through the combined use of photovoltaic and thermal techniques, the total energy of the entire system can be improved by 37% -59% [3].

B. Coating Technique

As we have talked in the first chapter, one main reason why PV is still hasn't been the major source of our energy is due to its efficiency. And this inefficiency comes from energy dissipation from overheating. Besides the water-cooling technique that we have already talked in order to tackle overheating, we can also do the coating technique to block loss due to reflection. We do this by coating anti-reflective material to the solar panel. The anti-reflective materials that can be used as the second layer are aluminium oxide and tantalum pentoxide (Al_2O_3-Ta_2O_5-Al_2O_3). We can coat them to the solar panel. By using this method, the reflection loss can be reduced and efficiency can be increased to 14% [2].

We can refer to the following chart for the comparison of coated and uncoated PV and its efficiency.

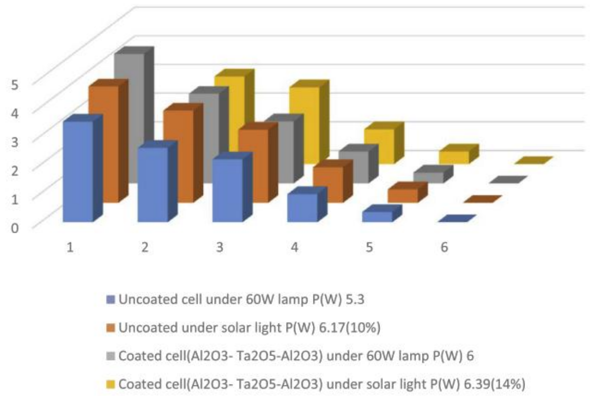

Fig. 3. Comparison of Coated and Uncoated PV Efficiency [5]

C. Adjusting Inclination Angle

Another method that we can use to increase PV efficiency is to frequently adjust its inclination angle to the horizontal plane to get the maximum exposure to the sunlight. By making this adjustment, sunlight should fall with a steep angle to extract maximum power from a solar panel. Note that this adjustment may vary across many regions in the world. As for this paper I have reviewed, the region that took place is in Khouribga city (latitude 32^{o}52' North and longitude -6^{o}54' West) and many major cities in Marocco.

From the research of constant adjusting of the inclination angle to the horizontal plane in the Khouribga city, we get the experimental data that shows how many fluxes that the solar panel get per month and how many energy is received.

The experimental data can be seen from the following table.

TABLE 1. Experimental Data from Khouribga City [1]

Experimental data of solar radiation from Khouribga city.

Month	No. of days	Days typical	Max flux kW/m^2	Energy received kWh/m^2
January	17	17	0,54	3,3
February	47	16	0,66	4,4
March	75	16	0,78	5,4
April	105	15	0,89	6,7
may	135	15	0,94	7,6
June	162	11	0,99	8,2
July	198	17	0,98	8,1
August	228	16	0,95	7,3
September	258	15	0,84	6,2
October	288	15	0,69	5,0
November	318	14	0,57	3,5
December	344	10	0,50	3,1

IV. CONCLUSION

Solar panel or photovoltaic cell efficiency is one of the major reason why it hasn't been widely used as a main source of energy as well as its instalment and maintenance cost. The second problem related to cost is what manufacturer of PV cells are trying to answer by doing continuous research in finding cheaper and cheaper material making up PV cell. But this paper isn't about the second problem rather about the first problem regarding the efficiency of PV cells. Many techniques have been found and applied in increasing PV cells efficiency. One main reason that cause inefficiency of the PV cell is overheating. It causes so much energy loss that the harvesting of electricity from solar energy process becomes inefficient. So, regarding minimizing the overheating, we got two techniques. The water-cooling techniques prove that it can increase the efficiency of the PV system to 59%. In comparison, the second technique is by coating PV cell by certain chemical layer. In this case, the coating materials are aluminium oxide and tantalum pentoxide (Al_2O_3-Ta_2O_5-Al_2O_3). This technique proves that it can increase efficiency to 14%. The third technique isn't related to blocking energy loss to heat frequently adjusting the PV panel itself by its inclination angle to the horizontal plane. The goal is to get a steep angle proportional to the sunlight angle. This technique also works in increasing efficiency.

REFERENCES

[1] Nfaoui, M., & El-Hami, K. (2018). Extracting the maximum energy from solar panels. *Energy Reports*, *4*, 536-545.

[2] Rajvikram, M., & Leoponraj, S. (2018). A method to attain power optimality and efficiency in solar panel. *Beni-Suef University journal of basic and applied sciences*, *7*(4), 705-708.

[3] Sahu, C. K., & Patel, S. (2016). Improvement of Conversion Efficiency and Enhancement in Output Power of Solar Panel. *International Journal of Science and Research (IJSR)*, *5*(3), 56-59.

[4] Idoko, L., Anaya-Lara, O., & McDonald, A. (2018). Enhancing PV modules efficiency and power output using multi-concept cooling technique. *Energy Reports*, *4*, 357-369.

[5] Shaikh, Mohd Rizwan & Shaikh, Sirajuddin & Waghmare, Santosh & Labade, Suvarna & Tekale, Anil. (2017). A Review Paper on Electricity Generation from Solar Energy. International Journal for Research in Applied Science and Engineering Technology. 887. 10.22214/ijraset.2017.9272.