Design and Build Solar Panel Temperature Control Using the Water Spray System Method

Hengki Sardi Tanjung, Hamdani

Abstract

This study discusses the design and testing of solar panel temperature control systems using the water spray system method as an effort to improve energy conversion performance and efficiency. Solar panels have limited efficiency due to rising temperatures that can lower the output voltage. The system is designed using temperature sensors, sprinkler pipes, as well as mechanical controls that manually regulate water splashes to lower the surface temperature of the panels. Testing was carried out on two solar panels, namely panels with water splashes and panels without water splashes. The results showed that the temperature of the cooled solar panels decreased significantly, on average from 52°C to about 32°C. This temperature drop has an impact on increasing the electrical voltage from the range of 18.6 Volts to more than 20 Volts. Thus, the water splash method has proven to be effective as a simple cooling system that can improve the performance of solar panels and potentially extend their operational life.

Keywords: Solar Panels, Temperature, Water Splash, Cooling, Electrical Voltage

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Introduction

Potential alternative energy sources, especially seen from the source that emits enormous energy and its long time. In addition, it is hoped that solar energy can be used as an environmentally friendly source of electrical energy. If this energy can be managed properly, it is hoped that the community's needs for energy can be met.

A device that can directly convert sunlight into electricity is called a photovoltaic. The main material used in the manufacture of photovoltaic is silicon. There are also other materials that are also developed with the aim of reducing (minimizing) prices and to increase efficiency.

Solar cells are a semiconductor element that can convert solar energy into electrical energy. A solar module is a collection of several solar cells, and a solar panel is a collection of several solar modules. The voltage and electric current generated by solar cells are influenced by two physical variables, namely the intensity of sunlight radiation and the ambient temperature. The intensity of sunlight radiation received by solar cells is proportional to the voltage and electric current generated by solar cells, while if the ambient temperature is higher with a constant intensity of sunlight radiation, the voltage of the solar panel will decrease and the resulting electric current will increase [1].

These changes in the temperature of the solar cells are caused by temperature, cloud conditions and wind speed in the environment around the solar panel placement area. Even very rapid and extreme temperature changes can cause disruption in electricity production in a Solar Power Plant. In the JOURNAL OF PROCESS TECHNOLOGY AND INDUSTRIAL INNOVATION, VOL. 2, NO. 1, NOVEMBER 2016, with the title The Effect of Temperature/Temperature on the Voltage Produced by Monocrystalline Type Solar Panels (Case Study: Baristand Industri Surabaya) concludes, that the electrical voltage generated by a solar panel does not only depend on the amount of radiation intensity it receives, but the increase in temperature on the surface of the solar panel can also reduce the amount of electrical voltage.

From here, the author got the idea to make a tool entitled, DESIGN AND BUILD SOLAR PANEL TEMPERATURE CONTROL USING THE WATER SPRAY SYSTEM. Functions to lower the temperature of the solar panel surface by watering method using water as coolant.

Literature Review

Solar Energy

The Sun is a solid sphere formed from very hot gaseous material with a diameter of 1.39 x 109 m and the distance of the sun to the earth is 1.5 x 1011 m [1]. The Sun has a density of about 100 times the specific gravity of water. The temperature in the central part of the sun is 8 x 106 K. Solar energy is generated in the region of 0 to 0.23R, where about 40% of the sun's mass is contained in that region.

The distance between the sun and the earth always varies throughout the year, varying from 1.47 x 108 km to 1.52 x 108 km so that the irradiance fluctuates between 1.325 W/m2 to 1412 W/m2. The average value of irradiance is called the solar constant. GSC solar constant = 1.367 W/m2. The radiation energy emitted by the sun is very large, which is 1000 W/m2 in sunny weather conditions. However, maximum insolation occurs when the weather is sunny and partly cloudy, which can reach 1,400 W/m2 because solar radiation is reflected by clouds.

The sun's energy reaches the earth's surface through an electromagnetic wave or called radiation. Solar radiation has a wavelength of 0.29 to 2.5 µm.

The radiation received by the Earth's surface varies according to its space and time. What this means is that solar radiation depends on the climatic conditions of each region. Every year, solar radiation that reaches the earth's surface is about 3.9 x 1024 Joules to 1.08 x 1018 kWh, then the energy absorbed by the atmosphere, oceans, and land is about 3,850,000 EJ per year, which can be interpreted that the energy that the earth receives from the sun is more than the availability of energy sources on earth. Solar radiation that reaches the earth's surface consists of various including:

1. Direct Solar Radiation, which is direct radiation from the sun that shines on the earth
2. Diffuse radiation, which is radiation that comes after being scattered or reflected by atmospheric molecules in clouds.
3. Surface Reflectivity, which is radiation that comes from the reflection of the earth's surface.

Photovoltaic

Photovoltaic comes from the English word "Photo Voltaic". In Greek, the word photovoltaic comes from two words, namely "photo" which means light and "volt" which means the name of the unit of measurement of electric current. If these two words are combined, then the definition of photovoltaic is a semiconductor material that can directly convert sunlight into electrical energy. Photovoltaic has been known in the 18th century, precisely since 1849.

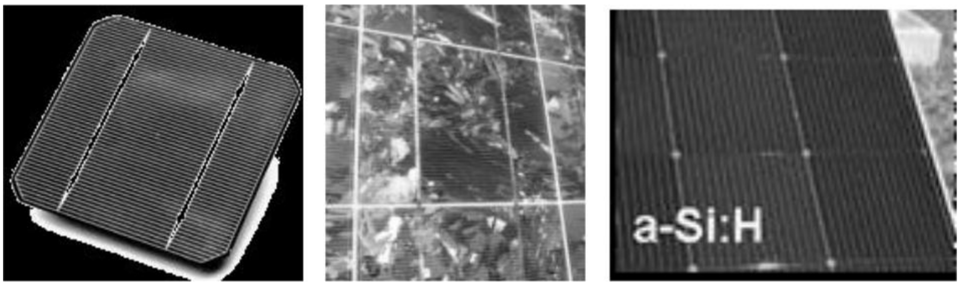
In 1839 sunlight and electric power were discovered by a physicist named Alexandre – Edmund Becquerel. Initially, the experiment was carried out by shining 2 electrodes with different lights. The electrodes are coated with light-sensitive materials and are carried out inside a black box. In the experiment, it was found that the electrical power increased as the intensity of the light increased. The word is combined, the definition of photovoltaic is a semiconductor material that can directly convert sunlight into electrical energy.

Photovoltaic has been known in the 18th century, precisely since 1849. In 1839 sunlight and electric power were discovered by a physicist named Alexandre – Edmund Becquerel. Initially, the experiment was carried out by shining 2 electrodes with different lights. The electrodes are coated with light-sensitive materials and are carried out inside a black box. In the experiment, it was found that the electrical power increased as the intensity of the light increased. In 1873, Willoughby Smith, a British engineer, discovered Selenium, an element of photoconductivity. In 1876 William Gryls and Richard Evans Day proved that Selenium could produce an electric current if it was illuminated with sunlight.

Selenium can convert solar energy into electricity. Furthermore, Charles Fritts in 1883 made the first Solar Cell with selenium material wrapped in a thin layer of gold, producing an efficiency of less than 1%. In 1905 Albert Einsten revealed that light is made up of a "quanta of energy" called photons. Then in 1916 Einsten's opinion was proven by a physicist, Robert Ndrew Milikikan. In 1927 the development of photovoltaic was designed using copper and copper oxide semiconductors, but still produced an efficiency of less than 1%. In 1941 Russel Ohl developed a modern solar cell using silicon material and produced an efficiency of about 4%. Furthermore, in 1954 Bell Laboratories developed solar cells to achieve an efficiency of 6% to 11%. In 1960 a photovoltaic material was discovered, namely gallium arsenide which could operate at high temperatures but the resulting cost was more expensive. (Kalogirou, 2004). Until 1980, solar cells could not be used because the efficiency produced was still low, which was still below 10%. In 1985 the efficiency of the sollar cell was raised to 20% under sunlight by the University of South Wales Australia.

Then the experiment was carried out again in the laboratory and produced a solar cell with an efficiency of more than 30% but has not been commercialized due to the very high cost. (Kalogirou, 2004) Furthermore, in 2007, the University of Delaware found a solar cell with an efficiency of 42.8%. Research and development of solar cells from the 18th to the 20th centuries encouraged commercialization in the production of solar cells as an electrical resource. Years of solar cell research have given rise to new innovations in semiconductor materials used in solar cells, among which can be seen in Figure 1.

1. Mono-crystalline (Si), monocrystalline is a material made from thinly sliced crystal bars. The resulting efficiency of monocrystalline reaches 15-20%. For now the manufacture of monocrystalline can reach a thickness of 200 microns and produce an efficiency of 24%.
2. Polycrystalline (Si), polycrystalline is a material made from several silicon crystal rods that are then melted and molded in a square mold. The process of making polycystalline is easier compared to monocrystalline so the price of polycrystalline is cheaper. The resulting efficiency of polycrystalline reaches 18% [2].
3. Thin-film Solar Cell (TFSC)/ Thin-film Photovoltaic Cell (TFPF), terdiri dari beberapa jenis bahan dasar diantarana A-Si:H, CdTe, dan CIGs. Efisiensi yang dihasilkan dari modul surya thin-film adalah 6,5 – 8%.



(a) (b) (c)

Figure 1. Types of solar cell materials (a) monocrystalline, (b) polycrstalline, (c) thin film

The types of solar cells with integrated silicon material (thin film) include the following:

1. Single crystalline, is a crystal that has one type and produces very high efficiency.
2. Polycrystalline, is a crystal with many types made of silicon crystals with an efficiency of 10 – 12%.
3. Amorphous Silicon (a-Si), an amorphous material that does not wear crystalline or non-crystalline with the resulting efficiency is about 4 – 6%.
4. Cadmium Telluride (CdTe), is formed from polycrystalline thin film material by depositing, spraying, and evaporation. The efficiency produced by the bajan reaches 16%.
5. Copper Indium Diselenide (CIS), is a material derived from polycrystalline with a resulting efficiency of 17.7%[2]

Research Methodology

The method in this study involves design and analysis techniques, which require the creation of a model or the formation of a research object. The object of this research will then be tested. In this study, the object of the research is a tool to control the temperature of solar panels using the water splash method. Water splashes serve to lower the temperature of the solar panels. When the temperature of the solar panel decreases, the performance of the solar panel is expected to be more optimal so that it can increase the electrical voltage.

Flow Chart

The research flow is shown in the following flowchart which explains the stages from tool preparation to data analysis

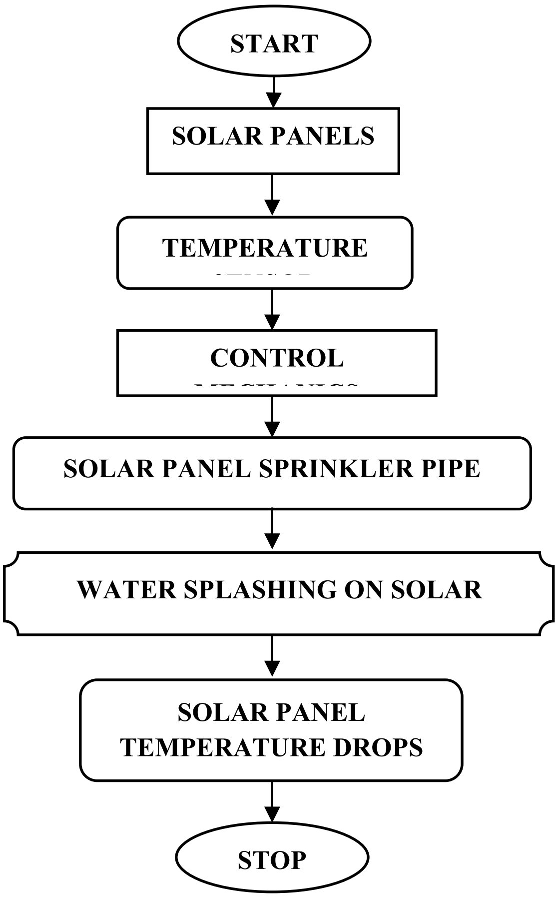


Figure 2. Flow Chart

Design

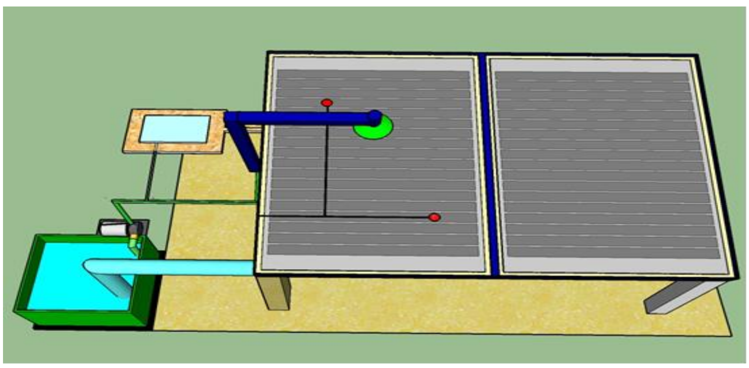


Figure 3. Design

Results

This research presents a practical approach in controlling the temperature of solar panels through a manual water splash system. The designed tool functions to lower the temperature of the panel and allows the analysis of the effect of cooling on the performance and efficiency of the panel. The working principle of the device is based on photovoltaic technology, in which the solar panels convert sunlight into electricity, but the efficiency decreases when the operating temperature exceeds the optimal limit of about 25°C [3].

Solar panels are generally only capable of converting about 15% of the sun's energy into electricity, while the rest is converted into heat. The high temperature conditions not only reduce the output voltage, but also accelerate the degradation of panel materials thereby reducing the service life [4]. Therefore, a cooling system is needed to keep the temperature of the panel in the optimal range of 15–35°C.

The water splash method has proven to be an effective strategy to overcome this problem. Cooling with water can quickly lower the temperature and increase the productivity of the solar panels. In this study, two panels were used to compare performance: a panel with water splash cooling and a panel without cooling. The test results show that manual water cooling is able to lower the temperature while increasing the voltage, so that the efficiency of the solar panels can be maintained at a more optimal level.

Figure 4. Design Results

Test Results

To ensure the effectiveness of solar panel coolers, systematic testing is carried out with the water splash method. The test was carried out for five hours, from 10.00 to 15.00 WIB in Medan Helvetia, Medan City, under optimal sun exposure conditions. Temperature and voltage data are recorded periodically to evaluate the performance of the panels with and without cooling. The results of the observations are tabulated so as to show a direct relationship between the temperature of the panel and its voltage output.

Table 1. Temperature and Voltage on Panel 1 and Panel 2

O'clock	PANEL 1		PANEL 2	
	TEMPERATURE	V	TEMPERATURE	V
10.00	38.6	20.1	39.2	19.7
10.30	52.6	19.1	52.7	18.8
11.00	54.8	19.2	54.3	18.9
11.30	53.4	18.9	54.1	18.8
12.00	51.3	19.1	51.8	18.8
12.30	50.8	18.8	51.3	18.6
13.00	52.6	19.3	52.4	18.9
13.30	53.2	19.1	53.5	18.7
14.00	51.6	18.9	52.2	18.6
14.30	52.3	19.0	52.5	18.7
15.00	50.8	19.2	51.3	19.8

The test was carried out from 10.00 to 15.00 WIB by comparing the temperature and voltage of two panels, namely the uncooled panel and the panel with water splash cooling. The data show an inverse relationship between temperature and voltage: the higher the panel temperature, the output voltage decreases. This phenomenon is caused by an increase in reverse saturation current as well as a decrease in semiconductor band gaps at high temperatures, which has an impact on reduced solar panel efficiency [5].

The results confirm that solar panels can only work optimally within a certain temperature range, generally around 25°C. When the temperature exceeds the optimal limit, performance decreases so a cooling system is required. In this study, cooling was carried out by the manual water splash method, which was proven to be able to lower the temperature of the panel and ultimately increase the resulting electrical voltage. Thus, the water splash system plays an important role in maintaining the efficiency and productivity of solar panels.

Figure 5. Water Splash Method

Figure 5 shows two solar panels, one of which is splashed with water through a sprinkler pipe connected to a reservoir, while the other panel is left uncooled. The effect of cooling on the temperature drop of the panel is shown in Table 4.2.

Table 2. Solar Panel Temperature Before and After Water Splash

JAM	TEMPERATURE	
	SEBELUM	AFTER
10.30	52.7	30.3
11.00	54.3	32.5
11.30	54.1	32.8
12.00	51.8	33.2
12.30	51.3	31.6
13.00	52.4	32.2
13.30	53.5	24.6
14.00	52.2	31.4
14.30	52.5	32.2
15.00	51.3	33.2

Based on Table 2, the temperature of the solar panel decreased significantly after being given a splash of water. In the range of 10.30–15.00 WIB, the temperature of the panel which was originally in the range of 51–55°C dropped to 24–33°C after cooling. This consistent pattern demonstrates the effectiveness of the water splash method in rapidly lowering the temperature and keeping the panel in optimal operating condition.

These results are in line with research [6], which proves that the water cooling system is able to significantly reduce the temperature of the panel and improve the energy conversion efficiency. The cooling effect of water is attributed to the evaporation mechanism, in which evaporated water absorbs heat from the panels. Thus, water splashes play an important role in maintaining the temperature of the solar panels, which in turn increases the voltage and efficiency of the system.

Furthermore, this study also compares the voltage before and after cooling (Table 3) to confirm the effect of temperature drop on the increase in output voltage.

Table 3. Electrical Voltage Before And After Water Splash

JAM	V	
	BEFORE	AFTER
10.30	18.8	20.3
11.00	18.9	20.1
11.30	18.8	20.1
12.00	18.8	20.3
12.30	18.6	20.1
13.00	18.9	20.2
13.30	18.7	19.8
14.00	18.6	20.1
14.30	18.7	20.2
15.00	19.8	20.0

Based on Table 3, the voltage of the solar panel increases consistently after being splashed with water in the time range of 10.30-15.00 WIB. Before cooling, the voltage was recorded in the range of 18.6–19.8 V, while after cooling it increased to 19.8–20.3 V. This pattern shows that cooling with water contributes significantly to the increase in the output voltage of the solar panel.

This effect is caused by a decrease in panel temperature that keeps the operating conditions optimal, so that energy conversion efficiency is increased. In addition, cooling can also help improve the surface conductivity of the panel, which favors better electron flow. Thus, the water splash method is proven to not only lower the temperature of the panels, but also increase the resulting electrical voltage. A more detailed comparison between the panels with and without cooling is shown in Table 4. Tabel 4 Perbandingan antara Panel 1 dan Panel 2.

Table 4. Comparison between Panel 1 and Panel 2

JAM	PANEL 1		PANEL 2			
	TEMPERATURE	V	TEMPERATURE		V	
			BEFORE	AFTER	BEFORE	AFTER
10.30	52.6	19.1	52.7	30.3	18.8	20.3
11.00	54.8	19.2	54.3	32.5	18.9	20.1
11.30	53.4	18.9	54.1	32.8	18.8	20.1

12.00	51.3	19.1	51.8	33.2	18.8	20.3
12.30	50.8	18.8	51.3	31.6	18.6	20.1
13.00	52.6	19.3	52.4	32.2	18.9	20.2
13.30	53.2	19.1	53.5	24.6	18.7	19.8
14.00	51.6	18.9	52.2	31.4	18.6	20.1
14.30	52.3	19.0	52.5	32.2	18.7	20.2
15.00	50.8	19.2	51.3	33.2	19.8	20.0

Table 4 shows the clear performance difference between the uncooled panel (Panel 1) and the panel with water splash cooling (Panel 2). Panel 1 consistently recorded higher temperatures and lower voltages, while Panel 2 showed lower temperatures and higher voltages throughout the test time. This pattern confirms that cooling with water splashes plays a significant role in lowering the temperature while increasing the solar panel's output voltage.

These findings are in line with research [7], which states that the water splash method is the most effective cooling technique in improving the performance of solar panels, even at low flow rates. Thus, the water splash system has proven to be efficient as a temperature control mechanism that is able to optimize the operational efficiency and productivity of solar panels in accordance with the research objectives.

Conclusion

The conclusion of this study shows that the water splash method has proven to be effective as a cooling technique to control the temperature of solar panels. The application of water splashes is able to significantly lower the surface temperature of the panel, thus having a direct impact on improving the performance of the panel. The temperature drop achieved through this method has been shown to increase the generated electrical voltage, where the panels given water splashes show a lower temperature and a higher voltage compared to the panels without cooling. Overall, the water splash method successfully fulfills its purpose of keeping the panel temperature stable as well as increasing the output voltage, thus confirming its important role in improving the efficiency and functionality of solar panels.

Suggestion

1. Conduct further research to optimize water splash techniques by exploring different water flow rates, angles, and frequencies to determine the most efficient cooling parameters for solar panels.
2. Investigate the long-term effects of water splashes on the performance of solar panels to assess durability, maintenance requirements, and potential impacts on the life of the panels.
3. Integrating the water splash system with intelligent technologies such as automation to develop adaptive cooling solutions that respond dynamically to environmental conditions to maximize the performance of solar panels as well as the voltage generated.

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