EFFICIENCY ANALYSIS OF SOLAR PANELS AS ALTERNATIVE ELECTRICITY SOURCES BASED ON FUZZY LOGIC

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Abstract. One of the potential renewable energy sources in Indonesia is solar energy. Indonesia, which is passed by the equator, has abundant sources of solar energy with an average solar radiation intensity of around 4.5 kWh/m2 per day throughout the region. In addition to the high cost of components and installation, the efficiency of solar cells is still low. Increasing the temperature of the solar panels due to continuous heating can reduce the efficiency of the panels. The decrease in solar cell efficiency is about 0.5% for an increase in the surface temperature of solar cells by 1o C. Therefore, the addition of a proper cooling system in solar power plants can also improve efficiency and increase the output power of solar panels. This research will design the efficiency of solar power generation system with fuzzy logic. The input system has an LDR sensor to move the solar panel to follow the direction of the sun, a temperature sensor as an input to control the temperature of the solar panel. From this study, it was found that solar panels with a solar tracker and cooling based on fuzzy logic obtained an efficiency percentage of 15,51%.

Keyword: efficiency, solar panels, fuzzy logic

1. Introduction

In Indonesia, the main energy sources for power generation come from fossil fuels, such as oil, natural gas, and coal. In 2020, energy sources for power generation from coal in Indonesia reached 38.46%, followed by oil (32.82%), natural gas (17.44%), renewable energy power plants (11.28%), biodiesel (3.85%), and the rest from various other renewable energy sources.[1]. In addition to depleting reserves, the use of fossil fuels also causes pollution and can lead to global warming [2]. Therefore, efforts to utilize renewable energy as an alternative energy source in Indonesia have now become a priority in the national energy policy.

One of the potential renewable energy sources in Indonesia is solar energy. Indonesia has abundant sources of solar energy with an average solar radiation intensity of around 4.5 kWh/m2 per day throughout Indonesia[3][4]. The potential for the construction of solar power plants using solar panels (photovoltaic cells) in remote locations or areas not covered by the electricity grid is still wide open, but there are obstacles related to the construction of this power plant. In addition to the high cost of components and installation, the efficiency of solar cells is still low [5]. Only a small part of solar energy, a maximum of about 24%, can be converted into electricity by PV cells[6].

There are several ways to increase the efficiency of solar panels: 1) making solar trackers[7][8], adding coolers to solar panels[9][10], and adding artificial intelligence such as fuzzy logic[11] and others.

This paper purpose to improve the efficiency of solar panels by incorporating a solar tracker, a solar panel cooler based on fuzzy logic.

1. Methods

This research method is presented in the system block diagram. Figure 1 is a Solar Tracker and coolant PV based fuzzy logic design, divided into input, process and output. On the input side there is an LDR sensor and a DS18B20 temperature sensor as a detector of the intensity of sunlight and the temperature value of the solar panel. The input data is processed using Fuzzy control in Arduino Uno. The output consists of an actuator motor and a DC water pump. The actuar motor output is used to drive the solar panels following the direction of the sun and a DC water pump to cool the solar panels when the temperature rises and lowers the efficiency of the solar panels. The PZEM 004T sensor is a sensor that is used to read the value of the voltage and electric current generated by the solar panel after it is controlled with fuzzy logic. The working steps of the tool are shown in figure 2.

LDR

INPUT

PROSES

OUTPUT

ARDUINO UNO

Relay+Motor Actuator A

DS18B20

Fuzzy Logic

Pompa air DC

PZEM 004T

Figure 1. Block Diagram of Solar Tracker and coolant PV based fuzzy logic

A brief process of the System of Solar Tracker and coolant PV based on fuzzy logic is presented in Figure 2 starting from the initialization of the input and output hardware. The LDR sensor reads the value of the sun's light intensity and the DS18B20 sensor reads the solar panel temperature value. From the input value, fuzzy logic control will be processed with the stages of fuzzification, fuzzy rule and defuzzification to get the decision value of the actuator motor movement and the duration of the active DC water pump. This actuator control is set to get the highest solar panel efficiency value by reading the voltage and current values. As for getting the efficiency of solar panels used the formula:

(1)

Description :

: Solar cell efficiency (%)

Ir : Intensity of solar radiation (Watt/m2)

P : The output power generated by the solar cell (Watts)

A : The surface area of ​​the photovoltaic module (m2)

The solar panels used are 20 WP polycrystaline solar panels with the following specifications:

Modul Type: SP-20-P36

Rated max power (Pmax) : 20W

Current at Pmax(Imp) : 1,15A

Voltage at Pmax (Vmp) : 17,4V

Short circuit (Isc) : 1,13 A

Open circuit voltage (Voc) :22,4V

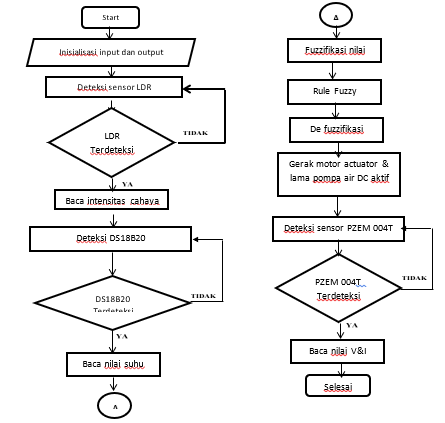
Dimension (mm) : 490x350x25

Number of cells : 36

Max system voltage : 700V

Temperature range : -45°C ~ +80°C

There are 2 solar panels with different treatments, the first using a solar tracker and coolant based on fuzzy logic. The second panel without treatment (static).



**Figure 2**. Flow Chart System of Solar Tracker and coolant PV based on fuzzy logic

1. Result

The test on this solar panel was carried out for 7 days (3-9 January 2022) with 2 stages, namely a solar panel designed to be static by placing 30° to the east under the sun and a solar panel designed with a solar tracker and coolant (dynamic). The data that the authors took for 8 hours with an average solar radiation of 1000 W/m2 (global light intensity at maximum radiation). The test in table 1 below aims to determine the maximum voltage capacity and maximum current capacity of the solar panels used. Tests for open-circuit voltage (Voc) and short-circuit current (Isc).

**Table 1**. Measurement of open-circuit voltage, short-circuit current and light intensity under static and dynamic conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Waktu**  **(Jam)** | **Statis** | | | **Dinamis** | | |
| **Voc (V)** | **Isc (A)** | **Intensitas (Lux)** | **Voc (V)** | **Isc (A)** | **Intensitas (Lux)** |
| **8.00** | 20.11 | 1.85 | 2260 | 20.32 | 1.81 | 3059 |
| **8.30** | 20.14 | 1.87 | 3140 | 20.42 | 1.83 | 4480 |
| **9.00** | 20.11 | 1.86 | 4780 | 20.56 | 1.85 | 6800 |
| **9.30** | 20.18 | 1.86 | 9100 | 20.60 | 1.87 | 9250 |
| **10.00** | 20.07 | 1.86 | 8850 | 20.72 | 1.89 | 9640 |
| **10.30** | 20.09 | 1.86 | 9000 | 20.77 | 1.91 | 9920 |
| **11.00** | 20.27 | 1.88 | 10320 | 20.82 | 1.91 | 10750 |
| **11.30** | 20.28 | 1.90 | 10260 | 20.80 | 1.92 | 11800 |
| **12.00** | 20.37 | 1.95 | 11990 | 20.92 | 1.99 | 13850 |
| **12.30** | 20.35 | 1.90 | 10990 | 20.90 | 1.96 | 12560 |
| **13.00** | 20.34 | 1.87 | 10750 | 20.77 | 1.90 | 11300 |
| **13.30** | 20.32 | 1.87 | 9190 | 20.66 | 1.85 | 10450 |
| **14.00** | 20.17 | 1.87 | 8660 | 20.62 | 1.84 | 9840 |
| **14.30** | 20.19 | 1.87 | 6640 | 20.59 | 1.83 | 8400 |
| **15.00** | 20.11 | 1.86 | 5220 | 20.52 | 1.81 | 6800 |
| **15.30** | 18.89 | 1.73 | 3080 | 20.44 | 1.79 | 5500 |
| **16.00** | 18.74 | 1.70 | 2440 | 20.40 | 1.76 | 4560 |

The next test is a test with a load and the following data are obtained:

**Table 2**. Measurement of voltage and current in batteries under static and dynamic load

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Statis** | | | | **Dinamis** | | | |
| **Waktu (Jam)** | **Vm (V)** | **Im (A)** | **P (Watt)** | **Vm (Volt)** | | **Im (A)** | **P (Watt)** |
| **8.00** | 13.32 | 1.17 | 15.69 | 13.07 | | 1.28 | 16.57 |
| **8.30** | 13.39 | 1.19 | 15.89 | 13.17 | | 1.31 | 17.10 |
| **9.00** | 13.44 | 1.22 | 16.09 | 13.27 | | 1.41 | 18.55 |
| **9.30** | 13.39 | 1.29 | 17.07 | 13.32 | | 1.53 | 20.22 |
| **10.00** | 13.34 | 1.33 | 17.88 | 13.43 | | 1.61 | 21.46 |
| **10.30** | 13.33 | 1.33 | 18.00 | 13.52 | | 1.75 | 23.49 |
| **11.00** | 13.34 | 1.32 | 17.56 | 13.53 | | 1.76 | 23.64 |
| **11.30** | 13.38 | 1.37 | 18.43 | 13.57 | | 1.77 | 23.85 |
| **12.00** | 13.45 | 1.56 | 20.78 | 13.70 | | 1.89 | 25.72 |
| **12.30** | 13.37 | 1.45 | 19.40 | 13.67 | | 1.83 | 24.84 |
| **13.00** | 13.27 | 1.37 | 18.29 | 13.42 | | 1.71 | 22.78 |
| **13.30** | 13.25 | 1.35 | 17.87 | 13.32 | | 1.66 | 21.95 |
| **14.00** | 13.24 | 1.33 | 17.72 | 13.30 | | 1.66 | 21.91 |
| **14.30** | 13.24 | 1.30 | 17.21 | 13.28 | | 1.61 | 21.22 |
| **15.00** | 12.88 | 1.24 | 16.22 | 13.17 | | 1.58 | 20.65 |
| **15.30** | 12.83 | 1.20 | 15.39 | 13.10 | | 1.36 | 17.66 |
| **16.00** | 12.81 | 1.17 | 14.72 | 12.93 | | 1.26 | 16.14 |

The efficiency of solar panels is influenced by the area of ​​​​the solar panels and the charge factor (FF). The area of ​​​​the solar panel according to the data is 490mm x 350mm = 171500mm2 = 0.1715 m2 . In calculating the filling factor (FF) is as follows:

(2)

By entering the second formula, the filling factor for static and dynamic conditions is obtained as follows:

**Table 3**. Calculation of static and dynamic state fill factor values

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Statis** | | | | | **Dinamis** | | | | |
| **Waktu (Jam)** | **Vm (V)** | **Im (A)** | **Voc (V)** | **Isc (A)** | **FF Statis** | **Vm (V)** | **Im (A)** | **Voc (V)** | **Isc (A)** | **FF Dinamis** |
| **8.00** | 13.32 | 1.17 | 20.11 | 1.85 | 0.42 | 13.07 | 1.28 | 20.32 | 1.81 | 0.46 |
| **8.30** | 13.39 | 1.19 | 20.14 | 1.87 | 0.42 | 13.17 | 1.31 | 20.42 | 1.83 | 0.46 |
| **9.00** | 13.44 | 1.22 | 20.11 | 1.86 | 0.43 | 13.27 | 1.41 | 20.56 | 1.85 | 0.49 |
| **9.30** | 13.39 | 1.29 | 20.18 | 1.86 | 0.46 | 13.32 | 1.53 | 20.60 | 1.87 | 0.53 |
| **10.00** | 13.34 | 1.33 | 20.07 | 1.86 | 0.48 | 13.43 | 1.61 | 20.72 | 1.89 | 0.55 |
| **10.30** | 13.33 | 1.33 | 20.09 | 1.86 | 0.47 | 13.52 | 1.75 | 20.77 | 1.91 | 0.60 |
| **11.00** | 13.34 | 1.32 | 20.27 | 1.88 | 0.46 | 13.53 | 1.76 | 20.82 | 1.91 | 0.60 |
| **11.30** | 13.38 | 1.37 | 20.28 | 1.90 | 0.48 | 13.57 | 1.77 | 20.80 | 1.92 | 0.60 |
| **12.00** | 13.45 | 1.56 | 20.37 | 1.95 | 0.53 | 13.70 | 1.89 | 20.92 | 1.99 | 0.62 |
| **12.30** | 13.37 | 1.45 | 20.35 | 1.90 | 0.50 | 13.67 | 1.83 | 20.90 | 1.96 | 0.67 |
| **13.00** | 13.27 | 1.37 | 20.34 | 1.87 | 0.48 | 13.42 | 1.71 | 20.77 | 1.90 | 0.59 |
| **13.30** | 13.25 | 1.35 | 20.32 | 1.87 | 0.47 | 13.32 | 1.66 | 20.66 | 1.85 | 0.58 |
| **14.00** | 13.24 | 1.33 | 20.17 | 1.87 | 0.47 | 13.30 | 1.66 | 20.62 | 1.84 | 0.57 |
| **14.30** | 13.24 | 1.30 | 20.19 | 1.87 | 0.46 | 13.28 | 1.61 | 20.59 | 1.83 | 0.56 |
| **15.00** | 12.88 | 1.24 | 20.11 | 1.86 | 0.43 | 13.17 | 1.58 | 20.52 | 1.81 | 0.49 |
| **15.30** | 12.83 | 1.20 | 18.89 | 1.73 | 0.47 | 13.10 | 1.36 | 20.44 | 1.79 | 0.48 |
| **16.00** | 12.81 | 1.17 | 18.74 | 1.70 | 0.47 | 12.93 | 1.26 | 20.40 | 1.76 | 0.45 |

By entering the 1st formula in table 3, the static and dynamic solar panel efficiency values ​​are shown in Figure 3.

**Figure 3**. the static and dynamic solar panel efficiency values

1. Conclusion

Based on the calculation of solar panel efficiency statically and dynamically, the highest efficiency value increased by 4.2% from the static efficiency value of 11.3% and dynamic efficiency of 15.51%.

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