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Optimization of Renewable Energy from Solar Panels for Environmental Monitoring Using Arduino

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ABSTRACT

Renewable energy is an alternative energy amid the issue of fossil-based energy running out. One of these alternative energies is solar panels that generate electricity to achieve environmentally friendly energy. The problem researched in this study is the need to optimize or energy efficiency of solar panels. The type of research is development research with a prototype model. This study aims to optimize the efficiency of the solar panel tracking system equipped with artificial intelligence and sensors to monitor the environment based on the Internet of Things. This research method integrates fuzzy logic Internet of Things for tracking solar panels based on light sensor input. The use of solar panels using polycrystalline types and the addition of temperature and humidity sensors is important to utilize. The result of this study is that the highest efficiency is obtained at 9.96%, meaning that the energy received by the system is 9.96% into useful power that is lost. In conclusion, solar panels depend highly on weather conditions and are the focal point of solar energy capture. This study implies that improving environmentally friendly energy efficiency, although not too high, can be further developed.

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1. INTRODUCTION

Technology has developed rapidly over time, followed by the development of energy used as a form of environmentally friendly energy application. Fossil-based energy will gradually begin to be abandoned because fossil-based energy is known to scientists to run out in the future. Renewable energy is an alternative to keep energy sustainability going. There are many types of renewable energy, including solar energy, wind energy, water energy, seawater waves, biofuels, biomass, and geothermal [1]. Electrical energy that has begun to be developed comes from solar and wind energy. Solar energy is one of the energies of concern because it is environmentally friendly. Indonesia is rich in natural energy that needs to be developed and is now the main thing to pay attention to. One of the renewable energies is solar energy, which is converted into electrical energy through solar panel technology. Renewable energy is energy that does not pollute the atmosphere [2]. This energy is easy to obtain because it comes from direct sunlight and can be applied. Solar energy is an alternative need in a place where it is difficult to get electricity. Many types of solar panels can be used to make a source of electrical energy. First, monocrystalline solar panels made of single silicon paper have an efficiency of 20%, are highly valued, and are used commercially. Second, polycrystalline solar panels have an efficiency of 15%, which is fairly cheap and sensitive to hot temperatures. Third, thin film amorphous solar panels made of semiconductors, often called flexible solar panels, have an efficiency ranging from 7% to 10%, are cheap and easy to use and adaptive, but have a short time. Fourth, concentrated PV cells have good performance and efficiency but require solar tracking and cooling systems [3]. The number of solar panels in Indonesia will be an energy need in every region. Environmentally friendly electrical energy is necessary to benefit the community.

Solar energy is an environmentally friendly natural energy and has reliability in producing electrical energy [4]. Solar energy is used for agriculture, electricity, energy storage, batteries, etc. Indonesia is a tropical region that crosses the equator and is an important area for using solar energy. Solar panels are a breakthrough made by scientists to provide environmentally friendly technology updates. These solar panels contain cells consisting of semiconductors such as silicon that can absorb sunlight energy and can be used for electrical energy [5]. Solar panels of various shapes have been produced, from the smallest to the largest. The utilization of solar energy can be taken from two angles, namely the elevation angle and the azimuth angle. Elevation is the angle of the range of the horizontal line from the earth to the sky or from east to west. Azitmuth is the amount of angle between the magnetic north and the point we are going to or a clockwise calculation [6]. The solar tracker system requires measurements of the actual azimuth and elevation angle of the solar panel to direct it to the desired angle where it will be pendicular to sunlight [7]. The Internet of Things is a device arranged according to its purpose and integrated with the Internet network. The Internet of Things is currently widely applied in various fields that allow many devices to be accommodated to be built according to needs, and an adequate network has data analysis and graph features [8]. Arduino is a device that is often used in experiments or prototypes of assembling tools, ranging from the Internet of Things, robotics, drones, and so on. Fuzzy logic is a part of artificial intelligence used to provide membership to each function and restrict certain categories. Two-axis solar panel tracked using four light sensors using fuzzy logic [9]. The process also involves inputs, processes, and outputs. The important role used by membership and rules or rules that are made to condition the process of tracking sunlight on solar panels. Solar tracker is an automatic solar power whose panel can follow sunlight to get maximum power [10].

Several previous studies have successfully made prototypes and tests of two-axis solar panels with sunlight tracking. First, the approach of using a dual-axis solar tracker that is connected to the Internet of Things [3]. Second, the dual-axis solar tracker approach is based on the Internet of Things software simulation and development of hardware [1]. Third, using three approaches, namely literature studies, IoT-based laboratory studies, and discussions with supervisors [11]. Fourth, a design and prototype approach with tracking using dual-axis [6]. Fifth, the approach of using smart wiping on solar panels that are tracked horizontally and vertically [12]. Sixth, the approach uses dual-axis solar panels for horizontal and vertical movement Using the fuzzy logic method [13]. Seventh, a prototype approach with a block system and implementation of electronic control circuits [9]. Eighth, Using a design, experiment, and development approach that focuses on battery charging [14]. Ninth, the approach used is the design and implementation of the solar tracking system [10]. Tenth, using a dual-axis solar tracker approach focuses on improving energy efficiency [15]. The research model used in previous studies has used many dual-axis solar systems with different approaches and focuses. Solar panels are generally made following the point of sunlight by following two axes moving vertically and horizontally. The Internet of Things monitors input data, especially voltage, power, current, and other sensor data. The approach also starts from design and simulation first so that a prototype model can be made physically and tested based on the movement where the LDR sensor captures light and is passed on to obtain the data. The fuzzy logic method is also used to relate variables such as servo movement values and LDR sensor values to provide processed inputs so that output is based on database decisions that have been made.

The gap that some previous researchers have not solved is that some do not examine environmental data, aspects of the Internet of Things security, and evaluation of the energy produced with what is consumed. Some use simulations and need to be optimized using the fuzzy logic method to increase the movement of the actuator. Development is needed using artificial intelligence, power optimization, and energy efficiency. There is also a smart wiping approach for data storage efficiency. The difference between this study and the previous research is that the researcher uses a development model with a prototype approach but integrates fuzzy logic methods and the Internet of Things. The data is the efficiency of 2 12 Volt 1.5watt polycrystalline mini solar panels and data on voltage, current, power, temperature, humidity, and rain detection. Researchers previously used solar panels, namely using one solar panel, 9 volts, 3W, but did not use artificial intelligence [3]. The data only looks for power, current, and voltage for dual-axis solar panels [1]. The variables studied are voltage, power, current, humidity, and solar irradiance [6]. 6 volt 100 mA solar panel by comparing two types of solar panels statically and solar panel tracker [12]. Testing solar panels with weather conditions without examining efficiency data [9]. There is a need to add voltage and current sensors [10]. Based on this, researchers try to design and develop solar panels concentrated in sunlight by using Arduino to record the efficiency of the solar panels. The researcher developed a prototype model based on fuzzy logic in an integrated design based on the Internet of Things. The contribution of this research to science is the development of solar panels based on the Internet of Things, which is used to analyze the state of the environment and the movement of solar panels for energy efficiency. This knowledge contributes to education, especially informatics practices, so students can have a direct learning experience.

2. RESEARCH METHOD

This type of research uses research and development methods. The development model used is a prototype model. Assemble a simple tool designed using an Arduino mega2560 and servo control via a light sensor using fuzzy logic. This algorithm produces boolean values limited to the numbers 1 and 0, which are still vague uncertainties [13]. An LDR connected to the Arduino will measure the intensity of the surrounding area of light depending on the amount received and affect it [16]. This study uses a prototype model based on simulations in Proteus 8 software. The flow diagram in Figure 1 is a prototype flow that begins with searching for supporting basic theories in the form of literature, scientific articles, theses or theses, and others. Discussions are also important to get information. After getting what literature is needed, collect materials from tools or devices used to make solar panel prototypes. The series of tools was first designed using Proteus 8. Programming circuits using the Arduino IDE with C++ language according to the tools needed. Before physically uploading to the Arduino, a simulation will be carried out using Proteus 8 or other software to ensure everything runs according to the target. After that, a solar panel prototype will be assembled, and testing will be conducted. Evaluation and completion will be carried out if the test is successful according to the parameters. If the results of the parameters are not obtained, they will be corrected first and then retested to get the desired results. The prototype model is presented in Figure 1.

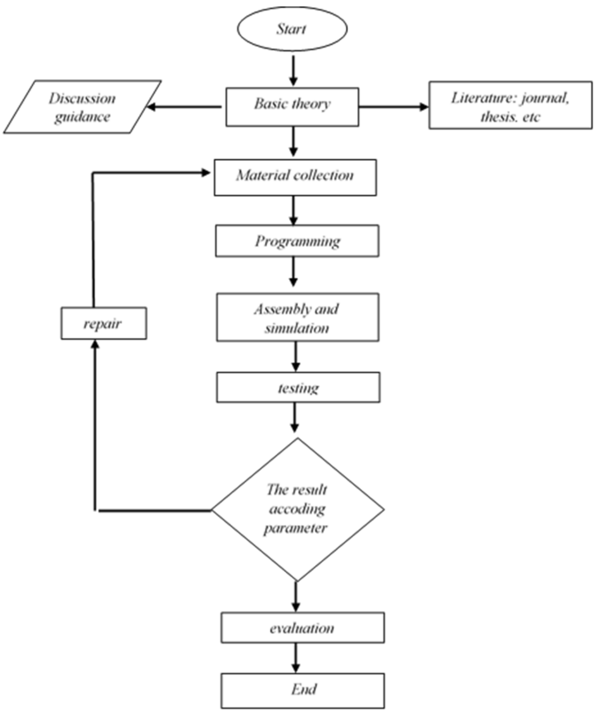
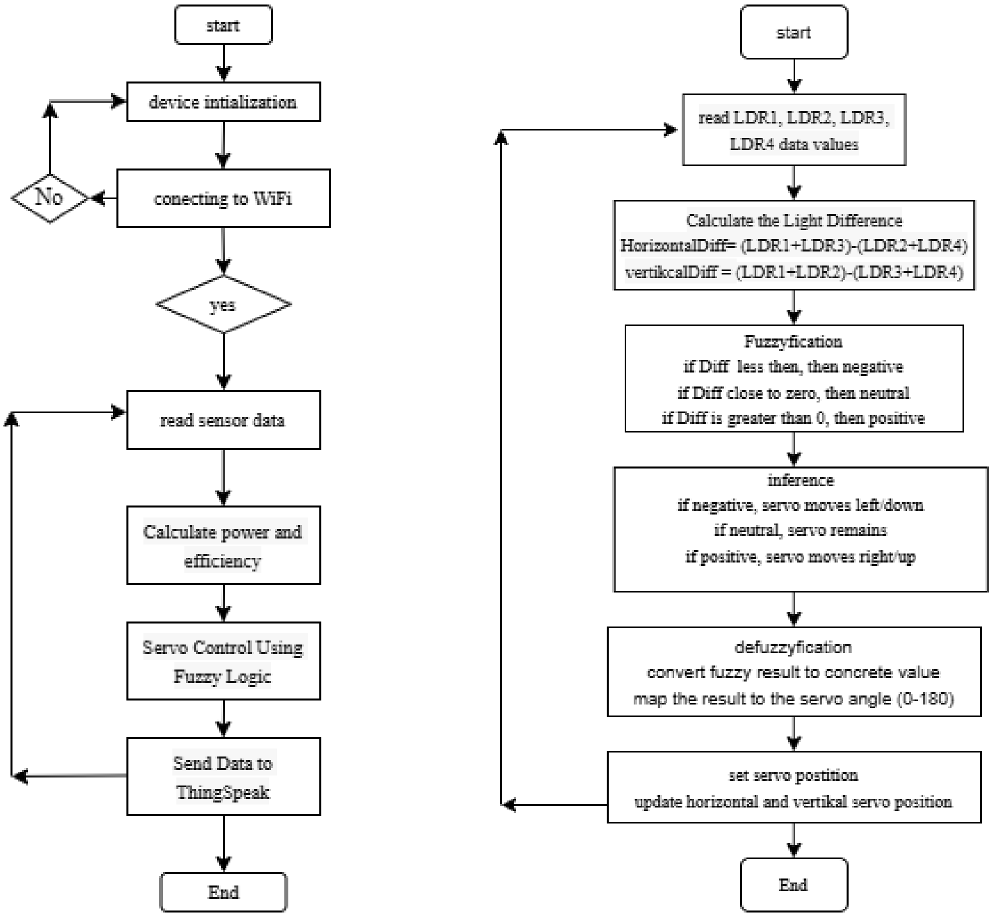


Figure 1. Prototype Models [17]

Further in testing, the solar panel series created starts from initializing the device and Wifi connection from the nodemcu; ESP 8266 connects to the smartphone hotspot and forwards to the laptop to be able to display data in think to speak. If it is well connected, the light, voltage, current, temperature, humidity, and rain sensors will be read by the Arduino mega 2560 device. Calculating power and efficiency is carried out, and then vertically and horizontally servos will be controlled through fuzzy logic. The data sent to thinkspeak is the efficiency of the solar panels during testing and is constantly updated through sensor data readings. This test process is shown in Figure 2 part (a). Part (b) is the fuzzy logic process; the focus is on the data of 4 light sensors read and then calculated the light difference, then continued the fuzzification process and input from horizontal and vertical differences. The inference process provides output to both vertical and horizontal servos. The defuzzification process converts the results to concrete values by mapping the servo angle range of 0 to 180 degrees so that the servo position will update from the reception of the light sensor input.



(a) (b)

Figure 2. Part (a) Overall Process and Part (b) Fuzzy Logic Process

The fuzzy logic method controls vertical and horizontal servos so that the solar panel can move according to the input of the light sensor value. There are two input variables, namely horizontal difference and vertical difference, which come from 4 light sensors. The horizontal and vertical differences inputs have the same values from three categories: Negative (Neg), Zero, and Positive (Post). The value of the range is between -2046 and 2046. The negative category has a value between [-2046 -1023 0], the zero category has a value of [-1023 0 1023], and the positive value is [0 1023 2046]. Figure 3 shows the membership function of each input and output in a variable. The variable output of the horizontal servo is 0 to 180, which consists of the left output value [0 45 90], the center output value [45 90 135], and the right output value [90 135 180]. Figure 4 shows the existence of horizontal servo variable output and vertical servo variable output.

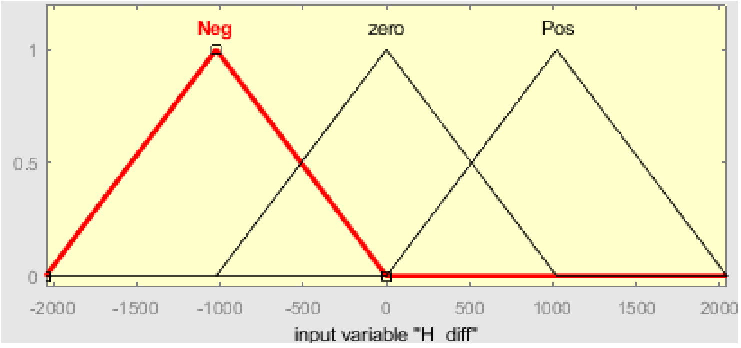


Figure 3. Input Variable Horizontal Difference

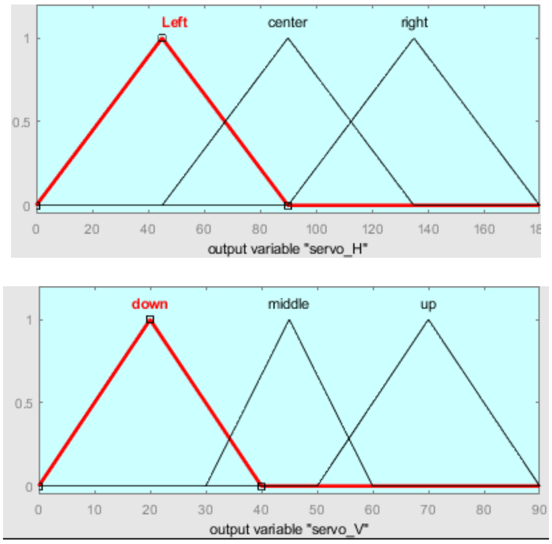


Figure 4. Output Variable Servo Horizontal dan Output Variable Servo Vertical

The input values and variables, horizontal difference, vertical difference, horizontal servo output, and vertical servo output are made by a rule of 9 to process solar panels to move vertically and horizontally. Table 1 shows the rules that have been created. One of the rules is that if the horizontal difference is negative and the vertical difference is negative, then the horizontal servo is in the left position, and the vertical servo is down. The process of simulating the fuzzy logic designer's rules created in matlab can be seen in Figure 5. If you look at this simulation, the horizontal difference is worth 247, the vertical difference is worth 592, the horizontal servo is worth 104, and the vertical servo is worth 60.9. All sensor inputs and variables in fuzzy logic are programmed in the Arduino IDE.

Table 1. Fuzzy Rules Servo Movement

HorizontalDiff	VerticalDiff	Servo horizontal	Servo vertical
Neg	Neg	Left	Down
Neg	Zero	Left	Middle
Neg	Pos	Center	Down
Zero	Neg	Center	Donw
Zero	Zero	Center	Middle
Zero	Pos	Center	Up
Pos	Neg	Right	Down
Pos	Zero	Right	Middle
Pos	Pos	Right	Up

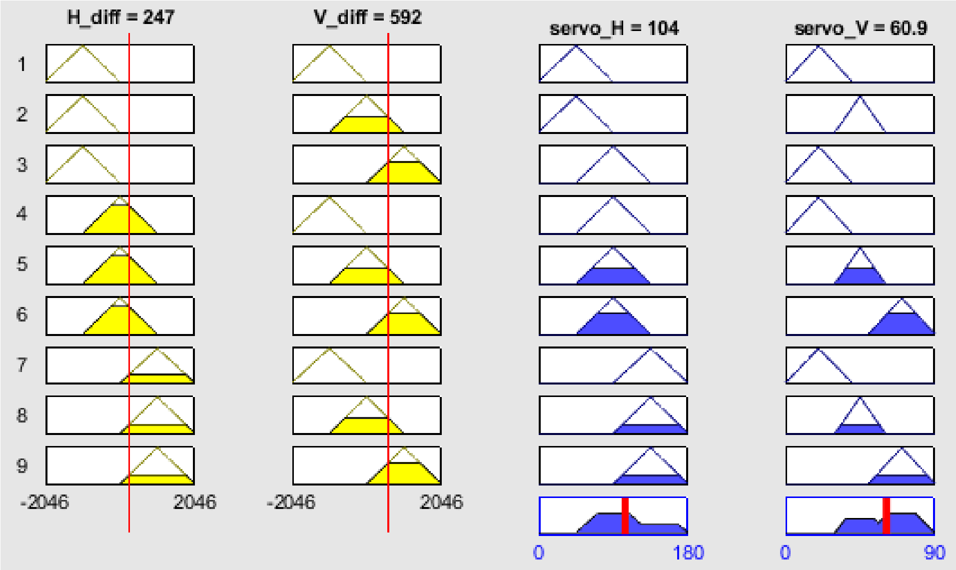


Figure 5. Rule Simulation in Matlab

3. RESULT AND ANALYSIS

The test for this solar panel uses two mini solar panels of 12 Volt 1.5 Watt each. The panel is arranged in parallel, and four light sensors are used to capture sunlight to control the right and left servos to rotate from top to bottom. One servo below functions to rotate right and left, namely servo rotation for sunlight tracking. In addition, there are voltage measurement sensors (ACS 712), current measurement sensors, rain sensors, temperature and humidity sensors, and ESP, which transmit efficiency data from solar panels. Here is a simulated design on proteus 8, which is further circuited physically, as shown in Figure 6. The results of the simulation and design above can be used for physical circuits because the code entered can display servo motion data horizontally and vertically, including light sensor data as well as temperature, voltage, and voltage. However, the focus is on solar panel efficiency data. After being simulated, a physical circuit of solar panel tracking is made, as shown in Figure 7.

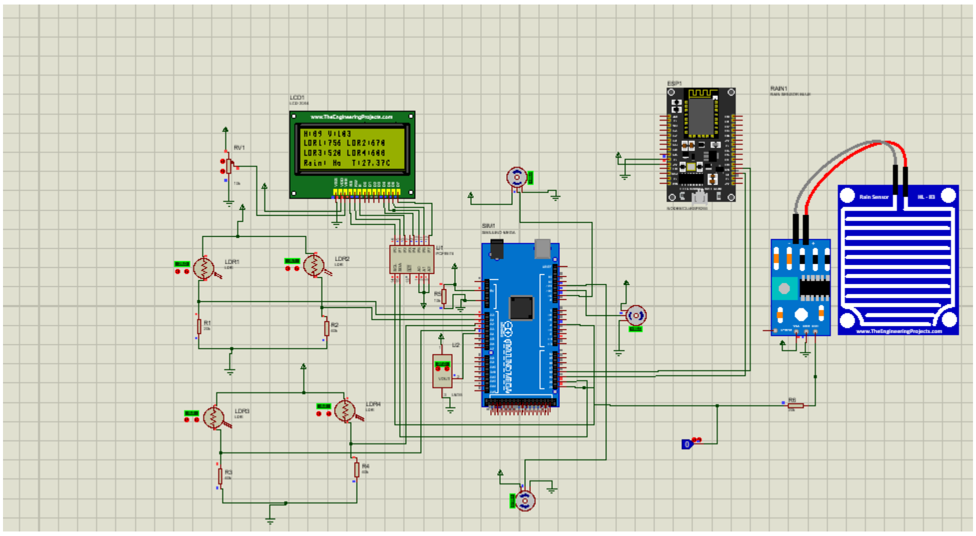


Figure 6. Solar Panel Wiring Simulation

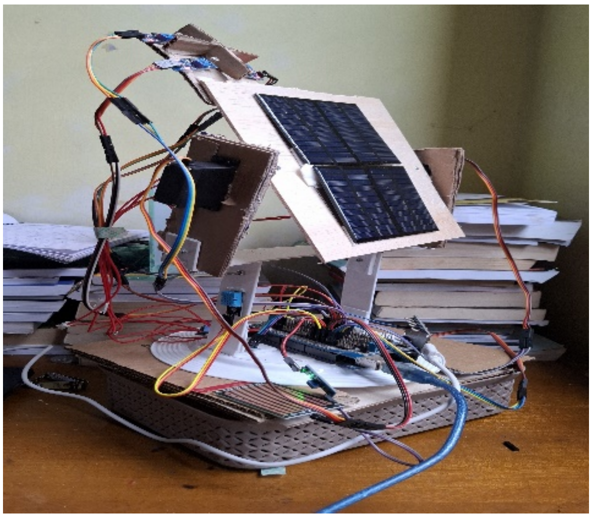


Figure 7. Physical Range of Solar Panel Tracking

The sensor test results shown in Figure 8 on the serial plotter show that the sensor is responsive to light and the environment. value 1 is LDR1 data; value 2 is LDR2 sensor, value 3 is LDR 4, value 5 is a rain sensor, value 6 is temperature, value 7 is humidity and value 8 is voltage. The fuzzy logic code in Figure 9 using Arduino programming the range values -2046 and 2046 are the inputs of fuzzy logic to control the vertical and horizontal movement of the servo from the sunlight captured by the light sensor according to the design in the design fuzzy logic and flowchart in Figures 2, 3 and 4.

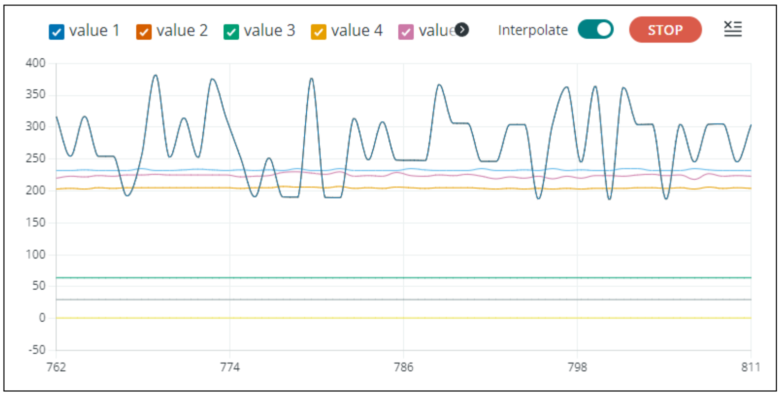


Figure 8. Sensor testing on serial plotters

```
int servoPosHorizontal = fuzzyController(horizontalDiff, -2046, 2046);
int servoPosVertical = fuzzyController(verticalDiff, -2046, 2046);

int fuzzyController(int diff, int minValue, int maxValue) {
  int fuzzyNeg = max(-minValue, min(diff, 0)); // Nilai negatif
  int fuzzyZero = max(0, 1023 - abs(diff)); // Nilai netral
  int fuzzyPos = max(-maxValue, min(diff, 0)); // Positif

  int result = ((-fuzzyNeg) + (fuzzyPos)) / (fuzzyZero + 1);

  int servoPos = map(result, -1023, 1023, 0, 180);
  return servoPos;
}
```

Figure 9. Code Fuzzy Logic On Servo

Based on the results of the test data obtained, after repeatedly improving the program for solar panels, it was found that two-axis sunlight tracking can be used for energy efficiency using the fuzzy logic method integrated with the Internet of Things. Efficiency data from solar panels when tested in cloudy weather and indoors. The results obtained from the data read in Thinspeak are shown in Figure 10. Data from morning to noon efficiency was obtained by 9.96%. The causative factor is that the test is carried out when the weather is cloudy, so the solar panels are slightly exposed to sunlight. The results of this study are supported by the explanation of the data that there is a type of solar panel, namely polycrystalline solar panels, that have an efficiency rate of 15%, which is fairly cheap and sensitive to hot temperatures, but the dual axis solar tracker system can increase energy efficiency with internet-of-things-based monitoring [3]. The results in Figure 11 are taken from the serial data of the Arduino monitor sent by the ESP nodemcu 8266 to think speak math work.

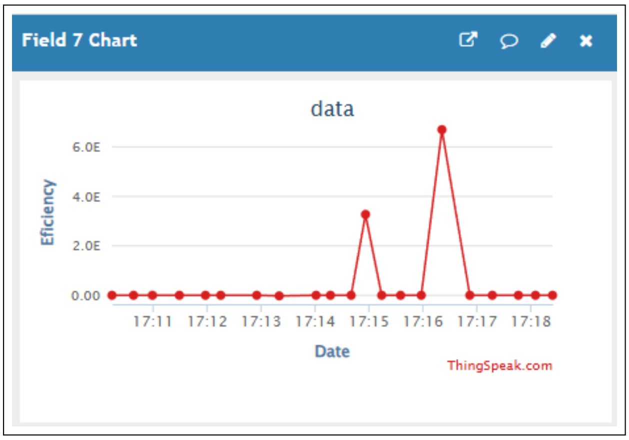


Figure 10. Monitoring the energy efficiency of solar panels using IoT

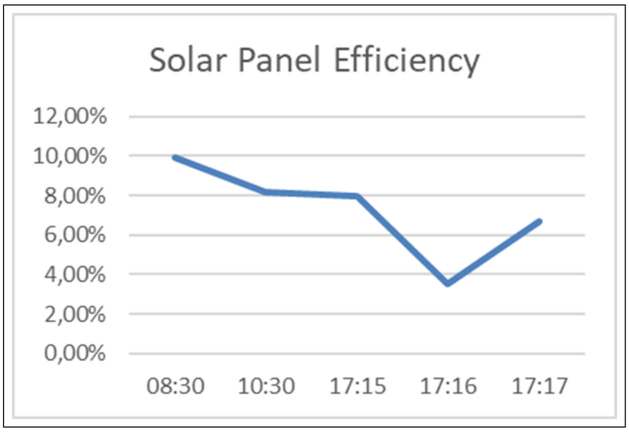


Figure 11. Panel Efficiency Data Results

Another confirmatory result from previous research is that dynamic systems produce 14.4% better electrical energy than static systems [6]. The efficiency produced by two-axis solar tracking with the water treatment method is 7.46% [13]. On the other hand, there is research that has succeeded in its efficiency, namely Producing the efficiency of a two-axis solar tracker of 38.03% [11]. The two-axis solar panel tracking system generates more power, voltage, and current can increase efficiency by 45.11% [1]. Two-axis solar tracker delivers 71.65% efficiency [15]. Generally, a two-axis solar tracker system can provide energy efficiency, as sunlight's focal point is tracked based on the method used. The determining factor is the tools' specification, especially the sensors and solar panels, and the weather climate factor.

4. CONCLUSION

Based on the test results using the integration of fuzzy logic and the Internet of Things and the data obtained, it can be concluded that solar panels can be tracked using light sensors and can move servos vertically and horizontally. Environmental monitoring from temperature and humidity sensor data and rain sensors can function properly and produce efficiency even though the value is small. This is due to cloudy weather factors, indoor testing, solar panel quality, etc. The suggestion in the future is to use better voltage and current sensors and solar panels tested with weather climate and integrate temperature and humidity as variable inputs in the fuzzy logic to be better. In addition, machine learning is an alternative as a differentiator to get better results.

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