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Automatic irrigation monitoring system based on photovoltaic solar energy with fuzzy logic

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Abstract. Indonesia's food self-sufficiency program requires the use of paddy fields with rice as the main food. That irrigation infrastructure problem also needs efficiency mitigation of cost impact using fuel oil in operation manually of engine irrigation. An automatic photovoltaic irrigation system can solve the problem of deficiency irrigation infrastructure, especially in the dry season as a more efficient power supply for irrigation infrastructure. In this research, implemented the automatic photovoltaic irrigation system is combined with the sunlight tracking system to get power supply, according to the direction of the sun. The irrigation pattern requires the suitability of soil moisture, water level, and power supply voltage as variables for the application of an automatic photovoltaic irrigation system. An automatic photovoltaic irrigation system is equipped with a website to monitor the irrigation variables. The Irrigation variables data is obtained from sensor readings then sent by NodeMCU to the website and calculates the suitability of irrigation variables as parameters using fuzzy logic to control automatic irrigation. The conclusion from this study was obtained after testing the system with the system running well, fuzzy logic parameters run with variables value of voltage > 9.9 Volt, water level < 2cm, and soil moisture < 69%.

1. Introduction

Paddy agriculture produces rice as the dominant food commodity in Indonesia's food self-sufficiency program. The area of rice fields in Indonesia in 2018 was 7,105,145 ha. However, 50% of the agricultural land does not have adequate irrigation infrastructure [1]. Generally, the rice fields that experience this problem are rainfed. So that independent efforts developed by farmers to meet irrigation needs in the fields, especially during the dry season.

Rainfed rice fields rely on rainwater for irrigation. During the dry season, farmers use rivers or wells as the closest source of water for irrigation. This water source requires lifting with a water pump because it is located at an elevation below the surface of the rice fields. The water pump requires a source of electrical energy. The alternative used is a portable water pump with an energy source of fuel oil (BBM) or LPG gas cylinders. However, the burden of fuel costs in using a portable pump is an obstacle in its operation. So that the growing use of irrigation pump technology with a more effective and efficient solar panel electric energy source.

Researches continue to be developed on the agricultural side, especially accompanied by the use of solar energy. The researcher develops automated irrigation that monitors and maintains the desired soil moisture content via automatic watering using ATMEGA328P microcontroller and soil moisture sensor on the Arduino Uno platform is used to implement the control unit. IoT with Thing speaks transmission is used to keep the farmers updated about the status of sprinklers. but this system needs improvement at power management sides like photovoltaic technology [2]. Photovoltaic Solar energy technology offers an alternative to irrigation system development. Research on the Solar Water Pumping System Using the IoT Monitoring System designed the concept of an AC and DC water pump system using solar panel power sources with battery backup [3-6]. Seeing this condition, it is necessary to develop a solar panel irrigation automation system using a microcontroller to control the irrigation water pump. The development of solar panel technology to capture sunlight according to the direction of the rays is also needed so that the solar panels can maximize power for irrigation pumps.

The amount of water needed for the growth process of rice plants is still not known with certainty. This causes farmers to give excessive water to paddy fields. Excessive water supply can lead to wasteful use of water. The way to maintain water availability without causing waste is to adjust the height of water inundation. The system of rice intensification (SRI) method of applying a minimum inundation height of 1-2 cm can save water use without reducing rice production [7]. The scale of soil moisture in agriculture also influences irrigation. Soil moisture is usually indicated by a sensor with three types of moisture, dry soil, humid soil, and wet [5,8].

In this study, built a system to monitor solar panel irrigation automation using fuzzy logic as a control of the irrigation pump status to suit irrigation needs with soil moisture parameters and water level and power source voltage.

2. Methods

Irrigation automation system using fuzzy as logic methods. Fuzzy Sugeno type is used to control the status of the irrigation pump based on parameters of voltage, water level, and humidity. The flow diagram of the Sugeno fuzzy method is shown in Figure 1.

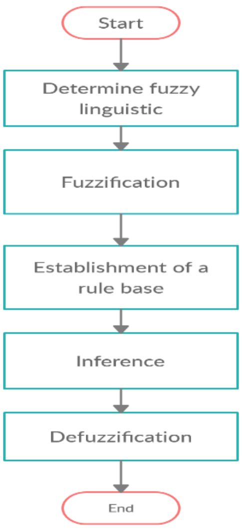

Figure 1. Sugeno fuzzy flowchart.

The fuzzy method consists of fuzzification, inference to defuzzification [9]. Sugeno fuzzy stages are shown as follows:

- Determine the linguistic value.
- Fuzzification

The fuzzification stage is changing the information from the input data input from the sensor to the fuzzy linguistic set data [10]. Fuzzification of membership degrees for humidity is shown in Figure 2, Fuzzification of membership degrees for water is shown in Figure 3, Fuzzification of membership degrees for voltage is shown in Figure 4.

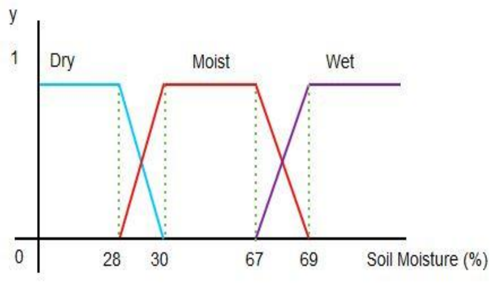

Figure 2. Membership degrees of humidity.

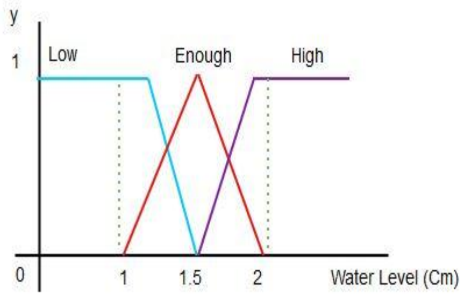

Figure 3. Membership degrees of water.

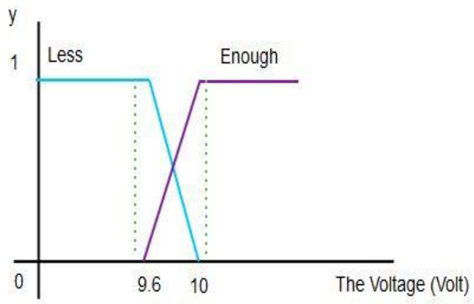

Figure 4. Membership degrees of voltage.

- The formation of a fuzzy knowledge base (Rule in the form of IF ... THEN).
- Inference, at this stage using the MIN implication function to obtain the α-predicate value for each rule (α1, α2, α3,…αn).
- Defuzzification, at this stage defuzzification, takes input in the form of αpredicate and z values of each rule. Defuzzification is done by calculating the center of singleton value, namely the sum of the multiplication between the membership value and the singleton value then divided by the total membership value. When the defuzzification result is> = 0.5, the pump output condition will turn on [11].

3. Design system

In the implementation of the system, the software and hardware requirements of the solar panel irrigation automation system using the fuzzy method are shown in table 1.

Table 1. Software and hardware requirement.

No	Software	Hardware
1	Windows Operating System 7/8/10	NodeMCU Microcontroller, DT-Avr Unoduino
2	Arduino IDE	Voltage sensor ina219, LCD, soil moisture sensor, water level sensor, servo motor
3	Sublime text editor, Xampp, Codeigniter	The solar panel voltage specification is 12V 10W 833mA, 12v 3.4aH battery, Solar charger controller, Water pump specification 12V/350mA, Water flow 240 L/H, maximum thrust maximal 350 cm, ADS1115 (Analog extender), relay.

Implementation in the form of miniature rice fields with a scale of 1: 24000 measuring $0{,}098m^2$ that is 35 x 28 cm. The water reservoir is placed with a height difference of 50 cm. A miniature rice field design is shown in Figure 5.

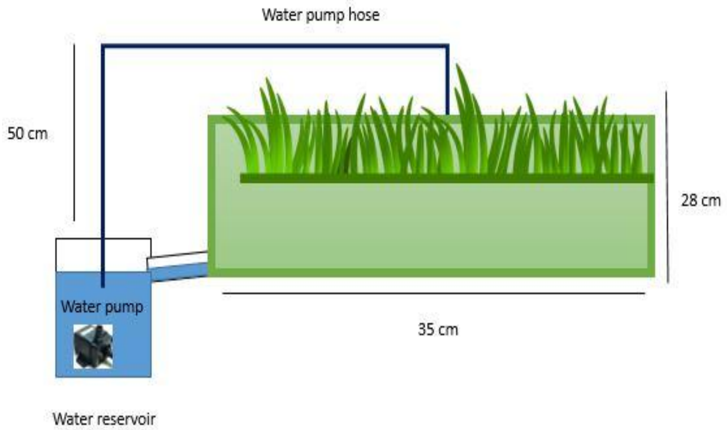

Figure 5. Miniature rice field design.

This system overview explains how the operation of the system functions as a whole shown in Figure 6.

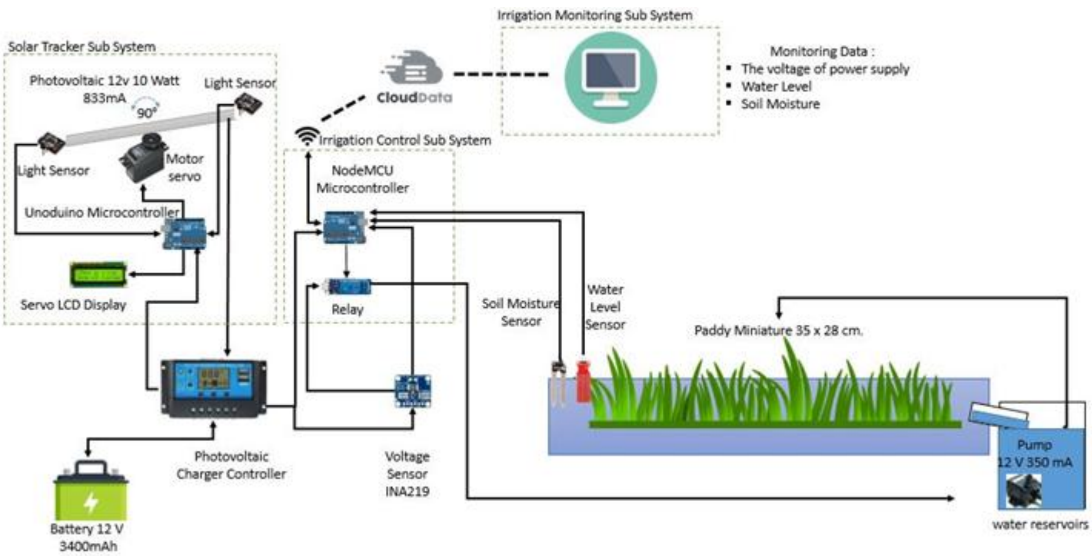

Figure 6. Irrigation automation and monitoring system implementation design.

4. Results and discussion

Testing of the irrigation automation system using the fuzzy method on 1-month old rice plants. Testing the Sugeno fuzzy algorithm calculation on the website system is shown in Figure 7.

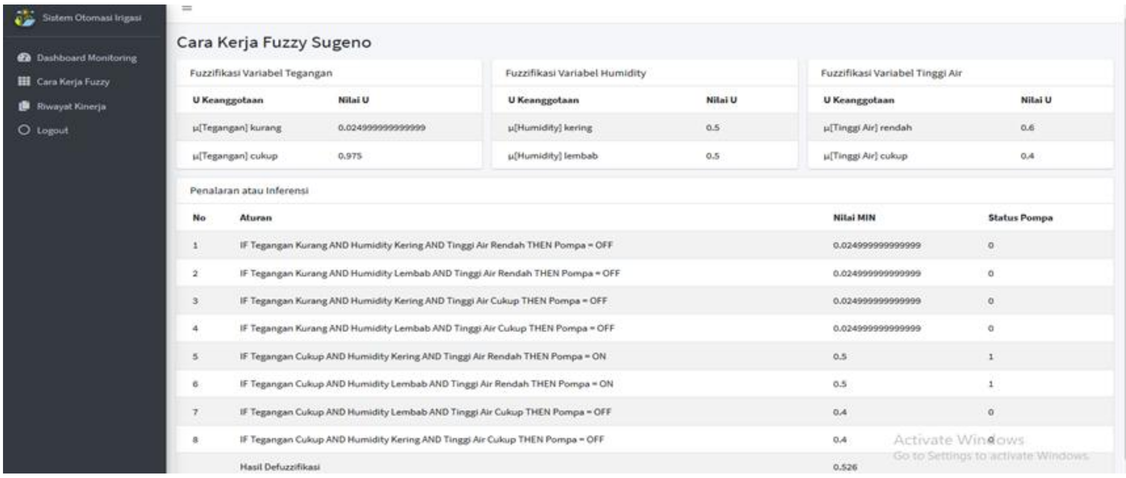

Figure 7. Sugeno Fuzzy calculations in the website.

The irrigation automation system test shows the received sensor data with the pump status output and the irrigation system status, and the results of the pump condition test are sent to the database. The test of the irrigation automation system from the data in the database is shown in table 2.

Table 2. Sensor data in the database.

No	Date Time	Voltage Sensor	Humidity Sensor	Water level sensor	Pump Status	Irrigation system status	Pump condition result
1	2020-06-15 11:34:39	10.8	50	1.02	ON	OFF	OFF
2	2020-06-15 11:35:11	10.78	50	1.04	ON	ON	ON
3	2020-06-15 11:35:49	10.84	51	1.07	ON	ON	ON
4	2020 06-15 11:36:22	11.24	51	1.13	ON	ON	ON
5	2020 06-15 11:36:55	11.09	51	1.12	ON	ON	ON
6	2020 06-15 11:37:25	11.08	51	1.08	ON	ON	ON
7	2020 06-15 11:37:57	10.75	51	1.1	ON	ON	ON
8	2020 06-15 11:38:34	10.89	51	1.14	ON	ON	ON
9	2020 06-15 11:39:12	10.88	51	1.17	ON	ON	ON
10	2020 06-15 11:39:47	10.82	51	1.2	ON	ON	ON
11	2020 06-15 11:40:24	10.82	51	1.29	ON	ON	ON
12	2020 06-15 11:40:54	11.05	51	1.41	ON	ON	ON
13	2020 06-15 11:41:24	11.34	51	1.7	OFF	ON	OFF
14	2020 06-15 11:41:54	11.38	50	1.58	OFF	ON	OFF
15	2020 06-15 11:42:30	11.13	49	1.55	OFF	OFF	OFF

Solar tracker system testing to show the movement of solar panels. The solar tracker system test is shown in Figure 8. The implementation of the rice field prototype measuring 35 x 28 cm. As well as a miniature water source with a size of 40 x 35 cm as a prototype of a well/river as a water source in the rice fields. Panel box measuring 30 x 20 x 12 cm as a place for placing Unoduino and NodeMCU microcontrollers, INA219 voltage sensors, relays, and batteries on the inside. Then on the outside wall-mounted LCD solar tracker and solar charger controller. As support for solar panels with a solar tracker system, a pipe with a height of 65 cm and a width of 35 cm is used. rice field prototype is shown in Figure 9.

Figure 8. Solar tracker trial.

Figure 9. Rice field prototype.

Testing of the irrigation automation website monitoring system is shown in Figure 10.

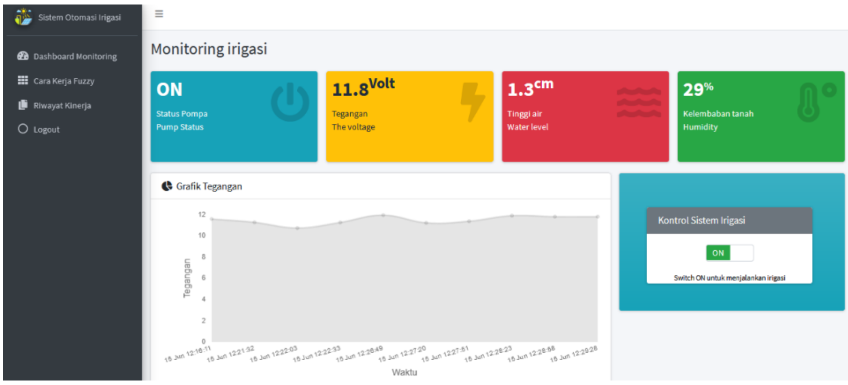

Figure 10. Irrigation automation website monitoring system.

5. Conclusion

From the test results, the solar tracker system can move the solar panel servo to follow the sun's motion automatically based on the light intensity received by the light sensor which is then processed by the Unoduino microcontroller. The degree of movement of the servo rotation is 0-90 degrees. Solar panels can charge batteries with a voltage of 11-12 Volts. The NodeMCU microcontroller reads and sends the INA219 voltage sensor data, soil moisture, and water level as parameters for the water pump status on the irrigation automation system website. Irrigation automation system based on Sugeno fuzzy calculations in making decisions to control the condition of the pump can work with parameters of voltage> 9.6 Volt, water level <2 cm, and soil moisture <69%. The irrigation automation system can work remotely and monitor it via the website. Sending sensor data through REST communication with HTTP sending protocol with a period of adding data every 30 seconds.

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