Fuzzy Logic-Based Electrical Conductivity Control System in Aquaponic Cultivation

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Abstract*—Cultivation technology in agriculture such as the aquaponics system is expected to be an alternative for people who have limited land or for those who want to simultaneously manage fish cultivation. Electrical Conductivity (EC) is one of the most influential parameters on plant growth in aquaponics cultivation. A good aquaponics system must have a controlled EC value. With technology, the EC value can be monitored automatically using the TDS sensor which is used to determine the number of dissolved nutrient particles. This study developed an EC content control system in aquaponics cultivation using Fuzzy logic control. The output of the fuzzy was the duration of the pump motor to drive the motor which will pour ABmix into the growing media of the aquaponics system. We did some testing to find out how well this fuzzy system performed. The results showed that this fuzzy logic system could control the aquaponics EC value. In addition, this fuzzy system fitted and ran well without overshoot.

***Keywords*—aquaponic, electrical conductivity, TDS sensor, fuzzy logic control**

I. INTRODUCTION

Aquaponics is a cultivation technology that combines fish cultivation with plants, which can significantly increase land productivity by 30 - 40% [1]. Aquaponics system is one of the best solutions in agricultural cultivation, where land prices are getting more expensive, water is getting scarcer, land conversion is massive, and the issue of climate change is the result of global warming. [2]. When compared to conventional agricultural cultivation, the aquaponics system has several advantages. The advantages of the aquaponic cultivation system include being able to be applied to narrow land, not requiring planting media, fertilizing, watering, saving water, being healthier, having high aesthetic value, and being free from contaminants. So, aquaponics is very prospective to be developed in places where water and soil are scarce and expensive, such as urban areas, dry areas, deserts, and small islands [3].

The EC control system is a system designed to be able to make the EC water in the reservoir according to the desired target [4][5]. EC itself is measured in units of Parts Per Million (PPM). To improve performance, automatic control can be well applied to the aquaponics system [6][7]. Many studies have been done to implement automatic control using different methods and different approaches [8][9].

Nutritional needs are the most influential thing in aquaponics cultivation on plant growth, and each type and age of the plant is different in the amount of Electrical Conductivity (EC). [10]. Therefore, testing of various EC values is carried out to determine the level of suitability and correctness of the nutritional content so that the nutritional sources contained therein can be utilized [11][12]. The method used in this control system is a method using fuzzy logic control.

The fuzzy set is based on the idea of extending the range of characteristic functions such that the function will include real numbers in the interval [0,1] [13]. Its membership value indicates that an item is not only true or false. A value of 0 indicates false, a value of 1 indicates true, and there are still values that lie between true and false [14][15].

Based on the need for EC levels in different aquaponics plants, a research on the development of automation of EC settings was carried out based on the desired EC value using Mamdani fuzzy logic control. With this fuzzy-based control system, it is hoped that the EC value in the aquaponics system will be more controlled according to the expected value.

II. A BRIEF EXPLANATION ABOUT PROPOSED FUZZY LOGIC-BASED ELECTRICAL CONDUCTIVITY CONTROL SYSTEM IN AQUAPONIC

A. Schematic Diagram

In this research, a closed-loop control system was used. In the processing system, there were two stages, the first was the design process using fuzzy logic in which there is a process of

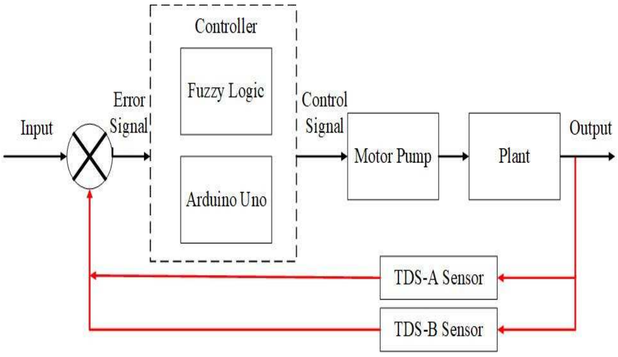

Fig. 1. System control diagram.

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fuzzification, fuzzy interface engine, and defuzzification, and the second was the coding process using Arduino by implementing membership function constraints that had been made previously using fuzzy logic. The process to control the EC level was carried out using a motor pump filled with ABmix liquid. The output value was read by the TDS-A and TDS-B sensors, the results are used as feedback and to provide notification whether the EC level in aquaponics was on target or needs to be increased. The diagram of the developed EC control system could be seen in Fig.1.

B. Fuzzy Logic Control Design

In this section, we describe fuzzy modeling to control EC values. Fuzzy input is obtained from the set point value and feedback from the TDS-A and TDS-B sensor. Researchers categorize this sensor into three EC levels, namely Vless, Less, and Enough. The output of this fuzzy is the duration of the pump motor. We categorize this output into three levels, namely Short, Medium, and Long. The linguistic terms of input and output can be seen in Table I and Table II and the rules of fuzzy logic can be seen in Table III.

1) TDS-A Sensor

The TDS-A sensor variable is formed into three sets, namely VLess, Less, and Enough. For this set, a trapezoidal shape is used to indicate the degree of membership. The degree of membership of the TDS-A sensor can be seen in Fig.2.

The membership function equation for the TDS-A sensor variable is stated as follows:

$$\mu_{VLess} = \begin{cases} 1, & x \leq 300 \\ \frac{550-x}{250}, & 300 \leq x \leq 550 \\ 0, & x \geq 550 \end{cases} \tag{1}$$

$$\mu_{Less} = \begin{cases} 1, & 550 \leq x \leq 800 \\ \frac{300-x}{-250}, & 300 \leq x \leq 550 \\ \frac{1050-x}{250}, & 800 \leq x \leq 1050 \\ 0, & 300 \geq x \leq 1050 \end{cases} \tag{2}$$

$$\mu_{Enough} = \begin{cases} \frac{500-x}{-250}, & 800 \leq x \leq 1050 \\ 1, & 1050 \leq x \leq 1300 \\ 0, & other \end{cases} \tag{3}$$

2) TDS-B Sensor

The TDS-B sensor variable is formed into three sets, namely VLess, Less, and Enough. For this set, the trapezoidal shape is used to indicate the degree of membership. The degree of membership of the TDS-B sensor can be seen in Fig.3.

The membership function equation for the TDS-B sensor variable is stated as follows:

$$\mu_{VLess} = \begin{cases} 1, & x \leq 300 \\ \frac{550-x}{250}, & 300 \leq x \leq 550 \\ 0, & x \geq 550 \end{cases} \tag{4}$$

$$\mu_{Less} = \begin{cases} 1, & 550 \leq x \leq 800 \\ \frac{300-x}{-250}, & 300 \leq x \leq 550 \\ \frac{1050-x}{250}, & 800 \leq x \leq 1050 \\ 0, & 300 \geq x \leq 1050 \end{cases} \tag{5}$$

$$\mu_{Enough} = \begin{cases} \frac{500-x}{-250}, & 800 \leq x \leq 1050 \\ 1, & 1050 \leq x \leq 1300 \\ 0, & other \end{cases} \tag{6}$$

3) ABmix Motor Time

The variable time of the ABmix motor is formed into three sets, namely Short, Medium, and Long. For this set, a trapezoidal shape is used to indicate the degree of membership. The degree of membership of the ABmix motor time can be seen in Fig. 4.

The membership function equation for the ABmix motor time variable is stated as follows:

$$\mu_{Short} = \begin{cases} 1, & x \leq 4000 \\ \frac{8000-x}{4000}, & 4000 \leq x \leq 8000 \\ 0, & x \geq 8000 \end{cases} \tag{7}$$

$$\mu_{Medium} = \begin{cases} 1, & 8000 \leq x \leq 12000 \\ \frac{4000-x}{-4000}, & 4000 \leq x \leq 8000 \\ \frac{16000-x}{4000}, & 12000 \leq x \leq 16000 \\ 0, & 12000 \leq x \leq 16000 \end{cases} \tag{8}$$

$$\mu_{Long} = \begin{cases} \frac{12000-x}{-4000}, & 12000 \leq x \leq 16000 \\ 1, & 16000 \leq x \leq 20000 \\ 0, & other \end{cases} \tag{9}$$

TABLE I. LINGUISTIC TERM OF INPUT

Electrical Conductivity (PPM)	Linguistic Term Input	
	TDS-A Sensor	***TDS-B Sensor***
[0 0 300 550]	VLess	VLess
[300 550 800 1050]	Less	Less
[800 1050 1300 1300]	Enough	Enough

TABLE II. LINGUISTIC TERM OF OUTPUT

Motor Time (Second)	Linguistic Term Output
[0 0 4000 8000]	Short
[4000 8000 12000 16000]	Medium
[12000 16000 20000 20000]	Long

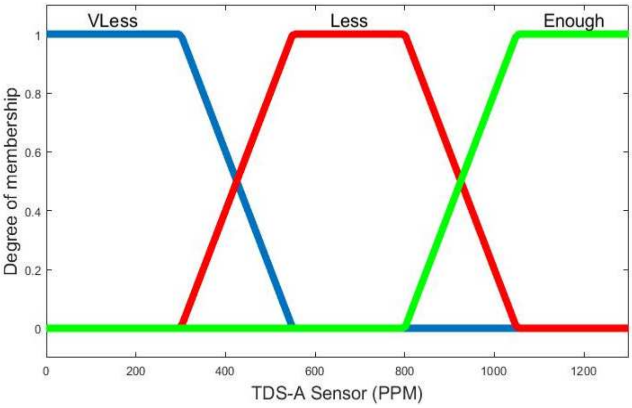

Fig. 2. Membership function of TDS-A sensor.

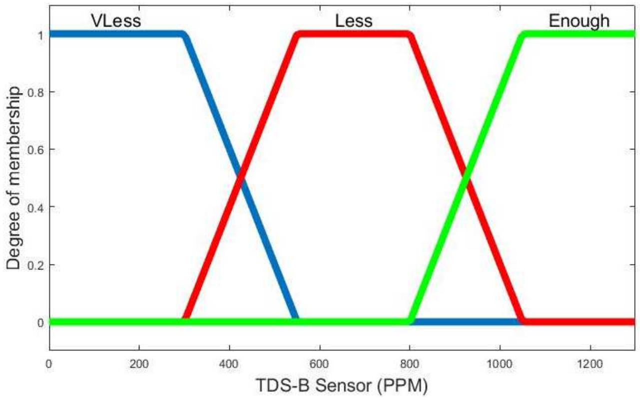

Fig. 3. Membership function of TDS-B sensor.

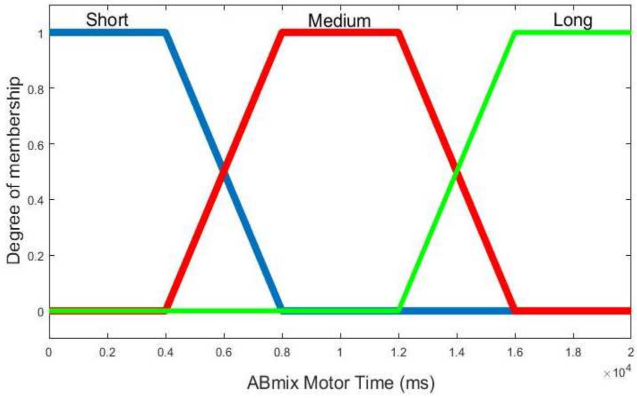

Fig. 4. Membership function of ABmix motor time.

TABLE III. FUZZY LOGIC RULE

Rules	Input		Output
	TDS-A Sensor	*TDS-B Sensor*	*Abmix Motor Time*
R1	VLess	VLess	Slow
R2	VLess	Less	Medium
R3	VLess	Enough	Fast
R4	Less	VLess	Medium
R5	Less	Less	Medium
R6	Less	Enough	Fast
R7	Enough	VLess	Medium
R8	Enough	Less	Medium
R9	Enough	Enough	Fast

C. Prototype Realization

The aquaponics prototype used a 36L aquarium with dimensions of 60cm x 40cm and a 3 inch PVC pipe as part of hydroponics. Fig. 5 shows the aquarium placed at the bottom and the pipe section with the Deep Flow Technique (DFT) system at the top. The DFT system is a cropping system that utilizes water flow as a nutrient distributor. With the DFT system, organic elements at the bottom of the pond can be channeled to plants better. Display of aquaponics implementation can be seen in Fig. 6.

The device components in aquaponics consist of a TDS-A sensor, a TDS-B sensor, relay, Arduino, and a Lippo battery whose design can be seen in Fig. 7 and its implementation in Fig. 8.

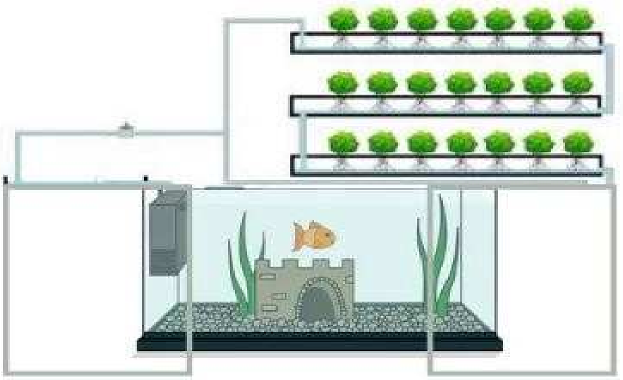

Fig. 5. Design aquaponic DFT.

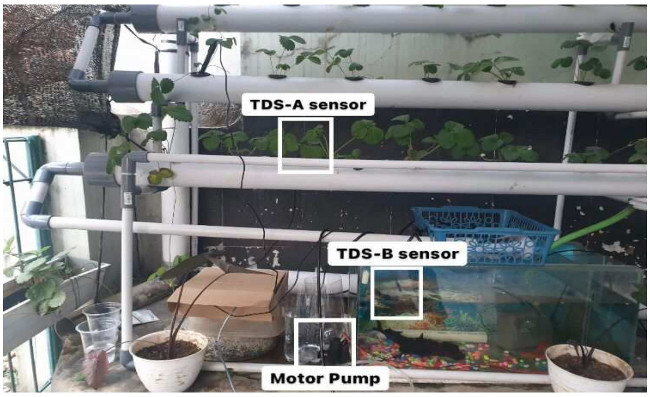

Fig. 6. Implementation aquaponic DFT.

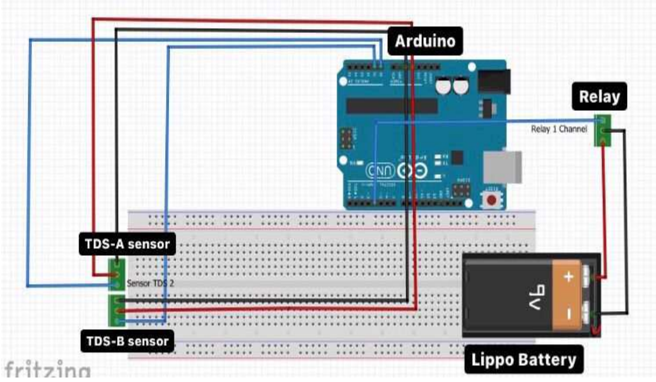

Fig. 7. Design sensor component.

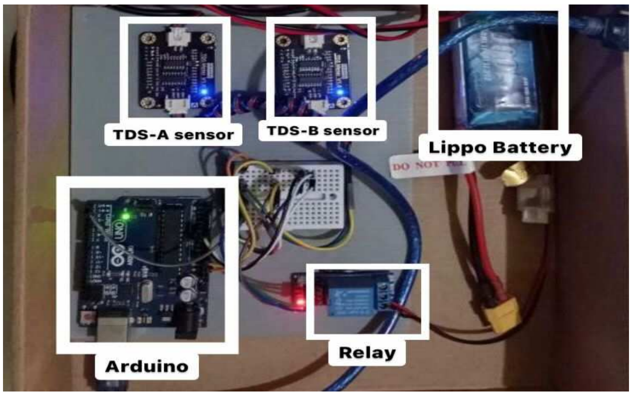

Fig. 8. Implementation of sensor component.

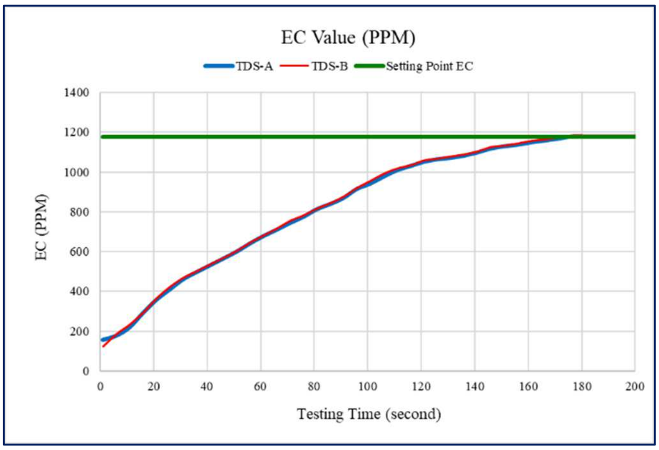

Fig. 9. System respon.

III. RESULTS AND ANALYSIS

Testing the response of the EC level stability system is carried out based on the working time of the motor to reach the set point that has been obtained. The provision of Abmix nutrition with a motor pump is carried out in stages. From the results of the experiment for 200 seconds, then compared the PPM values on the TDS-A and TDS-B sensors from before being given nutrition in the form of ABmix liquid with a motor pump until the EC value is stable whose duration follows the output of the fuzzy system. The motor pump that functions to provide Abmix liquid will stop for 5 seconds until the nutrients are evenly mixed between those detected in the aquarium by the TDS-B sensor and those detected in aquaponics by the TDS-A sensor. If the value has not reached the set-point, the pump motor will turn on again and provide Abmix nutrient liquid into the aquarium. This process will repeat until the set-point is reached.

In Fig.9 it can be seen that the EC level moves up and reaches a settling time where ts is 178 seconds, delay time td is 48 seconds, and rise time tr is 176 seconds. In addition, this fuzzy system runs well without overshoot. When compared to the system without fuzzy, the system without fuzzy has a smaller rise time, which is 101 seconds, but never reaches a steady state. Comparison of system response without fuzzy and with fuzzy can be seen in Fig.10.

IV. CONCLUSION

The EC content control system with fuzzy logic had been successfully created. The system had successfully controlled the aquaponics EC content well. Based on the response test to the system with fuzzy logic for 200 seconds, a rise time value of 176 seconds was achieved and a steady-state was achieved at 178 seconds. Meanwhile, the system without fuzzy logic reached a rise time of 101 seconds but never reached a steady state. The results achieved had shown that the addition of fuzzy logic had succeeded in assisting the system in controlling the EC content in the aquaponics system according to the targeted value.

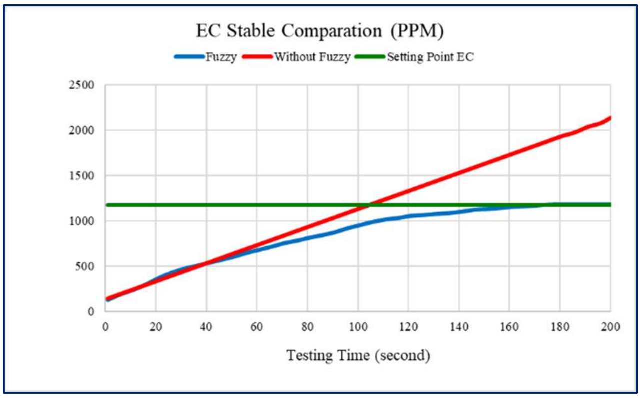

Fig. 10. Comparison of EC stability.

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