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Automation System of Water Circulation and Fish Feeding in Tilapia Fish Pond with Solar Panel Source

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A B S T R A C T

Tilapia cultivation requires good management of water quality and proper feeding to ensure optimal fish growth. One of the main challenges in this process is maintaining the water pH level within ideal limits and providing feed according to the needs of the fish based on their size. In addition, limited access to electricity in some locations makes fish pond management less efficient. This study aims to design an automated water circulation system that is regulated based on the water pH level and automatic feeding according to the needs of the fish, by utilizing solar panels as a power source. This system uses a pH sensor to monitor water conditions in real time and regulate water circulation to maintain ideal pH levels. Feeding is regulated based on the size and number of fish to ensure optimal feed efficiency and fish growth. This system is powered by solar panel energy, so it can operate independently without relying on conventional electricity networks. Test results show that the system is able to maintain water pH stability and automate feeding with high accuracy, while utilizing renewable energy effectively. The use of solar panels not only reduces dependence on electricity, but also reduces operational costs and supports environmental sustainability. This system is expected to increase the efficiency and productivity of tilapia cultivation, especially in areas with limited access to electricity.

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INTRODUCTION

Tilapia is one of the fishery commodities that is widely cultivated in Indonesia because it has high economic value and is relatively easy to cultivate. However, like other fishery commodities, the quality of tilapia cultivation results is greatly influenced by optimal water quality management and feeding (Andriani, 2018). One important parameter in maintaining water quality is pH levels. Inappropriate pH levels can cause stress, disrupt fish growth, and even trigger death. In addition, proper feeding, both in terms of time and quantity, is crucial to support fish growth and avoid waste.

Conventionally, water circulation management and feeding in tilapia ponds are carried out manually, which is often inefficient and prone to human error. This manual management makes it difficult to monitor water quality, such as pH levels, continuously. In addition, unscheduled feeding or feeding that does not meet fish needs can waste resources and decrease water quality due to unused feed residue. This condition triggers the need for an automation system that is capable of monitoring and regulating in real time and precisely (Adi & SURYANA, 2023).

Meanwhile, in many rural areas, especially those far from city centers, the availability of conventional electricity sources is a challenge in itself. This limited access to energy often hampers the adoption of automation technology in fish pond management. Therefore, the use of alternative energy sources, such as solar panels, can be an effective and environmentally friendly solution. Solar panels are able to provide a reliable source of renewable energy, so that the automation system can operate independently without relying on electricity from the main grid (Dwisari, Sudarti, & Yushardi, 2023).

This study aims to develop an automation system that is able to regulate water circulation based on pH levels and feed according to fish needs automatically. This system is powered by resources from solar panels, which allows its application in areas with limited access to electricity. With this technology, it is hoped that the tilapia cultivation process can be more efficient, reduce operational costs, and support sustainable and environmentally friendly resource management.

LITERATURE REVIEW

In fish farming, water quality and feeding are two key factors that greatly affect the growth and health of fish. The pH level of the water is one of the important parameters that affect the living environment of fish. A pH that is too low (acidic) or too high (alkaline) can cause stress and reduce the survival rate of fish. Therefore, a continuous monitoring system is needed to maintain the stability of the pH of the water in the pond. Automatic water circulation that is regulated based on the pH level of the water can maintain this balance, by ensuring that fresh water enters the pond when the pH level is outside the optimal range (Sholikin, Rozaq, Iqbal, & Setyaningsih, 2021).

In addition to water quality, proper feeding based on the size and number of fish is also very important for optimal fish growth. Excessive or inappropriate feeding can impact water quality, cause feed waste, and reduce cultivation efficiency (Azhari & Tomasoa, 2018). An automated feeding system that is adjusted to the size and number of fish will increase efficiency in feed use, while maintaining the condition of the pond water. With the increasing development of renewable energy technologies, such as solar panels, the challenge of providing a reliable energy source for automation systems can be overcome. Solar panels offer an environmentally friendly and sustainable solution, especially in areas that are difficult to reach by conventional electricity networks (Efendi, Sulistiyowati, Syahrorini, & Anshory, 2024). The use of solar energy allows this automation system to operate independently, without relying on mains electricity, making it more efficient and cost-effective in the long run. The theory of automation in aquaculture includes the use of sensors, controllers, and actuators to automatically regulate various parameters (Widharma, Sunaya, Sajayasa, & Sangka, 2020). In the context of this study, a pH sensor is used to measure water quality, while the automatic feeding system is controlled based on fish parameters in the pond. The integration of solar panels as an energy source supports the sustainability of this technology, making the system an innovative and efficient solution in tilapia cultivation (Pulungan, Putra, Hamdani, & Hastuti, 2020).

A. Tilapia

Tilapia (Oreochromis niloticus) is one of the most widely cultivated freshwater fish species in the world, including in Indonesia. This fish is known for its fast growth rate, ability to adapt to various environmental conditions, and high economic value. Tilapia has good tolerance to variations in temperature and salinity, but still requires maintained water quality, especially in terms of pH, oxygen, and temperature, to ensure its growth and health (Azhari & Tomasoa, 2018).

The pH level of the water is one of the main factors that affects the physiological condition of tilapia. The ideal pH for tilapia growth ranges from 6.5 to 8.5. If the water pH is outside this range, the fish can experience stress, metabolic disorders, and even death. Therefore, maintaining the stability of the pH level of the water in the pond is very important to ensure a conducive environment for tilapia. An automation system that can monitor pH levels in real time and regulate water circulation as needed can help maintain optimal water conditions for the fish (Al Rasyid et al., 2021).

In addition to water quality, proper feeding is also a crucial factor in tilapia cultivation. Tilapia have a feeding pattern that depends on their size and growth phase. Overfeeding not only causes waste, but also pollutes the water and increases ammonia levels, which have a negative impact on fish health. Conversely, feeding at the wrong time or in the wrong amount can inhibit fish growth. An automated feeding system that is adjusted to the number and size of fish will greatly assist in increasing the efficiency of feed use and minimizing negative impacts on water quality (Azhari & Tomasoa, 2018).

This research also integrates the use of solar panels as the main energy source. The use of renewable energy is very relevant in the context of tilapia cultivation in areas with limited access to the electricity network. With solar panels, the automation system can operate independently, reducing operational costs and supporting environmental sustainability. With an automated water circulation system based on pH levels and automated feeding, tilapia cultivation can be carried out more efficiently, environmentally friendly, and sustainably. This technology is expected to increase cultivation productivity while maintaining the health and quality of tilapia.

B. Controller and Sensor

In modern automation systems, controllers and sensors play a crucial role in enabling efficient, accurate, and integrated processes. Sensors function to collect data from the environment in real-time, while controllers act as processors of the data, decide on appropriate actions, and control devices to maintain optimal conditions. In the context of this study, automation of water circulation and tilapia feeding is based on data collected by various sensors, with the controller as the main controller (Satria, 2023).

The pH sensor plays an important role in this system to continuously monitor the pH level of the water. The pH level measured by this sensor is used as the main parameter to determine when water circulation needs to be carried out. If the pH level of the water is out of the ideal range for tilapia (6.5–8.5), the sensor will send data to the controller. The controller then activates the water circulation system to replace the less than optimal water with fresh water, maintaining the stability of the water quality in the pond (Nurdina, Sasmito, & Vendyansyah, 2022).

In addition to the pH sensor, fish size or weight sensors can also be used to automate feeding. The controller will receive data on the size and number of fish in the pond, then calculate the appropriate amount of feed to be given. This allows for more precise feeding, reduces waste, and ensures that the tilapia get enough nutrients for their growth.

A controller, such as a microcontroller or embedded system, processes data from these sensors and controls the system automatically. The controller also has programming logic that allows scheduling and setting the system according to predetermined parameters. For example, if the sensor detects an unstable pH, the controller will instruct the water pump to activate circulation. Likewise, the controller regulates automatic feeding based on the schedule or changes in fish size that are detected.

In this research, solar panels are the main source of power that supplies energy to run the controller and sensors. By using renewable energy, this system can operate independently without relying on conventional electricity, making it more efficient and environmentally friendly (Damanik & Silaban, 2023). Therefore, the role of the controller and sensor is vital in realizing an efficient automation system, where water circulation and feeding are regulated based on the actual conditions of the pond and the needs of the fish. The integration of sensors, controllers, and solar panels is expected to increase the productivity of tilapia cultivation while supporting the sustainability of operations economically and ecologically.

METHODOLOGY

In this study, the Automation System for Water Circulation and Fish Feeding in Tilapia Ponds with Solar Panel Source combines hardware and software parts, where the hardware consists of mechanical design requirements and electronic design. While the software part consists of programming requirements such as sensor work algorithms and automation systems.

A. Hardware Design

Hardware development consists of two core elements, namely mechanical system design and electronic system design. The mechanical design focuses on the physical aspects of the system, while the electronic design includes various electronic components such as controllers, sensors, and other electronic modules. The mechanical design of the system can be seen in Figure 1, while Figure 2 shows the block diagram for the overall hardware design.

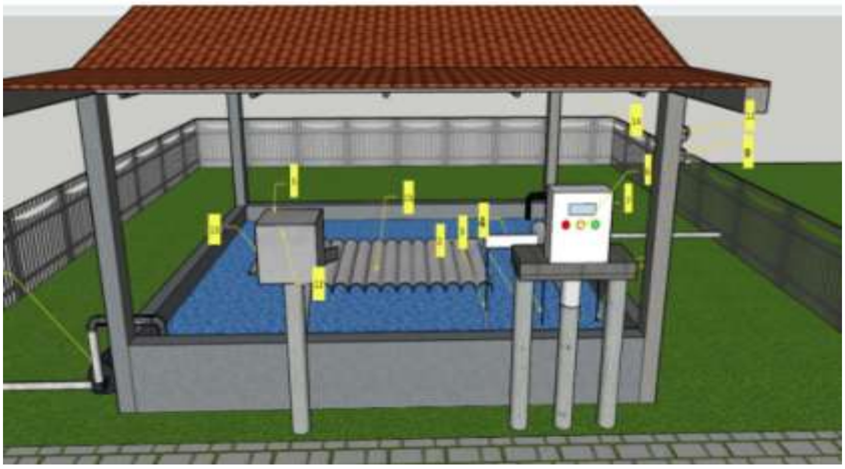

Figure 1. The Mechanical Design of System

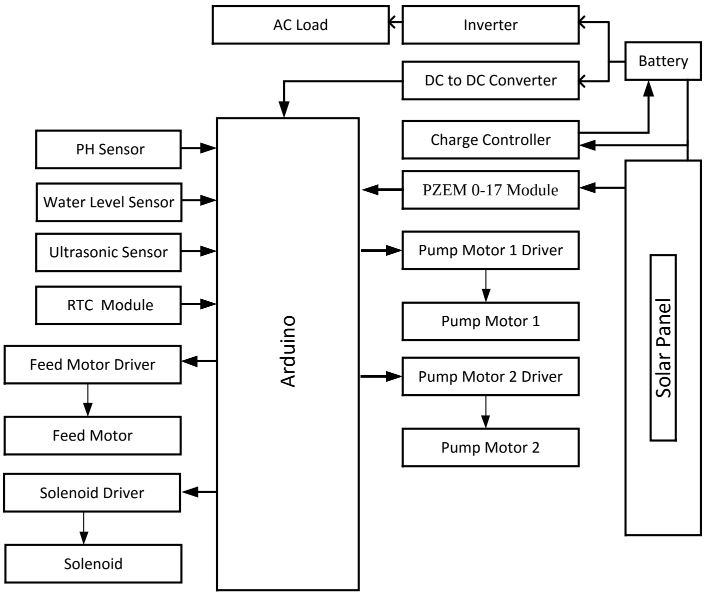

Figure 2. The Block Diagram for The Overall Hardware Design

In the picture above there is a main controller in the form of an Arduino that will be connected to the entire circuit. In addition to the Arduino, the solar panel that has been connected to the charge controller and battery functions as a supplier for the entire system so that the entire circuit can work well for the need for AC supply (via inverter) and DC (Converter), to determine the efficiency of the solar panel as a source of electrical energy the system is connected to the PZEM 017 module which can read the voltage, current and output power values of the solar panel. The pH sensor will check the pH level of the pond water, so that through this sensor data it can activate the work of pump 1 and pump 2 to circulate the pond water to adjust the sensor values in accordance with the set point that has been determined through the controller programming algorithm. The Ultrasonic Sensor will check the availability of feed through the height of the detected feed container, the RTC Module as a real timer that functions as a reference for the time of feeding tilapia by instructing the feed motor to open the feed container and solenoid valve, all system work is equipped with a sound indicator via a buzzer to find out the condition of the system that is running.

B. Software Design

Software development is done by programming using the C language through the Arduino IDE software, which functions as the main application for managing the system controller, including the control and monitoring process. An overview of this software display can be seen in Figure 3 below:

Figure 3. The Display of This Software Design

RESEARCH RESULT

Sensor Work Testing on Tilapia Fish Pond System aims to ensure that the pH sensor used in the tilapia fish pond circulation management system functions properly and accurately and the RTC Module in determining the time for feeding. Testing is carried out to evaluate the sensor's ability to monitor pond environmental conditions in real-time and provide the right response. With optimally functioning sensors, the pond automation system can maintain ideal water conditions and timely feeding to increase the efficiency of tilapia fish farming.

A. RTC (Real Time Clock) Module Testing

The RTC sensor test aims to determine whether the RTC can function properly as a timer for the day, date, month, and year so that it can be a time regulator when the fish feeder works automatically. RTC testing is carried out by observing sensor performance, so the results are shown in table 1 as follows:

Table 1. RTC (Real Time Clock) Module Testing

No.	Day	Time	Feed Valve	Status
1.	Monday	09.00-09.03	On	The system is working well
	07-10-2024	16.00-16.03	On	
2.	Tuesday	09.00-09.03	On	The system is working well
	08-10-2024	16.00-16.03	On	
3.	Wednesday	09.00-09.03	On	The system is working well
	09-10-2024	16.00-16.03	On	

The table above is the RTC sensor test data that was tested for 3 (days). The table shows the time at 09.00-09.03 WIB and at 16.00-16.03 WIB where this time is the programmed time for feeding to work for a duration of 3 minutes at 09.00 WIB and 16.00 WIB.

B. Ultrasonic sensor testing

Ultrasonic sensor testing is carried out to determine whether the sensor is working properly or not. Ultrasonic sensors are used to detect remaining feed in the feed tank, if the sensor works properly then the remaining feed in the tank will be detected.

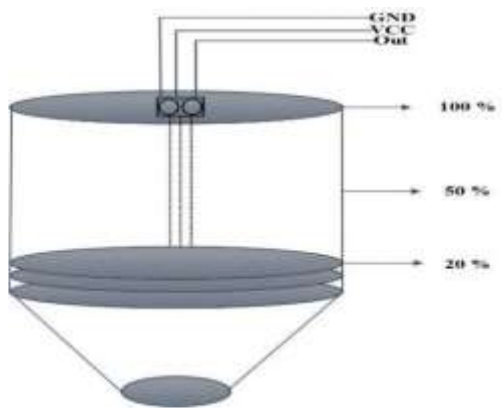

Figure 4. Ultrasonic Sensor Testing

The image above shows the placement of the sensor on the feed tank. Where the sensor is placed on the surface of the feed tank. The sensor will detect vertically from low to high levels. Ultrasonic sensor testing is carried out by measuring the output current on the sensor based on the distance of the object facing it, then the results are displayed in the following table:

Table 2 Test Results on Ultrasonic Sensors

No.	Distance	Sensor Measurement	Status
1.	40 cm	40,25	The system is working well
2.	30 cm	30,13	The system is working well
3	20 cm	20,03	The system is working well

The table above is the result of ultrasonic sensor testing, the test was carried out by taking data from 3 levels of feed in the tank, starting from 40 cm (high level), 30 cm (medium level), 20 cm (low level). The ultrasonic data will be a reference for the life of the indicator lights installed around the pool.

C. pH Sensor Testing

This test is conducted to determine whether the pH sensor can detect the pH level of water whether it is alkaline, acidic and neutral. If the pH condition of the water is acidic or alkaline, the sensor output will emit a voltage of 5V which is used to turn on the relay and the circulation process will take place. Testing of the pH sensor was carried out by measuring the current and output voltage of the sensor based on the pH level, then the results were obtained according to table 3.

Table 3. Test Results on the pH Sensor

No.	pH Buffer	Sensor pH reading	Status
1.	6	6,32	Pump Sirculation ON
2.	7	6,87	Pump Sirculation OFF
3.	9	8,89	Pump Sirculation ON

The table above is the result of testing the pH sensor with three types of pH buffers, namely pH 6,7 and 8. The circulation pump will be affected by the pH level of the water, at pH> 6 and> 9 the circulation pump will turn on, because these levels are not good for the growth of tilapia.

D. Solar Panel Testing

The solar panel testing in this automation system was conducted to evaluate the performance and efficiency of renewable energy use in supporting the operation of the automatic water circulation and feeding system. The testing was conducted in different tilapia pond environments to examine the system's capabilities in various weather conditions and lighting levels.

Energy Capacity and Efficiency The solar panel used in this study has a power capacity of 100 Watt peak (Wp), which is connected to a 12V 50Ah battery to store energy. During testing, the solar panel can produce power of 80–90% of its maximum capacity during sunny weather, while in cloudy conditions, its efficiency drops to 45–60%. On average, the solar panel can fully charge the battery in 6–8 hours during sunny weather.

Energy Use for the Automation System The water circulation and feeding automation system requires around 25–40 Watts of energy to operate, depending on the frequency of water pump activation and feeding. Based on the measurement results, the battery is able to supply enough energy to keep the system operating for 24 hours, even when lighting conditions are minimal (for example, on cloudy days). This shows that the power stored by the battery from the solar panel is able to support the continuous operation of the automation system without interruption.

Operational Stability The system was tested for 10 consecutive days to ensure its reliability under varying weather conditions. On days with maximum light, the solar panel was able to charge the battery quickly enough, so the system operated without any problems. On cloudy days, although the charge was reduced, the pre-charged battery was able to keep the system running well. There was no decrease in the performance of the automation system in terms of water pH monitoring and fish feeding during the test.

DISCUSSION

In tilapia cultivation, water quality factors such as pH levels and feed management are very important to maintain fish health and increase production. Manual monitoring and management of water and feed require considerable time and effort. Therefore, a system is needed that can automate the process. Renewable energy sources such as solar panels are an ideal choice to provide sustainable energy for this automation system, especially for areas that may have limited access to conventional electricity.

CONCLUSIONS AND RECOMMENDATIONS

This study successfully designed and tested an automation system for water circulation and fish feeding in tilapia ponds using energy sources from solar panels. This system has proven to be able to overcome challenges in maintaining water quality and efficient feeding, while utilizing renewable energy for more efficient and environmentally friendly operations. Based on the test results, several conclusions can be drawn, namely the developed automation system can function accurately in monitoring water pH levels in real-time and automatically regulating water circulation based on water conditions. In addition, feeding can also be done precisely according to the needs of tilapia based on their size and quantity, thereby reducing feed waste and increasing cultivation productivity. The use of solar panels as the main energy source has proven effective in maintaining the sustainability of the automation system. With sufficient power capacity and efficient energy storage, solar panels are able to support the system to work independently without the need for conventional electricity sources, even in varying weather conditions. This allows the application of this system in areas with limited access to electricity. The integration of solar panels into the automation system provides a sustainable solution for the fish farming industry. The use of renewable energy not only reduces long-term operational costs, but also contributes to reducing the carbon footprint and supporting environmentally friendly cultivation practices. With automation of water circulation and feeding regulated by sensors, controllers, and supported by solar panels, the tilapia cultivation process can be more efficient and productive. This system helps maintain stable pond water quality, increases fish growth, and reduces operational costs and risks associated with manual management.

ADVANCED RESEARCH

Research design on the control and monitoring system of tilapia fish ponds with integrated solar panel sources of the Internet of Things in the use of more complex variables, further development, such as increasing sensor accuracy, integration with the system's power control system. Trials in various locations with varying load and climate conditions can provide more representative results and help in improving the system for various system scenarios, focus more on power efficiency settings, processed with computerization (computer vision) and can be implemented on an industrial scale.

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