PROTOTYPE OF A PLC-BASED FLOOD DETECTION AND MONITORING SYSTEM WITH HMI SCADA CLOUD

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Abstract

Flooding is a problem that often occurs in Pontianak City, including at the Pontianak State Polytechnic Campus, especially the Laboratory Building of the Department of Electrical Engineering. To solve this problem, a model was created in the form of a prototype Flood Detection and Monitoring System based on PLC Outseal Mega V.2 and HMI Haiwell C7S-W connected to SCADA Cloud for real-time monitoring. The system uses a 10K Ohm potentiometer as a level sensor used to measure water level through a buoy mechanism with water level data every 1 cm converted into parameter data such as output voltage, ADC value, resistance, degree of rotation potentium processed and visualized on HMI and mobile phones. Based on the tests, the system is able to detect three levels of water level: level 1 Normal (10–50 mm) produces a voltage of 266 mV - 1,283 mV, level 2 Standby (>50–100 mm) produces a voltage of 1,510 mV - 2,544 mV, the system activates Pump 1 automatically and level 3 Hazardous (>100 mm) produces a voltage of 2,761 mV - 3,594 mV, the system activates pump 2 at the same time as pump 1 as well as the buzzer and warning indicator light. Both pumps work to drain the water until the water level drops below Level 1 (<10 mm) then the system is in a state of stanby. The results show that the system is responsive and effective in providing early warning and small-scale flood mitigation. Therefore, this research has the potential to be applied as an actual flood mitigation solution in the campus environment and become a learning module in the Industrial Automation course.

Keywords : *PLC, HMI, SCADA, Flood Detection, Real-Time Monitoring, Potentiometer, Water Pump.*

1. INTRODUCTION

Floods are one of the most destructive natural disasters and often affect many areas around the world, including Indonesia. In West Kalimantan, especially in Pontianak City, flooding has become a significant problem. Based on data from the Pontianak State Polytechnic, the Laboratory Building of the Department of Electrical Engineering often experiences flooding during the rainy season. This is due to high rainfall, suboptimal drainage systems and other environmental factors are the main causes of floods that disrupt academic activities.

Conventional flood management is less effective because it cannot respond automatically, so a real-time water level monitoring system integrated with an automatic control system is needed to increase the responsiveness and effectiveness of flood handling. Several relevant previous studies have been conducted by developing an automatic-based water level monitoring system. As research [1] has proven that the use of PLCs and HMI in water level control simulations can improve water management efficiency. However, this study has not yet utilized cloud technology or remote monitoring. The second researcher [2] focused on the integration of ultrasonic sensors with PLCs to detect water levels, but this study has not added about the use of HMI or SCADA for real-time monitoring and control of the system. The third research [3] designed and developed a prototype flood prevention system that can automatically control the water level by controlling the water in the reservoir. However, this study has not used an early warning system that can provide notifications to users if the water level is close to the critical limit.

This study aims to make and develop the shortcomings in the previous research, so a model was made in the form of a prototype of a PLC-based Flood Detection and Monitoring System with HMI SCADA Cloud using a potentiometer analog sensor as a water level detection sensor with a buoy mechanism. The system is capable of processing water level data in real-time, activating the pump, status indicator light for each level (normal, standby, hazardous) and buzzer as an alert alarm that can operate automatically. The data is processed by the PLC to be visualized through the HMI screen. This system, not only provides visual information on the HMI screen, but can also be monitored in real-time through mobile devices by utilizing the SCADA Cloud network. With these advantages, the results of this research have the potential to be applied as an actual flood manager directly and can be applied as a learning medium in the field of industrial automation.

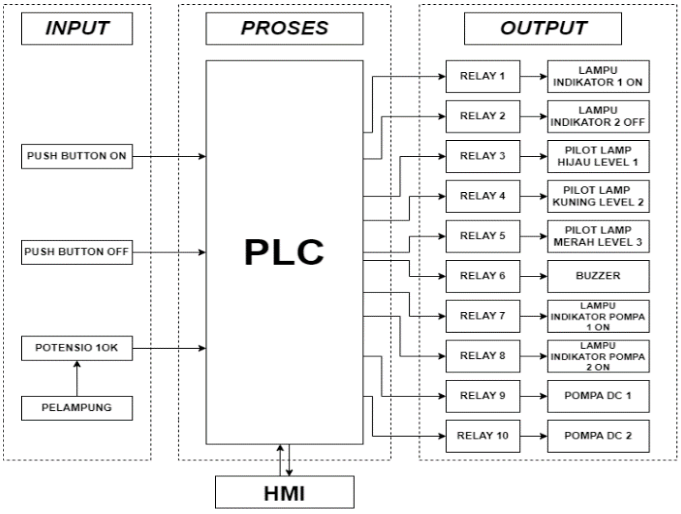
2. METHOD

2.1. System Block Diagram Design

The system designed is a prototype of the system used as a flood water level detector. The system is designed using Outseal Mega V.2 type *Programmable Logic Controller* (PLC) as the main controller and to process system data with *Human Manchine Interface* (HMI) as the system monitoring interface and displaying system parameters. *The Supervisory control and data acquisition* (SCADA) Cloud is integrated to enable remote monitoring over the internet network to be accessed via mobile phones and laptops.

The water level sensor uses a 10K Ohm potentiometer as an input driven by a buoy mechanism that functions as a water level detector through the movement of the degree of rotation of the potency so that it produces a resistance value which is converted into an analog voltage value, then read by the PLC analog input in the form of an ADC value. This data is converted into water level values which are classified into three statuses, namely, "Normal" with Level 1 water level (10 mm-50mm), "Alert" with level 2 water level (>50-100 mm) and "Hazard" with level 3 water level (>100 mm).

Based on the detected water level level, the system will activate the water pump and alert buzzer alarm automatically through the relay module. The pump operates to drain water if it reaches a standby status, is dangerous and will stop automatically when the water level is below normal limits. The indicator light on the control panel and the HMI screen display change according to the status of the water level. All data displayed on the HMI screen can be accessed through a laptop or mobile phone device by utilizing a SCADA Cloud server connected through the internet network for remote monitoring.



Picture 1. System Block Diagram

The diagran block above consists of 3 parts, namely Input, Process and Output. The following is an explanation of the block diagram

a. Voltage Source
To be able to activate the prototype of this system, it is necessary to use a 24 Volt DC power supply that functions or is used to convert inputs from electrical voltage sources such as AC (*Alternating Current*) to DC (*Direct Current*) current for the needs of devices such as PLC, HMI, push button, potentiometer, *pilot lamp*, relay, water pump and *buzzer*. This system also uses 2 *buck converters* (*step down*) which are used to lower the voltage. *Step down* 1 is used to lower the voltage from a 24 Volt DC source to 12 Volt DC which will be used to activate the 12 Volt DC relay module and to activate the 12 volt DC water pump. *Step down* 2 is used to lower the voltage from a 24 Volt DC source to 5 Volt DC which is used to provide voltage supply to the PLC analog inputs, namely A1 and A2 inputs, and is needed or functions to activate the 5 Volt DC relay module and the input voltage supply source for the 10K Ohm Potentiometer.

b. Input
This system is equipped with a push *button* that functions to control the operation of the system manually, namely the ON button to activate and the OFF button to turn off the system. In addition, a 10K Ohm potentiometer is used which acts as a water level sensor to measure the water surface level ranging from 1 cm – 20 cm which is assumed to be from 10 mm – 200 mm). The sensor is mechanically connected to a buoy that acts as a medium for detecting changes in the position of the water surface. The upward and downward movement of the buoy is caused by a change in the water surface resulting in a change in the resistance *wiper* at the potency, which is then converted into an analog input signal for the system. With this mechanism, the combination of buoys and level sensors using potency allows for water level monitoring that can provide system control, either manually or automatically. The data is processed by a control and monitoring system in the form of PLC with HMI SCADA Cloud.

c. Process
The main part of the processing of this system uses *the Programmable Logic Controller* (PLC) Outseal Mega V.2 with the voltage used which is 24 Volt DC. The PLC serves as the main controller to receive input data such as push *buttons* and water level sensors. The input data received is in the form of a potential wiper resistance value as a voltage divider, the value is in the form of an analog signal that is input through an Analog pin (A1) on the outseal and will

be converted by ADC (*Analog to Digital Converter*) to convert the analog signal from the pisor into a digital value. The value will be processed based on the PLC logic algorithm that determines three water level conditions, namely Level 1 "Normal", Level 2 "Alert" and Level 3 "Hazardous". Based on the processing results, PLC controls multiple relays to turn on or off output devices such as indicator lights, water pumps, buzzer alarms. System information and device controls are displayed in *real-time* through the *Human Machine Interface* (HMI) interface to facilitate effective monitoring and management of the system.

d. Output

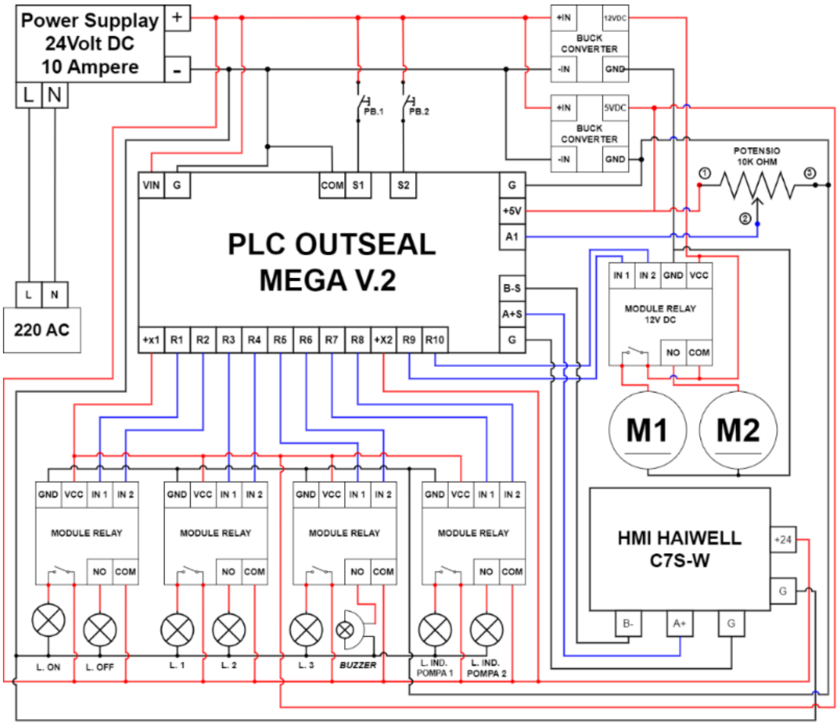
The output part of the system uses a relay that functions as a controller of output devices such as ON and OFF indicator lights, level 1, 2 and 3 indicator lights, buzzers, pump 1 and pump 2 indicator lights Active when operating as well as DC Pump 1 and DC Pump 2. The ON and OFF indicator lights are used to indicate the status of the system, while the Green level indicator light indicates that the water level is at level 1, the Yellow indicator indicates that the water level is at level 2 and the Red indicator indicates that the water level is at level 3 by displaying the status on the HMI screen "Normal", "Alert" and "Dangerous". When the water level reaches Level 2, DC Pump 1 is activated to drain the water, and if the water level reaches Level 3, the DC Pump 2 is also activated to assist in the draining process. A buzzer is used as an alarm to provide a sound warning when the water level reaches Level 3. The system is designed to automatically monitor and control water levels, thereby reducing the risk of flooding.

e. HMI Haiwell C7S_W

In this study, HMI is used which functions as an interface medium for inputs, processes and outputs to control and monitor the system and display the data received from the input components, outputs processed by the PLC.

2.2. Planning Addressing and Wiring

Wiring is the stage of stringing together the types of PLC inputs, PLC outputs, and HMI. In the design of this wiring, it includes all components used.



Picture 2. Wiring Network System

2.2.1. PLC Input Address

Table 1. PLC Input Address

No	Input	Address
1	Push Button ON	S1
2	Push Button OFF	S2
3	Potensiometer	A1
4	Sistem ON	B1
5	Sistem OFF	B2

In table 1. The PLC input address is the input on the PLC Outseal Mega V.2. This input includes *the Push Button* using the digital input Pin address (S1 and S2) while the potentiometer uses the analog input address (A1). At the ON and OFF system input addresses, using the internal addresses, namely B1 and B2, functions to activate the system using HMI.

2.2.2. Alamat Output PLC

Table 2. Alamat Output PLC

No	Input	Address
1	Indicator Light ON	R1
2	Indicator Light OFF	R2
3	Green Light Level 1 Normal	R3
4	Red Light Level 2 Alert	R4
5	Red Light Level 3 Danger	R5
6	Buzzer + Dangerous Warning Light	R6
7	Pump Indicator Light 1 ON	R7
8	2 ON Pump Indicator Light	R8
9	Air DC 1 Pump	R9
10	Air DC 2 Pump	R10

In table 2. The output address is the output on the Mega V.2 Outseal PLC. These outputs include DC Water Pump, Indicator Light and Buzzer.

2.2.3. Designing Parameter Display on HMI Screen

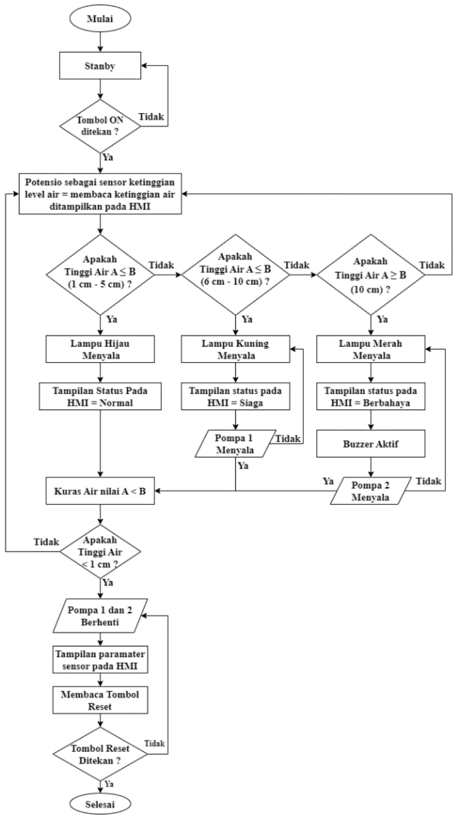
(a) (b)

Picture 3. (a) First Screen HMI Display. (b) Second Screen HMI Display

(a) (b)

Picture 4. (a) Third Screen HMI Display. (b) Display of the Fourth Screen HMI

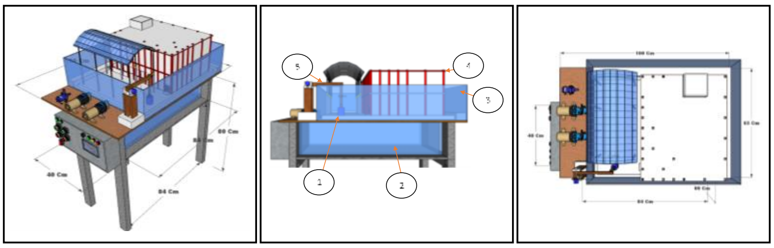
2.3. Flowchart Sistem



Picture 5. Flowchart Sistem.

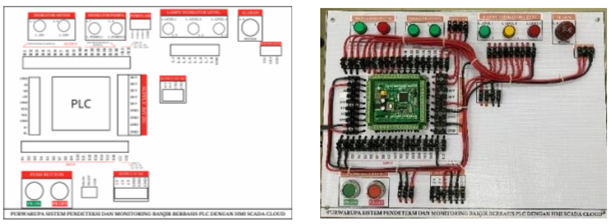
2.4. System Prototype Design Design

The design and layout of all components installed in the prototype PLC-based flood detection and monitoring system with HMI Scada Cloud can be seen from Figure 6. next.



Picture 6. 3D Prototype Design System

The panel box is used as the main control of the system to be able to operate the work of the tool and to activate the components that are already installed in the panel. The panel used can be seen in Figure 6 below.



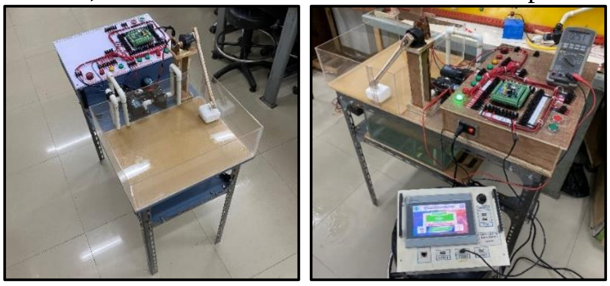
(a) (b)

Picture 7. Panel Box System

3. RESULTS AND DISCUSSION

3.1. Results of Creating a Prototype of the Flood Detection and Monitoring System

In making and designing a modeling in the form of a prototype of a PLC-based flood detection and monitoring system with HMI SCADA Cloud based on the design and drawings that the tool can be made, here is the documentation of the shape of the tool.



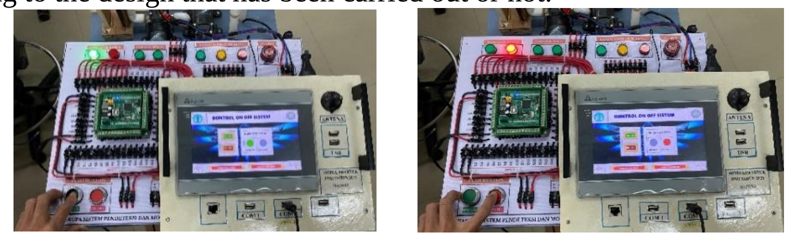
Picture 8. System Prototype

3.2. Results Obtained

After the mechanics, systems, control panels, and inspections are completed and the program is tested, the prototype of the system can produce the following data.

3.2.1. System Mechanism Testing

This test is carried out to test whether the ON and OFF buttons of the system function according to the design that has been carried out or not.



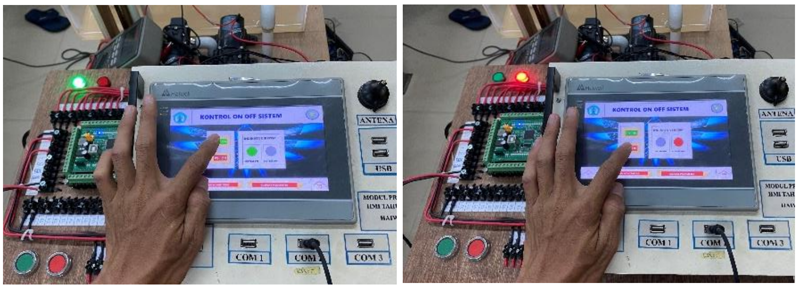
(a) (b)

Picture 9. (a) Active System Testing. (b) Testing of Dead Systems

Table 3. System ON and OFF Button Testing

Push Button ON (Green)	Push Button OFF (Red)	System Indicator ON (Green)	System Indicator OFF (Red)
Active	Inactive	ON	OFF
Inactive	Active	OFF	ON

For testing the ON and OFF system we only need to press the green ON push button whose address is made S.1 on the outseal studio software. In table 3. if the system ON button is pressed then the green indicator light will illuminate indicating the system is in a state of static. Conversely, if the red OFF button is pressed then the green indicator light turns off and the red indicator light comes on indicating the system is off. In figure 4. is the ON and OFF control of the system which is controlled through the HMI screen, the way it works is the same as in figure 4.8. Here are the test results on the HMI screen.



Picture 10. Testing ON System And OFF System On HMI

From the above test data, all components or mechanisms of the system are made in accordance with the design made so that the system can operate properly. To produce the desired data, it is embraced by calibration at the initial moment before the water level detection and monitoring system.

Table 4. System ON and OFF Testing On HMI

B.1	B.2	Indicator System ON	System Indicator OFF
Active	Inactive	ON	OFF
Inactive	Active	OFF	ON

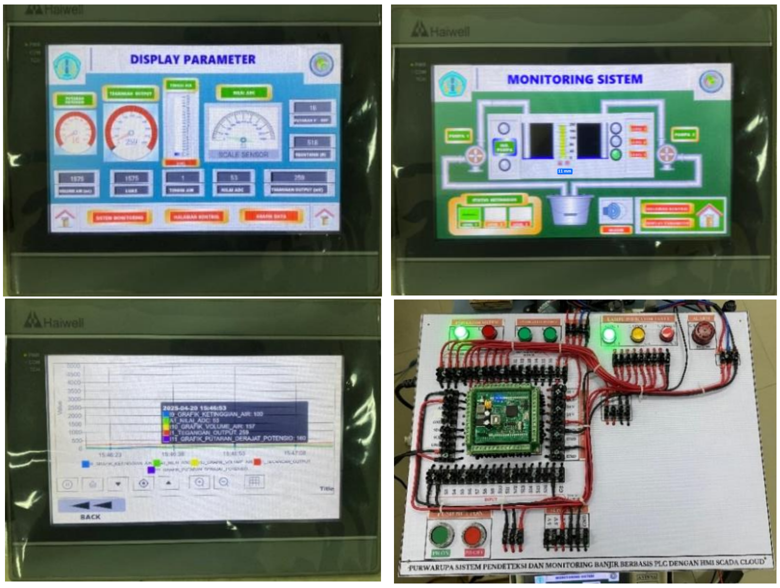
Picture 11. System ON and OFF Testing Using Android

3.2.2. Sersor Level Testing

The sensor test starts from the water level at level 1 which is 1 cm - 5 cm which is assumed to be 10 mm - 50 mm, the water level at level 2 is >5 cm - 10 cm which is assumed to be >50 mm - 100 mm, the water level at level 3 with a height of >10 cm - 20 cm which is assumed to be >100 mm - 200 mm. The test results are carried out as shown in the picture below:

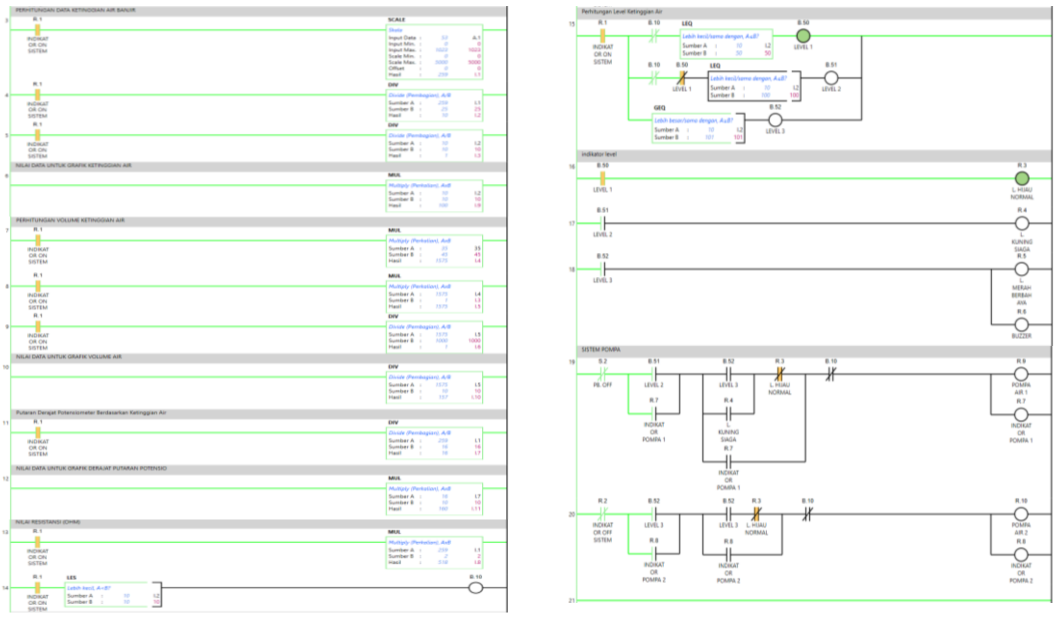
Picture 12. Water Level Testing and Voltage Measurement

In figure 12. Water level testing and output voltage measurement on potentiometers as water level sensors. At a water level of 1 cm, there are test results or measurements that have been carried out using a ruler. The results showed that the water level was above 1.1 cm (11 mm). The output voltage measurement using a multimeter showed the output voltage of the sensor was 266 mV (0.26 V) and the parameters are displayed on the HMI screen in figure 13.



Picture 13. Water Level Sensor Testing 1 cm (10 mm)

Picture 14. Test Results on Laptop Screen Through IP Address



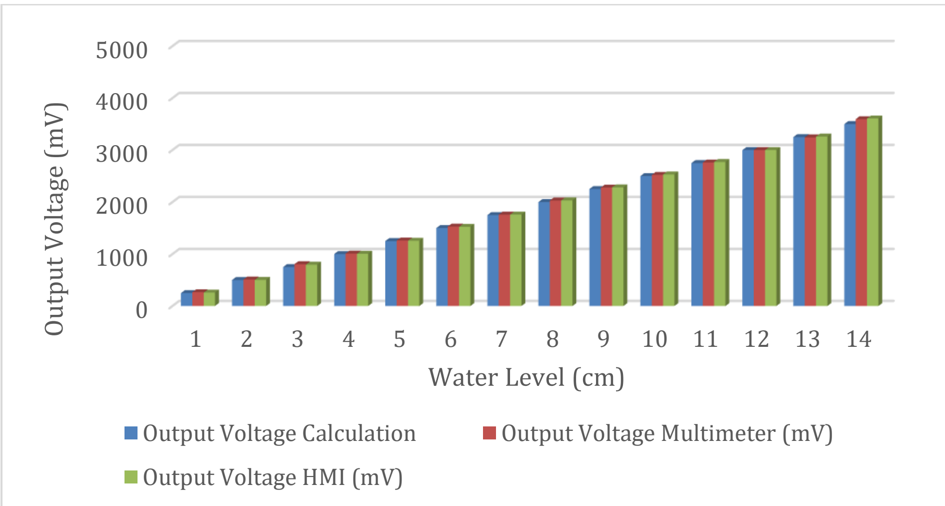
(a) (b)

Picture 15. Test Results on Outseak Studio Ladder Diagram

Figure 13 is the result of testing the level sensor at a water level of 1 cm, where the HMI screen display parameter display displays a water level of 1 cm. Meanwhile, on the HMI screen, the monitoring system displays a water level of 11 mm, which shows that the calculation and measurement data have a difference in value that is not too large. The difference between 1 cm and 11 mm is due to the ladder programming process in the Outseal Studio software which is differentiated to be able to read the change in water level from 1 cm which can be converted to 10 mm. The parameter data obtained shows that the output voltage displayed on the HMI screen is 259 mV or 0.25 V, while the measurement using a multimeter in Figure 4.11 shows a value of 266 mV or 0.26 V. On the HMI screen of the system monitoring section, the indicator light is active green with the status "Normal", and on the control panel, the level 1 indicator light is active green. Meanwhile, water pumps 1 and 2 are still dead. The results obtained on the system can be seen in Figure 12, Figure 13 and Figure 14. In addition, the results of level 1 parameters for water levels from 1 cm (10 mm) to 5 cm (50 mm) can be seen in Table 5. which presents the test results. Picture 15. Test Results on Outseak Studio Ladder Diagram. Section (a) is a ladder diagram in the Outseal Studio software used for comparison of the calculation of analog input values from level sensors. Meanwhile, Section (b) displays the results of the water level calculation, with the level 1 indicator condition in active green and "Normal" status. The pump is still inactive.

Picture 16. Testing At Level 3 (>10 cm)

Picture 17. HMI Screen Display Monitoring Section and System Parameters



Picture 18. Output Voltage Data Graph

The data in Table 5 and the data graph are data between the water level to the resistance value of the potentiometer, the value of the ADC integer, the output voltage read on the measuring instrument and the parameters displayed on the HMI screen. This test is carried out with water levels ranging from 10 mm - 14 mm, this adjusts the water container used with a maximum height of 14 cm with measurements made there are differences or differences that can be seen on the output voltage data graph. In the data graph, there are calculation and measurement data through a multimeter measuring instrument and parameters displayed on the HMI screen. This proves that the potentiometer used as a level sensor functions to read water level data through the resistance value generated from the rotation of the degree of potency that causes the rotation of its wipers with a buoy mechanism. This system shows or obtains almost the same results between the calculation data and the measurement. At a water level of 1 cm (10 mm) the output voltage calculation = 250 mV, from the test results obtained, namely, the measurement using a multimeter = 266 mV while the one displayed on the HMI screen = 259 mV. At a water level of 14 cm (140 mm) the output voltage calculation = 3,500 mV, from the test results obtained, namely, the measurement using a multimeter = 3,594 mV while the one displayed on the HMI screen = 3,607 mV. There is a voltage difference between the calculation with the measurement of the multimeter measuring instrument at a height of 10 mm = 16 mV and the difference between the measurement of the multimeter measuring instrument and the one read on the HMI screen = 7 mV. The voltage difference between the calculation and the measurement of the multimeter measuring instrument at a height of 140 mm = 94 mV and the difference between the measurement of the multimeter measuring instrument and the one read on the HMI screen = 13 mV. Thus, this study proves that the use of potency as a substitute for water level sensors is proven to be effective even though there is still a difference in values or data obtained, but it is due to the tolerance to the resistance used.

4. CONCLUSION AND SUGGESTIONS

4.1. Conclusion

Based on the results of the tests and analysis that has been carried out, the following can be concluded**.**

a. The Outseal Mega V.2 PLC-based flood detection and monitoring system with HMI SCADA Cloud has been successfully designed and implemented in prototype form. The system successfully detects the water level using an analogue potentiometer sensor, which is converted to digital values by the PLC, and displayed in real-time via HMI and SCADA Cloud.
b. The system works automatically with three status levels: Normal, Alert, and Hazard, each triggering a different response such as pump and buzzer activation.
c. Communication between PLC, HMI, and laptop or handphone can be communicated or controlled simultaneously using the IP address on the network used, thus allowing remote monitoring of flood conditions.
d. For the use of a level sensor that uses a 10K Ohm potentiometer, it can be used as a substitute for the level sensor, although the test data measured using a multimeter is slightly different from the results displayed on the HMI screen.

4.2. Suggestion

The suggestions submitted based on the results of observation and analysis during testing and data collection are as follows:

a. Conduct further research to optimize the control algorithm on the PLC, so that it can improve the efficiency and stability of the system.
b. For areas with a higher risk of flooding, use a water pump with a larger capacity to speed up the drainage process.
c. Integration of the system with cloud-based data storage can be done so that the history of water level data can be stored and used for future predictive analysis.

d. Addition of Internet of Thing (IoT)-based notification features, WhatsApp Messages, Email or mobile apps to provide immediate alerts to users if the water level reaches a critical level.

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