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Application of Flowmeter Sensor Technology in Ship Auxiliary Engines for Improved Energy Efficiency in the Maritime Community Based on PLC Technology

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Abstract: *The container transport system plays a crucial role in facilitating cargo transfer by simplifying the unloading process to make it more effective and efficient. In container vessel operations, fuel consumption management is a critical aspect that significantly impacts operational costs, accounting for approximately 70% of the total expenses. Therefore, shipping companies must closely monitor fuel consumption to prevent wastage. Without an effective monitoring system, the management cannot track fuel consumption in real-time, which may lead to misuse by crew members. This study aims to implement a flowmeter sensor technology based on Outseal PLC for automatic monitoring of fuel consumption on vessels. The data from the flowmeter sensor will be transmitted to a web server, allowing authorized personnel to access the information for transparent and accurate oversight. The test results of the flowmeter sensor show low error rates of 1.23%, 2.07%, and 2.06%. Thus, this system proves to be effective as a real-time fuel consumption monitoring solution for auxiliary engines, with a reading interval of approximately 1 minute and 58 seconds per liter. This research contributes to improving energy efficiency in the maritime sector while empowering the shipping community with technology that can be accessed by relevant parties, as part of a broader community service initiative.*

Keywords: *Fuel Oil (BBM), Monitoring, Outseal PLC, Webserver, Energy Efficiency, Community Service.*

Introduction

Indonesia, as a maritime country, urgently needs to enhance its naval fleet for both marine exploration and as a supporting tool for the economic development of Indonesia's maritime regions. One of the efforts that can support national economic development is through international trade, involving the export and import of goods using a container transport system. The container transport system, which integrates various modes of transportation using containers, aims to simplify the cargo handling process to make it more effective and efficient. In container vessel operations, fuel plays a crucial role, accounting for approximately 70% of the total operational costs of the vessel. Therefore, strict monitoring of fuel consumption is necessary to prevent waste, which can lead to increased operational costs (Nugraha, 2018).

Maritime transport and the shipping industry are not immune to the rapid advancement of technology that has spread across various sectors of human life. In the shipping industry, technology is utilized to improve operational efficiency, one of which is through the electrical system in the engine room connected to the central control room. In this room, the functions of each component in the vessel's machinery are monitored in real-time to ensure optimal vessel performance (Suharti, 2020). Technology-based monitoring systems are also applied to manage vessel fuel consumption more efficiently.

However, many shipping companies still rely on manual monitoring systems, which cannot provide real-time fuel consumption information. This manual system opens the door for potential misuse by crew members, which could harm the company. Therefore, an innovative solution is needed to monitor fuel consumption on vessels. This study aims to design a monitoring system based on flowmeter technology with Outseal PLC to automatically and real-time track vessel fuel consumption and prevent potential misuse (Yusuf, 2021).

This technology-based monitoring system also contributes to reducing fuel wastage, which directly impacts energy efficiency in the maritime sector. By implementing this system, it is expected that shipping companies can manage their resources more wisely and improve transparency in their operations. Furthermore, this technology can help enhance the capacity of communities involved in shipping operations to better understand the importance of efficient energy management.

Methodology

1. Fuel Types Used in the Vessel

Fuel is a substance that can burn rapidly in the presence of air (oxygen), producing heat and energy. The fuel used in the MV Meratus Benoa vessel's engine is Marine Diesel Oil (MDO). MDO is a diesel fuel used in medium-speed compression ignition engines (<1000 rpm) and is commonly employed in industrial applications. MDO primarily consists of paraffinic hydrocarbons, with a carbon chain length ranging from 10 to 22. Diesel fuel is refined from various components of crude oil to meet the necessary specifications, such as density, kinematic viscosity, pour point, sulfur content, and ash content (Santoso, 2019; Nugraha, 2020).

2. DC Mini Water Pump

A pump is a device used to move fluids from one place to another by increasing the pressure of the fluid to overcome flow restrictions, such as pressure differences, height differences, or friction. The pump converts mechanical energy from the motor into fluid flow energy, which is used to overcome the resistance in the piping system (Hidayat, 2021).

3. Outseal PLC

Outseal PLC is an electronic device used to control the logical status (ON or OFF) of connected electronic devices. Outseal PLC programming is done via Outseal Studio software in a ladder diagram format. This device has 16 digital inputs, 16 digital outputs, 2 analog inputs, and a maximum supply of 24V. Outseal PLC can communicate with external devices via Modbus RTU communication (Abdillah, 2019).

4. Flowmeter Sensor

A flowmeter is a measurement tool used to determine the amount of fuel consumed by the engine. It consists of a rotor that spins when fluid flows through it, with the speed of the rotor directly proportional to the flow rate of the fluid. The flowmeter measures the volume of fluid passing through the device, providing accurate data on fuel consumption (Supriyadi, 2018).

5. ESP32

ESP32 is a chip-based control system with built-in Wi-Fi and Bluetooth for data transmission. It functions as the brain of the system, processing sensor data and displaying it on mobile devices or IoT applications. The ESP32 enables wireless data communication (Halim, 2020).

6. Relay

A relay is a mechanical switch controlled by electronic signals. The relay's switch moves from off to on when electromagnetic energy is applied to the relay's armature. Relays are used to control electrical circuits and consist of a coil that generates a magnetic field when current flows through it, moving contacts (Setiawan, 2022).

7. Method

The method used for fuel monitoring in this system involves real-time monitoring of the auxiliary engine's fuel consumption. The input to this monitoring system is the flowmeter sensor, which measures the volume of fuel used, while the output is processed to control the pump and fuel usage.

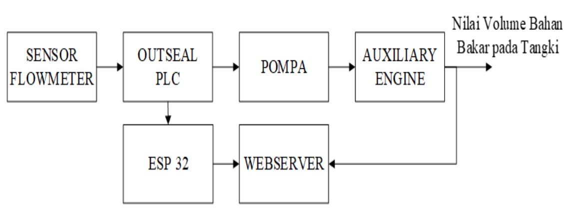

Figure 1. Block Diagram of System Monitoring Auxiliary Engine

In this monitoring system, RHSCU, WHSCU, and DIV instructions are used to read pulses from the flowmeter, which are then divided to convert the data into fuel volume in liters (Sari, 2021). The pulse readings from the flowmeter are used to control the pump state via relay, which turns the pump on or off depending on fuel demand.

Table 1. Input and Output Conditions During Control

Input *Conditions*	**Output *Conditions***
Volume Flowmeter 0 L	Pump ON
Volume Flowmeter 2 L	Pump ON
Volume Flowmeter 4 L	Pump ON
Volume Flowmeter 6 L	Pump ON
Volume Flowmeter 8 L	Pump OFF

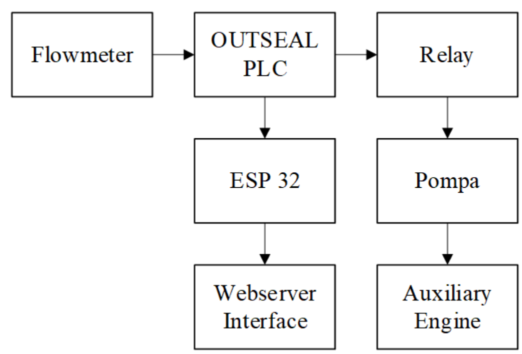

Figure 2. Block Diagram of the Auxiliary Engine Monitoring System

This diagram illustrates how the system monitors fuel consumption through a flowmeter and processes the data using Outseal PLC to control the pump operation and fuel flow.

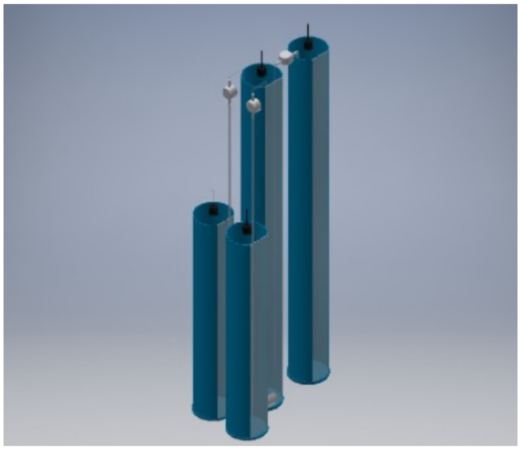

Figure 3. PLC System Design and Layout

The design for the fuel monitoring system consists of a flowmeter sensor, Outseal PLC, ESP32, mini DC pump, and relay. The mechanical design of the fuel tank system consists of four tanks, with two tall tanks and two short tanks. This design aims to improve operational efficiency and support better energy management in maritime communities.

Results and Discussions

This study conducted tests on the fuel consumption monitoring system for the Auxiliary Engine. The tests were divided into two sections: calibration of each flowmeter sensor and actuator used, and testing of the fully integrated system.

1. Calibration of Flowmeter Sensor 1

The purpose of testing Flowmeter Sensor 1 was to determine the accuracy of the flowmeter's reading of fluid flow. The testing method involved comparing the readings provided by the flowmeter via the Outseal Studio display with a 1000 mL measuring cup. The results of the test are shown in Table 2.

Table 2. Test Results of Flowmeter 1 Volume Readings (L)

Test No-	Reading Sensor (L)	Measuring Cup Reading (L)	*Error* (%)
1	1	1,02	1,96
2	2	2,01	0,49
3	3	3,03	0,99
4	4	4,03	0,74
5	5	5,06	1,18
6	6	6,09	1,47
7	7	7,1	1,4
8	8	8,13	1,59
	Average		1,23

Based on the data in Table 2, the average error percentage of the flowmeter is 1.23%. Therefore, the tested module is considered reliable for use in this project.

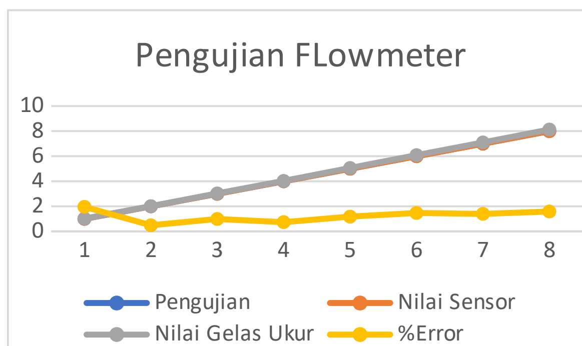

Figure 4. Flowmeter Sensor Reading Graph with Measuring Cup

2. Calibration of Flowmeter Sensor 2

Testing Flowmeter Sensor 2 aimed to assess the accuracy of the flowmeter readings. The method used was similar to that of Flowmeter 1, comparing the flowmeter's readings displayed on Outseal Studio with a

1000 mL measuring cup. The results are shown in Table 3.

Table 3. Test Results of Flowmeter 2 Volume Readings (L)

Testing	Sensor Value	Measuring Cup Value	%Error
1	1	1,04	3,84
2	2	2,04	1,96
3	3	3,05	1,63
4	4	4,07	1,72
5	5	5,07	1,38
6	6	6,09	1,48
7	7	7,15	2,09
8	8	8,2	2,43
	Average		2,07

The average error for Flowmeter Sensor 2 is 2.07%, which still qualifies the module for use in the final project.

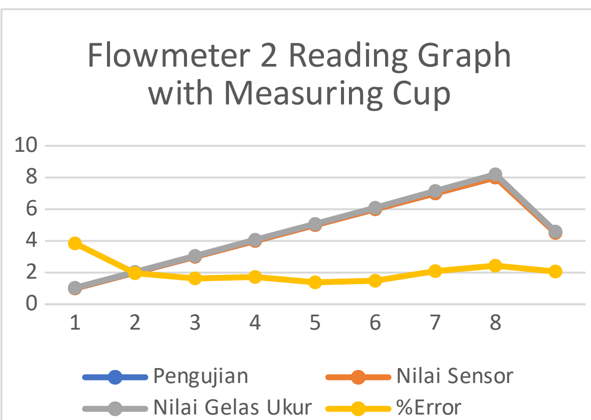

Figure 5. Flowmeter 2 Reading Graph with Measuring Cup

3. Calibration of Flowmeter Sensor 3

Testing Flowmeter Sensor 3, similar to the previous tests, aimed to evaluate the flowmeter's reading accuracy. The same method was used by comparing the flowmeter readings from Outseal Studio with a 1000 mL measuring cup. The results are provided in Table 4.

Table 4. Test Results of Flowmeter 3 Volume Readings (L)

Testing	Sensor Value	Measuring Cup Value	%Error
1	1	1,03	2,91
2	2	2,03	1,47
3	3	3,07	2,28
4	4	4,07	1,72
5	5	5,1	1,96
6	6	6,1	1,64
7	7	7,15	2,1
8	8	8,2	2,44
	Average		2,06

The average error for Flowmeter Sensor 3 is 2.06%, which also indicates the reliability of the system for this final project.

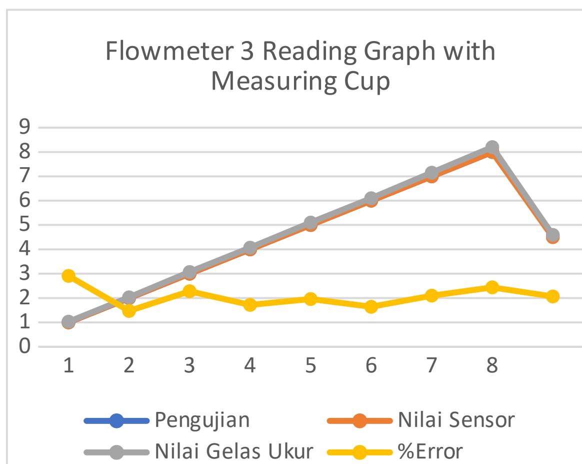

Figure 6. Flowmeter 3 Reading Graph with Measuring Cup

4. Flowmeter Reading Time on Outseal PLC

The time taken for the flowmeter to reach the set volume of each 1000 mL or 1L is shown in Table 5.

Table 5. Time to Reach Setpoint Volume at the Connection Hub (PHB)

Sensor Value	Time
1	1m 58s
2	3m 16s
3	5m 13s
4	7m 14s
5	9m 15s
6	11m 21s
7	13m 12s
8	15 minutes 15 seconds

The results in Table 5 show that the average time taken for each liter of fluid to pass through the flowmeter is 1 minute 58 seconds.

5. Discussion

Based on the calibration results of the input and output sensors, the comparison of readings from all sensors (three flowmeter sensors) for measuring the volume (L) of fluid entering from the pump to the flowmeter, and the data processed by Outseal, the error percentages were 1.23%, 2.07%, and 2.06%, respectively. The output actuator (pump) showed no error. Table 5 demonstrates the time it takes for each liter of fluid to pass through the flowmeter, with an average time of 1 minute 58 seconds per liter.

Conclusion

The flowmeter readings processed by Outseal can be used as a monitoring tool for fuel consumption and pump control. The calibration results indicated average errors of 1.23%, 2.07%, and 2.06%. Based on the testing results, it can be concluded that the flowmeter sensor system can be effectively used for monitoring fuel consumption in the Auxiliary Engine of ships, based on Outseal PLC technology.

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