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# The Experiment Practical Design of Marine Auxiliary Engine Monitoring and Control System

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**ABSTRACT** Maintaining the quality of transportation services and reducing operational costs are some of the problems in shipping companies. This problem can be solved by several solutions. One of them is a reliable machine alarm monitoring and operation system. This study aims to provide a practical design of the ship's auxiliary engine start-stop control system and alarm system. This study uses an experimental method with a descriptive explanation of the observations. The test results show that this system is able to provide a simple, inexpensive, and efficient engine alarm system design to develop this technology for shipping companies. The PLC used is suitable for controlling this system because of its fast response. In addition, the utilized HMI can communicate efficiently with the monitoring system showing the machine parameter interface directly. Direct application of the system has been created provides technology development solutions for monitoring and controlling systems auxiliary machines for shipping companies to reduce operational cost.

**INDEX TERMS** Auxiliary Engine, Control System, HMI, Monitoring System, PLC.

## I. INTRODUCTION

Ship operating costs are one of the issues in shipping companies [1] [2] [3]. These costs are mainly related to power generation: maintenance, repairs, fuel, and oil requirements [4] [5] [6]. Thus, it becomes a big challenge for shipping companies to maintain the quality of transportation services and reduce operational costs [7] [8] [9].

This problem considers several solutions. One of them is a reliable monitoring system and operating machinery alarms [10] [11]. With clear and informative supervision, the handling of engine damage can be more efficient [12] [13] [14]. Then, equipment lifetime can last longer and will reduce equipment repair costs [15] [16]. One reported machinery alarm problem is unclear warnings, uninformative reporting, and mixing of essential and non-essential warning conditions. Information from the warning system plays a vital role in maintaining safe operations on the ship because when equipment or machine experiences an abnormal condition, the alarm system automatically displays hazard information [17] [18] [19].

Many system developments have been carried out before, from the development of communication technology to complex system architectures. Choi in [20] researched wireless Fieldbus technology to use real-time data communication technology in the industry. This research was implemented using the CC2430 Zigbee development kit and tested on computer integrated manufacturing (CIM). In contrast to Choi, Adhane in [10] researched data transmission with cable technology, namely communication via controller area network (CAN) bus and Modbus. The CAN bus and Modbus are in parallel. Modbus is the primary communication protocol. Meanwhile, the CAN bus is a secondary communication that gives recovery data transmission and error detection.

In developing the architecture and design of the machinery alarm system, Changsun in [18] plans a structure of the alarm monitoring system in three layers, with the lowest layer being the acquisition module, the middle layer being the converter module, and the top layer being the human-machine interface (HMI). The Modbus RS485 communication protocol sends data from the acquisition module to the converter and the CAN bus to send data from the converter to the HMI.

Zaghloul in [21] made an alarm monitoring system for the entire ship system based on SCADA. All information from the remote terminal unit (RTU) or programmable logic control (PLC) sends to the SCADA central host. This research is based on the SCADA system, which retrieves information from the remote terminal unit (RTU) and sends it to the central host as a monitoring center.

Previous research shows that wireless and cable technology has weaknesses. The wireless technology in [20] is unsuitable for industrial environments, especially ships, because of the high-frequency acquisition engines and modules. This technology is also less capable of high-rate data transmission in real-time. Deep cable technology [10] is more suitable in industrial environments and ship engine rooms. Apart from being simple, inexpensive, and ready-to-use technology, this technology can be used in almost all communication media, including twisted-pair cable, fiber optic, ethernet.

The development of the alarm system architecture in n [18] has a data communication structure that is simpler than [10]. Unfortunately, this research is still in the form of an alarm system architecture plan, and there is no realization yet. Meanwhile, Zaghloul in [21] is still developing the alarm system in the interface design made through WinCC, and there is no SCADA architectural plan for the alarm system.

From previous research and several references, this study aims to provide a practical design of ship auxiliary engine start-stop control system and alarm system. The system is made using PLC Outseal with human-machine interface (HMI), the practical design of a reliable alarm system, and according to the needs of onboard monitoring and control. In addition, the work function of the system that is made adapts to the needs of the Indonesian Classification Bureau as the national classification ship in Indonesia. Thus, the goal is to maintain the quality of transportation services and reduce ship operating costs can be achieved, this can be proven through the application of a system using PLC and HMI with a simple, inexpensive, and efficient design.

## II. MATERIAL AND METHODS

### A. THE SYSTEM BLOCK DIAGRAM

FIGURE 1 shows the system block diagram. In simple terms, the system consists of three parts: the field device, junction box, and engine control room. A field device is an acquisition module on the auxiliary engine, and there are analog and digital acquisition modules. The analog module consists of a thermocouple as an exhaust gas temperature sensor and PT-100 as a lubricating oil temperature sensor. The temperature sensors connect with the temperature controller. In contrast, the output of the temperature controller is a digital switch. In addition, there is a pressure switch that is also connected to the digital input PLC and sends information of the oil pressure condition.

The junction box consists of local control and monitor panel. The placement of this panel is in the engine room near the auxiliary engine. The panel is the place for the controller, buttons, and relays. The operator can monitor the machine through this panel by observing the indicator lamp on the panel. The controlling function is by pressing the buttons on the panel—meanwhile, RS485 Modbus Protocol connects the controller to the HMI in the engine control room. So, the engine control room can be a monitoring place.

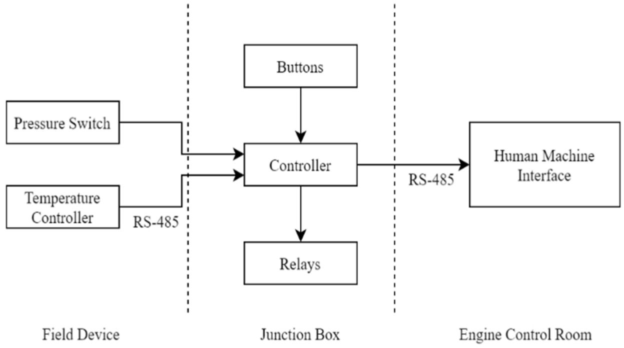



FIGURE 1. The System Block Diagram.

### B. MATERIALS AND TOOLS

This research uses PLC Outseal Mega V1.1. This PLC Outseal Mega V1.1 works on 24VDC voltage and has two analog input ports to accept 0-5V voltage or 4-20mA current. The communication facility between devices owned by this PLC is through the Modbus RS485 communication protocol [22].

However, this study also uses HMI, namely Logic Panel Autonics S070. The Logic Panel operates at 24 VDC. Apart from being a display, this device has a built-in PLC, which provides digital input/output. In addition, data processing becomes slow if this device functions as a PLC and display.

The HMI and PLC communicate via the Modbus RTU RS485 protocol. PLC Outseal still cannot do online monitoring and Modbus communication simultaneously. Thus, the HMI performs simulation functions in real-time. Communication between PLC Outseal and PC is only for sending program and PC to PLC or PC fetching program from PLC via USB port [23].

### C. INDONESIAN BUREAU REQUIREMENT

The national bureau agency is in charge of doing a statutory survey on board to verify congruency of the ship condition with the International Maritime Organization standard. This research discusses the Indonesian Bureau Requirement (BKI). Machinery alarm is one of the essential systems in charge of keeping the safe operation of the ship [17]. BKI give detailed requirement about machinery alarm monitoring system in Vol VII, Rules for Automation [24]:

1. The machinery alarm system shall provide an optical and audible signal of unacceptable deviation.

2. Alarm delays shall be kept within time limits to prevent any risk to the monitored system in the event of exceeding the limit value.
3. Optical signals shall be at a central position and identifiable by text or symbols
4. It shall be possible to acknowledge audible signals independent from the visual signal.
5. Acknowledgment of optical alarm shall only be possible where the fault occurs.
6. The acknowledgment of an alarm shall not inhibit an alarm that new causes have generated.
7. Transient faults which are self-correcting without intervention shall be memorized and indicated by optical signals.

BKI determines the alarm condition of three parameters in this research: lubricating oil pressure, lubricating oil temperature, and exhaust gas temperature [25]. TABLE 1 shows the alarm requirements of each parameter. The abnormal condition of lubricating oil pressure is a low-pressure condition. Lubricating oil and exhaust gas temperature are abnormal when both conditions reach a high temperature. Low or high conditions in TABLE 1 depend on the specification of each machine.

**TABLE I**
**ALARM REQUIREMENT**

| No | Parameter | Kondisi Alarm |
|---|---|---|
| 1 | The pressure of lubricating oil | Low |
| 2 | The temperature of lubricating oil | High |
| 3 | Exhaust gas temperature | High |

### *D. SYSTEM FLOWCHART*

The system flowchart describes the workflow of the ship's auxiliary engine start-stop control and alarm system. FIGURE 2 shows a flowchart of the engine's starting and the activation of the alarm system working principle. While FIGURE 3 shows a flowchart of the alarm system working principle. Meanwhile, FIGURE 4 shows the engine stop flowchart.

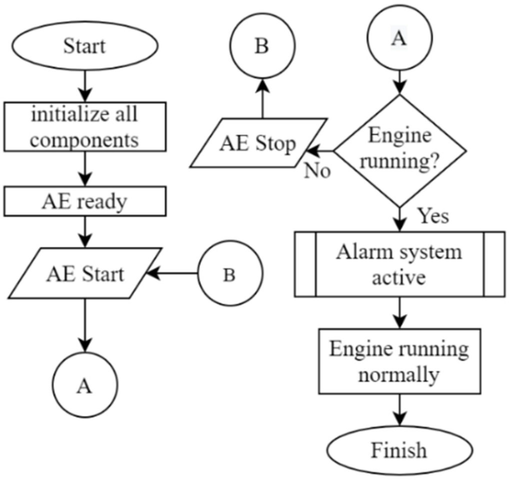



**FIGURE 2.** **Starting Engine Flowchart.**

Starting the engine is by pressing the start button on the panel door. If the engine is running normally, the alarm and safety system will be active. However, if the engine is not running, then press the start button again. Stopping the engine when the engine is working is by pressing the stop button on the panel door.

The work of the alarm system is suitable with the BKI provisions. The activation of the alarm system means that the system will stand by monitoring information from the engine. If the signal status from the acquisition modules is abnormal, the buzzer and flicker will be active. Then, the operator can acknowledge the condition by pressing the buzzer stop or reset button on the door panel. If the alarm list on the HMI displays an abnormal condition by the warning message, the error has not been corrected or has not returned to normal. So, it needs further action from the operator to make improvements. However, if the alarm list does not display a warning message, the engine is running normally, resolving the error.

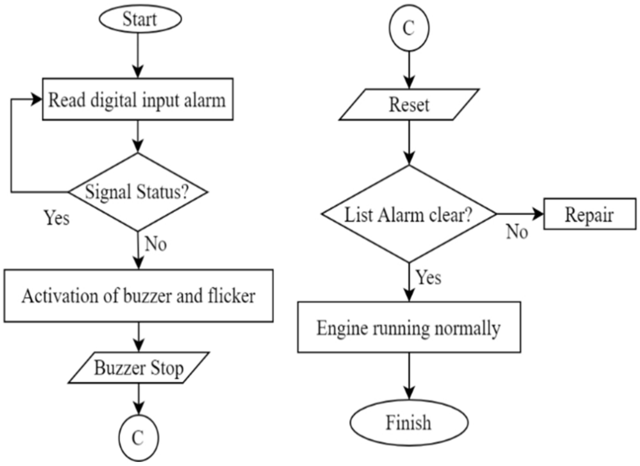



**FIGURE 3.** **Alarm System Flowchart**

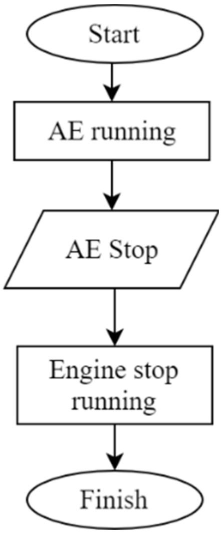



**FIGURE 4.** **Stop Engine Flowchart**

### *E. DESAIN INTERFACE*

It is making the interface design using the GP Editor application, the default HMI design application from Autonics. Figure 4 shows the interface design plan of this alarm system. There are engine indicators, engine alarm indicators, alarm lists, and alarm history sections. The engine indicator displays engine running and stopping conditions. The alarm indicator displays the condition of the pressure switch and temperature switch. The alarm list displays abnormal conditions that occur. Meanwhile, alarm history displays the history of alarm conditions that have occurred during one month of operation.

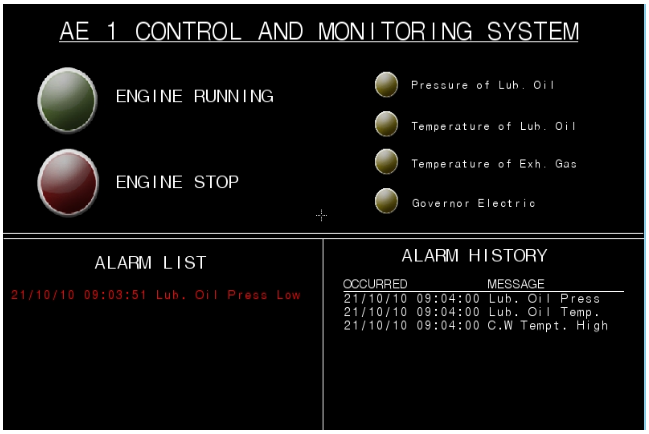



**FIGURE 5. The Interface Design**

### *F. DATA ANALYSIS*

Data analysis uses the work observation method of the system. The table shows the result. At the same time, this paper uses the descriptive explanation method to explain the observations. There is an explanation of points between previous research studies and this research. Moreover, there are results of adjustments between the work of the planned system and the regulations of the BKI.

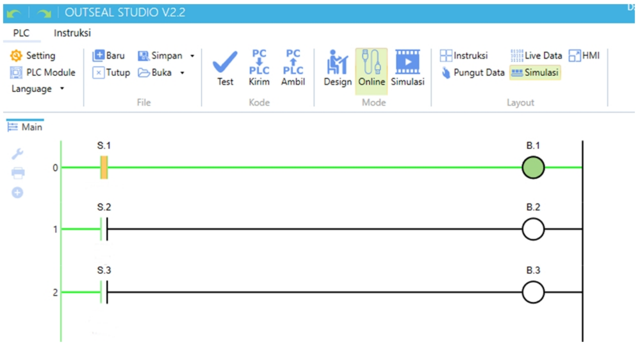
## III. RESULT

The tests in this study consisted of testing the digital input-output PLC, testing the Modbus PLC - HMI communication, and testing the system design. Furthermore, the test results will be evaluated according to the requirements of the BKI by describing the test results in each table using a descriptive explanation.

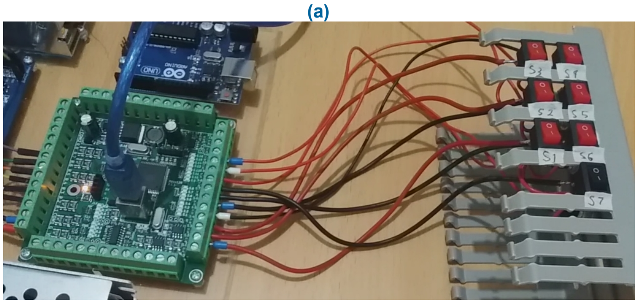
### *A. DIGITAL INPUT TESTING*

Digital input testing aims to determine the response of the PLC when the digital input gets a trigger from an external switch. FIGURE 6(a) shows the program of the PLC. Meanwhile, FIGURE 6(b) shows the PLC and switches.

Ports S1, S2, and S3 simulate the lubricating oil pressure switch, lubricating oil temperature switch, and exhaust gas temperature switch, respectively. TABLE 2 shows the results of testing and observations from online monitoring Outseal Studio.




**(a)**



**(b)**

**FIGURE 6. PLC Digital Input Testing**

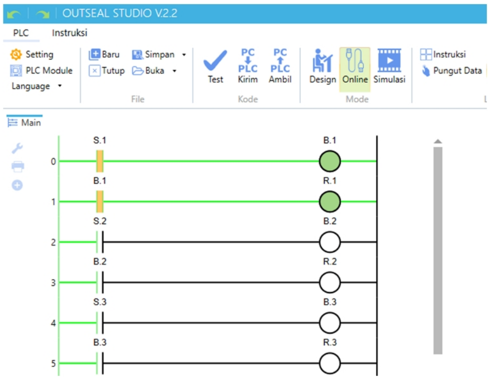
**TABLE 2**
**PLC DIGITAL INPUT TEST RESULT**

| No | Digital Input | Contact | Switch Condition (S) | Internal Memory Condition (B) |
|---|---|---|---|---|
| 1 | S1 | NO | 0 | 0 |
| | | | 1 | 1 |
| 2 | S2 | | 0 | 0 |
| | | | 1 | 1 |
| 3 | S3 | | 0 | 0 |
| | | | 1 | 1 |

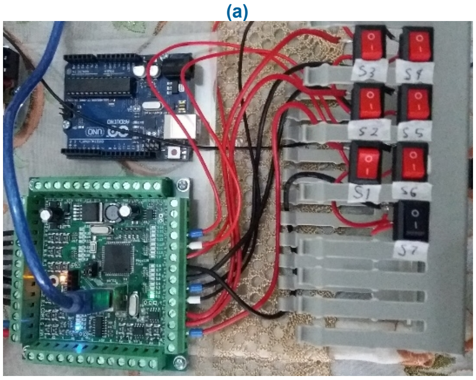
### *B. DIGITAL OUTPUT TESTING*

Digital output testing aims to determine the response of the PLC Output. The test procedure is to provide a trigger in the form of an on/off switch on the digital input of the PLC. Furthermore, by downloading the program in FIGURE 7(a) to the PLC, the PLC output digital response is obtained. FIGURE 7(b) shows the testing hardware.

Ports S1, S2, and S3 are the input ports of the trigger receiver, respectively. Ports R1, R2, R3 are PLC relays connected to external relays. TABLE 3 shows the results of testing and observing the responses of R1, R2, and R3 from the online monitoring Outseal Studio.




(a)



(b)

**FIGURE 7.** **PLC Digital Output Testing**

**TABLE 3**
**PLC DIGITAL OUTPUT TEST RESULT**

| No | Digital Input | Contact | Switch Condition (S) | Internal Memory Condition (B) | Relay respond (R) | Digital Output |
|---|---|---|---|---|---|---|
| 1 | S1 | NO | 0 | 0 | 0 | R1 |
| | | | 1 | 1 | 1 | |
| 2 | S2 | | 0 | 0 | 0 | R2 |
| | | | 1 | 1 | 1 | |
| 3 | S3 | | 0 | 0 | 0 | R3 |
| | | | 1 | 1 | 1 | |

### *C. MODBUS COMMUNICATION TEST*

The purpose of testing the communication between these two devices is to determine the speed of each device in receiving the trigger from switches. Communication between the two devices uses the Modbus RS485 protocol. Monitoring is through the HMI display.

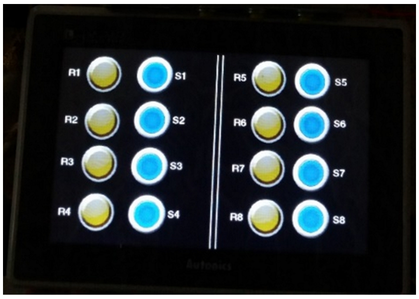
The first is to find out the HMI response to display the PLC input digital indicator when triggered by an external switch. FIGURE 8 shows a logic panel that displays PLC digital input indicator. In contrast, The PLC program is the same as the program in Figure 6(a). TABLE 4 shows the HMI test results in showing the PLC input digital indicator.


**FIGURE 8.** **Digital Input Communication Test**

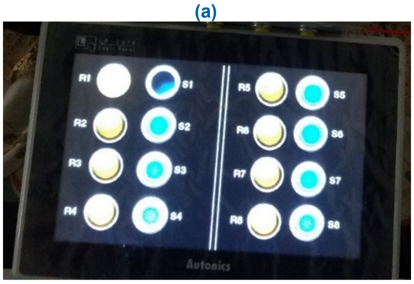
**TABLE 4**
**DIGITAL INPUT COMMUNICATION TEST**

| No | Input Digital | Contact | Switch Condition (S) | HMI Indicator Condition | Respond Time | |
|---|---|---|---|---|---|---|
| | | | | | <1s | >1s |
| 1 | S1 | NO | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |
| 2 | S2 | | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |
| 3 | S3 | | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |

The second test is to know the HMI response in displaying digital input and output indicators. The focus of the test is the response of the relays R1, R2, and R3. the program used is the same as the digital output test of Figure 7(a). FIGURE 9(a) shows the switch and relay-off conditions. Meanwhile, FIGURE 9(b) shows the condition of the switch and relay on. TABLE 5 shows the results of this test.




(a)




(b)

**FIGURE 9.** **Digital Output Communication Test**

TABLE 5
DIGITAL OUTPUT COMMUNICATION TEST

| No | Output Digital | Contact | Switch Condition (S) | HMI Indicator Condition | Respond Time | |
|---|---|---|---|---|---|---|
| | | | | | <1s | >1s |
| 1 | R1 | NO | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |
| 2 | R2 | | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |
| 3 | R3 | | 0 | 0 | ✓ | |
| | | | 1 | 1 | ✓ | |

### D. THE SYSTEM TEST

The system testing procedure is suitable for the flowchart in Figures 2, 3, and 4. with three stages of testing: engine start, alarm activation, and engine stop testing, each test is suitable to the rules of the BKI.

This experiment uses the interface design in FIGURE 5. First is the Engine Start Experiment. The results of this experiment are the work sequences in TABLE 6. Initialize all components is the flow of current to each component in the junction box and HMI. Auxiliary Engine (AE) is ready when the AE Stop indicator on the HMI is red. To activate the auxiliary engine, the operator can press the start button on the door panel. Immediately, the indicator R1 lights up for 2 seconds, and R2 will light up while the engine is running. R1 is the relay one that functions to turn on the starter motor. Meanwhile, R2 is a relay that activates the governor.

TABLE 6
START ENGINE SEQUENCES

| No | Description |
|---|---|
| 1 | All control and monitor components are on |
| 2 | AE Stop indicator lights red |
| 3 | Pressing the push-button start AE (green) |
| 4 | AE RUN indicator is green |
| 5 | The R1 (starter motor) indicator lights up for 2 seconds |
| 6 | The R2 (governor) indicator lights up |

Engine running means that the alarm system will be on standby. Activating a switch connected to the PLC's digital input will obtain the alarm condition. The normal condition of the engine pressure switch and temperature switch is normally closed (NC). So, if the switch is normally open (NO), the alarm will be active and activate the buzzer and flicker. TABLE 7 shows the sequence of work resulting from this experiment.

TABLE 7
ALARM ACTIVATION SEQUENCES

| No | Description |
|---|---|
| 1 | The AE RUN indicator lights up green |
| 2 | The indicator R2 (governor) lights up blue |
| 3 | Changing the switch position from NC to NO |
| 5 | Buzzer on |
| 6 | Warning indicator on |
| 7 | The alarm list displays the description of the Alarm condition |

TABLE 8 provides a work sequence for the engine stop experiment. The operator can deactivate the engine in operation by pressing the AE stop button on the panel door. Then, the governor and the machine will turn off.

TABLE 8
STOP ENGINE SEQUENCES

| No | Description |
|---|---|
| 1 | The AE Run indicator lights up green |
| 2 | The R2 (governor) indicator lights up |
| 3 | Press the push button AE Stop (red) |
| 5 | R2 (governor) indicator is off |
| 7 | The AE Stop indicator lights up red |

## IV. DISCUSSION

The test results show that the PLC can read the trigger on the digital input and respond to the digital output quickly and according to the program. Also, online monitoring shows results that match the conditions on the hardware. PLC and HMI communication testing can communicate via the RS485 Modbus protocol. HMI can respond or display the condition of the PLC according to the existing conditions. That is, Energizing S1 means that the indicator with the address S1 will also be active. System testing is appropriate with the planning flowchart. This condition also proves that the engine alarm system complies with the rules of BKI.

Previous research has shown that both wireless and wired technologies have drawbacks. The wireless technology in [20] is not suitable for industrial environments, especially ships, due to high-frequency acquisition engines and modules. Deep cable technology [10] is more suitable in industrial and ship engine room environments. The alarm system architecture development in [18] has a data communication structure that is simpler than [10]. Unfortunately, this research is still in the form of an alarm system architecture plan and has not yet been realized. Meanwhile, Zaghloul in [21] is still developing the alarm system on the interface design made through WinCC, and there is no SCADA architecture plan for the alarm system.

Compared to previous studies that still prioritize design and planning, this research provides application-oriented research. This study provides a system block diagram, a system workflow diagram, and a description of the requirements of BKI. The system design is not only limited to the alarm system but also the engine start-stop system.

The drawback of this study was no onboard experiments. The system is tested only in the laboratory. Thus, the condition of the ship's engine room with a high level of interference is not getting. Also, communication testing is only at a distance of 1m. Thus, the communication of PLC and HMI over long distances, from the machine to the machine control room, is not yet known. Even so, this research resulted in a cheap, simple, and efficient system design for the development of machinery alarms on ships.

## V. CONCLUSIONS

This research resulted in the planning of the auxiliary engine alarm with lubricating oil pressure and temperature and cooling water temperature as parameters. This system uses PLC as controller and HMI as interface. The communication protocol used is Modbus RTU. In addition, this research not only provides alarm systems but also engine start-stop planning. Tests only on a laboratory scale. This research shows that this system provides a simple, inexpensive, and efficient design of a machine alarm system to develop this technology.

In the future, this research still needs a lot of development and improvement. Expanding control with additional parameters can improve the practical side of this system. Furthermore, experiments can be carried out in the field or industry to obtain more accurate data. Thus, it is possible to test the reliability level of this system.

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