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Prototype of an automatic ballast system for cargo ships based on Outseal PLC

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ABSTRACT

The ballast system is crucial for maintaining the stability of ships, especially cargo ships that generally still use manual systems. The weaknesses of manual systems include low efficiency, long operational times, and the potential for technical errors (human error) that can increase the risk of accidents. This research aims to develop an automatic ballast system using Outseal PLC as the control center. The process begins by activating the system through the start button. Objects are placed on the prototype, and the system's response to tilt angles is measured using a gyroscope sensor. When a tilt angle is detected, the system automatically fills the tank with water to restore stability. The volume of water entering the tank is measured using a flowmeter sensor. Test results show that when the tilt reaches 10 degrees or -10 degrees, the system automatically fills the tank with water. This process continues until all tanks are optimally filled with a volume of 450 ml, after which the system empties all tanks. The research results indicate that the system can effectively manage stability through water filling in the tanks, and the designed program functions according to the desired specifications.

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1. INTRODUCTION

The application of industrial automation can involve various technologies with the main goal of increasing productivity and efficiency in the work environment [1]-[3]. In the maritime industry, automation systems are integrated to improve the operational performance of ships in terms of fuel efficiency, environmental sustainability, safety, comfort, and security of ships [4]-[8]. On cargo ships, it is very important to have an automation system that is able to maintain the stability and efficiency of ship performance during the loading and unloading process at the port, including in trim and roll situations due to changes in ship cargo [9]-[12]. Ship stability is very important to return the ship to its original position after experiencing a tilt due to external and internal forces acting on the ship such as changes in cargo on cargo ships [13]. Ballast is a system for regulating the stability of ships that transport water and aims to adjust the level of tilt of the ship caused by changes in ship cargo, so that with this system the stability of the ship can be maintained and can improve safety in work operations on the ship. After the ship is stable and the ship's cargo is in optimal condition, the ballast system will release the water in the ship [14].

The development of the ballast system on cargo ships in Indonesia still uses a manual system involving human power. With the repeated application of this manual ballast system, it can affect the ballasting response, causing stability to be disturbed and the performance process on the ship to be less effective and efficient. This is due to the length of time for action and the possibility of technical errors in managing the piping system, which can increase the risk of ship accidents and work accidents on ships [15]. Based on data on the main causes of shipping accidents investigated by the National Transportation Accident Committee (KNKT) from 2018 to 2022, it shows that technical factors contribute 52%, human factors (human error) 47%, and weather factors only 1% of the total 75 ship accidents. In addition, KNKT investigation data in the same period showed four types of shipping accidents, with ships sinking 27%, ships burning 29%, collisions 17%, and running aground 14%, while 13% are included in the other category. Data on accident victims from 2018 to 2022 recorded 687 victims, with 85% of them dying and 15% suffering injuries [16].

In previous studies, several ballast systems have been created, but they still have shortcomings. In research [17], this study still applies water level sensors and microcontrollers, so that in the ballasting process the water volume cannot be monitored and the controlled ballast system is still on a small scale. While the ballast system in research [18] already uses PLC, this study creates a ballast system with a PLC trainer program simulation model by applying the analysis control method, so that the gyroscope parameters are only set without following the real conditions of the stability value [19]. Based on the problems above, a manual to automatic ballast control development system is needed that can increase efficiency and safety when the ship is operating. With the automatic ballast control system on cargo ships, the loading and unloading process at the port can be carried out effectively and efficiently. The ship's crew simply monitors and activates the ballast system directly through the control panel by viewing the sensor parameters without having to activate the system manually [20]. The automatic ballast control system is designed entirely using outseal PLC as the control center. Outseal PLC is a controller that is easier to use because the tools can be seen directly on the software and this controller is also industry standard [21],[22].

2. METHOD

The research method used for data collection from the tool experiment uses the adaptive parameter control method. The research steps to be taken must be planned in detail and clearly so that the research process can run systematically and measurably to produce an organized system. This research begins with the creation of a block diagram and hardware design. The next stage is testing and analyzing the tool to fill in several prepared trial tables. This stage is carried out to evaluate the performance of the tool and ensure that the designed system can function properly as desired.

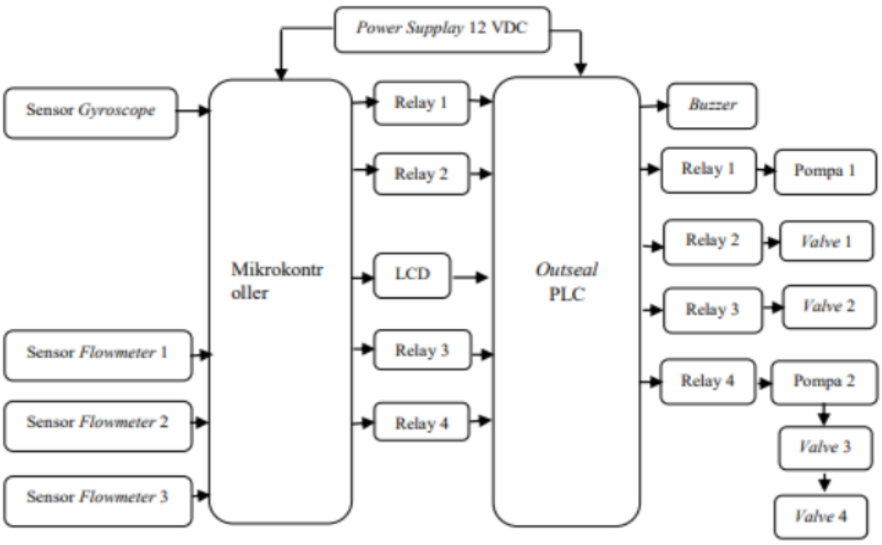

Figure 1. Diagram block of proposed system

Figure 1 shows a block diagram consisting of 1) 12 VDC power supply provides voltage to the microcontroller and outseal PLC. 2) Microcontroller functions as a sensor data processor. 3) Outseal PLC as the main control center of the automatic ballast system. 4) Gyroscope sensor functions to read the stability angle value and control the ballast system. 5) Flowmeter sensor functions to monitor the amount of water entering the tank and control the emptying of water in the tank. 6) Relay functions to forward sensor data to the outseal PLC input. 7) LCD is used to display the results of sensor data readings. 8) Buzzer as a system warning. 9) Pump 1 to put water into the tank 10) Valve functions to open and close the piping system. 10) Pump 2 is used to remove water from the tank. All components are assembled according to the shape and size of the prototype and the ballast system panel that has been designed. The size used in the ballast system prototype is 600 mm x 200 mm x 180 mm as shown in Figure 2 below.

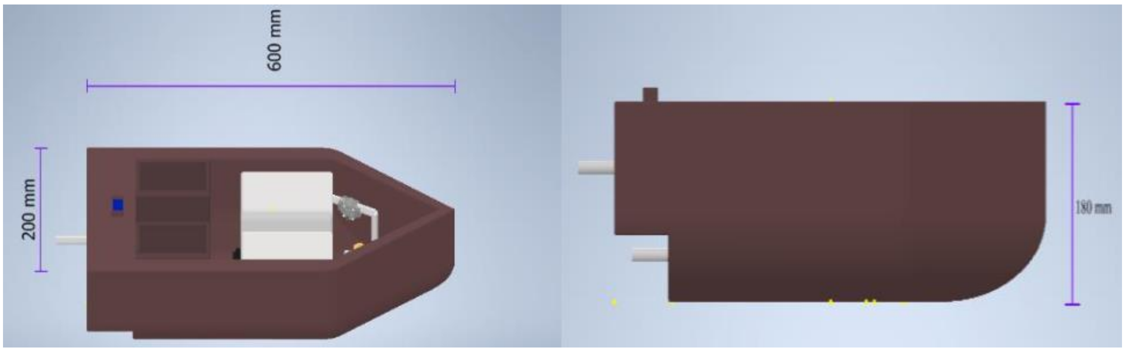

Figure 2. Ballast Prototype Design

Meanwhile, the design size of the ballast system panel to be used is 200 mm x 120 mm x 300 mm. Figure 3 below shows the design of the automatic ballast system panel in this study.

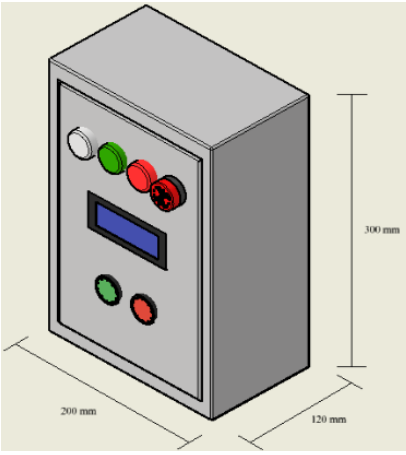

Figure 3. Ballast System Panel Design

After the panel frame and ballast system are completed, the next step is to assemble the electrical circuit in the panel. The circuit plays a very important role in the control system of the tool in this study. In the process of assembling the electrical circuit in the ballast system, an electrical circuit image is required, which is shown in the following Figures 4.

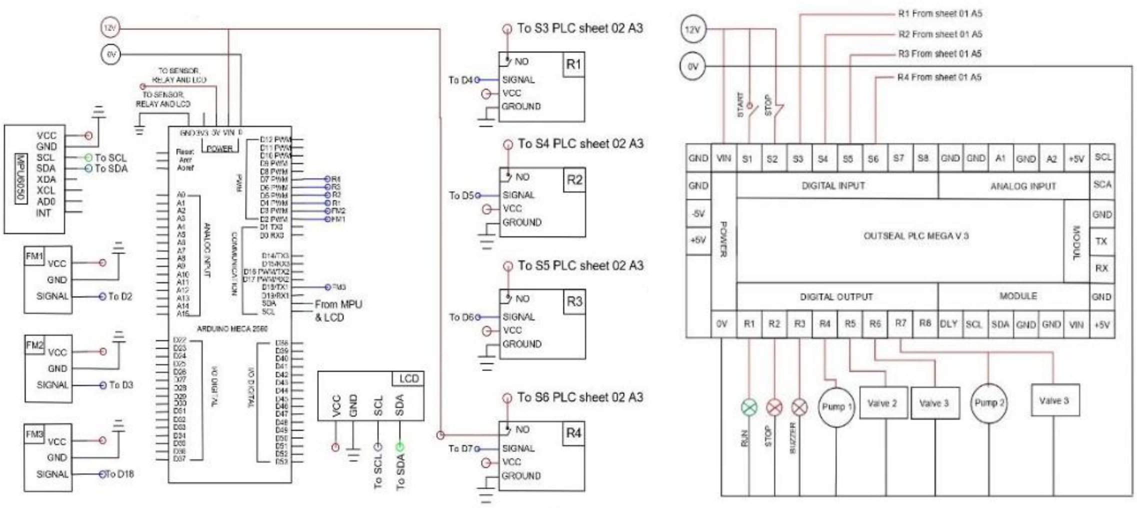

Figure 4. Electrical circuit

Next, the assembled ballast panel and system are programmed using Arduino IDE software for the atmega 2560 type microcontroller as a sensor data processor. Outseal PLC is programmed using outseal studio software for the outseal PLC mega nano v.5 type which functions as the ballast system control center. Program input is provided from the MPU6050 gyroscope sensor and the YF S201 flowmeter sensor to run the actuator on the automatic ballast system. The system is controlled and monitored through the designed panel. When the sensor reads the angle and water volume values in the system, the microcontroller will activate the relay when the set point is at the specified value, then the relay is active as input for the outseal PLC in activating the actuator. Figure 5 below shows the flowchart of the automatic ballast system created in this study.

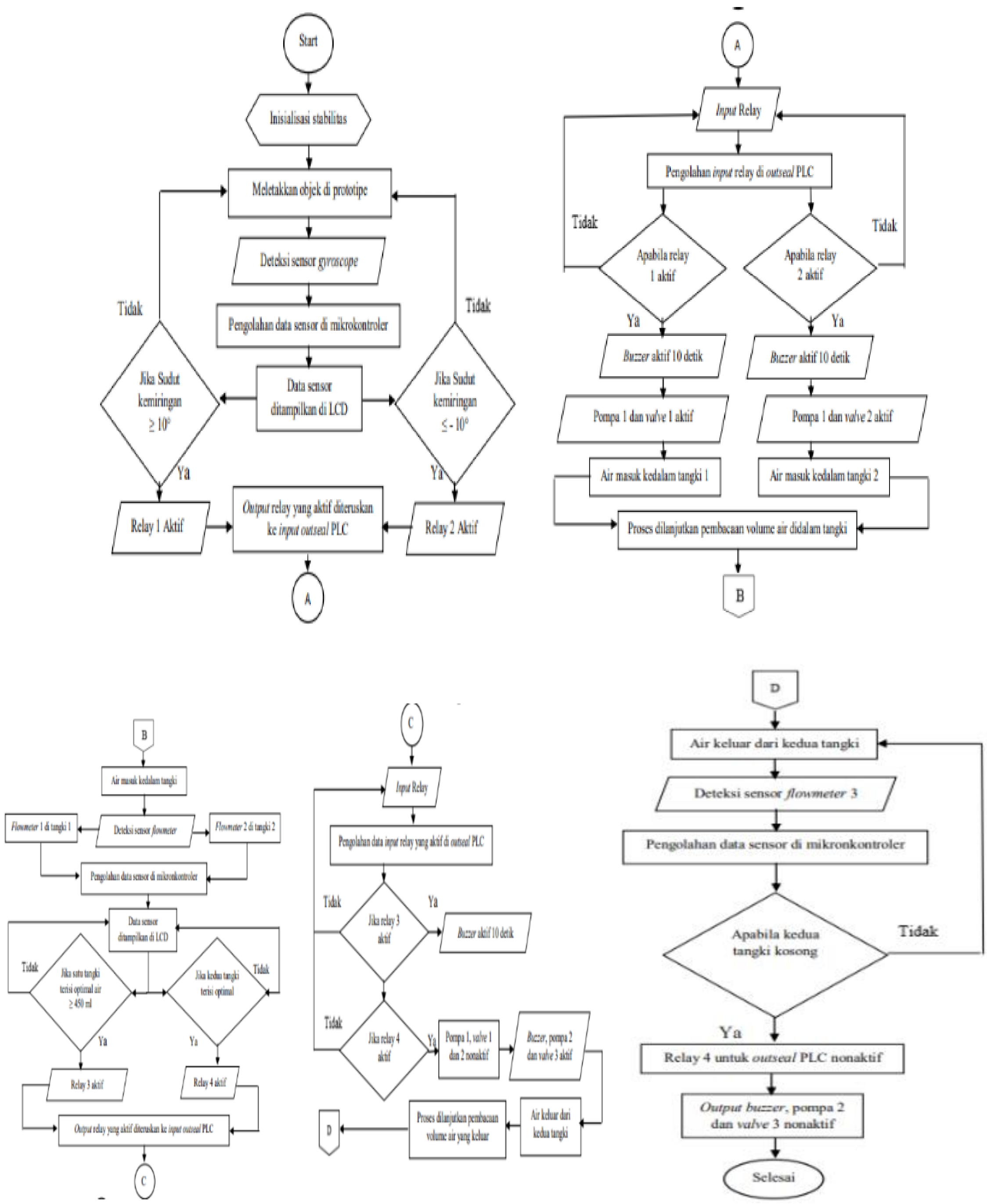

Figure 5. Automatic Ballast System Flowchart

3. RESULTS AND DISCUSSION

The result of this tool is an automatic ballast system controlled by a specially designed panel. The automatic ballast system has been made in such a way according to the design that can be seen in Figure 6.

Figure 6. Hardware results

In the tool testing, the object is placed on the tool to provide the desired tilt angle value. The test is carried out in stages to observe the sensor response in reading the angle value. The process begins by pressing the push button start button. After the button is pressed, the object is placed on the prototype, and the MPU6050 sensor will detect and display the results of the tool's tilt angle. If the tilt angle has reached the set value, the buzzer will be active for 10 seconds, followed by the activation of pump 1 and the filling valve to put water into the tank. During the filling process, pump 1 and the valve will remain active as long as the tilt angle is not stable and the tank is not fully filled. Water volume data is detected by the YF-S201 sensor and displayed on the LCD control panel.

If during the test the tank has been filled optimally, pump 1 and the filling valve will be deactivated. Furthermore, pump 2 and the valve on the emptying channel are active to release water from both tanks. If no water flow is detected by the sensor, pump 2 and the valve on the emptying channel will be deactivated, and the ballast system process is completed by pressing the stop push button. There are two testing processes in the ballast system, namely testing on tank 1 and testing on tank 2. Testing on tank 1 contains 3 objects that are placed gradually to see the system's response to the stability value of the tool. The test results on tank 1 can be seen in Table 1.

Table 1. Test result data on Tank 1

Objects	Angle (deg)		Volume (ml)		Fruitfulness (%)
	Initial	End	Initial	End	
1	5,2	5,2	0	0	100
2	10,3	0,5	0	23	100
3	11,7	0,8	233	456	100

From the test, it can be concluded that the system responds when the tilt of the tool is at a large value of 10 deg by filling tank 1. After the final value returns to a small value of 1 deg, the tank filling will stop. With a success rate of 100%, this system has proven effective in maintaining stability when the tool is tilted. Testing on tank 2 also contains 3 objects that are placed gradually to see the system's response to the stability value of the tool. The test results on tank 2 can be seen in Table 2.

Table 2. Test result data on Tank 2

Objects	Angle (deg)		Volume (ml)		Fruitfulness (%)
	Initial	End	Initial	End	
1	-5,3	-5,2	0	0	100
2	-10,2	-0,7	0	238	100
3	-11,5	-0,4	238	465	100

From the test, it can be concluded that the system provides a response when the tilt of the tool is at a small value equal to -10 deg by filling tank 1 for tool balance. After the final angle value returns to a large value equal to -1 deg, then filling in tank 2 will stop. With a success rate of 100%, this system has proven effective in maintaining stability when the tool is tilted.

4. CONCLUSION

The automatic ballast system using outseal PLC works well according to the design that has been designed. This system can detect angle values and water volume with fairly good accuracy. The test results show that when the tool experiences a slope reaching 10 deg or -10 deg, the system automatically activates the pump to fill the tank with water, so that the stability of the tool can be restored. Once stable, the pump is deactivated and the stability of the tool is well maintained. After all tanks are optimally filled, the system continues the emptying process by activating the pump to remove water from the tank. This study succeeded in meeting the set target, namely the system is able to effectively regulate stability by filling the tank with water. In addition, the results of the designed program have been in accordance with the desired performance of each component.

REFERENCES

[1] N. Zhou, D. Li, V. Vyatkin, V. Dubinin and C. Liu, "Toward Dependable Model-Driven Design of Low-Level Industrial Automation Control Systems," *IEEE Transactions on Automation Science and Engineering*, vol. 19, no. 1, pp. 425-440, Jan. 2022, doi: 10.1109/TASE.2020.3038034.

[2] J. Li, Y. Zhou, X. Zhang, S. Liu and Q. Li, "Assessment of Industrial Internet Platform Application in Manufacturing Enterprises: System Construction and Industrial Practice," *IEEE Access*, vol. 9, pp. 103709-103727, 2021, doi: 10.1109/ACCESS.2021.3098940.

[3] V. Lesi, Z. Jakovljevic and M. Pajic, "Security Analysis for Distributed IoT-Based Industrial Automation," *IEEE Transactions on Automation Science and Engineering*, vol. 19, no. 4, pp. 3093-3108, Oct. 2022, doi: 10.1109/TASE.2021.3106335.

[4] I. S. Shipunov, K. S. Voevodskiy, A. P. Nyrkov, Y. F. Katorin and Y. A. Gatchin, "About the Problems of Ensuring Information Security on Unmanned Ships," *2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus)*, Saint Petersburg and Moscow, Russia, 2019, pp. 339-343, doi: 10.1109/EIConRus.2019.8657219.

[5] S. Elgafoss, T. Skramstad and V. Dalberg, "Maritime automation, and emergency handling - software: Design, system integration and quality," *2009 IEEE Electric Ship Technologies Symposium*, Baltimore, MD, USA, 2009, pp. 86-92, doi: 10.1109/ESTS.2009.4906498.

[6] Z. Jin, S. Liu and B. Xing, "Research on the control effect of ship information system under hazard factor based signal attack for motion control task," *2017 36th Chinese Control Conference (CCC)*, Dalian, China, 2017, pp. 7315-7320, doi: 10.23919/ChiCC.2017.8028512.

[7] S. Sun, Z. Zhang, Q. Pan and C. Sun, "Controller design for anti-heeling system in container ships," *2016 35th Chinese Control Conference (CCC)*, Chengdu, China, 2016, pp. 5798-5803, doi: 10.1109/ChiCC.2016.7554263.

[8] H. Wang, G. Wang and L. Zhang, "Research on the Encryption of Ship-to-Shore Control Commands for Unmanned Surface Vehicle," *2022 7th International Conference on Automation, Control and Robotics Engineering (CACRE)*, Xi'an, China, 2022, pp. 8-13, doi: 10.1109/CACRE54574.2022.9834176.

[9] Q. Xu, X. Meng and N. Wang, "Ship Manipulation Evaluation System," *2009 International Conference on Measuring Technology and Mechatronics Automation*, Zhangjiajie, China, 2009, pp. 859-862, doi: 10.1109/ICMTMA.2009.461.

[10] K. D. Huu, T. D. Anh and T. H. Duc, "A 3D Dynamic Model Applied for Cargo Ships to Study Ship Motion Control," *2023 17th International Conference on Engineering of Modern Electric Systems (EMES)*, Oradea, Romania, 2023, pp. 1-4, doi: 10.1109/EMES58375.2023.10171777.

[11] K. D. Do, Z. P. Jiang, and J. Pan, “Universal controllers for stabilization and tracking of underactuated ships,” *Syst. Control Lett.*, vol. 47, no. 4, pp. 299–317, 2002, doi: 10.1016/S0167-6911(02)00214-1.

[12] H. Q. Nguyen, A. D. Tran, and T. T. Nguyen, “The bilinear model predictive method-based motion control system of an underactuated ship with an uncertain model in the disturbance,” *Processes*, vol. 7, no. 7, 2019, doi: 10.3390/pr7070445.

[13] H. Yasukawa and Y. Yoshimura, “Introduction of MMG standard method for ship maneuvering predictions,” *J. Mar. Sci. Technol.*, vol. 20, no. 1, pp. 37–52, 2015, doi: 10.1007/s00773-014-0293-y.

[14] J. Hun Ha and T. Gourlay, “Full-Scale Measurements and Method Validation of Container Ship Wave-Induced Motion at the Port of Fremantle,” *J. Waterw. Port, Coastal, Ocean Eng.*, vol. 144, no. 6, pp. 1–24, 2018, doi: 10.1061/(asce)ww.1943-5460.0000480.

[15] D. Yang and B. Tian, "Development of ballast water control simulation system for solid bulk carriers," *2023 3rd International Conference on Robotics, Automation and Intelligent Control (ICRAIC)*, Zhangjiajie, China, 2023, pp. 1-7, doi: 10.1109/ICRAIC61978.2023.00008.

[16] K. Qi *et al.*, "Ship Fire Accident Analysis Based on Association Rules," *2023 International Conference on Algorithms, Computing and Data Processing (ACDP)*, Qingdao, China, 2023, pp. 224-229, doi: 10.1109/ACDP59959.2023.00043.

[17] G. Bakalar and M. B. Baggini, "Automated remote method and system for monitoring performance of ballast water treatment system operation on ships," *2016 International Symposium ELMAR*, Zadar, Croatia, 2016, pp. 229-232, doi: 10.1109/ELMAR.2016.7731793.

[18] P. P. Stehouwer, A. Buma, and L. Peperzak, “A comparison of six different ballast water treatment systems based on UV radiation, electrochlorination and chlorine dioxide ”, *Environmental Technology*, doi: 10.10.1080/09593330.2015.1021858.

[19] M. Cvetković, B. Kompare, and A. Krivograd Klemenčić, “Application of hydronamic cavitation in ballast water treatment ”, *Environ. Sci. Pollut. Res.*, vol. 22, pp. 7422–7438, 2015. doi: 10.10.1007/s11356-015-4360-7.

[20] G. Bakalar, V. Tomas, and Z. Sesar, “Remote Monitoring of Ballast Water Treatment System Quality by Using Flow Cytometry and Satellite Communication Technologies ”, 54th International Symposium ELMAR 2012, Procceedings, pp. 290–295., 2012.

[21] I. Rifaldo and M. Yuhendri, “Sistem Monitoring Kecepatan Motor Induksi dengan HMI Berbasis PLC,” *JTEIN J. Tek. Elektro Indones.*, vol. 3, no. 2, pp. 319–325, 2022.

[22] Risfendra, Yoga Maulana Putra, H. Setyawan, and M. Yuhendri, “Development of Outseal PLC-Based HMI as Learning Training Kits for Programmed Control Systems Subject in Vocational Schools,” in *5th Vocational Education International Conference*, 2023, pp. 506–511.