Conference of Electrical, Marine and Its Application
Vol. xx, No xx, Month-Year ISSN:

Study on Controlled Rectifiers with Optocoupler Integration: Evaluating Impact on DC Motor Voltage Stabilization and Rotational Speed Control

Khoirun Nasikhin
Otomation Engineering, Shipbuilding Institute of Polytechnic Surabaya, Indonesia
Correspondence author: khoirun.nasikhin@student.ppns.ac.id

ABSTRACT

This research explores a voltage regulation method for DC motor speed control using an optocoupler and a Silicon Controlled Rectifier (SCR). Traditional methods for controlling DC motor speed include varying frequency and adjusting input voltage, with voltage regulation being the most common approach. The SCR regulates the input voltage through its gate terminal, while the optocoupler provides the control signal. This study focuses on integrating optocouplers with SCRs to create an efficient controlled rectifier circuit for stable and reliable motor performance. The power circuit uses a 120V AC source to power a 190V DC motor, ensuring precise voltage stabilization and improved speed control. Through theoretical analysis and practical experimentation, the research examines the role of controlled rectifiers in motor control systems, aiming to address gaps in existing literature. The integration of optocouplers is expected to enhance system response time, stability, and motor performance. The findings offer potential improvements in DC motor control, with applications across various industrial settings where voltage regulation and speed control are essential. This study contributes a novel approach to motor control, offering valuable insights for enhancing motor stability and efficiency in engineering practices.

Key Word: *DC Motor, Speed Control, Voltage Regulation*

I.INTRODUCTION

Technological advancements have profoundly influenced everyday life, particularly through the widespread adoption of household appliances powered by single-phase induction motors. In the context of these applications, the focus extends beyond the type of motor itself to the motor speed regulation systems used. Effective regulation of a motor's rotational speed is directly tied to the motor control circuitry[1], which adjusts the input voltage to meet the desired performance criteria. The ability to control motor speed is fundamentally dependent on the system's capacity to vary the input voltage and, consequently, the motor's operating speed[2]. Monitoring the performance of these systems can be achieved through visual inspection of waveforms and observing the motor speed display[3][4].

In practical applications, the use of a DC motor with a voltage rating of 190 Volts is a prime example of how motor speed regulation is implemented. The rotational speed of the motor is directly influenced by the magnitude of the input voltage. A higher voltage results in faster motor rotation, allowing the motor to reach its maximum speed more quickly[5]. Conversely, a lower voltage leads to slower rotation, requiring a longer period to achieve maximum speed. This dynamic underscores the importance of precise voltage regulation in optimizing motor performance and controlling rotational speed, which is vital in many engineering applications, from household appliances to industrial machinery[6].

The integration of controlled rectifiers and optocouplers in regulating motor voltage offers a promising solution to enhance speed control systems.[7] By using a combination of Silicon Controlled

Rectifiers (SCRs) and optocouplers, the system can effectively stabilize the input voltage to the DC motor, ensuring smoother and more reliable speed regulation. This approach not only improves the motor's responsiveness to voltage changes but also ensures greater energy efficiency and stability[8][9], which are crucial for both performance and longevity in motor applications.

Furthermore, as the study on controlled rectifiers progresses, it is essential to evaluate their impact on various parameters, including voltage stabilization and rotational speed control. These evaluations are particularly important in the engineering context, where optimizing motor speed control can lead to more efficient and sustainable solutions in industrial and residential systems. The use of SCR-based rectifiers presents a significant advancement in the ability to manage voltage fluctuations and ensure consistent motor operation.

This research contributes to the broader engineering field by providing an in-depth exploration of controlled rectifiers and their application in DC motor speed regulation systems. The integration of these components offers a robust solution to challenges associated with voltage regulation, ensuring both optimal performance and reliability in DC motor applications. As technological development continues, advancements like these will play a pivotal role in shaping the future of motor control systems across various sectors.

II.METHODOLOGY

1. Material

A. DC Motor

A DC motor is an electromechanical device that converts direct electrical energy into mechanical energy through rotational force (torque)[10]. This conversion process is crucial in applications where precise speed control and torque regulation are essential, such as in robotics, electric vehicles, and industrial automation systems. The ability to manipulate the motor speed and torque can be achieved through voltage control, by adjusting the input voltage provided to the motor[11][12]. The variation in voltage directly influences the motor's rotational speed, providing flexibility for different operational requirements.

In the context of engineering applications, DC motors are integral to systems like servomotors and driving dynamos. These motors are composed of two main components: the stator, which is the stationary part of the motor, and the rotor, which is the rotating element[13]. The interaction between these components, particularly the magnetic fields created in the stator, allows the rotor to rotate, thereby generating mechanical output. This fundamental construction is common in single-phase induction motors and is key to ensuring consistent motor performance across various industrial and consumer applications[14].

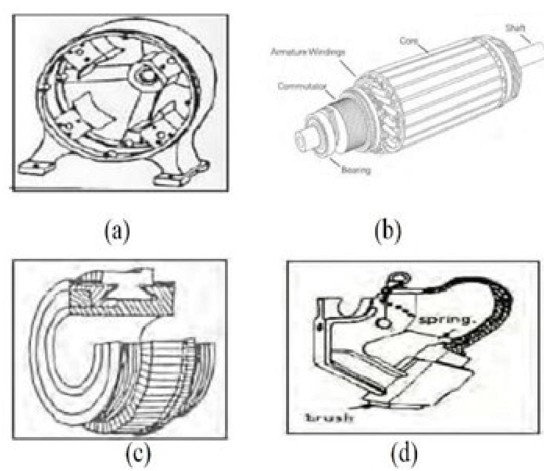

Figure 1. Part of DC Motor

The integration of advanced control systems is critical for enhancing the performance of DC motors. In modern systems, the incorporation of components such as Silicon Controlled Rectifiers (SCRs) and optocouplers plays a vital role in regulating motor voltage. These technologies allow for more accurate voltage stabilization and speed control, ensuring that DC motors can operate efficiently under varying load conditions. This is particularly relevant in electronic control systems, where maintaining consistent performance is paramount for automated processes and other high-precision applications.

B. SCR (Silicon Controlled Rectifier)

Thyristors, commonly known as Silicon Controlled Rectifiers (SCR), are key semiconductor devices used in power control applications. These devices play a critical role in regulating large and small alternating currents by enabling both the rectification of AC to DC and DC to AC conversion [15]. In engineering and industrial applications, SCRs are essential for efficiently managing power flow and controlling motor speeds, particularly in DC motor systems where precision is required. The ability of an SCR to handle both high voltage and current makes it an invaluable component in electrical control systems and power electronicserational principle of an SCR is similar to that of a diode, but with an added level of control. Unlike a diode, which allows current to flow when forward biased, an SCR requires an external trigger signal at its gate terminal to allow current to pass through[16]. This feature enables precise regulation of the voltage delivered to the motor, and by extension, control over its rotational speed. The SCR has three main terminals: anode (+), cathode (-), and gate, which is used to trigger the device[17]. When the gate is activated, the SCR conducts, allowing current to flow from the anode to the cathode, influencing the motor's operation.

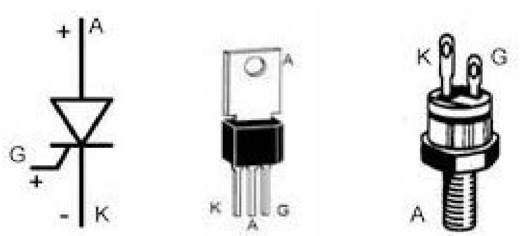

Figure 2. SCR Symbol and Shape

the SCR operates similarly to the base of a transistor, with current adjustments typically ranging from 1 mA to 100 mA [9]. By controlling the gate current (Ia), the output voltage at the anode can be adjusted across a broad range, typically from 50 Volts to 5,000 Volts. This provides flexibility in controlling the motor's power, with the SCR being capable of managing current levels ranging from 0.4 A up to 1500 A. This ability to regulate both voltage and current makes the SCR an ideal component in voltage stabilization systems and motor speed control circuits, particularly in applications requiring precise power management and dynamic control[18].

C. Optocoupler

An optocoupler is an essential electronic component used to transfer electrical signals between different circuits through optical light, providing electrical isolation while maintaining signal integrity[19]. It typically consists of two main parts: a transmitter, which emits light, and a receiver, which detects the light signals. In controlled rectifier circuits, the optocoupler plays a critical role by acting as a controller for the motor speed. It achieves this by influencing the DC supply voltage provided to the anode, which in turn controls the gate voltage on the Silicon Controlled Rectifier (SCR). By adjusting the gate signal, the optocoupler allows precise control over the SCR, which regulates the voltage and current applied to the DC motor.

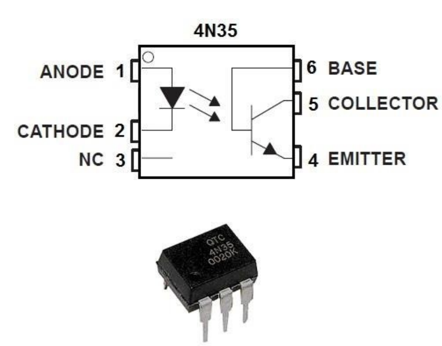

Figure 3. Optocoupler

In this context, the optocoupler not only serves as a means of voltage regulation for controlling the speed of the motor but also contributes to the stability of the entire system. By modulating the input voltage to the motor, the optocoupler ensures smoother operation and helps in achieving the desired rotational speed, providing the system with both accuracy and reliability. Additionally, optocouplers offer protection against electrical interference and circuit faults, as they can isolate the control section from high-voltage components, preventing damage from short circuits or voltage spikes.

D. Software PSIM

PSIM is a powerful simulation software widely used in the engineering and electronics fields for analyzing and simulating the behavior of electronic circuits and electric power systems [20]. This software, compatible with MS Windows XP and later operating systems, provides a user-friendly interface for simulating various components, including controlled rectifiers, DC motors, and voltage regulation systems [21]. Its functionality makes it a valuable tool in the research and development of power electronics and motor control systems, as it allows engineers to model and test circuit behaviors before implementing them in real-world application size PSIM effectively for simulation purposes, users begin by installing the software from the master program. The installation process follows the same steps as most Windows-based software installations, ensuring ease of use for engineers and researchers. Once installed, the software provides an intuitive environment for users to design, simulate, and analyze different components, making it ideal for researchers and engineers looking to optimize the performance of controlled rectifiers and other complex systems such as DC motor voltage stabilization and speed control mechanisms.

2. Methode

The research simulation was performed using the Power Simulator (PSIM) software. This software was selected for its suitability in simulating the effects of a thyristor on voltage regulation, specifically for controlling the speed of a single-phase AC motor. The primary objective was to understand how the thyristor regulates voltage and influences motor speed through various circuit parameters. The use of PSIM allowed for detailed modeling and analysis of the system, ensuring precise measurement of voltage and current variations during the experiment.

The procedure for the simulation involved several key steps to determine the effectiveness of the thyristor in voltage regulation. First, the necessary tools and components were gathered, followed by the construction of the circuit as per the provided diagram. The next step involved calculating the conversion angle and adjusting the angle potentiometer to achieve the desired voltage settings. Measurements were then taken for input RMS voltage, input current, DC output voltage, and output current. An oscilloscope was used to observe the waveforms of the input and output voltages, which helped assess the performance of the circuit under different conditions.

Data analysis was a critical part of the methodology, where the measurement results were compared with theoretical values [22]. This comparison was used to determine the percentage difference between observed and expected values, providing insights into the accuracy and effectiveness of the voltage regulation method. The final stage involved calculating the circuit's characteristic parameters, analyzing the results, and drawing conclusions based on the data gathered from the simulation. This comprehensive procedure aimed to evaluate the role of the thyristor in enhancing the control of motor speed through voltage regulation.

A. Circuit Schematic

In the field of engineering, specifically in DC motor speed control, simulations are an essential tool for evaluating the performance of various control systems. This study utilized PSIM software to design and simulate a DC motor speed regulation system, focusing on a controlled rectifier circuit for AC voltage regulation. The purpose of this simulation was to assess the impact of voltage regulation on the rotational speed of the DC motor, with an emphasis on stability and efficiency. PSIM was selected for its advanced modeling capabilities, allowing for precise analysis of the control mechanisms in play.

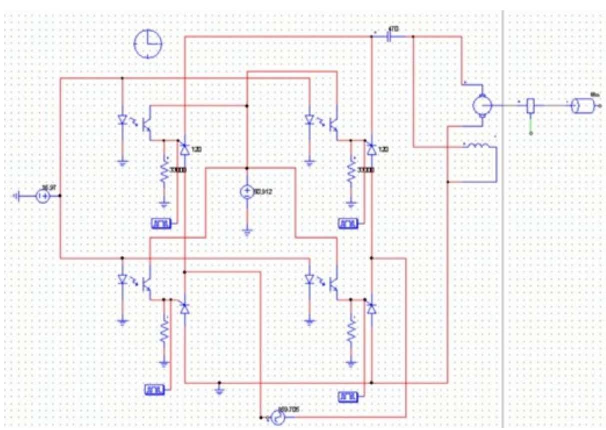

Figure 4. PSIM Schematic

The system under investigation consists of two main circuits: the control circuit and the power circuit. The control circuit includes a DC voltage source, an optocoupler, and a Silicon Controlled Rectifier (SCR). The optocoupler plays a critical role in transferring the control signal while maintaining isolation, ensuring the stability and reliability of the system. The power circuit, on the other hand, is composed of an AC voltage source, a capacitor, and the DC motor itself [13]. This configuration allows the SCR to regulate the input voltage supplied to the motor, thus controlling its speed.

The integration of optocouplers within the control circuit is a key feature of this study, as it enhances the voltage regulation process and provides better control over motor performance. By using this setup, the voltage-to-speed controlled rectifier circuit allows for fine-tuned adjustments in motor speed, resulting in improved efficiency and stability. This research contributes to the ongoing development of motor control systems, offering valuable insights into the application of controlled rectifiers and optocouplers for voltage stabilization in industrial motor applications.

III.RESULT & DISCUSION

A controlled rectifier circuit utilizing thyristors is designed to regulate the voltage supplied to a DC motor using an optocoupler for precise control. This system incorporates four SCRs (Silicon Controlled Rectifiers) or thyristors connected in a configuration that forms an integrated control circuit. The output from this control circuit is then used to regulate the power circuit, which is powered by a 120V AC supply. The implementation of the optocoupler allows for electrical isolation between the control and power circuits, improving system stability and ensuring the protection of sensitive components.

In the power circuit design, key components such as an alternator, a 470µF capacitor, and a 12V DC motor are utilized. The alternator serves as the source for AC voltage conversion, while the capacitor is used to filter and smooth the rectified output, ensuring stable voltage delivery to the DC motor. This setup, as illustrated in Figure 6, demonstrates a practical application of controlled rectifiers for voltage stabilization and motor speed regulation.

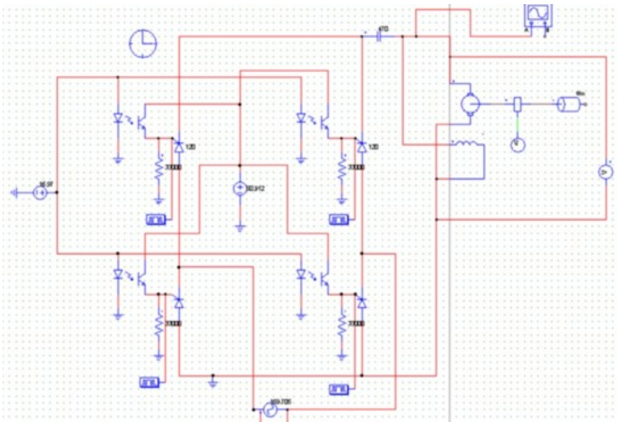

Figure 6. Control Circuit and power circuit

- Voltage on Circuit

The power circuit is designed to operate with a 120 Volt AC input source, which is used to supply voltage to the motor. This AC voltage is then converted and regulated through a controlled rectifier circuit to provide the appropriate DC voltage required for the motor's operation. By utilizing a controlled rectifier, the system ensures precise voltage regulation, which is critical for optimizing motor performance and stability, particularly in systems where rotational speed control is essential.

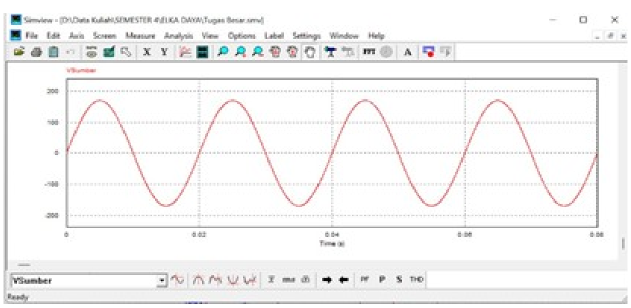

Figure 7. Voltage Source waveform

Source Voltage Calculation :

Amplitude = Source Voltage × $\sqrt{2}$

= 120 Volt × $\sqrt{2}$

= 169,705

Table 1. Result simulation

Voltage Control (Vdc)	Motor Peak Voltage	Motor Time to Max Speed
15 Volt	9.5 Volt	23,08 s
18 Volt	10.25 Volt	22.20 s
24 Volt	14.25 Volt	21.03 s
36 Volt	17.75 Volt	19.70 s
45 Volt	27.0 Volt	16.25 s

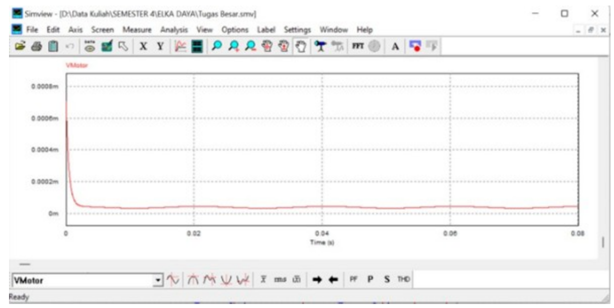

Figure 8. Voltage wave DC Motor

The voltage supplied to the DC motor is not perfectly smooth, as residual sinusoidal fluctuations are present due to the nature of the motor being an induction motor. These fluctuations can cause instability in the motor's operation, particularly at the moment of startup. At 0 seconds, a voltage spike is observed, which is a typical characteristic during motor startup. This transient is primarily caused by the initial inrush current required to overcome the motor's inertia.

To mitigate this issue and improve voltage stability, the implementation of a capacitor is crucial. By incorporating a capacitor into the circuit, the voltage waveform can be smoothed out, reducing the amplitude of the voltage spike and ensuring a more stable and consistent power supply to the motor. This adjustment enhances the overall DC motor performance, particularly in applications that require precise speed control and voltage stabilization.

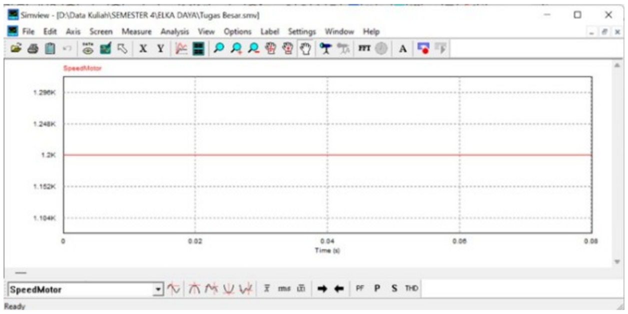

Figure 9. Motor Speed Graphic

The motor speed performance graph shows a steady value of 1200 RPM, indicating that the motor has reached its maximum operational speed. This stable speed is a direct result of the optimal input voltage being supplied to the motor. As the AC input voltage is adjusted, the speed of the motor is directly affected— increasing the input voltage leads to an increase in motor speed, while reducing the input voltage results in a decrease in speed.

In the control circuit, the rate of acceleration is heavily influenced by the control voltage. If the input voltage is raised, the motor reaches its maximum speed more quickly, as the motor accelerates at a faster rate, reducing the overall time required for full speed. Conversely, if the control voltage is reduced, the motor's acceleration becomes slower, resulting in a longer time to reach the maximum speed.

This relationship between voltage control and motor speed highlights the importance of an accurate and responsive control circuit. The ability to adjust the AC input voltage efficiently is essential for achieving the desired motor performance, especially in applications that require precise speed control and voltage stabilization. These aspects are central to the effective operation of controlled rectifiers integrated with optocouplers, as outlined in the study's focus on optimizing motor performance.

IV.CONCLUSION

In conclusion, the experiments reveal that the power circuit operates on AC voltage, while the control circuit uses DC voltage. These circuits work together to control the motor's performance. The key findings are as follows:

- The power circuit supplies AC power to the motor, while the control circuit regulates the voltage using SCRs to control the motor's behavior.
- Increasing input voltage raises the motor's speed, and adjusting control voltage affects the acceleration rate.
- A voltage surge occurs at startup, which can be stabilized with a capacitor, improving energy efficiency and motor control.

V.REFERENCE

[1] Nugraha, Anggara Trisna, and Rachma Prilian Eviningsih. Penerapan Sistem Elektronika Daya: AC Regulator, DC Chopper, dan Inverter. Deepublish, 2022.

[2] Ivannuri, Fahmi, Anggara Trisna Nugraha, and Lilik Subiyanto. "Prototype Turbin Ventilator Sebagai Pembangkit Listrik Tenaga Angin." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.2 (2022).

[3] Nugraha, Anggara Trisna, Faris Riyadi, and Fajar Rahmat Adzani. "Making a Turtle Conservation Website and Sumbreng Sea Pearl Education Tour for Ecosystem Balance." Frontiers in Community Service and Empowerment 2.4 (2023).

[4] Prakosa, J. A., Gusrialdi, A., Kurniawan, E., Stotckaia, A. D., Adinanta, H., & Suryadi. (2022). Experimentally robustness improvement of DC motor speed control optimization by H-infinity of mixed-sensitivity synthesis. *International Journal of Dynamics and Control*, *10*(6), 1968-1980.

[5] Rikwan, R., & Ma'arif, A. (2023). DC Motor Rotary Speed Control with Arduino UNO Based PID Control. *Control Systems and Optimization Letters*, *1*(1), 27-31.

[6] Nugraha, Anggara Trisna, et al. "Comparative Analysis of Buck-Boost Converter with Sepic Converter for Optimization of Wind Power Plant Output Voltage." International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023). Atlantis Press, 2024.

[7] Xian, B. (2024, September). DC Motor Angular Speed Stability Study Using The Fuzzy PID Controller. In *2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)* (pp. 327-338). Atlantis Press.

[8] Nugraha, Anggara Trisna, Oktavinna Dwi Pratiwi, and Annas Singgih Setiyoko. "SIMULASI GANGGUAN SAAT TERJADI GANGGUAN UNDERVOLTAGE DAN UNBALANCE LOAD PADA SUB-SUB DISTRIBUSI PANEL." MEDIA ELEKTRIKA 16.2 (2024): 162-173.

[9] Teng, J., Sun, X., Zhang, Y., Fu, H., Liu, X., Zhao, W., & Li, X. (2021). Two types of common-mode voltage suppression in medium voltage motor speed regulation system based on solid state transformer with dual DC bus. *IEEE Transactions on Power Electronics*, *37*(6), 7082-7099.

[10] Nugraha, Anggara, and Ghafirul Sugianto. "Implementasi Sensor Cahaya Sebagai Level Bahan Bakar pada Tangki Harian Kapal."

[11] Koondhar, M. A., Malak, A. A., Koondhar, M. A., & Channa, I. A. (2020). Experimental based Comparative Analysis and Characteristics of DC Series Motor by using Different Techniques. *Sukkur IBA journal of emerging technologies*, *3*(1), 1-15.

[12] As' ad, Reza Fardiyan, and Anggara Trisna Nugraha. "Rancang Bangun Penstabil Kinerja Panel Hubung Bagi Tegangan Rendah." Journal of Computer, Electronic, and Telecommunication (COMPLETE) 3.1 (2022).

[13] Zare, R., Mohajery, H., & Shayeghi, P. (2022). Optimal FOTID controller design for regulation of DC motor speed. *International Journal on Technical and Physical Problems of Engineering*, *14*(1), 57-63.

[14] Achmad, Irgi, and Anggara Trisna Nugraha. "Implementation of Voltage Stabilizers on Solar Cell System Using Buck-Boost Converter." Journal of Electronics, Electromedical Engineering, and Medical Informatics 4.3 (2022): 154-160.

[15] Jamil, M. H., et al. "The existence of rice fields in Makassar City." IOP Conference Series: Earth and Environmental Science. Vol. 681. No. 1. IOP Publishing, 2021.

[16] Arifuddin, Rahman, et al. "Baby Room Temperature and Humidity Control System Using Fuzzy Logic." Emitor: Jurnal Teknik Elektro (2024): 275-280.

[17] Sheila, Sindy Yurisma, et al. "Coffee Drying Tool with LQR-PID Control." MEIN: Journal of Mechanical, Electrical & Industrial Technology 1.2 (2024): 18-23.

[18] Paluga, Ary Pratama, et al. "Renewable Energy System Optimization: Mppt Inverter Integration, Energy Storage Systems, And Its Impact on Sustainability and Efficiency Use Of Energy." MEIN: Journal of

Mechanical, Electrical & Industrial Technology 1.2 (2024): 12-17.

[19] Almunawar, Deni, et al. "Perancangan Sistem Pendukung Keputusan Mesin e-Fill Berbasis ANFIS." COMPLETE-Journal of Computer, Electronic, and Telecommunication 5.1 (2024).

[20] Saputra, Fahmi Yahya, et al. "Efficiency Of Generator Set On Changes In Electrical Load On Fishery Vessels." MEIN: Journal of Mechanical, Electrical & Industrial Technology 1.2 (2024): 1-4.

[21] Nugraha, Anggara Trisna, et al. Rancang Bangun Ship Alarm Monitoring (SAM) Sebagai Solusi Keamanan Pengoperasian Auxiliary Engine. Deepublish, 2021.

[22] Randa, Y. A., Syukri, M., & Multazam, T. (2024, June). DC motor speed control using boost converter DC-DC chopper type based on the PID controller. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1356, No. 1, p. 012083). IOP Publishing.