Journal of Marine Electrical and Electronic Technology **Vol. …...., No. …….**
ISSN xxxxxx **Publication Periode**

Assessment and Performance Analysis of a Full-Wave Three-Phase Uncontrolled Rectifier in Powering a Single-Phase DC Motor

Abimanyu Manap
Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Indonesia
abimanyumanap01@student.ppns.ac.id

Abstract

This research investigates the design and performance of a full-wave three-phase uncontrolled rectifier used to drive a single-phase DC motor, with a particular focus on its practical application in industrial environments. Three-phase DC motors are widely utilized in industry due to their ease of operation and efficiency. However, challenges arise in converting the power supply, as much of Indonesia's electrical grid is based on alternating current (AC). To resolve this, a rectifier circuit is crucial to convert the AC input into a stable DC output using diodes, ensuring compatibility with the DC motor's requirements. The need for high-capacity and reliable DC power sources in industrial applications makes three-phase rectifiers necessary, as they can deliver higher power output compared to single-phase systems. This paper examines the operating principles, circuit topology, and diode configuration of the three-phase uncontrolled rectifier. By integrating these components, the rectifier enables efficient energy conversion and meets the operational demands of single-phase DC motors in industrial settings. Additionally, this study presents performance metrics such as power efficiency, voltage regulation, and thermal characteristics based on experimental results. The findings contribute to the optimization of rectifier systems in engineering, highlighting their importance in improving the reliability and scalability of DC motor systems for industrial automation and energy applications.

Keywords: Resource, Rectifier, Controlled, DC motor

1. Introduction

A full-wave rectifier is an essential circuit in power electronics, designed to convert an alternating current (AC) sine wave into a direct current (DC) output. This conversion is achieved by using two parallel sets of diode blocks, enabling the rectification of both the positive and negative cycles of the AC waveform. Compared to half-wave rectifiers, full-wave rectifiers deliver a more stable DC voltage with considerably less ripple, as they utilize both the positive and negative cycles of the sine wave to produce continuous output throughout the entire signal period. This makes full-wave rectifiers crucial for applications that demand consistent and dependable DC power (Rasyid, 2020).

In modern electronic devices, most operate on a 220V power supply from the national grid (PLN) in Indonesia, which provides electricity in AC form. To make this AC suitable for electronic devices, a conversion system is required. This system, known as a rectifier, comprises essential components such as transformers, diodes, and capacitors. The transformer adjusts the voltage level, either stepping it up or down based on the circuit's needs (Ali, 2018)(Fatkhorrozi, 2011). Diodes perform the dual role of converting the electrical signal to DC and protecting the circuit from reverse current. Capacitors are used to filter and stabilize the rectified signal, ensuring smooth operation by reducing ripple and temporarily storing energy.

Full-wave rectifiers are also significant in industrial systems, especially for powering DC motors. With the increasing reliance on automation and motor-driven systems, the need for efficient and reliable DC power sources is growing. This paper investigates the performance and operational advantages of a full-wave three-phase uncontrolled rectifier in driving single-phase DC motors, highlighting its capability to address industrial challenges like power stability and scalability. The analysis provides engineers and researchers with valuable insights into the rectifier’s design, functionality, and its role in enhancing power electronics systems for industrial applications.

2. Material and methods

2.1. Material

2.1.1. Circuit of 3 Phase Rectifier

Power rectifier circuits can be classified based on three key factors: the input voltage source, the output waveform, and the type of load connected to the circuit (Abdillah et al., 2011). From the perspective of the input voltage source, rectifier circuits are divided into two main categories: (1) Power Rectifier Circuits using a Single-Phase AC Voltage Source and (2) Power Rectifier Circuits using a Three-Phase AC Voltage Source. Regarding the output waveform, rectifiers are further classified into (1) Half-Wave Rectifier Circuits and (2) Full-Wave Rectifier Circuits. Lastly, based on the type of load connected, rectifiers can be categorized as (1) Rectifiers with Resistive (R) Loads and (2) Rectifiers with Resistive-Inductive (RL) Loads, as explained by Ali (2018) (Ali, 2018).

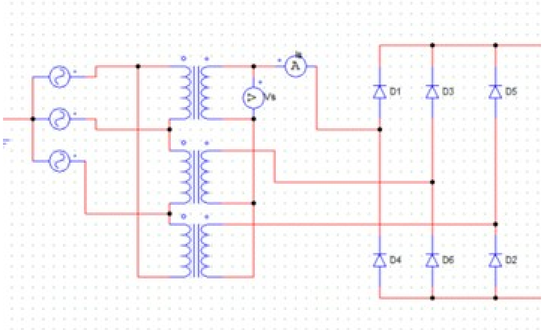

Figure 1. Three-Phase Rectifier Circuit

A three-phase rectifier circuit is designed to convert three-phase AC power into a DC output and is a crucial component in industrial applications . This type of circuit is widely used in various industrial systems, either as a standalone unit or integrated into more complex electrical systems. Compared to single-phase rectifiers, three-phase rectifier circuits provide substantial benefits, such as a smoother and more stable DC output. The enhanced quality of the waveform reduces ripple, which in turn decreases the size and capacity of filter capacitors. This makes three-phase rectifiers especially efficient and cost-effective for high-power applications, as emphasized by Ali (2018) (Ali, 2018).

2.1.2. Diode

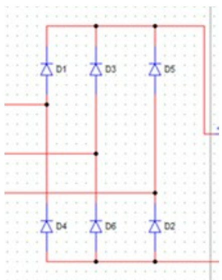

Figure 2. Diode in schematic

Diodes are crucial components in rectifier circuits, acting as the primary elements responsible for converting alternating current (AC) signals into direct current (DC) signals. As a type of active semiconductor device, diodes are highly valued for their simplicity, reliability, and versatility in electronic circuit design. The extensive use of diodes has led to the development of various rectifier configurations, including the Half-Wave Rectifier, Full-Wave Rectifier, Clipper Circuit, Clamper Circuit, and Voltage Multiplier (Mustofa, 2021). Each configuration provides specific functions tailored to particular industrial and engineering needs, showcasing the flexibility and essential role of diodes in modern technology.

Diodes are made from semiconductor materials, primarily silicon or germanium, and are known for their unidirectional current flow. This characteristic is due to their P-N junction structure, where one side is composed of P-type semiconductor material and the other side is made of N-type material. This setup allows current to flow only from the P-side (anode) to the N-side (cathode), effectively blocking reverse current. These properties make diodes essential for rectification, voltage regulation, and signal shaping. Over time, the development of diodes has led to specialized types, such as Zener diodes for voltage stabilization and Schottky diodes for high-speed switching, further extending their use in advanced engineering systems (Supatmi, 2010).

2.1.3. DC Motor 1 Phase

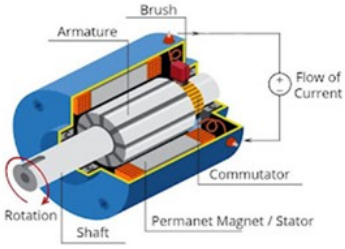

Figure 3. DC Motor 1 Phase

Electric motors are essential components that convert electrical energy into mechanical energy, enabling a wide variety of applications in both industrial and domestic settings. This mechanical energy drives critical systems, such as pump impellers, fans, blowers, compressors, and material handling equipment. Due to their versatility and high efficiency, electric motors are often referred to as the "workhorses" of industry, representing about 70% of total industrial electrical energy consumption. In residential applications, electric motors are used in devices such as mixers, electric drills, and ventilation fans. The efficiency and reliability of these motors are key to the smooth functioning of both household and industrial systems, highlighting their important role in engineering design and application.

2.1.4. Transformator

Transformers are classified based on their construction and the specific applications they serve. Core-type transformers are typically used in applications that require high voltage ratings, such as power transmission lines (Zuhal, 1988). The straightforward design of core-type transformers makes them ideal for large-scale energy distribution, where voltage needs to be either stepped up or stepped down for efficient transmission over long distances. In contrast, shell-type transformers are preferred in situations that demand better shielding and reduced electromagnetic interference. Their design allows for a more compact and efficient form, making them particularly suited for industrial environments where space limitations and safety concerns are important. The versatility of transformers makes them essential in various engineering fields, especially in the integration of electrical power systems for both industries and homes. With ongoing advancements in transformer technology, their performance continues to improve, solidifying their role as a cornerstone in modern power management and distribution systems (Siburian, 2019).

2.2. Methods

This study adopts a scientific approach for data collection and analysis, utilizing a quantitative research method to assess the performance of a full-wave three-phase uncontrolled rectifier. This method is particularly suited for evaluating the rectifier's efficiency and behavior when used in a single-phase DC motor system (Nugraha, 2013). The research focuses mainly on simulations performed using PSIM software, which accurately models the rectifier circuit's behavior under various operating conditions. Through these simulations, the study aims to gather empirical data that illustrates the effects of the rectifier on motor performance, voltage regulation, and the overall system efficiency.

2.2.1. Circuit

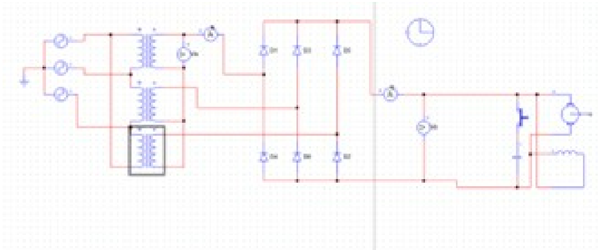

Figure 4. Simulation Circuit

To gain insight into the operational characteristics of the rectifier and assess its output, a series of simulations are necessary. PSIM software, renowned for its precision in power electronics simulations, is utilized to model the rectifier circuit. The simulation aims to examine the conversion process from alternating current (AC) to direct current (DC) and evaluate the rectifier's efficiency in powering a single-phase DC motor.

3. Results and discussion

In this circuit experiment, the output voltage from a three-phase transformer is initially 380V, which is then stepped down to 30V, 45V, and 60V using a series of voltage reduction stages. This lower voltage is subsequently passed through six rectifier diodes, which convert the alternating current into direct current. The resulting DC current is then supplied to the DC motor, enabling it to operate efficiently. By using this setup, the experiment aims to demonstrate how the rectifier system impacts motor performance and the overall energy conversion process.

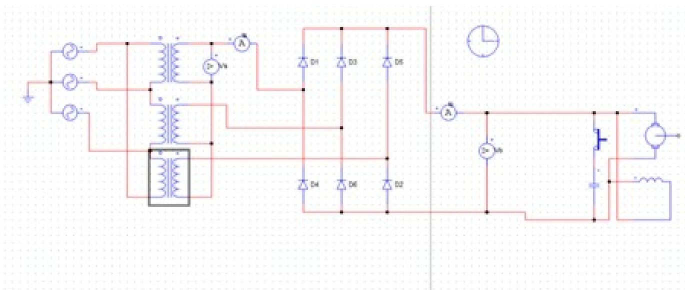

Figure 5. DC Motor 1 Phase

From the three experiments conducted without a load, using three different input voltages of 30V, 45V, and 60V, the output produced is as follows: It is important to note that the output characteristics, including voltage stability and ripple, were observed under each of these voltage conditions, providing insight into the rectifier's performance and efficiency at varying input levels.

Table 1. Simulation result

VO(rms) L-N	*Vo(dc)*	*Io(dc)*	*VO(rms)*	*Io(rms)*
30	***10.38***	***8.15e-04***	***13.10***	***8.77e-04***
45	***69.20***	***5.53e-04***	***87.37***	***5.84e-04***
60	***51.90***	***4.07e-04***	***65.52***	***3.47e-04***

Table 2. Test result

VO(rms) L-N	*Vo(dc)*	*VO(rms)*	*Is(rms)*
30	***49.62***	***49.662***	***6.94e-04***

DOI xxxxxx

Journal of Marine Electrical and Electronic Technology **Vol. …...., No. …….**
ISSN xxxxxx **Publication Periode**

45	*74.43*	*74.493*	*4.62e-04*
60	*99.24*	*99.324*	*3.47e-04*

By calculating V0(dc) and V0(rms) as follows, the no-load circuit calculation provides insight into the rectifier's performance under different conditions. The DC output voltage (V0(dc)) can be calculated by determining the average value of the rectified waveform, while the RMS voltage (V0(rms)) represents the effective value of the rectified output. These calculations are crucial for understanding how the rectifier performs in converting AC to DC without a load, and how the output voltage is affected by the variations in the input voltage.

- $V_{s(max)L-N} = 30\,Volt$

  $V_{o(dc)} = 1.654\,x\,V_{s(max)L-N}$

  $V_{o(rms)} = 1.6554\,x\,V_{s(max)L-N}$

  $V_{o(dc)} = 1.654\,x\,30 = 49.62\,V$

  $V_{o(rms)} = 1.6554\,x\,30 = 49.662\,V$

- $V_{s(max)L-N} = 45\,Volt$

  $V_{o(dc)} = 1.654\,x\,V_{s(max)L-N}$

  $V_{o(rms)} = 1.6554\,x\,V_{s(max)L-N}$

  $V_{o(dc)} = 1.654\,x\,45 = 74.43\,V$

  $V_{o(rms)} = 1.6554\,x\,45 = 74.493\,V$

- $V_{s(max)L-N} = 60\,Volt$

  $V_{o(dc)} = 1.654\,x\,V_{s(max)L-N}$

  $V_{o(rms)} = 1.6554\,x\,V_{s(max)L-N}$

  $V_{o(dc)} = 1.654\,x\,60 = 99.24\,V$

  $V_{o(rms)} = 1.6554\,x\,60 = 99.324\,V$

Based on the data and calculations above, when the voltage is reduced to 30V, 45V, and 60V, there is a corresponding decrease in current. This reduction in current leads to a decrease in the RPM (revolutions per minute) of the DC motor. As the voltage and current drop, the motor's power output is reduced, resulting in lower rotational speed and overall performance. This behavior illustrates the direct relationship between voltage, current, and motor speed in a DC motor system.

- Waveform at a voltage of 30 v

DOI xxxxxx

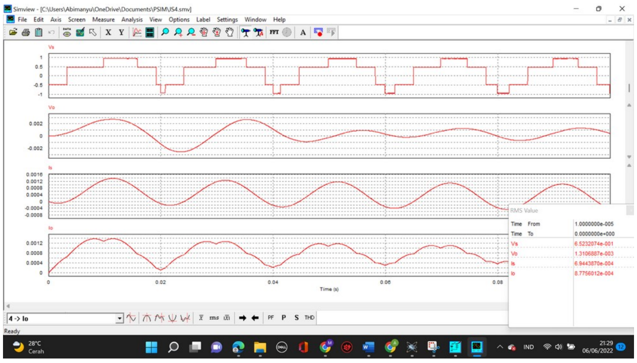

Figure 6. rms waveform of experiment 1 with a 30 v

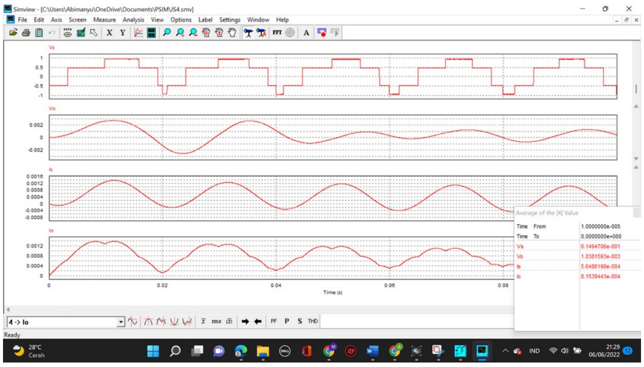

Figure 7. average waveform of experimental rectifier 1 with a 30 V

- Waveform at a voltage of 45 v

Figure 8. rms waveform of experimental rectifier 2 with a 45 v

Figure 9. average waveform of experimental rectifier 2 with a 45 v

- Simulation results at a voltage of 60 v

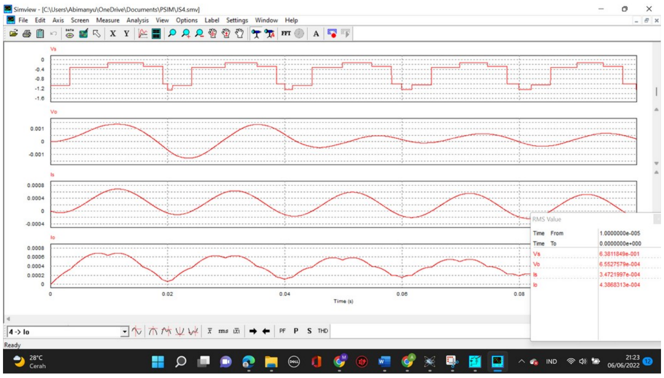

Figure 10. rms waveform of experimental rectifier 3 with a 60 v

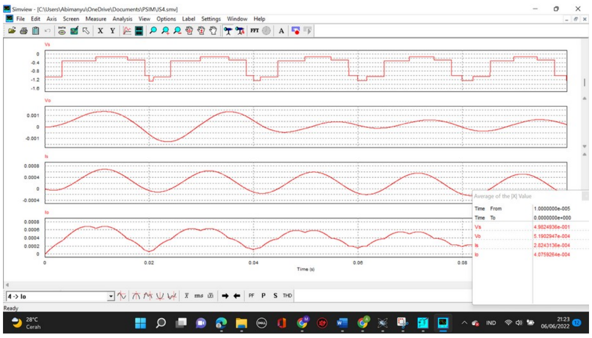

Figure 11. average waveform of experimental rectifier 3 with A 60 v.

4. Conclusion

- The simulation results show that the three-phase uncontrolled rectifier successfully powers a single-phase DC motor across three voltage levels (30V, 45V, and 60V), providing stable and consistent output under varying conditions.
- As the input voltage decreases, the current supplied to the DC motor also drops, leading to a reduction in rotational speed (RPM), demonstrating the motor's dependence on the rectifier’s output voltage.
- The analysis reveals a direct correlation between voltage and motor speed: higher voltage results in increased current and higher RPM. These findings emphasize the importance of voltage regulation for optimal motor performance, offering a basis for future improvements in rectifier circuit designs for industrial motor control.

Credit authorship contribution statement

Author Name: Conceptualization, Writing – review & editing. **Author Name**: Supervision, Writing – review & editing. **Author Name**: Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdurrahman Rasyid, S. (2020, april). Diambil kembali dari Pengertian dan fungsi dioda penyearah: https://www.samrasyid.com/2020/04/pengertian-dan-fungsi-dioda-penyearah.html

ali, m. (2018). APLIKASI ELEKTRONIKA DAYA PADA SISTEM TENAGA LISTRIK. yogyakarta: UNY PRESS.

fatkhorrozi. (2011). Diambil kembali dari https://pdfcoffee.com/makalah-rangkaian-penyearah-gelombang-penuh-tiga-fasa-pdf-free.html

Mochammad Abdillah, E. W. (2011). Rancang Bangun Rangkaian AC to DC Full Converter.

Mustofa, M. J. (2021). perancangan penyearah terkendali untuk pengaturan motor dc.

siburian, j. (2019). jurnal teknologi energi 2. Diambil kembali dari http://jurnal.darmaagung.ac.id/index.php/teknologienergi/article/view/121/139

Supatmi, S. (2010). Dioda. Diambil kembali dari https://repository.unikom.ac.id/34247/1/dioda.pdf

Zuhal. (1988). Diambil kembali dari https://staff.ui.ac.id/system/files/users/chairul.hudaya/material/dcmotorpaperandqa.pdf

Nugraha, E. (2013). Upaya Meningkatkan Hasil Belajar Siswa pada Materi Elektronika Dasar Menggunakan Media Pembelajaran Berbasis Augmented Reality. Diambil kembali dari https://repository.upi.edu/38751/1/Upaya%20Meningkatkan%20Hasil%20Belajar.pdf