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Design and Performance Analysis of a Controlled Single-Phase Half-Wave Rectifier Using a Single-Phase Generator for Efficient Power Conversion

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ABSTRACT

This research focuses on the analysis and experimental evaluation of a Single-Phase Controlled Half-Wave Rectifier integrated with a Single-Phase Generator. The primary aim of the study is to analyze and compare experimental results with theoretical calculations and simulation software outputs, thereby providing a comprehensive evaluation of the rectifier's performance. The experiments are conducted on a rectifier circuit using diode-based components, with data collected through both authentic assessment methods and direct observation of the outcomes displayed in the experimental setup. The findings of the study indicate that the inclusion of a thyristor component in the AC circuit plays a crucial role in influencing the rectifier's performance. The thyristor enables the transformation of an alternating current (AC) waveform into a direct current (DC) signal, highlighting the importance of controlled power conversion in electrical systems. The presence of the thyristor allows for the conversion of an AC-powered system into a controlled DC output, which is a significant contribution to efficient energy management in various electrical engineering applications.

Key Word: *Controlled Rectifier, Single Phase Generator, Half Wave*

I.INTRODUCTION

As technological advancements continue to evolve, technology plays an increasingly integral role in simplifying and enhancing various aspects of human life. In particular, power electronics has emerged as a pivotal field of study, focusing on the design and application of electrical systems that handle high power demands, such as pumps, electric motors, compressors, and various other industrial equipment [1]. Power electronics offers substantial solutions to the industrial sector by minimizing conventional energy losses, making it a critical component in the development of more efficient and sustainable power systems[2][3].

One of the fundamental components of power electronics is the rectifier circuit, which is responsible for converting alternating current (AC) to direct current (DC)[4][5]. Rectifiers play an essential role in modern electrical systems, where AC is typically used as the input power source. Depending on the design and application, rectifiers can be categorized into two main types: controlled rectifiers and uncontrolled rectifiers. Controlled rectifiers are used to convert AC voltage sources into regulated DC voltage, offering precise control over the output, whereas uncontrolled rectifiers provide a fixed, unregulated DC output, which limits their use in specific applications[6].

In this research, we focus on the design and performance analysis of a single-phase controlled half-wave rectifier circuit using a single-phase generator. A key aspect of this study is the integration of thyristors alongside diodes to enhance the control and stability of the rectifier output. Thyristors are critical in enabling manual control over the rectifier circuit, making them an essential component for achieving controlled DC conversion. By utilizing thyristors, the system can dynamically adjust the rectifier's output voltage to meet specific load requirements, offering greater flexibility and efficiency compared to simple diode-based rectifiers. This level of control is especially valuable in applications that require precise regulation of DC voltage to optimize motor performance or other industrial processes.

Additionally, the research provides a deeper understanding of the performance characteristics of the controlled half-wave rectifier, including its efficiency, output stability, and response to varying loads. By analyzing the behavior of the rectifier under different operating conditions, the study aims to identify potential areas for improvement in the design of rectifier circuits. The integration of thyristors also highlights the potential for further advancements in rectifier technology, which could lead to more robust, energy-efficient solutions for industrial applications. This research contributes to the growing body of knowledge in power electronics, providing valuable insights that could help optimize rectifier circuit design and improve overall system performance in both commercial and industrial settings.

II.METHODOLOGY

A rectifier circuit is a crucial component in power electronics, involving both circuit analysis and mathematical calculations to determine the magnitude of voltage and current in a system where the rectification process is controlled. Rectifiers are widely used in applications where the conversion of alternating current (AC) to direct current (DC) is essential, such as in motor control systems, power supplies, and various industrial processes. The design and performance of rectifiers directly impact the efficiency and stability of the systems they power, making their analysis and optimization critical in power electronics research[7].

The study focuses on understanding the behavior of a single-phase half-wave controlled rectifier circuit, specifically examining the functionality of the thyristor component within this system. The half-wave rectifier is a basic but essential configuration, converting half of the AC input cycle into usable DC output. In a controlled rectifier circuit, the thyristor acts as a switch that regulates the conduction time, allowing for more precise control over the DC output compared to an uncontrolled rectifier, where the diode conducts without any control. The study investigates how the thyristor's timing and firing angle affect the efficiency and quality of the rectified output.

The primary issues addressed in this research include the operational principles of the rectifier circuit, the role of the thyristor in controlling the rectification process, and the comparison between controlled and uncontrolled circuits[8][9]. Understanding the operational principles involves examining how AC voltage is converted to DC, while also analyzing the differences in output characteristics between circuits with and without the thyristor control. The research also highlights the advantages of controlled rectifiers, such as improved voltage regulation and the ability to adjust the output to meet specific load demands, compared to the fixed, unregulated output of uncontrolled circuits.

By examining these factors, this study contributes to a deeper understanding of rectifier performance and the role of thyristors in optimizing power conversion. It provides valuable insights into how controlled rectifiers can be used to enhance the efficiency and stability of power systems. The findings also inform the design of future power electronics systems, especially in applications requiring precise control of DC voltage for reliable operation, making this research significant for both academic and industrial advancements in the field of power electronics.

The following section outlines the system requirements, detailing the components used in the rectifier circuit. This configuration has been documented in Table 1, which illustrates the components and their respective roles in achieving optimal performance of the controlled rectifier.

Table 1. illustrates the components and their respective

No	Components	Laying	Method of Work
1	Alternator	installed at the beginning of the circuit before *the transformer*	Provides AC voltage to the circuit constantly
2	*Thyristors*	Installed after the alternator	AC current to the anode and changes the direction of flow by blocking the AC flow from the alternator to DC, so that it exits to the cathode in the same direction as
3	Resistors	Installed after the diodes are in series after the push button series	Provides resistance or load on the
4	Amperemeter	Installed in series after and before the diode	Capturing the amount of current that passes through the cable directly attached in series
5	Volt Meters	Installed in parallel after the transformer and after	Capturing the amount of voltage that passes through components or cables that are installed in parallel

1. Single-Phase Half-Wave Rectifier

The process of converting alternating current (AC) and alternating voltage into direct current (DC) is fundamental to the operation of a rectifier. A rectifier is a key component in power electronics systems, responsible for transforming AC power, which fluctuates in polarity, into a stable DC output suitable for various applications [10][11]. The principle behind this conversion is based on the rectification process, where the alternating voltage and current are manipulated to produce a unidirectional current flow, which is essential for the operation of many electrical devices.

In this study, a single-phase half-wave rectifier circuit is employed, which is illustrated in Figure 1. This configuration utilizes a single-phase AC input and passes it through a rectifier circuit, typically using components such as diodes or thyristors, to produce the desired DC output[12][13]. The characteristics of the output waveform, as influenced by the rectifier design, are presented in Figure 2, showcasing the rectified voltage that varies in magnitude but provides a direct current output.

The analysis of this waveform is critical for evaluating the performance of the rectifier, which directly impacts the efficiency and stability of power conversion in engineering applications[14][15]. The half-wave rectification process, in particular, offers insights into the efficiency losses and potential for optimizing the design of power systems that rely on rectifiers for converting AC to DC[16].

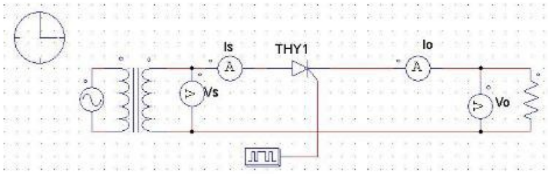

Figure 1. circuit used for a single-phase half-wave rectifier

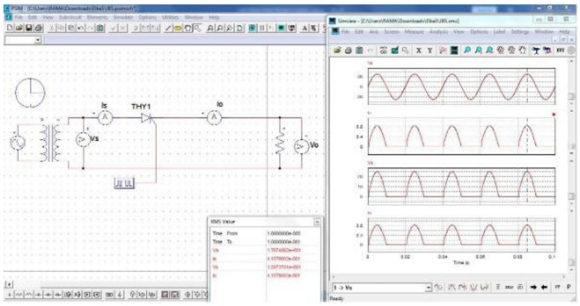

Figure 2. Output

2. Calculation Analysis Calculations

The analysis is performed using two key formulas, as detailed below. These mathematical formulations are essential for accurately determining the performance characteristics and efficiency of the controlled single-phase half-wave rectifier [17][18]. The formulas are derived to calculate the average DC output voltage and the ripple factor of the rectifier, which are critical in assessing how effectively the rectifier converts AC to DC and how smooth the resulting DC output is. The use of these formulas allows for a quantitative evaluation of the system's performance and provides insights into its operational efficiency under varying conditions.

These mathematical expressions are not only fundamental in the design and optimization of the rectifier but also serve as a benchmark for comparing experimental results with theoretical predictions. By applying these formulas, the research ensures that the rectifier's performance is analyzed under controlled conditions, taking into account the effects of various factors such as load, firing angle, and the characteristics of the thyristor. This approach guarantees that the experimental data aligns with the expected behavior of the system and allows for a detailed understanding of its performance, including its ability to maintain a stable DC output and minimize voltage ripple.

The formulas facilitate the comparison of experimental results with theoretical predictions, ensuring a comprehensive understanding of the rectifier's behavior within the power conversion system [19][20]. This comparison is essential for verifying the accuracy of the rectifier's design and operation, ensuring that the theoretical models hold true in practical applications[21]. The accuracy of the measurements and the alignment between theory and practice provide confidence in the system's reliability and efficiency, which is particularly important in industrial applications where stable power conversion is critical.

The following presents the mathematical expressions used in the evaluation of the rectifier's performance: the first formula calculates the average DC output voltage, which is crucial in determining the efficiency of the rectification process, while the second formula calculates the ripple factor, which indicates the level of voltage fluctuation in the DC output. These formulas together offer a comprehensive means of evaluating the rectifier's overall performance, guiding improvements in system design and enhancing its practical application in various power electronics systems.

- Voltage *Output* DC

$$V_{0(DC)}=\frac{Vmax}{2\pi}\left[1+\cos a\right]$$

- Voltage *Output* RMS

$$V_{0(rms)}=\frac{Vs\left(max.\right)}{2\pi}\sqrt{1-\frac{a}{\pi}-\frac{\sin\left(2a\right)}{2\pi}}$$

- Error Percentage

$$\text{Error\%}=\frac{\left(Theory-practice\right)}{Theory}\times 100\,\%$$

III.RESULT & DISCUSION

The experiment begins by constructing the circuit using PSIM simulation software, which is a widely recognized tool for simulating power electronics systems. The input voltage magnitude, Vin, is set to a predetermined value, and three different load resistor values of 80, 160, and 1600 ohms are applied at each voltage setting. Following this, the Root Mean Square (RMS) and average measurements of the output voltage and current are carefully recorded for each experimental setup. These measurements are then compared against theoretical predictions to assess the accuracy of the system's performance. The experimental results, along with the corresponding mathematical calculations, are documented in a comprehensive table for further analysis. The objective is to determine the consistency between the simulation outcomes and calculated values, thereby verifying the accuracy of the controlled single-phase half-wave rectifier circuit design.

1.Result

The measurement data derived from manual calculations and software, which includes the DC output voltage and RMS output voltage (80, 160, 1600).

- Measurement results with a load resistor attached to the circuit of 80

Table 2. Circuit Data with R 80

Vs (rms) (LN) (Volt)	A	Vo (dc) Theory (Volt)	Vo (dc) Prac (volts)	Io (dc) Prac (A)	Vo (rms) Theory (Volt)	Vo (rms) Prac (Volt)	Io (rms) Prac (A)	Error Vo (dc) %	Error Vo (rms) %
25	15	7.54	7.81	0.26	12.35	12.47	0.41	3.5	0.9
25	30	7.30	7.42	0.24	12.28	12.31	0.41	1.6	0.2
25	45	6.60	6.78	0.22	11.85	11.91	0.39	2.7	0.5
25	60	5.52	5.96	0.19	11.15	11.20	0.37	2.2	0.4
25	75	4.98	5.00	0.16	10.16	10.17	0.33	0.4	0.1
25	90	3.85	3.97	0.13	8.75	8.82	0.29	3.1	1.0
25	100	3.20	3.28	0.10	7.78	7.80	0.26	2.5	0.2

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As the current increases, the discrepancies between theoretical and practical values also increase, but the errors remain within reasonable limits (less than 5%). This suggests that while higher currents introduce some minor variations, these deviations are not significant enough to undermine the overall system's reliability or performance. The low error margin demonstrates that the rectifier system operates consistently and efficiently even under varying load conditions. These results are crucial for confirming the accuracy of the rectification process and ensuring that the system can be relied upon for precise control and stable output in practical applications. Overall, the measurements indicate that the system's performance is reliable and the measured values are consistent with theoretical predictions, further reinforcing the validity of the experimental setup and the design of the rectifier circuit.

- Measurement results with a load resistor installed in the circuit of 160

Table 3. Circuit Data with R 160

Vs (rms) (LN) (Volt)	A	Vo (dc) Theory (Volt)	Vo (dc) Prac (volts)	Io (dc) Prac (A)	Vo (rms) Theory (Volt)	Vo (rms) Prac (Volt)	Io (rms) Prac (A)	Error Vo (dc) %	Error Vo (rms) %
25	15	7.54	7.81	0.13	12.35	12.47	0.20	3.5	0.9
25	30	7.30	7.42	0.12	12.28	12.31	0.20	1.6	0.2
25	45	6.60	6.78	0.11	11.85	11.91	0.19	2.7	0.5
25	60	5.52	5.96	0.09	11.15	11.20	0.18	2.2	0.4
25	75	4.98	5.00	0.08	10.16	10.17	0.16	0.4	0.1
25	90	3.85	3.97	0.06	8.75	8.82	0.14	3.1	1.0
25	100	3.20	3.28	0.05	7.78	7.80	0.13	2.5	0.2

This table presents experimental data similar to the previous one, but with slightly smaller values for Io (dc) Prac (A) (measured DC current) compared to the earlier measurements. The comparison between the theoretical and practical values for both Vo (dc) and Vo (rms) shows excellent accuracy, with error percentages for both DC and RMS voltages remaining small (under 5%). The small error margins suggest that the system is performing as expected and that the rectifier is effectively converting AC to DC with minimal loss or distortion. This level of precision is crucial in ensuring that the system operates reliably in practical applications, where maintaining stable and accurate voltage levels is essential.

As the current increases (from 15 A to 100 A), the measured Io (current) decreases, while the errors in both DC and RMS voltage remain stable and small. The consistency of the error percentages across varying currents further emphasizes the robustness of the system. Specifically, the error in DC voltage ranges from 1.6% to 3.5%, while the RMS voltage error is consistently below 1%. This indicates that despite changes in current, the rectifier and its associated circuitry maintain a high level of performance, with only minor variations in voltage readings. These results underscore the reliability of the system in converting and regulating power, even as load conditions fluctuate.

Overall, the experimental results show that the practical measurements closely match the theoretical values, indicating a consistent and reliable system performance. The low error margins and stable measurements across different operating conditions demonstrate the accuracy and efficiency of the rectifier circuit. These findings validate the system’s design and confirm that it operates within the expected parameters, providing confidence in its use for applications requiring stable and reliable DC power conversion. The results reinforce the system’s potential for integration into various industrial and commercial settings, where performance consistency and reliability are critical.

- Measurement results with the load resistor installed in the circuit of 1600

Table 4. Circuit Data with R 1600

Vs (rms) (LN) (Volt)	A	Vo (dc) Theory (Volt)	Vo (dc) Prac (volts)	Io (dc) Prac (A)	Vo (rms) Theory (Volt)	Vo (rms) Prac (Volt)	Io (rms) Prac (A)	Error Vo (dc) %	Error Vo (rms) %
25	15	7.54	7.81	0.013	12.35	12.47	0.020	3.5	0.9
25	30	7.30	7.42	0.012	12.28	12.31	0.020	1.6	0.2
25	45	6.60	6.78	0.011	11.85	11.91	0.019	2.7	0.5
25	60	5.52	5.96	0.009	11.15	11.20	0.018	2.2	0.4
25	75	4.98	5.00	0.008	10.16	10.17	0.016	0.4	0.1
25	90	3.85	3.97	0.006	8.75	8.82	0.014	3.1	1.0
25	100	3.20	3.28	0.005	7.78	7.80	0.013	2.5	0.2

This table shows experimental results with Io (dc) Practical (A) (measured DC current) values even smaller than before, indicating precise current measurements. The comparison between Vo (dc) and Vo (rms) theoretical and practical values still demonstrates excellent accuracy. The errors for both DC and RMS voltages remain very small (below 5%), showing a good match between theoretical predictions and actual measurements. This consistency across various values reinforces the reliability of the measurement techniques used and indicates that the rectifier circuit is performing as expected, with minimal deviation from the predicted theoretical results.

As the current increases (from 15 A to 100 A), Io (current) continues to decrease, while the error in DC and RMS voltage remains minimal. The Error Vo (dc) (%) ranges from 0.4% to 3.5%, and the Error Vo (rms) (%) ranges from 0.1% to 1.0%. These small error percentages, particularly in RMS voltage, demonstrate that the rectifier system is able to maintain voltage stability even under varying load conditions. The minimal error increases in DC voltage, but they remain well within an acceptable range, indicating that the system is robust and resilient to changes in current and load.

In summary, the practical measurements align very closely with the theoretical values, showing a high level of accuracy and indicating that the system is operating reliably with minimal measurement discrepancies. The consistency and accuracy of the data confirm the effectiveness of the rectifier system in converting AC to DC, with minimal loss or distortion. This level of performance is crucial for applications that require stable and consistent power output, and it suggests that the system is suitable for a variety of industrial and commercial applications where precise power conversion is critical.

IV.CONCLUSION

After the research, the following conclusions can be drawn:

- Impact of Thyristors on AC to DC Conversion: The presence of thyristor components in AC circuits plays a crucial role in the rectification process, effectively converting AC waveforms into controlled DC output.
- Efficient DC Conversion with Thyristors: AC power sources can be efficiently converted into controlled DC by incorporating thyristors, allowing for precise regulation of the output voltage and current.
- Reliability of Measurement: The experimental results show minimal error between theoretical and practical values, confirming the high accuracy and reliability of thyristor-based circuits in rectification processes.

V.REFERENCE

[1] Satrianata, Lugas Jagad, et al. "EXAMINING OPTIMAL CONTROL THROUGH THE APPLICATION OF (LQR) AND (LQT) APPROACHES IN THE CONTEXT OF DC MOTORS." Jurnal Teknologi Maritim 6.1 (2023): 17-22.

[2] Nugraha, Anggara Trisna, and Rachma Prilian Eviningsih. Konsep Dasar Elektronika Daya. Deepublish, 2022.

[3] Khan, M. A., Zahid, H., Anwar, M. F., Mehmood, S., Zulqarnain, M., & Naveed, M. STABILITY AND CONTROL ASPECTS OF MICRO-GRID ARCHITECTURES OF WIND POWER SYSTEM.

[4] Nugraha, Anggara Trisna, and Ahmad Sayid Fathin. "IMPLEMENTASI BIDIRECTIONAL DC-DC CONVERTER BERBASIS TOPOLOGI CASCADED PADA PEMBANGKIT LISTRIK TENAGA

ANGIN DENGAN METODE PID." MEDIA ELEKTRIKA 17.1 (2024): 22-29.

[5] Rahman, Farhan Wahyu Nur, et al. "Application of Ant Colony Optimization Algorithm in Determining PID Parameters in AC Motor Control." Brilliance: Research of Artificial Intelligence 4.2 (2024): 538-549.

[6] Dermawan, Deny, et al. "Pengontrol Kecepatan Respon Motor dengan Pid dan Lqr." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[7] Alzahrani, A. (2023). Experimental Investigation of Controlled and Uncontrolled Rectifiers for Low-Power Wind Turbines. Applied Sciences, 13(7), 4120.

[8] Mude, K. N. (2024). Single-Phase Controlled Rectifiers. In Power Electronics Handbook (pp. 201-225). Butterworth-Heinemann.

[9] Nugraha, Anggara Trisna. "DESAIN SISTEM PROPULSI HYBRID PADA FAST PATROL BOAT 28 METER." Proceedings Conference on Marine Engineering and its Application. Vol. 6. No. 1. 2023.

[10] Kopchak, B., & Kushnir, A. (2022, February). Analysis of transition processes of single-phase collector motor with inverter supply model. In 2022 IEEE 16th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET) (pp. 325-330). IEEE.

[11] Dermawan, Deny, et al. "Penyearah Setengah Gelombang 3 Fasa Tak Terkendali dari Generator AC 3 Fasa." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[12] Eldali, F. (2024). Power Electronics for Distributed Energy. In *Power Electronics Handbook* (pp. 977-992). Butterworth-Heinemann.

[13] Dermawan, Deny, et al. "Kendali Kecepatan Motor Dengan Kontrol Pid Menggunakan Metode Metaheuristik." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[14] Wibowo, Muhammad Ferdiansyah, and Anggara Trisna Nugraha. "PERENCANAAN SISTEM PROPULSI ELEKTRIK PADA FAST PATROL BOAT 28 METER." Proceedings Conference on Marine Engineering and its Application. Vol. 6. No. 1. 2023.

[15] Agna, Diego Ilham Yoga, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Penyearah Gelombang Penuh 3 Fasa Tak Terkendali dari Generator Kapal AC 3 Fasa." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[16] Apriani, Mirna, et al. "Coastal Community Empowerment Recovery of cockle shell waste into eco-friendly artificial reefs in Mutiara Beach Trenggalek Indonesia." Frontiers in Community Service and Empowerment 1.4 (2022).

[17] Prastyawan, Rikat Eka, and Anggara Trisna Nugraha. "PENERAPAN TEKNOLOGI INFORMASI UNTUK PEMBELAJARAN TEST OF ENGLISH FOR INTERNATIONAL COMMUNICATION PREPARATION." Jurnal Cakrawala Maritim 5.1 (2022): 4-8.

[18] Aljafari, B., Indragandhi, V., Kumar, A., & Selvamathi, R. (2023, December). Analysis of Welding Power Source Using a Double Star Rectifier with Interface Transformer. In *2023 Innovations in Power and Advanced Computing Technologies (i-PACT)* (pp. 1-8). IEEE.

[19] Nugraha, Anggara Trisna, et al. "Anticipation of Deep Discharge of Batteries in Solar Panels Based on the Particle Swarm Optimization (PSO) Algorithm." SAGA: Journal of Technology and Information System 2.2 (2024): 212-227.

[20] Mu'in, Misbakhul, et al. "ANALISIS ALIRAN DAYA DAN CAPASITOR PLACEMENT PADA SISTEM KELISTRIKAN PT BLAMBANGAN BAHARI SHIPYARD DENGAN SOFTWARE ETAP." Jurnal 7 Samudra 8.1 (2023).

[21] Ainudin, Fortunaviaza Habib, Muhammad Bilhaq Ashlah, and Anggara Trisna Nugraha. "Pengontrol Kecepatan Respon Motor dengan Pid dan Lqr." Seminar MASTER PPNS. Vol. 7. No. 1. 2022.