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

Uncontrolled Single-Phase Half-Wave Rectifier with a DC Motor

Dwi Rizky Anto
Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya
dwirizkyanto@student.ppns.ac.id

Abstract

Uncontrolled Rectifiers are circuits that convert alternating current (AC) voltage sources into direct current (DC) voltage sources. These rectifiers operate without external control or adjustment. Typically, they utilize a single diode, and when only one diode is used, a half-wave rectification is produced. In a single-phase uncontrolled rectifier circuit connected to a DC motor load, the output voltage and current amplitude depend significantly on the motor's applied torque. The higher the motor's torque, the higher the speed achieved; similarly, the higher the applied voltage, the greater the current and speed of the motor. In the context of engineering applications, understanding the dynamics of uncontrolled single-phase half-wave rectifiers is essential for optimizing motor control systems, particularly where cost-effective solutions are required. While such rectifiers are simple in design, their efficiency and impact on motor performance, such as speed regulation and energy consumption, require thorough investigation. Furthermore, exploring the relationship between the torque applied to the motor and the resulting electrical parameters can provide valuable insights for applications in low-power motors, renewable energy systems, or devices where simplicity and efficiency are prioritized over advanced control mechanisms.

Keywords: rectifier, diode, PSIM, DC motor

1. Introduction

The rapid development of industrial technology is increasingly seen as a solution to the growing demands of human society, particularly in the fields of electrical power and beyond (Nugraha & Eviningsih, 2022). As industries progress, there is a constant need for technology that operates automatically within existing systems, which includes devices such as rectifiers that convert alternating current (AC) to direct current (DC) (Agna et al., 2022). These devices are critical in various industrial applications such as uninterruptible power supplies (UPS), constant voltage regulators, motor speed controllers, and power factor correction systems. Understanding the underlying principles and optimizations of these systems is essential for advancing the performance and efficiency of industrial processes (Yuniza et al., 2022).

In particular, uncontrolled rectifier circuits play a significant role in this context. These circuits are considered "uncontrolled" because they rely on diodes semiconductor devices that allow current to flow in only one direction without requiring external control mechanisms (As'ad et al., 2022). Along with diodes, transformers are used to step up the voltage, while capacitors act as filters to smooth out the output DC voltage. The half-wave rectifier, a type of uncontrolled rectifier, uses a single diode in the circuit, making it simpler but also less efficient compared to controlled rectifiers. The characteristics of such a circuit make it an ideal candidate for applications where simplicity and low cost are more important than high performance and precision.

A key component often used to demonstrate the effectiveness of this system is the DC motor, which serves as an indicator of the rectification process (Bintari et al., 2022). The DC motor's behavior, such as its speed and torque, is directly influenced by the output characteristics of the rectifier. When a DC motor is connected to a single-phase half-wave rectifier, the amplitude of the voltage and current depends on factors such as the applied torque (Jamil et al., 2021). Increased motor torque leads to higher speeds, and consequently, greater voltage and current are required to drive the motor at higher speeds. This relationship underscores the importance of understanding the dynamic interaction between the rectifier and motor in real-world applications.

To better understand and optimize this process, simulations are often performed using software such as PSIM (Power Simulation), which allows for the detailed analysis and visualization of the rectifier's performance (Nugraha & Eviningsih, 2023). These simulations enable engineers to monitor the voltage and current waveforms, calculate key electrical parameters, and explore how the system operates under different conditions.

DOI xxxxxx

By using PSIM, researchers and engineers can gain valuable insights into the behavior of the uncontrolled single-phase half-wave rectifier and assess its potential for use in various industrial systems (Kandpal et al., 2022). Moreover, these simulations provide a platform for refining circuit designs and improving system efficiency, thereby contributing to advancements in the field of power electronics..

2. Material and methods

2.1. One phase half wave rectifier circuit

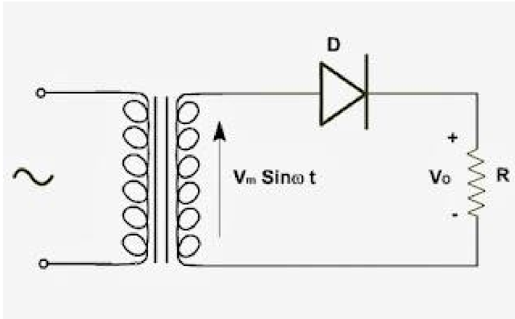

Figure 1. One phase half wave rectifier

A half-wave rectifier is a circuit used to rectify electric current and consists of diodes (Nugraha & Ravi, 2023). The half-wave rectifier circuit receives a voltage from the secondary transformer in the form of a sinusoidal voltage. vi = Vm Sin weight. Figure 1 is a photo of a single-phase single-phase rectifier circuit with a resistive load. If the input voltage is positive by half a turn, the diodes will conduct and produce an output voltage across the load, and if the input voltage is negative, the diodes will be inactive and the output voltage will be zero.

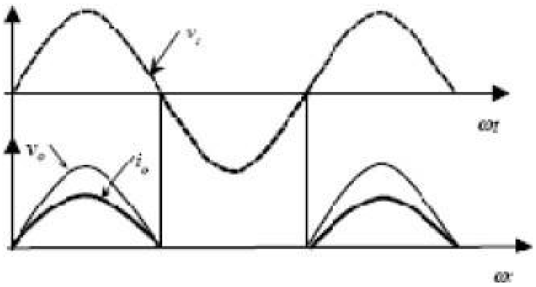

Figure 2. One phase half waveform

2.2. DC Motor

DC motors require a one-way power supply (Yildirim, 2021). This is converted into mechanical energy by the field coil. DC motors have two coils. The field coil is used to generate a magnetic field and the armature coil is used to generate electromotive force (EMF) (He & Guo, 2020). Armature When the coil current interacts with the magnetic field, a torque (T) is generated as the motor rotates. These motors are commonly used in industries as compressor drives, pumps, drives, etc..

2.3. Diode

Diodes are active components that have two poles and are semiconductors that can only conduct electric current and voltage in one direction only and inhibit current in the opposite direction (Ishihara & Abe, 2020) (Nugraha & Arifuddin, n.d.). Diodes are made from germanium and silicon. However, some types of diodes also have functions that are not intended for rectification use.

2.4. Transformer

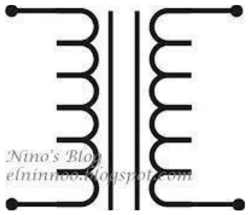

Figure 3. Transformer symbol

A transformer is a static electromagnetic electrical device that helps transfer/convert electrical energy from one circuit to another at the same frequency and specific conversion ratio (Hao et al., 2023). Transformers distribute energy using Faraday's law of induction and Lorenz's law theory. When the primary coil is connected with an AC voltage source, current flows through the primary coil and the magnetic flux of the iron core changes (Asiri & Shwehdi, 2007).

2.5. PSIM

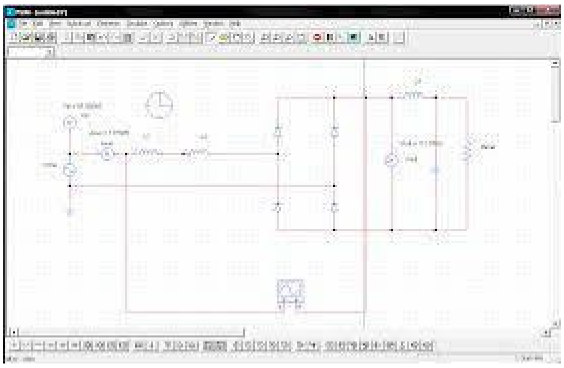

Figure 4. PSIM Interface

PSIM is one of the software products created by the Powersim company for simulation purposes in the field of power electronics, similar to several other similar products that have become industry standards (Mude, 2024). However, the full version of PSIM is not free, if you want to use its full features, users legally have to pay. The simulation results from PSIM are good enough to be used as a comparison or learning material.

2.6. Capacitor

Figure 5. Capacitor

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals (Lin & Yang, 2004). The effect of a capacitor is known as capacitance. While some capacitance exists between two electrical conductors near a circuit, a capacitor is a component designed to add capacitance to a circuit. Capacitors were originally known as condensers or condensers (Xu, 2023).

2.7. Oscilloscope

DOI xxxxxx

Figure 6. Oscilloscope

The oscilloscope is the fault of one electronic measuring instrument that functions to project into the form of electrical frequencies so that they can be reviewed & studied (Nugraha et al., 2021). In the oscilloscope there is still a cathode ray tube, then the electron emitting device will project the electron beam onto the cathode ray tube screen. The electron beam will make an impression on the screen. The circuit on the oscilloscope will create a dotted beam repeatedly based on left to right (Koga et al., 2023). This iteration process results in a continuous frequency shape as a result can be studied. An oscilloscope can be used to record the voltage frequency during a certain period of time. The sense capture will record frequencies up to 16 independent sense frequencies for digital frequencies. A simplified set of input & output logic components can facilitate the understanding of digital circuits.

2.8. Methods

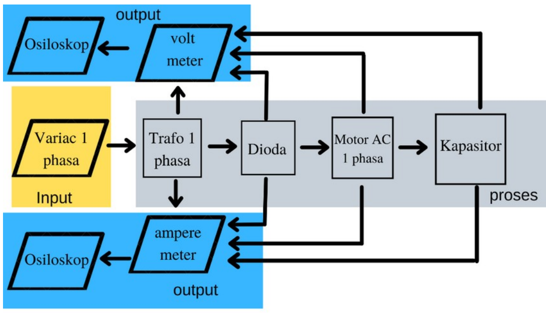

Figure 7. Block diagram

In this PSIM experiment, the first step is to prepare the necessary equipment and components. Next, the circuit is built, and the variac is adjusted to achieve the desired input RMS voltage of 30V, 45V, and 60V. After the setup, measurements are taken for the input RMS voltage, input RMS current, DC output voltage, DC output current, output RMS voltage, and output RMS current under no-load conditions using a DC motor as the load.

Next, the input and output voltage waveforms are observed using an oscilloscope to examine the characteristics of both signals. This process is then repeated with the circuit under load (DC motor) to observe any changes in the waveforms of both the input and output voltages.

Subsequently, the output voltage waveform and ripple voltage are analyzed, and the value of ΔVo is calculated to assess the fluctuations in the output voltage. The obtained measurement results are compared with several data sets to check for consistency and accuracy in the experiment.

The percentage difference between the measured results and theoretical values is also calculated to analyze any experimental errors. Finally, the characteristic parameters of the circuit are determined, and an analysis is conducted to draw conclusions about the performance of the tested circuit.

DOI xxxxxx

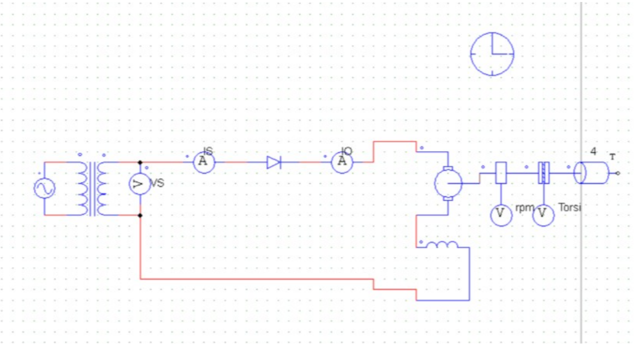

Figure 8. PSIM Simulation Circuit

3. Results and discussion

3.1. Result

- Torque 4

Table 1. Parameter Simulation Result with torque 4

Vs	Is (rms)	Is (dc)	Vo (rms)	Vo (dc)	Io (rms)	Io (dc)	RPM
30	0,27	0,17	20,7	13,1	0,27	0,17	2,7
45	0,4	0,2	31,4	19,8	0,4	0,26	2,65
60	0,55	0,35	42	26,5	0,55	0,35	2,6

- Torque 7

Table 2. Parameter Simulation Result with torque 7

Vs	Is (rms)	Is (dc)	Vo (rms)	Vo (dc)	Io (rms)	Io (dc)	RPM
30	0,27	0,17	20,8	13,1	0,27	0,17	9,6
45	0,4	0,2	31,4	19,8	0,4	0,26	2,65
60	0,55	0,35	42	26,5	0,55	0,35	9,4

- Torque 9

Table 3. Parameter Simulation Result with torque 9

Vs	Is (rms)	Is (dc)	Vo (rms)	Vo (dc)	Io (rms)	Io (dc)	RPM
30	0,27	0,17	20,7	13,1	0,17	0,17	12,3
45	0,4	0,2	31,4	19,8	0,4	0,26	12,26
60	0,55	0,35	42	26,5	0,55	0,35	12,1

3.2. Simulation Waveform

DOI xxxxxx

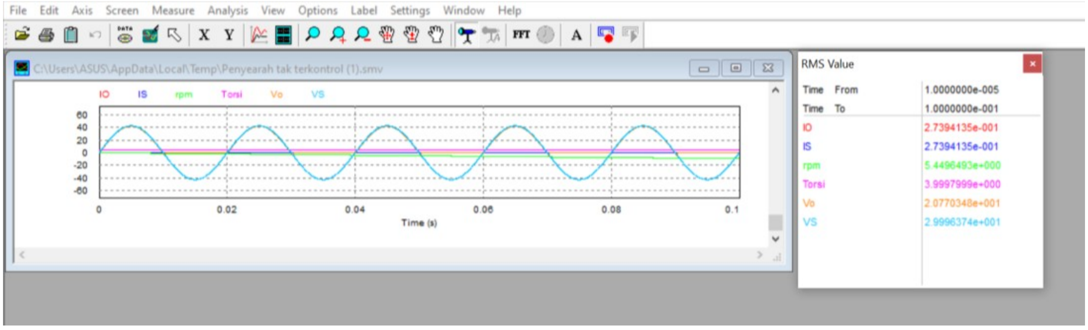

Figure 9. waveform 30V source

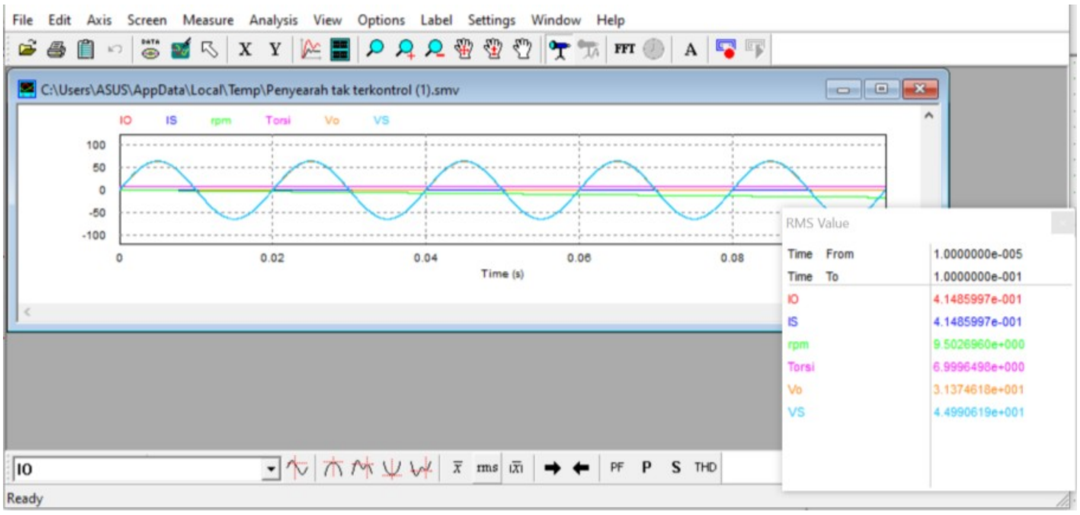

Figure 10. waveform 45V source

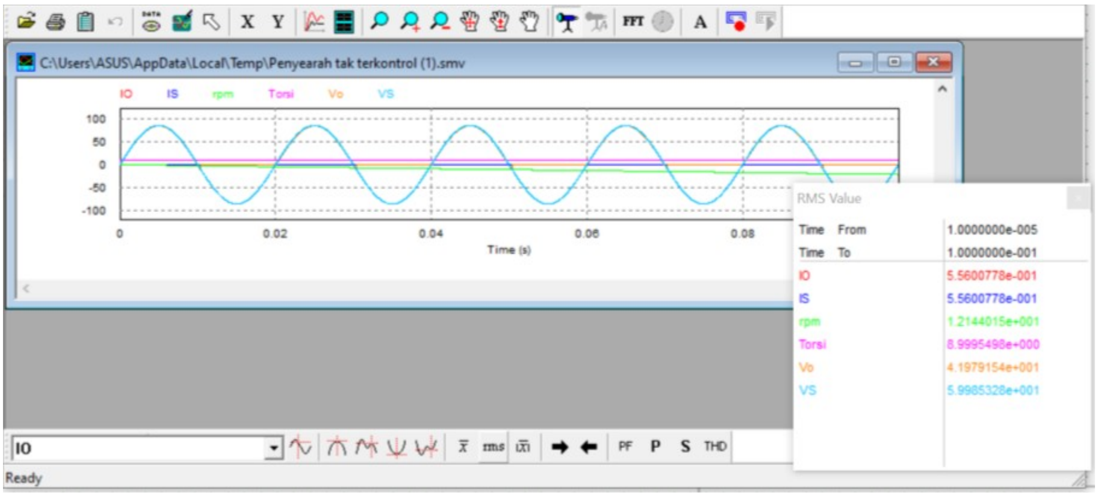

Figure 11. waveform 60V source

4. Conclusion

Based on the results of the PowerSIM simulation practicum, the following conclusions can be drawn:

Diodes act as rectifiers of AC to DC (direct current) waves. The rectifier wave generated in the circuit with load R is a positive sine wave with no valley. The wave characteristics are similar to those of a single-phase hall rectifier because the differences in this circuit cause the amplitude value to never touch the zero point. Angular difference of each phase. The Io (rms) value measured and recorded in the table is the sum of the difference between the current and the measured value due to the high peak at the time of measurement, and the RMS value is significantly different. The higher the torque value of the DC motor, the more directly proportional to the speed generated by the DC motor.

DOI xxxxxx

Credit authorship contribution statement
Author Name: Conceptualization, Writing – review & editing. **Author Name**: Supervision, Writing – review & editing. **Author Name**: Conceptualization, Supervision, Writing – review & editing.

References

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

Agna, Diego Ilham Yoga, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Single-Phase Controlled Half Wave Rectifier with Single-Phase Generator Circuit Model to Establish Stable DC Voltage Converter Result." International Journal of Advanced Electrical and Computer Engineering 3.3 (2022).

Yuniza, Salsabila Ika, Diego Ilham Yoga Agna, and Anggara Trisna Nugraha. "The Design of Effective Single-Phase Bridge Full Control Resistive Load Rectifying Circuit Based on MATLAB and PSIM." International Journal of Advanced Electrical and Computer Engineering 3.3 (2022).

As'ad, Reza Fardiyan, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Effect of 3 Phase Full Wave Uncontrolled Rectifier on 3 Phase AC Motor." International Journal of Advanced Electrical and Computer Engineering 3.2 (2022).

Bintari, Ayu, Urip Mudjiono, and Anggara Trisna Nugraha. "Analisa Pentahanan Netral dengan Tahan Menggunakan Sistem TN-C." Elektriese: Jurnal Sains dan Teknologi Elektro 12.02 (2022): 92-108.

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.

Nugraha, Anggara Trisna, and Rachma Prilian Eviningsih. Penerapan Sistem Elektronika Daya: AC Regulator, DC Chopper, dan Inverter. Deepublish, 2022..2023.110715.

Kandpal, S., Ghosh, T., Rani, C., Tanwar, M., Sharma, M., Rani, S., ... & Kumar, R. (2022). Bifunctional application of viologen-MoS2-CNT/polythiophene device as electrochromic diode and half-wave rectifier. ACS Materials Au, 2(3), 293-300.

Nugraha, Anggara Trisna, and Alwy Muhammad Ravi. "Experimental Study of the Effect of Excitation Current on the Output Voltage of a Self-excited Synchronous Generator." (2023).

Yildirim, M. (2021). Design of low-voltage and low-power current-mode DTMOS transistor based full-wave/half-wave rectifier. Analog Integrated Circuits and Signal Processing, 106(2), 459-465.

He, L., & Guo, D. (2020). An active switched-capacitor half-wave receiver with high efficiency and reduced components in WPT system. *IEEE Transactions on Industrial Electronics*, *68*(12), 12119-12129.

Ishihara, R., & Abe, T. (2020, November). A Study on the Efficiency Improvement for Half-Wave Rectified Variable Field Flux Motor with Different Turns Ratio. In *2020 23rd International Conference on Electrical Machines and Systems (ICEMS)* (pp. 2005-2009). IEEE.

Nugrahaa, Anggara Trisna, and Rahman Arifuddin. "O2 Gas Generating Prototype In Public Transportation.

Hao, D., Kong, L., Zhang, Z., Kong, W., Tairab, A. M., Luo, X., ... & Yang, Y. (2023). An electromagnetic energy harvester with a half-wave rectification mechanism for military personnel. *Sustainable Energy Technologies and Assessments*, *57*, 103184.

Asiri, Y., & Shwehdi, M. (2007, April). Performance of single phase full wave rectifier controlled by PWM. In *2007 Canadian Conference on Electrical and Computer Engineering* (pp. 1155-1158). IEEE.

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

Lin, B. R., & Yang, T. Y. (2004). Single-phase half-bridge rectifier with power factor correction. *IEE Proceedings-Electric Power Applications*, *151*(4), 443-450.

Xu, R. (2023). Simulation Of Single-Phase Half-Wave Rectifier Circuit Based on Wind Energy Storage Circuit. *Highlights in Science, Engineering and Technology*, *71*, 112-120.

Nugraha, Anggara Trisna, et al. "Penyearah Setengah Gelombang Tiga Phasa Tak Terkontrol Menggunakan Motor Induksi Tiga Phasa." Elektriese: Jurnal Sains dan Teknologi Elektro 11.02 (2021): 78-88.

Koga, T., Abe, T., Otomo, Y., Yamamoto, M., & Rosu, M. (2023). Reduced order modeling of half-wave rectified brushless synchronous motor for model-based design. *IEEJ Journal of Industry Applications*, *12*(4), 826-834.