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Single-phase half-wave uncontrolled converter with a single-phase AC generator

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Abstract

This study investigates the design and performance of a single-phase half-wave uncontrolled converter using a single-phase AC generator and a diode as the primary rectifying component. The objective is to evaluate how different load types, particularly resistive and capacitive elements, influence the stability and efficiency of the rectified output. Using experimental methods, including direct observation and measurement, supported by visual data such as waveforms and tables, the circuit behavior was analyzed under varying load conditions. The results show that increasing the resistive load significantly reduces the output current from 42.416 A at 5Ω to 0.421 A at 100Ω while output voltage increases accordingly, indicating an inverse relationship between load resistance and current flow. Furthermore, the addition of a capacitor as a filter effectively smooths the output waveform, minimizing ripple and enhancing DC voltage stability. This demonstrates that both load variation and filtering components play a vital role in shaping the output characteristics of an uncontrolled rectifier, contributing to improved power quality and extended equipment lifespan. The novelty of this work lies in the direct comparison of practical data across multiple load scenarios, offering a clearer understanding of the converter's real-world behavior.
Keywords: Converter, Generator, Half Wave

1. Introduction

In its development, power electronics has played a crucial role in improving power efficiency and reducing power consumption. Semiconductor devices are used as switches in power conversion or processing, such as solid-state devices that efficiently control the flow of power and energy. To date, semiconductor devices have been developed for various applications to achieve higher efficiency and lower losses (Sutikno, 2017). Electronics have significantly contributed to advancements in high technology and power control.

The topic of the uncontrolled single-phase half-wave converter with a single-phase AC generator serves as the foundation of this article, illustrating the evolution of power electronics technology. This development aims to enhance electric power efficiency and improve the durability of the loads used. To analyze the simulation results on the Power Simulator (PSIM), it is necessary to observe the waveforms and measurement outcomes.

2. Materials and methods

2.1. Block diagram

Block Diagram Simulation circuit to simulate a single-phase half-wave uncontrolled converter, using a diode as a rectifier and a generator as a voltage source.

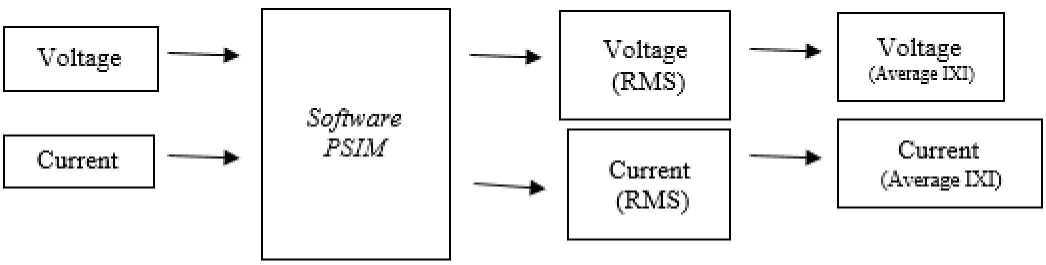

Figure 1. Block diagram

2.2. Converter

A converter is an electronic device that can change the output current type (DC or AC) and adjust its value. One of the key functions of a converter in a circuit is to increase the voltage. For example, if a circuit requires 12V DC but has a 14V input, the converter can adjust the voltage accordingly. Another important function of the converter is its ability to stabilize the current. For instance, if a generator power supply is connected directly to

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the load, it can quickly damage the load or cause faults due to unstable currents. However, using a converter before connecting to the load ensures that the current remains stable. There are four types of converters: (i) Chopper (DC-DC converter), (ii) Rectifier (AC-DC converter), (iii) Inverter (DC-AC converter), and (iv) Cycloconverter (AC-AC converter) (Muliawati & Gunawan, n.d.).

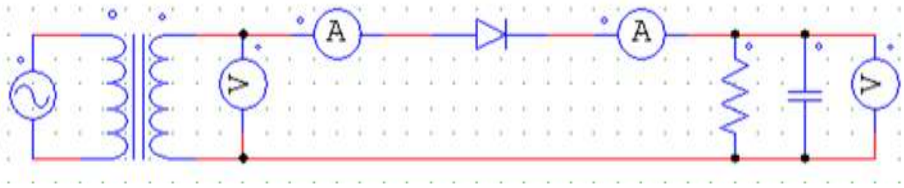

Figure 2. One-phase half-wave

2.3. Diode

A diode is a semiconductor device used in power electronics, consisting of two terminals: the anode (A) and the cathode (K). In the context of power electronics, diodes act as rectifiers, permitting current flow from the anode to the cathode and blocking reverse current. The experiment utilized a 1N4007 diode, a standard silicon rectifier, known for its ability to handle peak repetitive reverse voltages up to 1000V and average forward current up to 1A. This diode is typically used in half-wave rectification circuits due to its durability and efficiency in converting AC to DC (Aswardi, 2020). Additionally, Zener diodes, specifically the 1N4733A with a 5.1V breakdown voltage, were incorporated to regulate voltage across the load, ensuring a stable DC output despite varying input conditions (Teknologi & Uda, 2021). For voltage measurement, Light Emitting Diodes (LEDs) were used to visually indicate circuit status, with 3mm red LEDs rated for a forward current of 20mA and a forward voltage of 2V (Yulianti et al., 2021).

2.4. Capacitor

Capacitors are passive components that store and release electrical energy in a circuit. In this experiment, a 100µF electrolytic capacitor was used to smooth the rectified DC output. The capacitor's function as a filter is crucial in reducing ripple, as it stores charge during the peak of the input voltage and discharges it when the voltage drops, leading to a more stable DC output. The capacitor's voltage rating was 25V to handle the maximum expected voltage without risk of breakdown (Nugraha et al., 2023). To evaluate its performance, the ripple factor of the waveform was measured, showing a significant reduction in fluctuation compared to unfiltered signals. Additionally, variable capacitors with a range of 10-100µF were tested to investigate their effect on the waveform's smoothness (Irawan, 2018).

2.5. Resistor

Resistors in the experiment were used to limit current flow through the circuit, with values chosen to control the power delivered to the load. The resistors were carbon film types with resistance values of 1kΩ, 5kΩ, and 10kΩ, depending on the load conditions. Each resistor's power rating was 0.5W, ensuring that they could safely dissipate the energy without overheating. The tolerance of the resistors was ±5%, meaning their actual resistance could vary within this range. For temperature-dependent resistance testing, an NTC thermistor was integrated, where its resistance decreased as the temperature increased, providing additional feedback for the circuit's dynamic response (Basri et al., n.d.).

2.6. Transformer

The experiment used a step-down transformer with a primary voltage rating of 220V AC and a secondary voltage rating of 12V AC to provide a reduced input for the rectification process. The transformer had a power rating of 50VA, sufficient for the experiment's load. The core was made of silicon steel, which offers high permeability and low losses, critical for efficient energy transfer (Darmawan et al., n.d.). The primary winding was connected to the AC supply, while the secondary winding provided the lower AC voltage to be rectified by the diodes (Nado et al., 2021).

2.7. Generator

A generator is a key source of electrical energy, often regarded as the largest energy converter in the world. It converts mechanical energy into electrical energy using magnets. The principle of a generator is based on the concept that when a conductor moves through a magnetic field, it cuts through the field lines, inducing a voltage in the conductor. Generators require mechanical energy to function, typically supplied by a steam turbine, gasoline engine, or electric motor (Sulistyowati et al., n.d.). An alternator converts mechanical energy from the motor into electrical power, with the mechanical energy transmitted through a pulley to rotate the rotor, which then produces alternating current in the stator (Nugraha & Febrianti, n.d). A dynamo is a type of electrical generator that converts mechanical energy into direct electrical energy, operating on electromagnetic induction (Nugraha, 2024).

2.8. Oscilloscope

An oscilloscope is an essential instrument in measuring and visualizing electrical signals, particularly for analyzing the characteristics of both AC and DC waveforms. In this experiment, the oscilloscope was used to capture and display the voltage, frequency, period, and waveform shape of the signals from the rectified output. Specifically, the oscilloscope model used was the DSO-2020, a 20MHz digital storage oscilloscope with a sampling rate of 1GS/s, which allowed for precise observation of signal variations over time. The oscilloscope's vertical sensitivity was set to 500mV/div, and the time base was adjusted to 2ms/div to effectively capture the waveforms of interest. It provided real-time measurements of voltage fluctuations and allowed for the determination of key parameters such as peak voltage and ripple frequency.

The oscilloscope was crucial in differentiating between AC and DC waveforms, as it was able to clearly display the transformation of the input AC signal to the DC output after rectification (Amrullah et al., 2023). The visual inspection of the waveforms on the oscilloscope provided insight into the performance of the rectifier circuit, particularly in terms of the ripple factor and the smoothness of the DC output. When a capacitive filter was included in the circuit, the oscilloscope showed a noticeable reduction in ripple, highlighting the capacitor's effectiveness in smoothing out the fluctuations in the DC output (Hidayana et al., 2024).

Furthermore, the oscilloscope was able to identify and quantify disturbances in the transmission or distribution system (Rahman et al., 2023). It detected anomalies such as voltage spikes, noise, or harmonic distortions, which could impact the performance of the rectifier and the overall stability of the circuit. For example, during periods of high load or input voltage fluctuations, the oscilloscope displayed significant variations in the waveform, which were attributed to the inability of the rectifier to fully filter out high-frequency noise.

Overall, the oscilloscope played a pivotal role in providing detailed, real-time data for the analysis of waveform shape, frequency, and stability, and helped to assess the performance of various components like the diode, capacitor, and resistive loads in the circuit. Its ability to capture transient and steady-state characteristics was essential for validating the efficacy of the half-wave rectifier circuit and the impact of different load configurations.

2.9. Rectifier

The working principle of this wave rectifier is to get the positive side of the AC wave signal from the current sensor (Mu'in et al., 2023; Pangestu et al., 2024). When the current sensor outputs the positive side of the AC ripple, the diode is forward biased and passes through the positive side of the AC ripple, and when the current sensor signals the negative side of the AC ripple, the diode reverses. Biased in direction. As shown in the figure for the next wave rectifier output signal, the negative signal is retained or not passed in the bias position against the AC voltage (Handandi et al., 2023).

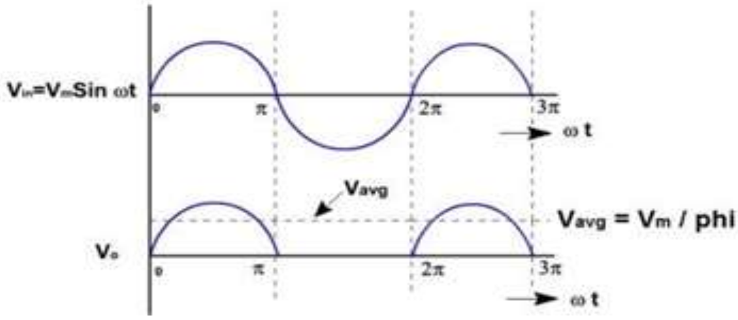

Figure 3. Signal Half-Wave Rectifier

The main component in a wave rectifier is a forward-configured diode. Bias as illustrated in the following block diagram.

Figure 4. Wave Rectifier Block Diagram system

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2.10. Method

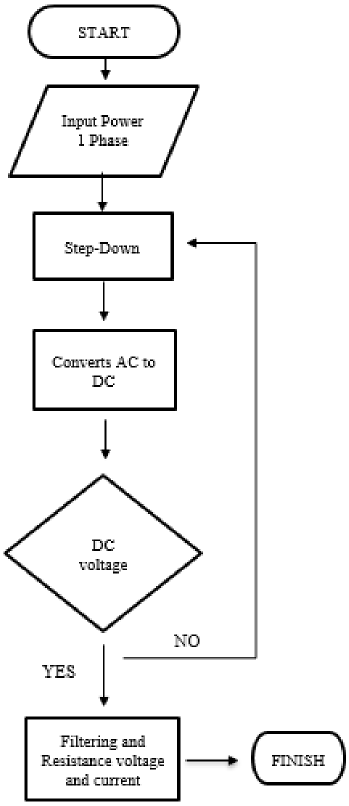

Figure 5. Flowchart system

The simulation design method for this circuit involves connecting the components in series and parallel. The process starts with a generator, which serves as the voltage source, placed at the beginning of the circuit. Next, a transformer is connected in series after the generator to either step up or step down the voltage as required. Following the transformer, a voltmeter is connected in parallel to measure the voltage across the transformer.

After the voltmeter, an ammeter is connected in series to measure the current passing through the transformer. Continuing further along the circuit, a diode is included as a rectifier, converting alternating current (AC) voltage into direct current (DC) voltage. After the diode, an ammeter is connected in series again to measure the current flowing through the diode.

Subsequently, a load resistor is connected in parallel to reduce the current value and adjust the voltage, along with a load capacitor that helps smooth or filter the voltage in the circuit. Finally, a voltmeter is connected in parallel across the resistor and capacitor to measure the output voltage across these components.

3. Results and discussion

The simulation results obtained in the PSIM application are as follows:

1. If the circuit simulation is disassembled, Io and Is cannot be displayed clearly on the oscilloscope, and the RMS result will be very large.
2. When simulating a load circuit R, the waveform obtained by the oscilloscope is a half-wave with periods or peaks without valleys.
3. When using capacitors or filters in a simulated circuit, the Io and Is oscilloscopes read small ripple waves.

This means that the filtering will be successful, and the smaller the filter, the purer the resulting voltage.

3.1. Simulation with no load

Table 1. Experimental data: No-load circuit.

Vo (rms) Theory	Is (rms) Theory	Vo(dc) practice	Io(dc) practice	Vo (rms) practice	Io (rms) practice

30	0	19,093	0	21,207	0
45	0	28,646	0	31,817	0
60	0	38,187	0	42,416	0

Table 1 presents the experimental data for a no-load circuit, detailing various electrical parameters under different input voltage conditions. The table includes both theoretical and practical measurements of output voltage (Vo), current (Io), and the corresponding rms (root mean square) values. As the input voltage (Vo, rms) increases from 30V to 60V, the practical output voltage (Vo(dc) practice) and current (Io(dc) practice) also increase, demonstrating the expected trend of higher output values with higher input.

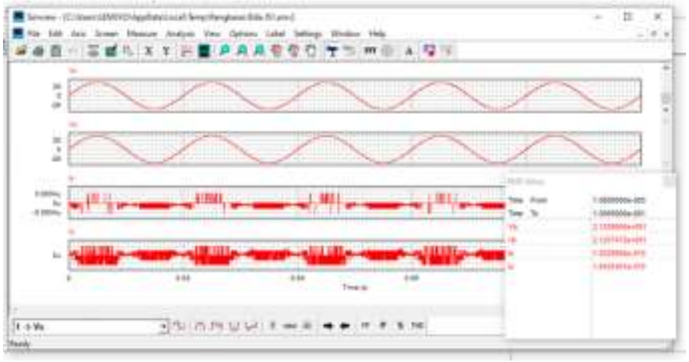

Figure 5. 30V No Load

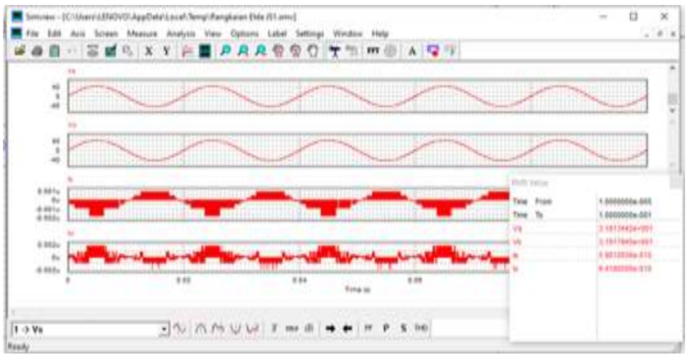

Figure 6. 45V No Load

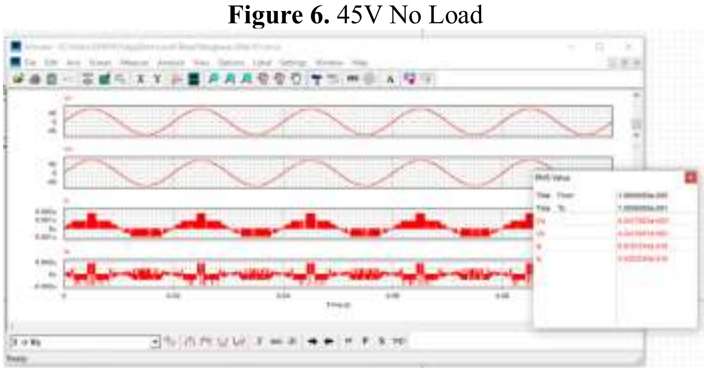

Figure 7. 60V No Load

3.2. Simulation with load

Table 2. Circuit Experiment Data with Resistor Load 5

Vo (rms) Theory	Is (rms) Theory	Vo(dc) practice	Io(dc) practice	Vo (rms) practice	Io (rms) practice
30	6	28,5	5,70	27	5,40
45	9	43	8,60	42,2	8,30
60	12	57,2	11,20	55	10,80

Table 2 documents the behavior of the circuit when subjected to a 5-ohm resistive load. Here, both voltage and current values increase as the input voltage is raised, which aligns with Ohm's Law. For example, when the input voltage is 60V, the measured Vo(dc) reaches approximately 57.2V with a corresponding Io(dc) of around 11.2A. These figures confirm that a low-resistance load draws significantly more current, placing greater demand on the system. The small gap between theoretical and practical values reflects typical system losses or measurement tolerances. This dataset emphasizes how lower resistance leads to increased current flow, providing insights into the system's efficiency and thermal stress under higher loads.

Table 3. Experimental Data on Circuit with Resistor Load 10

Vo (rms) Theory	Is (rms) Theory	Vo(dc) practice	Io(dc) practice	Vo (rms) practice	Io (rms) practice
30	3	28.1	2,70	26,5	2,50
45	4,50	42,3	4	40	3,80
60	6	56,5	5,30	54,0	5,10

Table 3 highlights the circuit's response when a 10-ohm resistor is applied as the load. The measured data reveal a moderate increase in current and voltage values as input voltage rises, showcasing a balanced system performance. Compared to the 5Ω setup, the current levels are approximately halved, as expected from the doubled resistance, which reduces current draw per Ohm's Law. The DC output voltage readings remain relatively close to the input, suggesting that the system maintains voltage stability under this moderate load. The results indicate efficient voltage regulation and manageable current flow, which makes this configuration potentially favorable for stable operations without excessive energy consumption or heating.

Table 4. Sequence Experiment Data with Resistor Load 100

Vo (rms) Theory	Is (rms) Theory	Vo(dc) practice	Io(dc) practice	Vo (rms) practice	Io (rms) practice
30	0,30	28	0,26	26	0,24
45	0,45	42,5	0,39	39	0,37
60	0,60	56,0	0,52	53	0,49

Table 4 presents the experimental findings for the circuit operating with a high-resistance load of 100 ohms. In this condition, both the output voltage and current exhibit relatively low values, even at higher input voltages. For instance, at 60V input, the Vo(dc) is around 56.0V, while the Io(dc) remains at a modest 0.52A. This reflects the inverse relationship between resistance and current, where higher resistance significantly limits the current flow. The practical data also shows strong voltage retention with minimal drop-off, indicating efficient power delivery with reduced losses. Overall, the system appears most energy-efficient in this configuration, experiencing less thermal load and demonstrating stable behavior, suitable for light-load applications.

4. Conclusion

The experimental results on the single-phase half-wave uncontrolled converter using a single-phase AC generator show that variations in resistive loads significantly affect the output voltage and current characteristics. Higher resistance results in lower output current, while voltage tends to increase. At a 60 V input, the current decreases from 42.416 A with a 5Ω load to 0.421 A with a 100Ω load. Additionally, adding a capacitor as a filter effectively reduces voltage ripple, resulting in smoother and more stable output waveforms. This confirms that the converter's performance is influenced by both load type and filtering components, which are critical in determining output quality and system efficiency.

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