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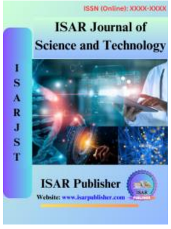

ISAR Journal of Science and Technology
Abbriviate Title- ISAR J Sci Tech
ISSN *(Online)*- 2584-2056
https://isarpublisher.com/journal/isarjst
Vol-2, Iss-8 (Aug- 2024)

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Controlled Half-Wave Rectifier Analysis to Change Alternating Current (AC) to Direct Current (DC)

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Article History
Received: 17.06.2024
Accepted: 23.07.2024
Published: 01.08.2024

Abstract: A controlled half-wave rectifier is a device used to convert alternating current (AC) into direct current (DC) with more precise control than a regular half-wave rectifier. The main component used in this device is the Silicon Controlled Rectifier (SCR) which allows for the timing of conduction during the positive cycle of AC waves.

A controlled half-wave rectifier works by allowing an electric current to flow only on the positive half of the AC wave, based on the trigger signal (gate signal) provided to the SCR. This trigger signal determines when the SCR starts conducting during the positive cycle of the AC wave, thus allowing for better control of the output voltage and current.

Keywords: Controlled Wave, AC Current, DC Current, Silicon Controlled Rectifier (SCR).

Cite this article:
Adrama, I. N. G., Pancane, I. W. D., Suriana, I. W., Asna, I. M.., (2024). Controlled Half-Wave Rectifier Analysis to Change Alternating Current (AC) to Direct Current (DC). *ISAR Journal of Science and Technology*, *2*(8), 1-4.

I. Introduction

Controlled half-wave rectifiers are one of the important devices in the conversion of electrical energy, especially in converting alternating current (AC) into direct current (DC). In many industrial and electronics applications, the need to control and regulate voltage and electrical current is vital, especially to maintain system performance and efficiency. The device uses a Silicon Controlled Rectifier (SCR) as the main component, which allows for precise control of the conduction cycle of the AC waves. In contrast to a regular half-wave rectifier that conducts fully on each positive cycle of an AC wave, a controlled half-wave rectifier allows for the timing of conduction start by providing a trigger signal to the SCR gate. This provides flexibility in adjusting the voltage and current outputs according to the needs of the application. Controlled half-wave rectifiers are widely used in a variety of applications such as DC motor speed control, battery charging, lighting control, and heating systems. Its ability to precisely control output current and voltage makes it a very useful component in modern electronic circuits.

The analysis of a controlled half-wave rectifier covers a wide range of aspects, from the working principle, the characteristics of the output voltage and current, to the efficiency, to the mathematical calculations that describe the performance of these devices. A deep understanding of these factors is essential for designing and implementing an optimal and efficient system. In this analysis, we will discuss in detail how a controlled half-wave rectifier works, the components involved, as well as the operational parameters that affect performance. As such, it is expected to provide a comprehensive overview of the uses and benefits of controlled half-wave rectifiers in a wide range of applications.

II. Literature Review

Literature review is an important part of a study because it provides a strong theoretical foundation and frame of reference based on previous studies. In the context of controlled half-wave rectifier analysis, this literature review will discuss the basic concepts, working principles, as well as the latest applications and innovations related to this technology.

2.1. Basic Concepts and Working Principles

Controlled half-wave rectifiers use Silicon Controlled Rectifier (SCR) as the main component to control the flow of electric current. According to Rashid (2004), SCR is a semiconductor device that has three terminals: an anode, a cathode, and a gate. Current conduction occurs when sufficient voltage is applied to the gate terminals, allowing for precise control of the conduction time.

2.2. Control and Efficiency

As explained by Mohan, Undeland, and Robbins (2003), the firing angle control on the SCR allows the rectifier to regulate the output voltage. The average voltage of the output can be calculated using the equation:

$$V_{dc} = \frac{Vm(1+\cos(\alpha))}{2\pi}$$

where Vm is the peak voltage of the AC and α is the starting angle. By changing the ignition angle, we can control the amount of DC voltage generated.

2.3. Applications in Industry and Electronics

Controlled half-wave rectifiers are widely used in industrial and electronics applications. According to Bimbhra (2011), these applications include DC motor speed control, battery charging, and lighting control. In DC motor control, a controlled half-wave

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rectifier allows for speed variation by regulating the voltage applied to the motor.

2.4. Latest Innovations and Developments

Recent research shows developments in the design and efficiency of controlled half-wave rectifiers. For example, Zhang et al. (2018) introduced a more advanced start-up angle modulation technique to improve energy conversion efficiency and reduce ripple at DC output. This technique uses a digital control algorithm to optimize the SCR ignition angle in real-time.

2.5. Limitations and Solutions

While controlled half-wave rectifiers have many advantages, there are some limitations such as high ripple at output voltage and lower efficiency compared to full-wave rectifiers. As a solution, the use of LC filters can help smooth out the output voltage, as explained by Hart (2011).

2.6. Case Studies and Implementation

Case studies of several practical applications show the successful use of controlled half-wave rectifiers. For example, Gupta and Singh (2015) in their study on battery charging showed that with the right setting of the starting angle, charging efficiency can be increased by up to 85%.

This literature review outlines the theoretical basis, applications, innovations, and solutions related to controlled half-wave rectifiers. With a comprehensive understanding of the existing literature, further research can be conducted to improve the efficiency and performance of these devices in various industrial and electronics applications.

III. Methodology

The controlled half-wave rectifier analysis methodology involves several stages that include circuit design, simulation, measurement, and data analysis. This systematic approach ensures that every aspect of the rectifier is evaluated in detail and accurately. Here are the steps taken in this analysis:

3.1. Circuit Design

The first stage is to design a controlled half-wave rectifier circuit to be analyzed. The main components used in this circuit include:

- **Transformer:** Adjusts the AC input voltage.
- **SCR (Silicon Controlled Rectifier):** Controls the flow of electrical current.
- **Trigger Circuit:** Provides a trigger signal to the SCR gate.
- **Load:** A device that will receive DC voltage and current.

Steps in circuit design:

1. Specifies the desired input and output voltage and current specifications.
2. Select the appropriate components based on those specifications.
3. Design circuit schematics using circuit design software (e.g., LTspice or Multisim).

3.2. Circuit Simulation

Once the circuit is designed, the next stage is a simulation to verify the performance of the circuit. The simulation was carried out using software that can model the dynamic characteristics of the SCR and other components.

Steps in the simulation:

1. Importing circuit designs into simulation software.
2. Sets simulation parameters, such as AC input voltage, SCR ignition angle, and load.
3. Run simulations to obtain output voltage and current data.
4. Analyze the simulation results to ensure that the circuit is functioning according to the desired specifications.

3.3. Experimental Measurements

After the simulation, the circuit is physically built for experimental measurements. This stage aims to validate the simulation results and understand the real behavior of the controlled half-wave rectifier.

Steps in measurement:

1. Assemble the circuit according to the simulated design.
2. Connecting measuring instruments, such as oscilloscopes, multimeters, and power supplies, to measure voltage and current at various points in a circuit.
3. Record output voltage, load current, and other parameters during circuit operation.
4. Compare the measurement results with the simulation results for validation.

IV. Data Analysis

The final stage is the analysis of data obtained from simulations and experimental measurements. This analysis aims to evaluate the performance of the circuit based on important parameters such as average output voltage, efficiency, and ripple.

Steps in data analysis:

1. Process simulation and experimental data to obtain the average output voltage, load current, and ripple factor.
2. Compare results with existing theory and literature to ensure accuracy.
3. Identify factors that affect circuit performance, such as variations in ignition angles and load characteristics.
4. Compile a report on the results of the analysis that includes graphs, tables, and data interpretation.

Using controlled half-wave rectifier analysis methodologies include circuit design, simulation, experimental measurements, and data analysis. This approach ensures a comprehensive and accurate evaluation of the rectifier's performance, so that the results can be used for practical applications in various fields of industry and electronics.

4.1. Discussion

1. Average Output Voltage (V_dc):

$$\mathrm{Vdc} = \frac{V\mathrm{m}(1+\cos(\alpha))}{2\pi}$$

Where V_m is the peak voltage of the AC and α is the angle of the SCR start-up.

2. Average Load Current (I_dc):

$$IDC = \frac{Vdc}{RL}$$

Where RL is the load resistance.

It can be used on:

Controlled half-wave rectifiers are used in a variety of applications such as:

- DC motor speed control.
- Lighting control.
- Battery charging.
- Power control system.

Advantage:

- Better control of output voltage and current.
- Simple design and low cost.

Limitations:

- Ripple high output voltage.
- Lower efficiency compared to full-wave rectifiers.

With an in-depth analysis of the working principles, key components, and operational parameters, controlled half-wave rectifiers can be used effectively in a wide range of electronics applications that require precise voltage and current control.

4.2. Results of the Discussion

In this discussion, we will calculate the average price of the output current from a controlled half-wave rectifier using SCR (Silicon Controlled Rectifier). This rectifier is used to control the speed of a DC motor that requires direct current (DC) from an alternating voltage (AC) source. We will calculate the average current received by the motor by considering the SCR ignition angle.

Specifications and Parameters

- AC input voltage (V_m): 220 V (rms)
- Load resistance (R_L): 10 ohm
- SCR ignition angle (α): 45 degrees

Calculation Steps

1. Calculating Peak Voltage (V_m):

The peak voltage of the AC voltage is:

$Vm= V_{rms} \text{ x } \sqrt{2}$

$Vm =220 \text{ x } \sqrt{2}$

$Vm =220 \text{ x } 1.414$

$Vm \approx 311 \text{ V}$

2. Calculating the Average Voltage Output (V_dc):

The average output voltage of a controlled half-wave rectifier is:

$$Vdc = \frac{Vm(1+\cos(\alpha))}{2\pi}$$

$$Vdc = \frac{311 \text{ x } (1+\cos(45^o))}{2\pi}$$

Because cos(45o) $= \frac{1}{\sqrt{2}} \approx 0.707$

$$Vdc = \frac{311 \text{ x } (1+ 0.707}{2\pi}$$

$$Vdc = \frac{530.497}{6.2832}$$

$$Vdc \approx 84.44 \text{ V}$$

3. Calculating the Average Load Current (I_dc):

The average current of the load (I_dc) can be calculated using Ohm's law:

$$IDC = \frac{Vdc}{RL}$$

$$IDC = \frac{84.44}{10}$$

$$Idc = 8.444 \text{ A}$$

With an SCR starting angle of 45 ^{o} and a load resistance of 10 ohms, the average current received by the DC motor is 8,444 amperes. This calculation shows how the ignition angle control can be used to regulate the current and voltage applied to the load, in this case the DC motor. Thus, the controlled half-wave rectifier can effectively control the speed of the motor through the setting of the average received current.

4.3. Results of the Discussion

To calculate the RMS (Root Mean Square) price of the output current, a controlled half-wave rectifier uses SCR (Silicon Controlled Rectifier). This rectifier is used to deliver power to a resistive load, and we'll calculate the RMS current received by the load.

Specifications and Parameters

- AC input voltage (V_m): 220 V (rms)
- Load resistance (R_L): 10 ohms
- SCR ignition angle (α): 45o

Calculation Steps

1. Calculating Peak Voltage (V_m):

The peak voltage of the AC voltage is:

$Vm=V_{rms} \times \sqrt{2}$

$vm=220 \times \sqrt{2}$

$vm=220 \times 1,414$

$Vm \approx 311\ V$

2. Calculating Output RMS Voltage (V_rms_output):

The output RMS voltage of the controlled half-wave rectifier is:

$$Vrms_{\_output} = V_m \times 1\sqrt{\frac{1+\cos(a)}{2}}$$

Because cos (45o) = ≈ $0.707\frac{1}{\sqrt{2}}$

$$Vrms_{\_output} = 311 \times \sqrt{\frac{1+707}{2}}$$

$$V_{rms\_output} = 311 \times \sqrt{\frac{1.707}{2}}$$

$$Vrms\_{output} = 311 \times \sqrt{0.8535}$$

$$Vrms\_{output} = 311 \times 0.9238$$

$$Vrms\_{output} \approx 287.29\ V$$

3. Calculating Load RMS Current (I_rms):

The load RMS current (I_rms) can be calculated using Ohm's law:

$$Irms = \frac{Vrms\_output}{R_L}$$

$$Irms = \frac{287.29}{10}$$

$$Irms = 28.729\ A$$

Conclusion

With an SCR ignition angle of 45^o and a load resistance of 10 ohms, the RMS current received by the load is 28,729 amperes. This calculation shows how the ignition angle control can affect the RMS voltage and current applied to the load. The controlled half-wave rectifier allows for effective regulation of the power delivered to the load through the regulation of the RMS current received.

A controlled half-wave rectifier is a very useful device in the conversion of alternating current (AC) to direct current (DC) with precise control. Using a key component of a Silicon Controlled Rectifier (SCR), this rectifier allows for conduction timing during the positive cycle of AC waves, so that the output voltage and current can be adjusted according to the needs of the application.

1. **Ignition Angle Control:**

   The firing angle control on the SCR greatly affects the output voltage and current. By setting the ignition angle, we can control the average voltage (V_dc) and average current (I_dc) received by the load.

2. **Efficiency and Ripple:**
   Controlled half-wave rectifiers have lower efficiency than full-wave rectifiers because they use only half a cycle of AC waves. Ripple at output voltage is also higher, requiring additional filters to smooth out the resulting DC voltage.

3. **Practical Applications:**

   These rectifiers are widely used in DC motor speed control, battery charging, and lighting control. In these applications, the ability to precisely regulate current and voltage is essential for optimal performance.

4. **Voltage and Current Calculations:**

   The calculation of the average output voltage and the average current of the load shows that the controlled half-wave rectifier can produce voltage and current in accordance with the specification through the setting of the SCR start-up angle.

Analyzing controlled half-wave rectifiers shows that this device offers a simple yet effective solution for a wide range of applications that require direct current conversion and control. While it has some limitations such as lower efficiency and high ripple, the use of additional components such as filters can overcome this problem. Controlled half-wave rectifiers remain a popular choice in electronic and industrial system designs due to their ease of control and relatively low cost.

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