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

Performance Analysis of a Single-Phase Half-Wave Uncontrolled Rectifier on Lamp Flicker

Ilham Akbar Syafa'atullah[1], Rama Arya Sobhita[2]
[1,2] Marine Electrical Engineering, Surabaya State Shipping Polytechnic
[1] ilhamakbar28@student.ppns.ac.id ,[2] ramasobhita@student.ppns.ac.id

Abstract

An uncontrolled rectifier is an electrical circuit designed to convert sinusoidal waveforms from an alternating current (AC) voltage source into direct current (DC) voltage. The single-phase half-wave uncontrolled rectifier utilizes a diode as both the rectifying component and the circuit switch. This type of rectifier significantly impacts the performance of lighting systems, particularly the flickering behavior of light-emitting diode (LED) lamps within electrical circuits. This study evaluates the rectifier's influence on lamp flicker characteristics under varying operational conditions, focusing on its effectiveness in improving lighting stability and identifying potential drawbacks such as harmonic distortions. The findings aim to contribute to the development of enhanced rectifier designs tailored to modern engineering applications in power electronics and sustainable lighting systems.

Keywords: Rectifier, Diode, Proteus

1. Introduction

The technological advancements of the 20th century represent a significant culmination of scientific progress, leading to transformative developments across various industrial sectors (Nugraha & Eviningsih, 2022). Among these, the field of electricity has emerged as one of the most pivotal, underpinning innovations and applications in industries such as artificial intelligence, automation, and power management. Modern technological achievements in electrical systems have been built upon fundamental advancements in power electronics and microcontroller-based systems.

One of the critical technological needs in today's industrial landscape is voltage regulation technology (Cui, 2022). This includes systems capable of delivering either variable or fixed outputs depending on operational requirements. To achieve this, various electronic components such as diodes, transformers, and light-emitting diodes (LEDs) are utilized. Designing and assembling these components into functional circuits requires a structured approach aligned with specific design principles and objectives (Nugraha & Eviningsih, 2022).

Aligned with the study's title, "Performance Analysis of a Single-Phase Half-Wave Uncontrolled Rectifier on Lamp Flicker," this research investigates the impact of an uncontrolled rectifier on the behavior of LED lighting. The source of input for this analysis is an alternating current (AC) source. In essence, a rectifier circuit is designed to convert a sinusoidal AC waveform into a sequence of direct current (DC) pulses (Nangka et al., 2019).

In this study, the rectification process begins with the transformer, a primary component connected to the AC input source. The transformer's role is to step up or step down the voltage, as necessary, for subsequent circuit stages. Following the transformer, the electrical current passes through a diode, which acts as the rectifier, converting the sinusoidal AC input into a half-wave DC output.

This paper explores the observable changes and transitions in LED performance, specifically focusing on flicker phenomena caused by the single-phase half-wave uncontrolled rectifier. By examining these effects, the study aims to identify the rectifier's influence on lighting stability, thereby contributing to advancements in electrical and power engineering applications.

2. Material and methods

2.1. Diode

Diodes are essential active electronic components made from semiconductor materials, designed to allow electric current to flow in only one direction while blocking current in the opposite direction. This unidirectional flow property makes diodes a critical component in rectifier circuits, which are commonly used to convert alternating current (AC) into direct current (DC). Typically, a diode has two terminals: an anode (+) and a

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cathode (-). The junction between the p-type semiconductor and the n-type semiconductor forms the core of the diode's functionality.

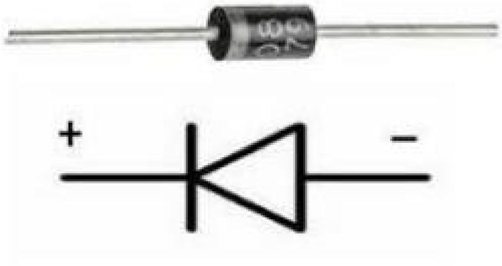

Figure 1. Diode Symbol and shape

When a diode is forward biased (with the positive terminal connected to the anode and the negative terminal to the cathode), it allows current to flow through it, effectively conducting electricity (Alzahrani, 2023). Conversely, when the diode is reverse biased, the current flow is blocked, as the diode presents a high resistance in this configuration, preventing any current from passing through. This behavior is critical in applications such as rectification, where the goal is to control the direction of current and convert AC to DC by allowing current to pass only during specific portions of the input waveform (Shneen, Ahmedhamdi, & Al-Ghezi, 2022).

In the context of rectifiers, diodes serve to regulate the current in circuits, preventing reverse current that could damage sensitive components such as LEDs or other electronic devices. In single-phase half-wave rectifiers, the diode ensures that only one half of the AC waveform passes through, effectively converting AC to pulsating DC, which can have significant implications for the operation of downstream components (Yuniza, Agna, & Nugraha, 2022).

2.2. Transformer

Transformers are essential static electromagnetic devices used to transfer or convert electrical energy between two or more circuits, operating at the same frequency but with a specific transformation ratio. They function based on the principles of Faraday's Law of Induction and Lorentz's Law, which govern the distribution of power in electrical systems (As'ad, Yuniza, & Nugraha, 2022). When an alternating voltage source is connected to the primary coil of a transformer, a current flows through the coil, generating a change in the magnetic flux within the iron core of the transformer.

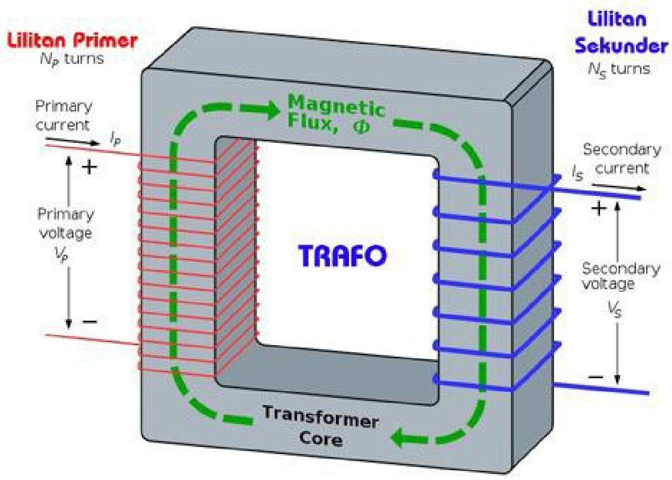

Figure 2. Transformer

The process begins with the application of an alternating current (AC) voltage source to the primary winding of the transformer. This AC current generates a magnetizing current that induces a magnetic flux in the core material. As the magnetic flux fluctuates, it induces a counter-electromotive force (emf) in the primary coil (E1), which in turn induces a secondary counter-emf (E2) in the secondary coil. This interaction enables the transformer to either step-up or step-down the voltage level, depending on the design of the winding ratio between the primary and secondary coils.

Transformers play a crucial role in adjusting voltage levels for efficient power transmission across electrical grids, ensuring that electricity can be safely and effectively delivered to homes, industries, and commercial facilities (Bintari, Mudjiono, & Nugraha, 2022). In rectifier circuits, such as the single-phase half-wave uncontrolled rectifier, the transformer adjusts the voltage before it reaches the rectifying diode, ensuring that the proper level of voltage is applied to the circuit.

2.3. Uncontrolled rectifier

A power rectifier is an essential component in power electronics, designed to convert an alternating current (AC) input voltage—typically a sinusoidal waveform—into a direct current (DC) output voltage, which is constant. Rectifier circuits are fundamental in converting AC to DC voltage, and the primary component used in these circuits is the diode (Jamil et al., 2021). This is due to the diode's ability to conduct electric current in only one direction, while blocking current from the opposite direction. When an AC current is applied to the diode, only half of the sinusoidal waveform is allowed to pass through, while the other half is blocked.

Rectifiers are generally categorized into two main types: controlled and uncontrolled rectifiers. In uncontrolled rectifiers, the output DC voltage remains fixed or unregulated, regardless of the changes in the input AC voltage. These circuits typically use diodes as switches. The uncontrolled rectifier's role is to provide a reliable DC output without the need for additional regulation circuitry, making it a cost-effective solution for various applications where precise voltage control is not critical (Pambudi et al., 2021).

Uncontrolled rectifiers can be further classified based on the type of input voltage source they are connected to. Specifically, they can be single-phase or three-phase rectifiers, depending on whether the AC input is single-phase or three-phase. The single-phase uncontrolled rectifier is the focus of this research, where an AC input is transformed into DC, typically used in simpler applications such as small power supplies or in scenarios where the load does not require sophisticated voltage regulation.

2.4. LED

Light Emitting Diodes (LEDs) are semiconductor devices that emit light when forward biased, converting electrical energy into light energy (Parbrook et al., 2021). LEDs are available in various colors such as red, orange, yellow, blue, green, and white, with each color corresponding to a specific wavelength determined by the material properties and semiconductor compound used in their construction (Ando et al., 2020). These diodes offer significant advantages over traditional light sources due to their energy efficiency, durability, and longer lifespan.

LEDs have a broad range of applications across various industries, particularly in lighting solutions for homes and roadways. They are commonly used as indicator lights in electronic and electrical devices, offering high visibility and low energy consumption (Bui, Nguyen, & Seo, 2023). Furthermore, LEDs are extensively employed in decorative lighting and signage, where their brightness and color options provide enhanced visual appeal (Lee & Chow, 2011). The growing use of LEDs is especially relevant in the context of power electronics, where efficient control of their brightness and performance is crucial (Prasad, Ziogas, & Manias, 1991).

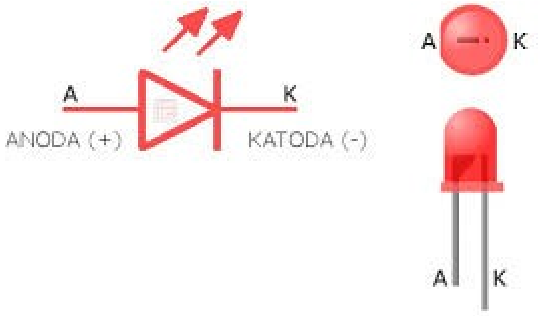

Figure 4. LED Symbol and shape

2.5. Methods

This paper presents a study that investigates the effect of a single-phase half-wave uncontrolled rectifier on lamp brightness, focusing specifically on the flicker phenomenon and its implications for power electronics applications (Nurhidayat et al., 2022). The research methodology involves conducting controlled experiments using Proteus 8 simulation software. This software allows for precise manipulation of variables, enabling an in-depth analysis of circuit behavior under various conditions (Mal et al., 2023).

For the experimental setup, the AC current source (alternator) was configured with an amplitude of 12V and a frequency of 1 Hz. The transformer in the circuit was set to operate in step-up mode, achieved by designing the secondary winding to have a higher number of turns than the primary winding (Ghosh et al.,

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2023). This configuration increases the voltage level before rectification, aligning with the study's aim to explore the impact of voltage transformation on LED performance.

The research process began with the assembly of essential components, including the alternator, transformer, diodes, and LEDs. These components were meticulously arranged within the Proteus schematic environment, enabling a digital simulation of the circuit (Bhuyan & Hasan, 2020). The assembled circuit was then simulated to generate data, which were subsequently measured and analyzed to evaluate the impact of the rectification process on lamp brightness and stability (Rahman & Taali, 2023).

Through this approach, the study aims to provide insights into the behavior of single-phase half-wave uncontrolled rectifiers in practical applications, contributing to a deeper understanding of their performance and limitations. The findings are expected to enhance design strategies for power electronic systems, particularly in optimizing lighting stability and reducing flicker in LED applications.

- .Experiment Series

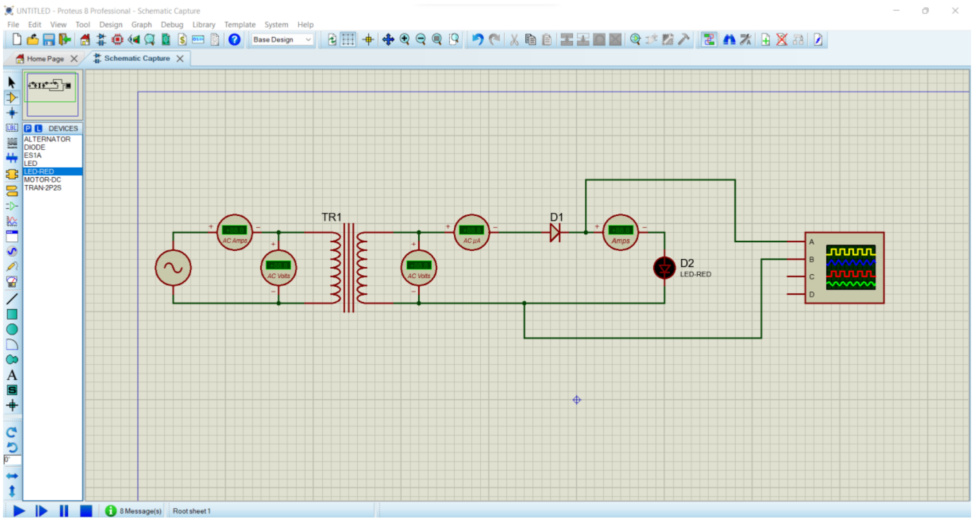

Figure 5. Proteus circuit

The figure above illustrates the design of a single-phase half-wave uncontrolled rectifier circuit. In this configuration, the electrical source originates from an alternator, which is then stepped up using a transformer to increase the voltage level. The electric current subsequently flows through a diode, where it is rectified, and is directed to the LED (D2). To analyze the performance of the circuit, an oscilloscope is employed to measure and visualize the waveform produced by the rectification process.

Simulation Procedure

1. Preparation of Tools and Components:
   Set up all necessary components and equipment in the Proteus 8 simulation software, ensuring accurate configurations for experimentation.
2. Circuit Construction:
   Assemble the circuit beginning with the alternator as the AC power source. Connect the alternator to the transformer for voltage stepping, followed by a connection to the diode and then the LED to complete the rectification process.
3. Integration of Measurement Instruments:
   Add essential measurement devices such as an AC voltmeter, AC ammeter, DC ammeter, and an oscilloscope. These instruments are used to monitor the voltage, current, and waveform characteristics of the circuit.
4. Data Recording:
   Run the simulation and record the output data, including voltage levels, current flow, and the resulting waveform observed on the oscilloscope.
5. Calculation and Analysis:
   Calculate the key parameters of the circuit, such as rectification efficiency and power characteristics. Perform a thorough analysis of the data to evaluate circuit performance and draw meaningful conclusions.

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This study focuses on the performance analysis of a single-phase half-wave uncontrolled rectifier and its impact on LED operation, emphasizing the flicker phenomenon. The simulation approach provides a controlled environment to explore the circuit's behavior, making the findings relevant for applications in power electronics and lighting systems. The inclusion of measurement instruments and calculated parameters ensures a comprehensive evaluation of circuit dynamics, aligning with engineering research standards.

3. Results and discussion

3.1. Result

This section presents the results of circuit simulation and the corresponding measurement data, focusing on the behavior of the LED when subjected to a single-phase half-wave uncontrolled rectifier.

- Simulation Results Using Proteus 8

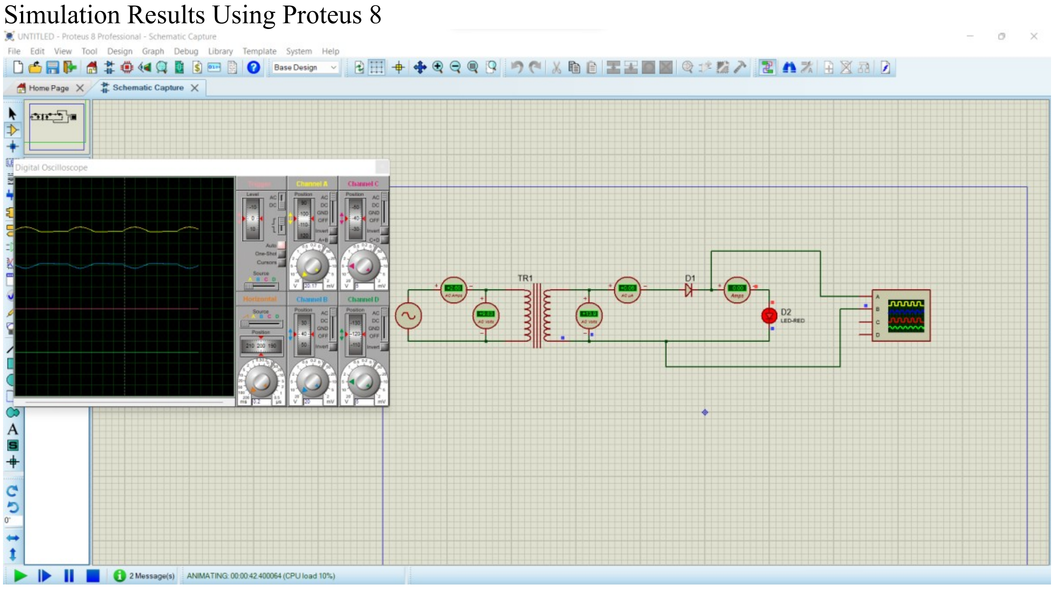

Figure 6. Simulated Circuit

Upon simulating the circuit in Proteus 8, significant effects on the LED illumination were observed. The electric current flowing through the LED originates from an AC voltage source, which is converted into a pulsating DC voltage by the uncontrolled rectifier. This conversion leads to the LED flickering—alternating between on and off states at regular intervals. This phenomenon arises due to the transformation of the full AC sine wave into a half-wave by the rectifier, which effectively blocks one half of the AC cycle through diode operation.

The rectifier circuit plays a pivotal role in power supply systems, where it functions to transform an AC (Alternating Current) signal into a DC (Direct Current) signal. The circuit in this study employs a single diode as its core component due to the diode's inherent ability to conduct current in only one direction while blocking the reverse flow. When supplied with an alternating current, the diode permits the passage of only the positive half of the AC waveform, suppressing the negative half.

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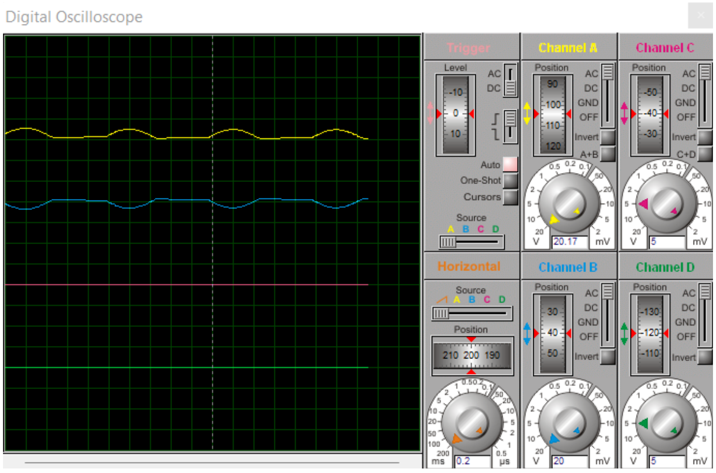

Figure 7. Waveform as Captured by Oscilloscope

In alignment with the theoretical principles of a single-phase half-wave uncontrolled rectifier, the oscilloscope readings from the simulation clearly display a half-wave output. The half-wave rectifier is recognized as the simplest type of rectification system, utilizing just one diode to eliminate the negative segment of the AC waveform while transmitting the positive portion. This process simplifies the circuit design by reducing the component count, though it also introduces periodic interruptions in the current flow, which directly contribute to the observed flicker in the LED illumination.

The positive half of the AC waveform causes the diode to be forward-biased, allowing current to pass through and illuminate the LED. Conversely, during the negative half-cycle, the diode becomes reverse-biased, blocking current flow and causing the LED to turn off. This cyclical operation underscores the limitations of the half-wave rectifier in delivering continuous DC output, particularly in applications where stable illumination or operation is required.

Table 1. Effect of LED light

Time(s)	LED state
0.5 s	Dead
1 s	on
1.5 s	Dead
2 s	on
2.5 s	Dead
3 s	on

Based on the data collected, the observed results show that the LED turns off after approximately 0.5 seconds. Unlike a typical DC circuit, the LED does not illuminate continuously in this setup. This behavior is due to the AC voltage source used in the circuit, which is modified by a step-up transformer and a diode acting as a rectifier. The sinusoidal waveform output from the AC voltage source is converted into a half-wave signal by the rectifier. During the negative half-cycle, the diode prevents the reverse current from flowing, effectively blocking the return of electrons and causing the LED to remain off.

4. Conclusion

Based on the research conducted, it can be concluded that the diode serves as a rectifier, converting AC to DC. The resulting waveform exhibits a positive sine wave with no negative half-cycle, meaning that only the crest of the wave is present. This characteristic is indicative of a single-phase half-wave rectifier. A notable feature of this circuit is that the amplitude does not reach the zero point, which occurs due to the phase difference. As observed in the simulation results, the LED does not remain continuously on; instead, it turns on and off intermittently. This phenomenon can be applied in practical technologies, such as vehicle marker lights or boundary indicator lamps, where periodic flicker or flashing is desired for visibility.

Credit authorship contribution statement

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

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