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Original Research Article

Implementation of Livewire Software in Output Waveform Analysis for Rectifier Circuit

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Abstract: A diode performs a vital job as a rectifier, which changes alternating current (AC) into direct current (DC). Both half-wave and full-wave rectifier circuits in electronics can use diodes. Rectifiers are fundamental in electronics because many devices, such as computers, smartphones, and power supplies, require DC power. They ensure that the electrical current flows in a single direction, which is necessary for the proper functioning of these devices. The choice of rectifier type depends on the application's specific requirements, including the desired output voltage and current. The output voltage waveform can be analysed through an oscilloscope in the laboratory for education purposes. Instead of using an oscilloscope in the lab, we can also analyze output waveforms using electrical schematic software. In this study, the virtual oscilloscope offered by Livewire software's schematic simulation application will investigate the output signal from a half-wave and full-wave rectifier circuit. In conclusion, the waveform output from the rectifier circuit can be analyzed from livewire software successfully. Through the analysis obtained, we can determine the formation of each cycle for the output voltage rectifier for both half-wave and full-wave. It demonstrates how Livewire's virtual experiments can be utilized as a substitute for practical activities when learning online. Based on the Livewire simulation result, the halfwave rectifier's output only appears during the positive half cycle; meanwhile, the fullwave rectifier's output of both half cycles appeared according to the input voltage.

Keywords: Rectifier circuit; virtual oscilloscope; Livewire software; virtual experiments

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1. Introduction

There are affordable options for AC electricity. Since producing DC power is more expensive than producing AC power, a cheap way to manufacture DC is required. Rectifiers can transform AC power into DC power. (Mahato *et al.*, 2017). Rectification, one of the fundamental signal processing operations, is heavily employed in instrumentation, measurement, communication circuits, and systems, including a variety of nonlinear analogue signal processors, peak value detectors, ammeters, AC voltmeters, and wattmeter, RF demodulators, piecewise linear function generators, signal polarity detectors, and averaging circuits (Petrović, 2022).

Electronic components come in two varieties: passive and active. The capacity of the diode to transform an AC (alternate current) power source into DC (direct current) for use in daily life makes it one of the most widely utilized electrical components. Both full-wave and half-wave rectifiers can be made of diodes. In soft computing engineering, full-wave rectifiers are frequently used with bridge circuit theory. This feasibility study, based on circuit simulation, effectively applies bridge circuit theory in a half-wave rectifier by substituting two diodes from a block with two resistors and supplying only one positive input. The experimental findings demonstrate that the bridge circuit theory functions reasonably well with a half-wave rectifier, and the output is identical to that of a straightforward half-wave rectifier circuit (Dirgantoro & Yang, 2018). According to (Gao, D.W 2015), a single phase of AC electricity is used as the rectifier's input in a single-phase rectifier. Half-wave rectifier and full-wave rectifier are the two primary types of AC-DC rectifiers. These two varieties of rectifiers have fundamental structural designs and do not need a control signal.

This study analyses the rectifier's output voltage waveform as it appears on the oscilloscope monitor. Depending on the input signal, the waveform can show the output voltage for both half-wave and full-wave rectifiers for the positive and negative cycles. Livewire software was used during this research to simulate rectifier circuits and generate the output waveform for analysis. In addition to being hands-on in the laboratory using a manual oscilloscope, this simulation is crucial to improving knowledge, especially for students learning about the output of rectifiers for half-wave and full-wave. This method coincides with (Yulisa *et al.*, 2020), who think some issues with students' conceptual comprehension frequently arise, such as letting them continue to have misconceptions and Numerous variables, such as students' lack of enthusiasm in studying the content and the usage of media that does not pique students' interest in learning, might contribute to students' limited understanding of concepts.

In this session, we approach this kind of application because Livewire software is one of the virtual experimental tools that can be used to support learning. According to (Zulfa *et al.*, 2019), students may find it simple to comprehend the fundamentals of electrical and electronic theory and apply Ohm's Law and Kirchoff's Law learning materials using the Livewire software. Students can use this simulation software to conduct virtual experiments to learn about the material.

1.1 Problem statement

Covid-19 has caused a shift in the educational system toward online education. Obstacles forced the replacement of practical activities with virtual experiments. In this time of online learning, virtual experiments are an option. Virtual experiments give a broad overview of physics ideas that are challenging to witness directly. This makes learning engaging, and students can control various complex processes (Billah & Widyatmoko, 2018). In this study, we replaced the hands-on lab session with a virtual lab using the Livewire software to draw the rectifier circuit. This virtual lab can also be implemented if the apparatus in the lab cannot be used in the learning process. Virtual experiments offer an option to replace harmed laboratory apparatus (Fiscarelli *et al.*, 2013). This investigation intends to determine how virtual experiments are used in online courses for fundamental electronics.

1.2 Objectives

- Implement Livewire software to simulate the rectifier circuit and obtain the output waveform.
- Draw the rectifier circuit using a simulation schematic rather than a physical laboratory.
- To analyze the output voltage waveform that appears from the virtual oscilloscope through Livewire software.

1.3 Importance of study

Every scientific study is not designed without significance and benefits. This study is expected to give the significance listed below:

- It is helpful for students in electrical fields to study rectifier output and relate this result to the theory they have learned.
- Some replacements for the rectifier circuit laboratory for the virtual experiment will be made using Livewire software.
- To share experience and knowledge about electrical wiring schematic software with others.
- To analyze the output voltage waveform in positive and negative cycles for both half-wave and full-wave rectifier circuits.
- It motivates other researchers to use Livewire software to simulate the electronic circuit.

2. Materials and Methods

2.1 Diode

According to research by Lubis (2018), electronics-related things are a part of the environment we frequently encounter. Electronic gadgets like lightbulbs, laptops, televisions, and many others are contained there. These devices contain a circuit, including a diode as a crucial part. A diode is a two-poled active electrical component that controls current rectification. A scientist from England named JA Fleming invented the diode, a vacuum tube-like component with two electrodes, in 1904. A diode has an internal structure comprising a plate that encircles the cathode and a heater section housed inside the cathode. For a diode to function, electrons must first be heated at the cathode and then go from the cathode to the plate.

According to (Boylestad, R.L. *et al*., 2018), the diode is the first electronic device invented. Although it is the most basic semiconductor device, it is essential to electronic systems. A diode is an electrical device allowing current to move through it in one direction. It is a semiconductor device with a combination of N-type and P-type materials. The diode has two terminals, the anode and cathode, as shown in Figure 1.

Figure 1. Diode

2.2 Rectifier

A rectifier, usually called a diode, is a component that only permits electricity to flow in one direction, converting alternating current (AC) into direct current (DC). The usual characteristic of a diode is that it can only allow current to flow in one direction. The rectifier permits full-wave rectification without needing an extra circuit, allowing for better integration and downsizing. An impedance transformer is added between the input port and the bridge diode to increase the rectification efficiency (Saen *et al.*, 2011). Bridge rectifiers and full-wave rectifiers with centre-tapped transformers are the two forms of single-phase full-wave rectifiers (Rashid, 2011).

Research by Somano (2022) shows that it is a two-terminal electrical component with low (preferably zero) resistance in one direction and high (ideally infinite) resistance in the other that conducts current primarily in one way. Electrons in a vacuum tube with two electrodes, a heated cathode and a plate can only go in one direction from the cathode to the plate when called a diode vacuum tube or thermionic diode. The most often used semiconductor diode nowadays is a crystalline piece of material with a p–n junction coupled to two electrical terminals. German physicist Ferdinand Braun discovered asymmetric electrical conduction at the contact between a crystalline mineral and a metal 1874. Although silicon makes up the majority of diodes nowadays, other semiconducting semiconductors, including germanium and gallium arsenide, are also utilized.

2.3 Half Wave Rectifier

The positive or negative half of the AC wave is passed while the other half is blocked in half-wave rectification. It is highly inefficient if utilized for power transfer since only half of the input waveform reaches the output. One diode in a one-phase or three diode in a three-phase supply can rectify half-wave. Figure 2 shows the half-wave rectification.

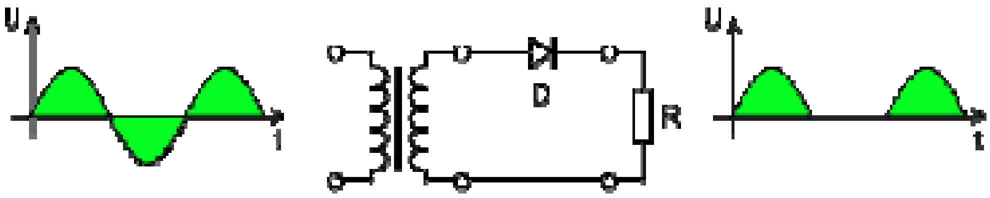

Figure 2. Half-wave rectification. (Source: Ramesh *et al.* (2013))

2.4 Full Wave Rectifier

A full-wave rectifier changes the input waveform in its entirety to an output waveform with a constant polarity (positive or negative). Full-wave rectification is more effective and converts the waveform's two polarities to DC (direct current). Nevertheless, four diodes are needed in a circuit with a non-centre transformer instead of the one needed for half-wave rectification. A bridge, or bridge rectifier, is an arrangement of four diodes, as shown in Figure 3.

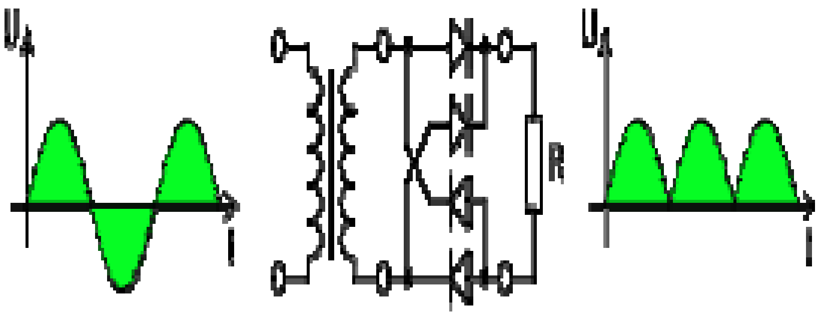

Figure 3. A full wave rectifier used for diodes (Source: Ramesh *et al.* (2013))

Anode-to-anode or cathode-to-cathode diodes placed back-to-back can create a full wave rectifier for single-phase AC power if the transformer is center-tapped. In contrast to the bridge rectifier, twice as many windings are needed on the transformer secondary to get the same output voltage. Figure 4 shows a full-wave rectifier using a centre-tapped transformer.

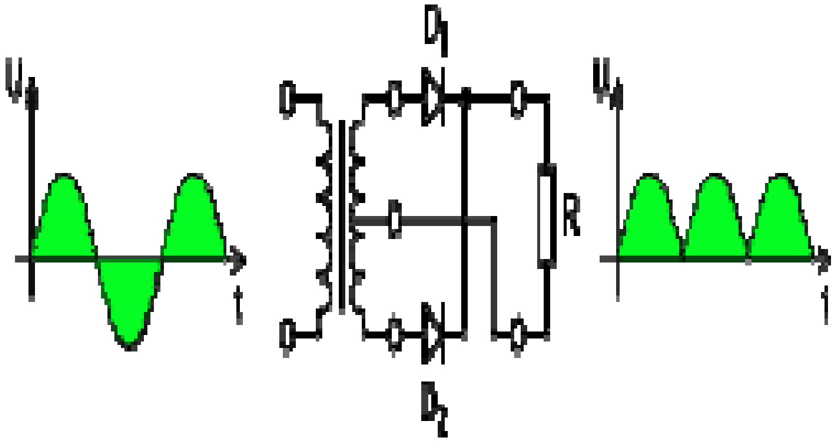

Figure 4. A full-wave rectifier using a centre-tapped transformer (Source: Ramesh *et al.* (2013))

2.5 Virtual Experiment

Virtual experiments are a set of computer programs that may represent complex experiments or abstract phenomena that are conducted in actual laboratories. They boost learning activities and develop problem-solving skills (Yusuf & Subaer, 2013). Through computer simulation, the virtual experiment shows or explains a problem. Students might engage in conversation to react to these situations. Virtual media experiments are those that make use of digital simulations or other digital lab material (*Makhrus et al.,* 2020). Virtual laboratories have the benefit of being able to explain abstract concepts that cannot be stated verbally (Saputra H., *et al.,* 2018). In order to facilitate communication and construct ideas about the material content of abstract physics, virtual laboratory-based media are used (Saregar, 2016).

2.6 Methodology

This study uses a few methods to simulate the circuit to obtain the output waveform for half-wave and full-wave rectifier circuits.

2.6.1 The design of the rectifier circuit

The design of this rectifier is using Livewire software. This software is an alternative to help with virtual experiments in introductory electronics courses. This study aims to design and construct half-wave and full-wave rectifier circuits virtually to analyze the output voltage waveform that appeared from the virtual oscilloscope in Livewire software. Figure 5 shows the Getting Started front page before we create the circuit.

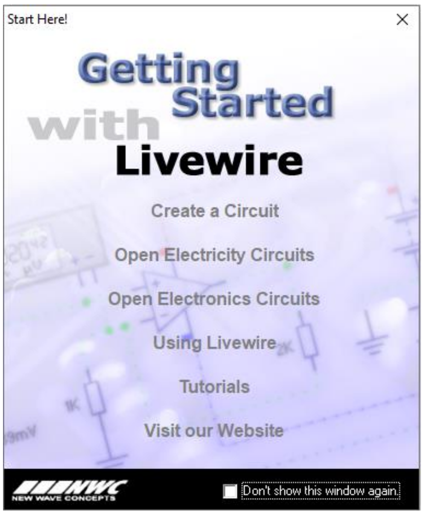

Figure 5. Getting Started front-page for Livewire software

Choose "Create a Circuit" on the Getting Started page to create the electronic circuit. The essential parts that a user needs to build a circuit are included in a Gallery box, such as power supplies, connectors, logic gates, passive parts, integrated circuits, measurement devices, and more. Figure 6 shows the display of Livewire when operated on a computer.

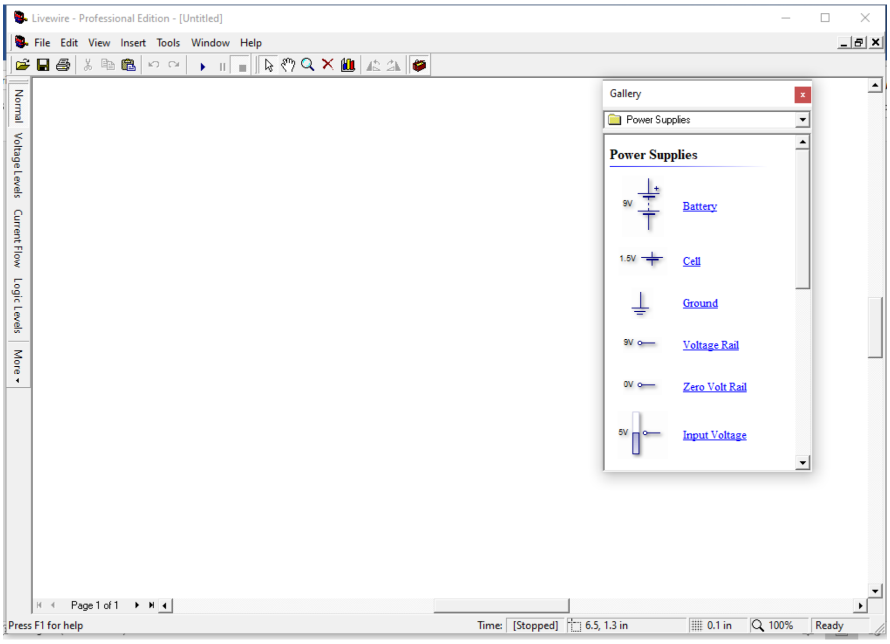

Figure 6. Display Livewire when operated on a computer

2.6.2 Analyzing the output waveform of half-wave and full-wave rectifier

To analyze the output waveform after creating the circuit, we need to set it in the setting box that can be found in the toolbar above the livewire window. Click on Tools, then select Simulation, and go to Timing Control. Figure 7 shows the timing control setting to run the simulation process.

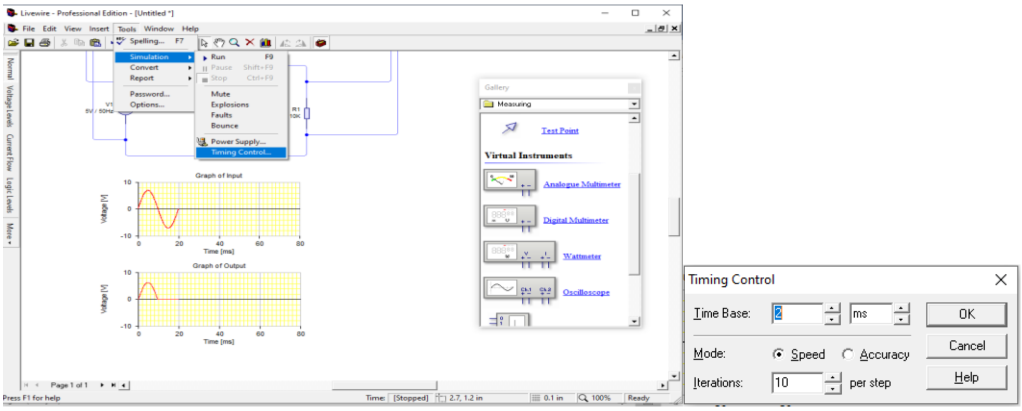

Figure 7. Timing Control

To display the output waveform from virtual oscilloscope, choose Measuring then select Oscilloscope on Virtual Instruments that can be found in the Gallery box as shown in Figure 8. The oscilloscope is connected to the circuit to display the input and output waveform.

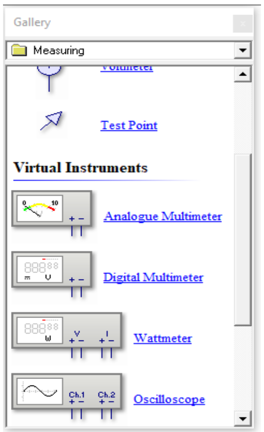

Figure 8. Oscilloscope on Virtual Instruments

3. Results and Discussions

3.1 Analysis of Halfwave Rectifier Circuit

Using the Livewire tool, designing a halfwave rectifier is a straightforward task. Single diode and single load resistor with AC input voltage make up the halfwave, as depicted in Figure 9. The virtual oscilloscope is connected to the circuit to display the waveform. Here, we display the input and output waveforms using two separate oscilloscopes.

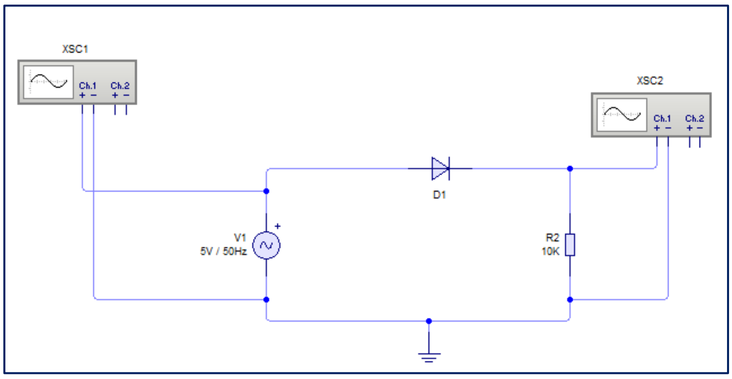

Figure 9. Halfwave rectifier circuit

We adjusted the voltage's maximum and minimum axes to -10V and 10V, respectively, to obtain the optimal output waveform display. Concurrently, we have both displays' periods set to 10 milliseconds on the graph properties, as shown in Figure 10.

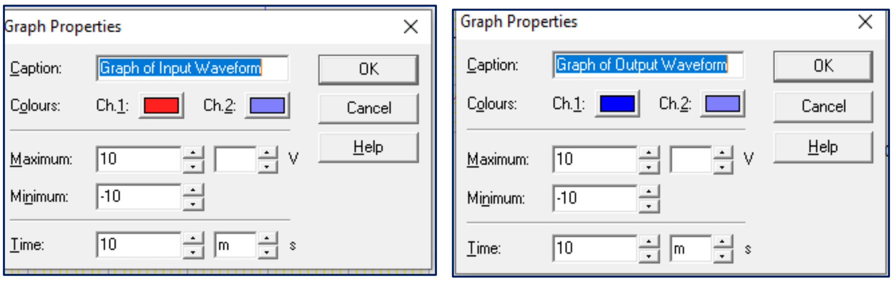

Figure 10. Setting of Graph Properties for waveform display

According to the simulation result, we analyze both positive and negative half cycles for halfwave circuits. When positive half cycle, the diode is forward biased or in an ON state. So it will be conducted. While conducting, the diode acts as a short-circuit so that the circuit current flows. The positive half-cycle of the input a.c voltage is dropped across the load resistor. So, the output waveform is similar to the input voltage waveform.

When negative half cycles, the diode is reverse-biased or OFF. So, it does not conduct current—the diode acts as an open circuit, so there is no current flow. There is no voltage drop across the load resistor. The negative input half-cycle is suppressed.

In conclusion, as Figure 11 illustrates, the half-wave rectifier's output only appears during the positive half-cycle and cuts off during the negative half-cycle.

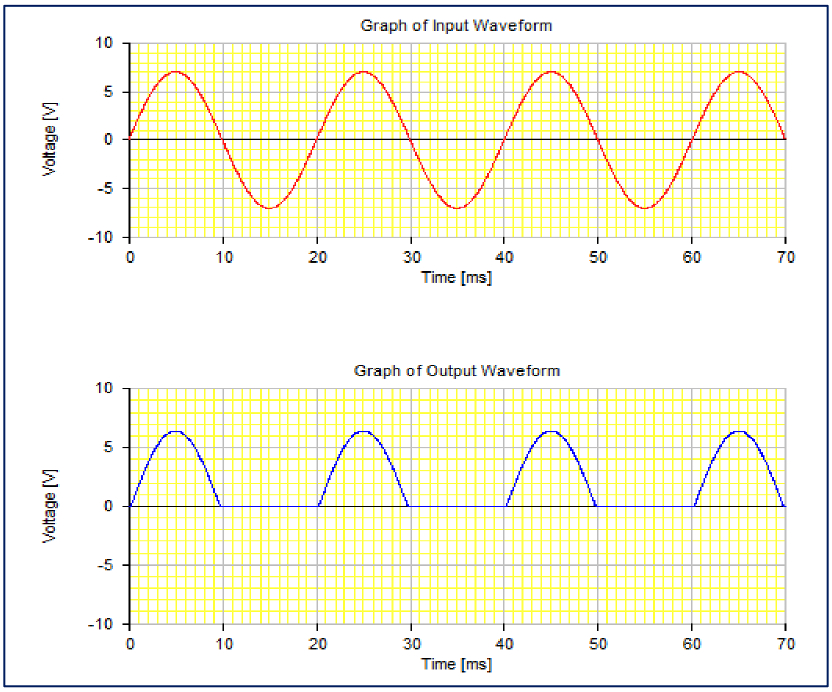

Figure 11. Output waveform of half-wave rectifier

3.2 Analysis of Full-Wave Rectifier Circuit

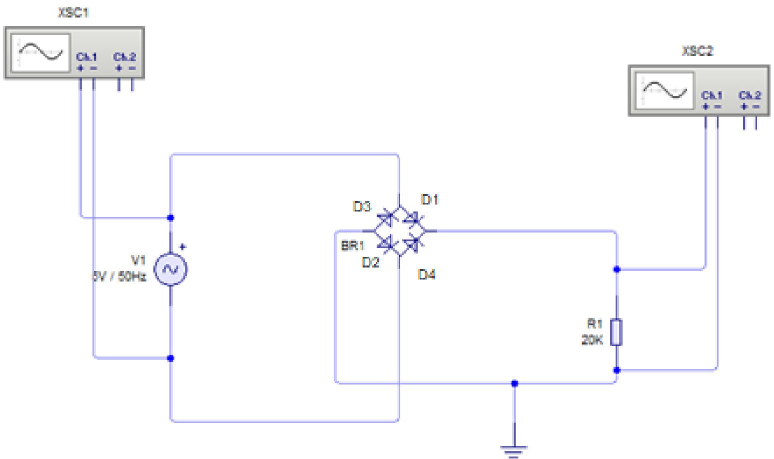

Figure 12. Full-wave bridge rectifier

A single load resistor and four diodes, or bridges with an AC input voltage, comprise the full-wave bridge rectifier design depicted in Figure 12. The Livewire software was used to simulate this circuit, and Figure 13 shows the outcome. D1 and D2 become forward-biased during a positive half cycle, while D_3 and D_4 become reverse-biased. Current flows along D_1, load resistor, D_2 to the Ground. It produces a positive half-wave waveform across the load resistor.

D3 and D4 become forward-biased during the negative half cycle, while D_1 and D_2 become reverse-biased. Current flows along D_3, load resistor, D_4 to the Ground. It produces a positive half-wave waveform across the load resistor.

In conclusion, current keeps flowing through the load resistor in the same direction during both half-cycles of the a.c input supply. It means the output voltage waveforms of both half cycles have the same shape, as shown in Figure 13.

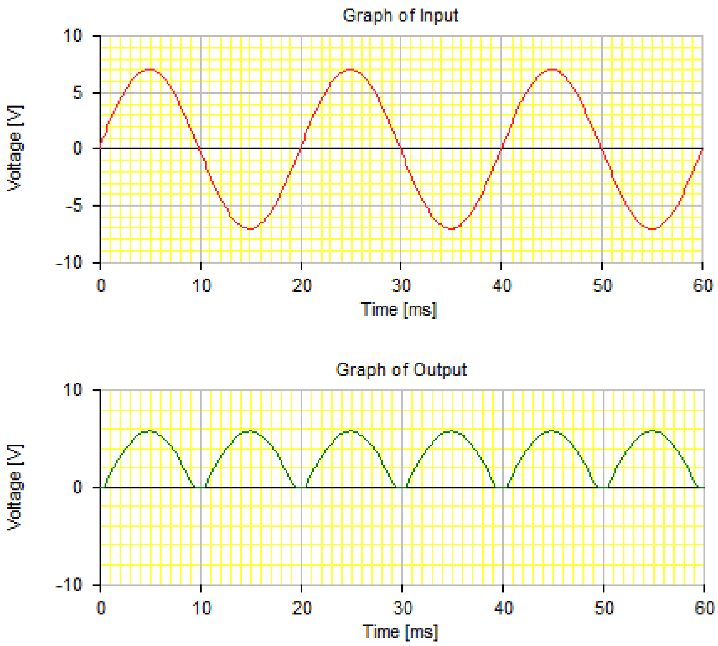

Figure 13. Output waveform of full-wave rectifier

4. Conclusions

The simulation results using Livewire software are consistent with the theoretical analysis. The half-wave and full-wave rectifier circuits with resistive load have been analyzed using Livewire as a virtual lab. The output voltage waveform that is obtained has been compared. Based on the Livewire simulation result, the half-wave rectifier's output only appears during the positive half cycle; meanwhile, the full-wave rectifier's output for both half cycles appeared according to the input voltage. The application Livewire simulation can flexibly change the simulation parameters in the simulation process and directly observe the simulation results that vary with parameters. The simulation research of rectifier circuits with the application of Livewire lays the foundation for the analysis of rectifier circuits, and it is an essential simulation software that is simple to apply. It is also a good assistant tool for the experiment of primary electronics circuits. For further research, we can study the effect of the filter circuit (R, L, C) on the output waveform as we know it can filter unwanted signals in the rectifier circuit.

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Conflicts of Interest: The authors declare no conflict of interest.

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