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Experiment 2

Full Wave Rectifier

2.1 Aim

To design and implement Single Phase Full Wave Uncontrolled and Controlled rectifiers, and simulate them with R and RL loads.

2.2 Software Used

MATLAB R2020a

2.3 Theory

A full-wave rectifier is an electronic circuit that converts an alternating current (AC) input signal into a unidirectional pulsating direct current (DC) output signal. It is a rectifier that uses both halves of the input sinusoidal waveform. It is essentially two half-wave rectifiers connected together to feed the load. The rectification is done by passing the positive half of the waveform while inverting the negative half of the sine wave. This results in a pulsating DC output. However, the output does not reverse direction, as it uses the full 100

The full-wave rectifier is a more efficient rectifier compared to the half-wave rectifier because it produces a smoother DC output. Additionally, it has a higher output voltage and lower output ripple than a half-wave rectifier.

In a single-phase full-wave rectifier, four diodes are used in a bridge configuration to rectify the AC input signal. The input AC voltage is applied across the two AC input terminals of the rectifier, and the output voltage is taken from the two DC output terminals. The four diodes are connected in such a way that the input voltage is rectified, producing a DC output voltage across the output terminals.

The four diodes used in the bridge rectifier are arranged in a way such that when the AC input voltage is positive, diodes D1 and D3 are forward-biased and conduct, while diodes D2 and D4 are reverse-biased and do not conduct. Conversely, when the AC input voltage is negative, diodes D2 and D4 are forward-biased and conduct, while diodes D1 and D3 are reverse-biased and do not conduct. This process of rectification occurs for each half-cycle of the AC input voltage, producing a unidirectional DC output signal.

2.4 Theoretical Calculations

In the theory of full-wave rectifiers, the average output voltage and current for controlled full-wave rectifiers with resistive (R) load can be calculated using the following equations:

$$V_0 = \frac{V_{phase}}{\sqrt{2}} \frac{(1+\cos\alpha)}{\pi} \tag{2.1}$$

$$V_0 = \frac{V_m(1+\cos\alpha)}{2\pi} \tag{2.2}$$

$$I_0 = \frac{V_0}{R} \tag{2.3}$$

where α is the thyristor's firing angle. It should be noted that in uncontrolled rectifiers, the thyristor is switched out for a diode and α is equal to 0.

For a single-phase full-wave uncontrolled rectifier, the average output voltage and current can be calculated as follows:

$$V_0 = 2\sqrt{2}V_{rms} \tag{2.4}$$

$$I_0 = 2I_{rms} \tag{2.5}$$

where V_{rms} is the root mean square value of the input voltage and I_{rms} is the root mean square value of the input current.

For a single-phase full-wave controlled rectifier, the average output voltage and current can be calculated as follows:

$$V_0 = \frac{2\sqrt{2}V_{rms}(1-\cos\alpha)}{\pi} \tag{2.6}$$

$$I_0 = \frac{2I_{rms}(1-\cos\alpha)}{\pi} \tag{2.7}$$

Consider an AC source with an RMS voltage of 230V and a resistive load of 10Ω. The output voltage and current for a single phase full-wave uncontrolled rectifier are given by:

$$V_0 = 207.07\text{V} \tag{2.8}$$

$$I_0 = 20.70\text{A} \tag{2.9}$$

2.5 Single Phase Full Wave Uncontrolled Rectifier with R load

2.5.1 Circuit used for simulation

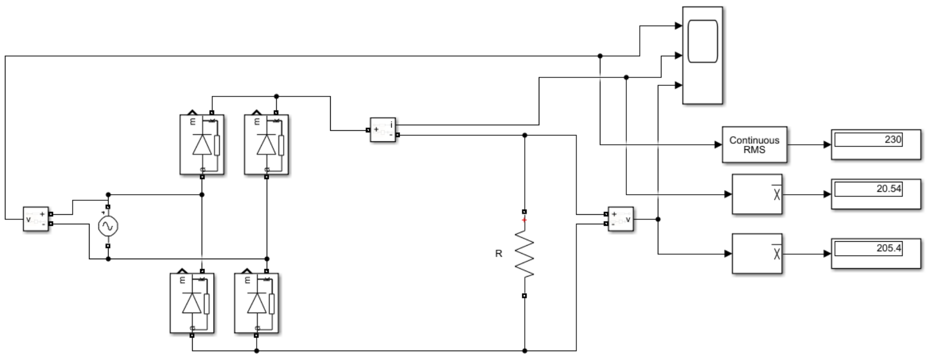

Figure 2.1: Circuit used for simulation

2.5.2 Components Required

Sr. No	Parameters	Ratings	Quantity
1	AC Single Phase Voltage Source	230V (V_{rms})	1
2	Resistor	10Ω	1
3	Diode	-	1
4	Voltmeter	-	2
5	Ammeter	-	1

Table 2.1: Components for Single Phase Full Wave Uncontrolled Rectifier with R load

2.5.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	207.07V	205.4V
Output Average Current ($I_{o,avg}$)	20.70A	20.54V
DC Input Power (P_{DC})	4218.916W	4173W
Efficiency (%)	79.73	79.73

Table 2.2: Observations for Single Phase Full Wave Uncontrolled Rectifier with R load

Upon careful observation, it can be inferred that the simulated values exhibit a close resemblance to their theoretical counterparts. Given that the load is resistive, the output current waveform is found to be in phase with the output voltage waveform. Moreover, it is worth noting that as a result of full-wave rectification of the input AC signal, the output DC signal is characterized by a frequency that is double that of the input signal.

2.5.4 Resultant Waveforms

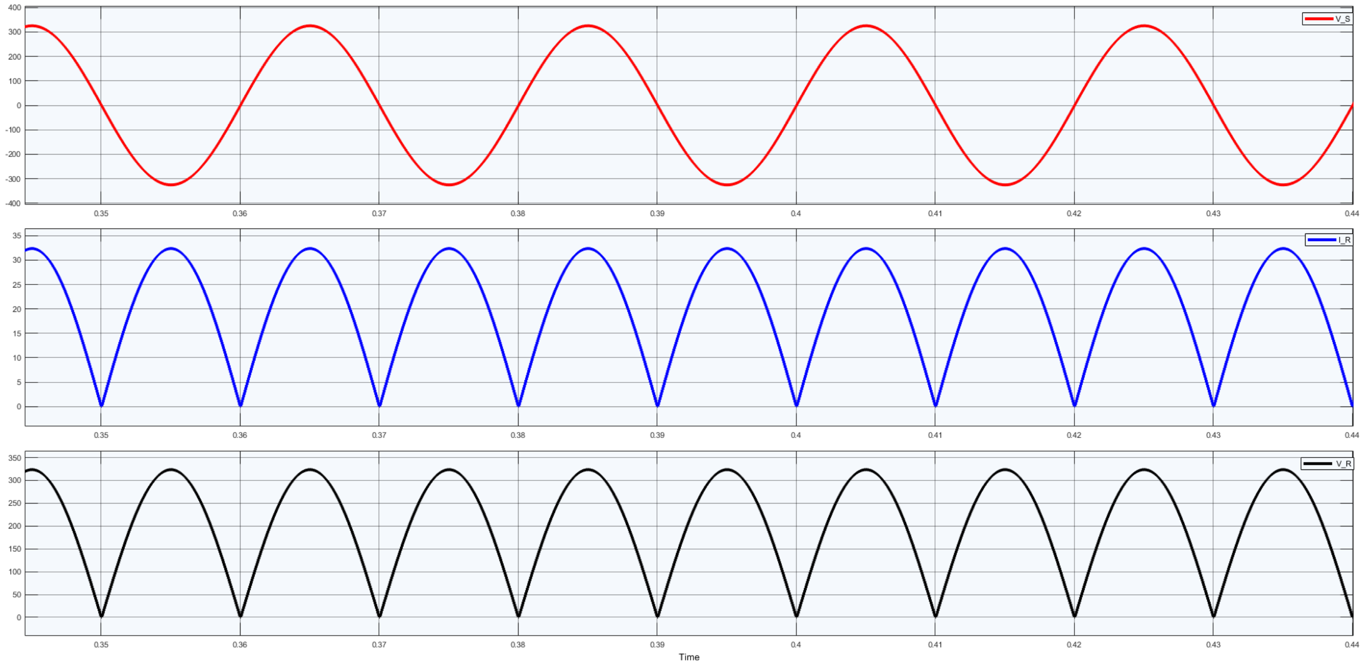

Figure 2.2: Scope Waveforms for Single Phase Full Wave Uncontrolled Rectifier with R load waveforms

2.6 Single Phase Full Wave Controlled Rectifier with R load

2.6.1 Circuit used for simulation

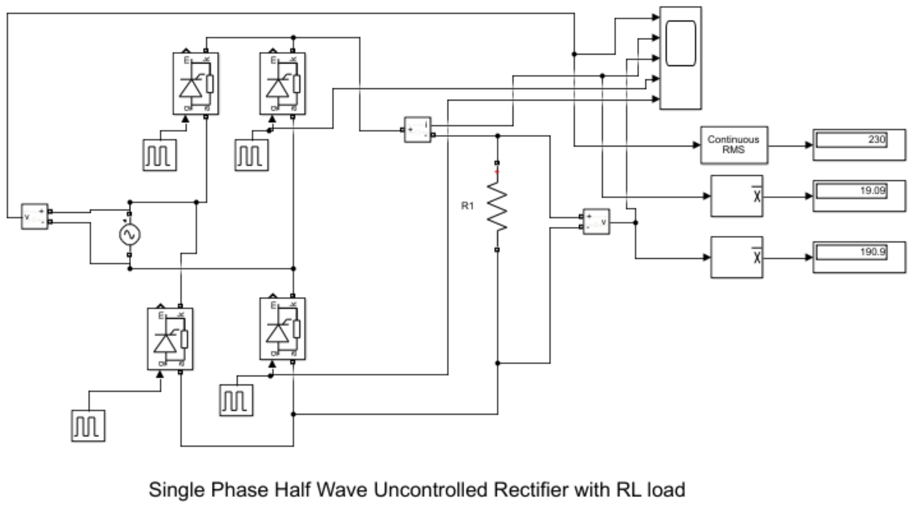

Figure 2.3: Circuit used for simulation

2.6.2 Components Required

Sr. No	Parameters	Ratings	Quantity
1	AC Single Phase Voltage Source	230V (V_{rms})	1
2	Resistor	10Ω	1
3	Inductor	10mH	1
4	Diode	-	1
5	Voltmeter	-	2
6	Ammeter	-	1

Table 2.3: Components for Single Phase Half Wave Uncontrolled Rectifier with RL load

2.6.3 Observations

Upon observation, it is noted that the simulated values exhibit a level of conformity with the theoretical values. Due to the presence of an inductive component in the load, the output current lags behind the output voltage, resulting in a period during which the output voltage becomes negative while the diode conducts until the output current attains a value of zero. The diode then ceases to conduct, and both the output voltage and current return to zero. The efficiency of uncontrolled rectifier with RL load is 44.84%.

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	193.2V	190.9V
Output Average Current ($I_{o,avg}$)	19.32A	19.09A
AC Input Power (P_{AC})	2389.5 (W)	2318 (W)
DC Input Power (P_{DC})	1071.53 (W)	1017 (W)
Efficiency (%)	44.84	43.84

Table 2.4: Observations for Single Phase Half Wave Uncontrolled Rectifier with RL load

2.6.4 Resultant Waveforms

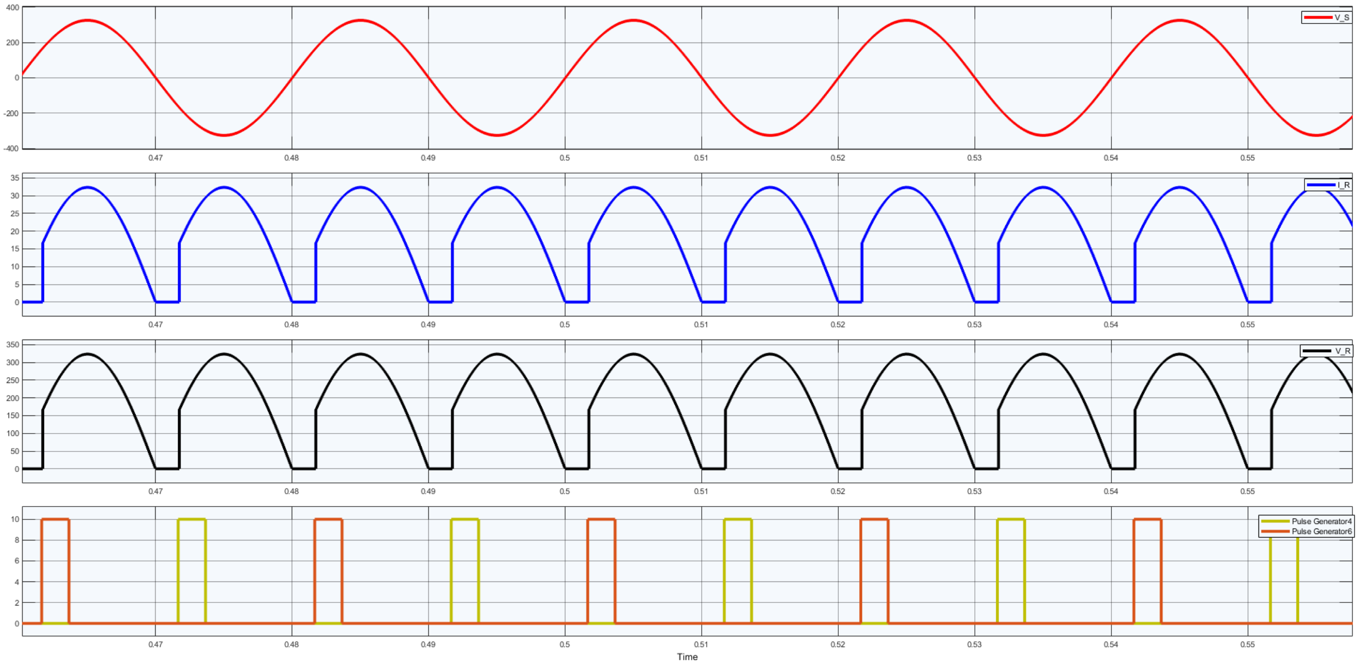

Figure 2.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

2.7 Single Phase Full Wave Controlled Rectifier with RL load

2.7.1 Circuit used for simulation

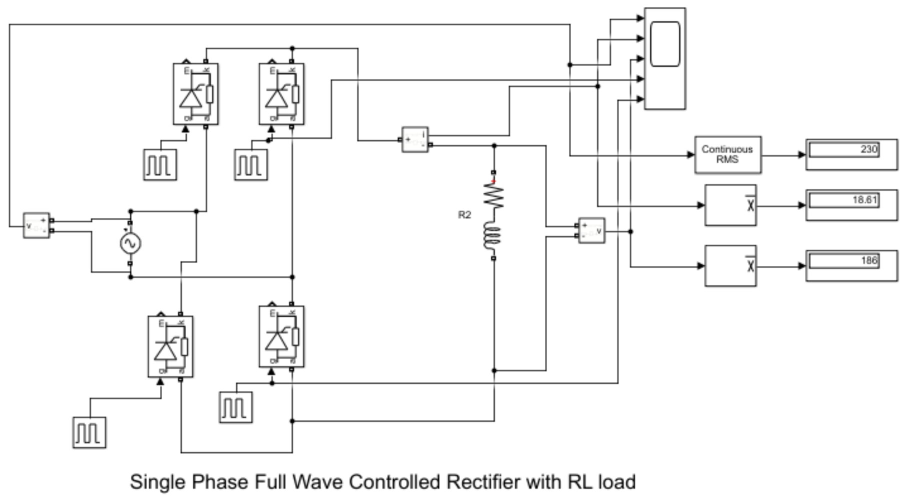

Figure 2.5: Circuit used for simulation

2.7.2 Components Required

Sr. No	Parameters	Ratings	Quantity
1	AC Single Phase Voltage Source	230V (V_{rms})	1
2	Resistor	10Ω	1
3	Inductor	10mH	1
4	Diode	-	1
5	Voltmeter	-	2
6	Ammeter	-	1

Table 2.5: Components for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

2.7.3 Observations

Upon analysis, it has been observed that the simulated output voltage closely approximates the calculated voltage, whereas the simulated output current significantly deviates from the calculated current. The incorporation of the freewheeling diode results in a sudden cessation of output current in the rectifier circuit when the AC supply source drops to zero volts, as the lagging current shifts to flow through the freewheeling diode rather than the rectifier circuit. The efficiency of uncontrolled rectifier with RL load with freewheeling diode is 44.8%.

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	103.53V	103V
Output Average Current ($I_{o,avg}$)	10.35A	10.3A
AC Input Power (P_{AC})	2389.5 (W)	2266 (W)
DC Input Power (P_{DC})	1071.53 (W)	1015 (W)
Efficiency (%)	44.84	44.8

Table 2.6: Observations for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

2.7.4 Resultant Waveforms

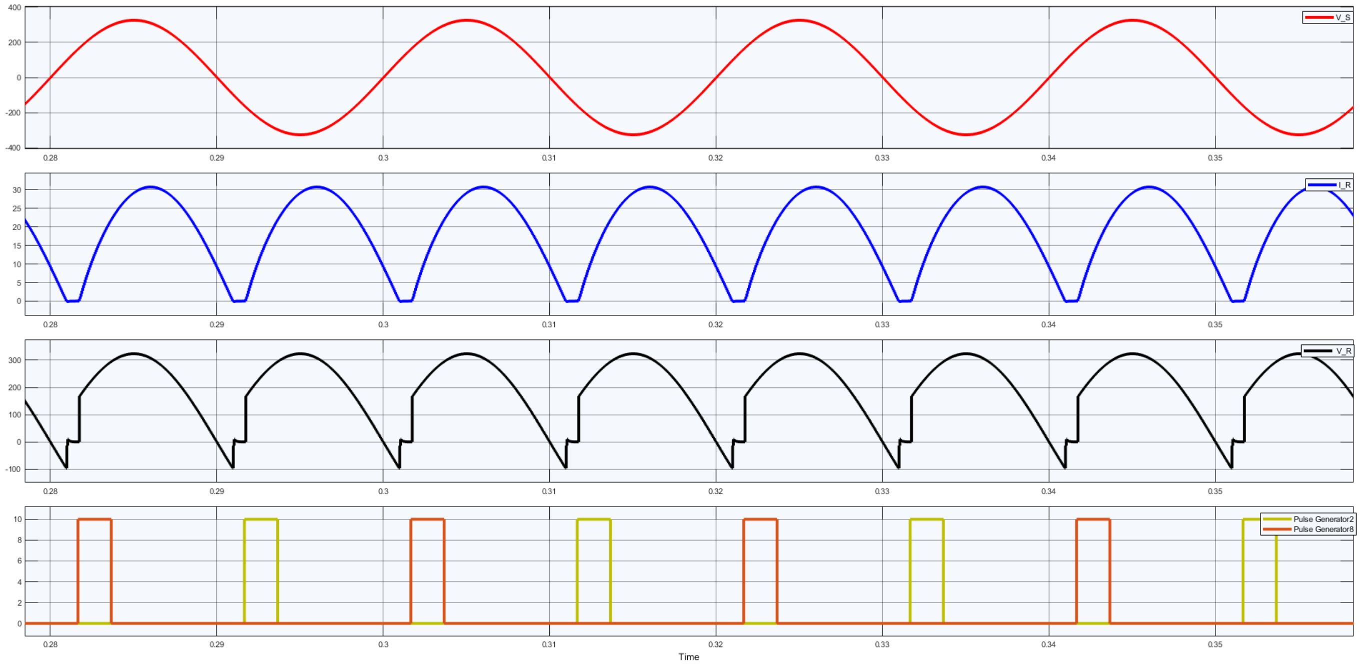

Figure 2.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

2.8 Conclusion

Utilizing the MATLAB Simulink platform, the design of single phase full wave rectifiers with both controlled and uncontrolled R and RL loads was carried out with remarkable success. Voltage and current output waveforms were attained and output parameter values, both theoretically calculated and simulated, were juxtaposed. The full-wave uncontrolled rectifier's efficiencies with R and RL load are measured to be 89.32%. Furthermore, the full-wave controlled rectifier's efficiencies with R and RL load were measured to be 83.41% and 81.33%, respectively.

In conclusion, the full-wave rectifier is a more efficient and practical alternative to the half-wave rectifier because it produces a smoother DC output, has a higher output voltage and lower output ripple. The four diodes used in a bridge configuration ensure that the input AC voltage is rectified, producing a DC output voltage across the output terminals. This process of rectification produces a unidirectional DC output signal that can be used for various applications. The average output voltage and current for full-wave rectifiers with R load can be calculated using the above equations. It is important to note that these calculations are based on idealized conditions and practical circuits may have additional factors that affect their performance.