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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

The process of rectification involves the use of electronic components such as diodes, thyristors, and transistors to convert an AC voltage source into a constant DC voltage supply. The conversion can take on various forms such as half-wave, full-wave, uncontrolled, and fully-controlled rectifiers. In fully-controlled rectifiers, two thyristors are used per half-cycle to regulate the average DC load voltage. The two thyristors are turned on in pairs during each half-cycle, and the switching between the pairs of thyristors is done in such a way as to maintain a constant DC output voltage. The main advantage of fully-controlled rectifiers is their ability to regulate the DC output voltage very precisely.

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

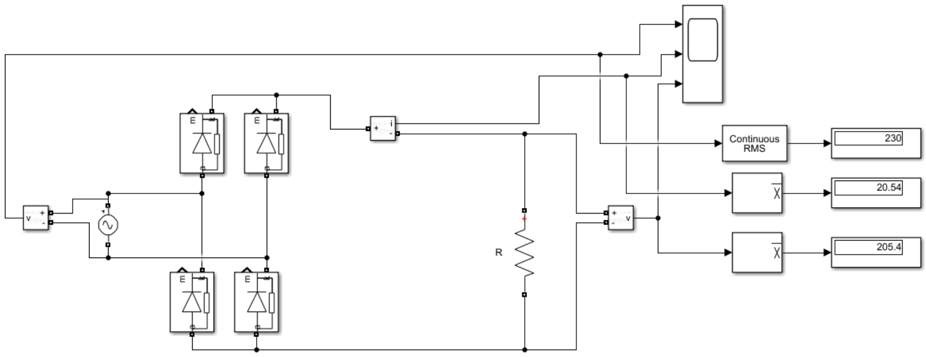


Figure 2.1: Circuit used for simulation

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

The simulation results demonstrate that the theoretical values and the simulated values are almost identical. The circuit has a resistive load, which ensures that the output voltage and current are in phase. The full-wave rectification of the AC signal results in an output DC signal with twice the frequency of the input signal. This high-frequency DC signal can be advantageous in applications that require high-frequency power, such as in motor control circuits.

2.5.4 Resultant Waveforms

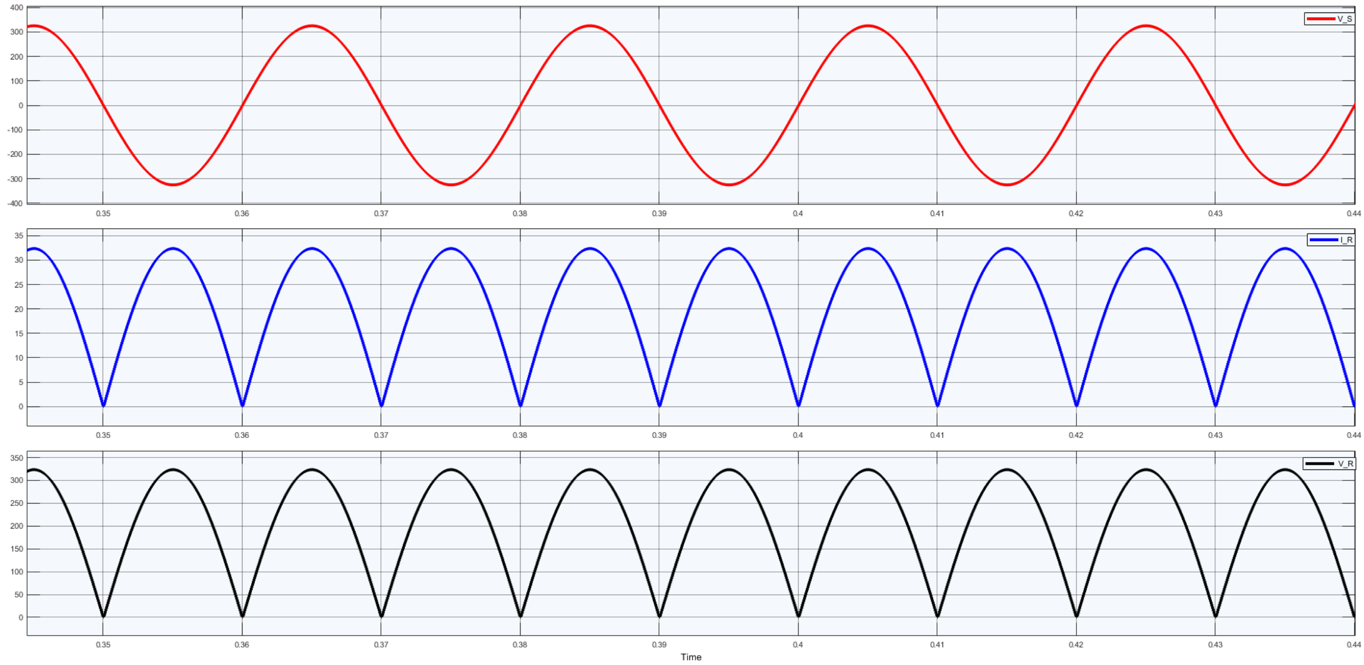
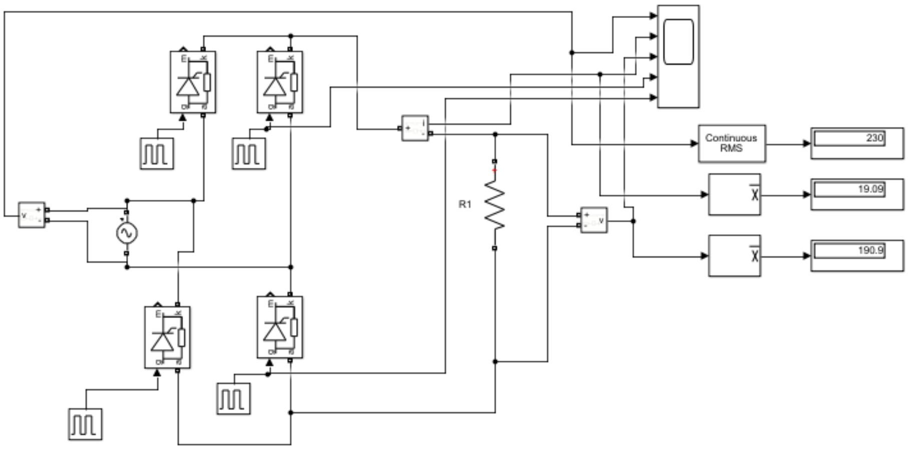


Figure 2.2: Scope Waveforms for Single Phase Full Wave Uncontrolled Rectifier with R load waveforms

2.6 Single Phase Full Wave Controlled Rectifier with R load

2.6.1 Circuit used for simulation



Single Phase Half Wave Uncontrolled Rectifier with RL load

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

The circuit requires firing pulses to generate an output voltage. Once the thyristors are triggered, the circuit acts as a full bridge uncontrolled rectifier. The simulation results show a good agreement with the theoretical values. The load is resistive, so the output voltage and current are in phase. The output DC signal has twice the frequency of the input AC signal, which is due to full-wave rectification. 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

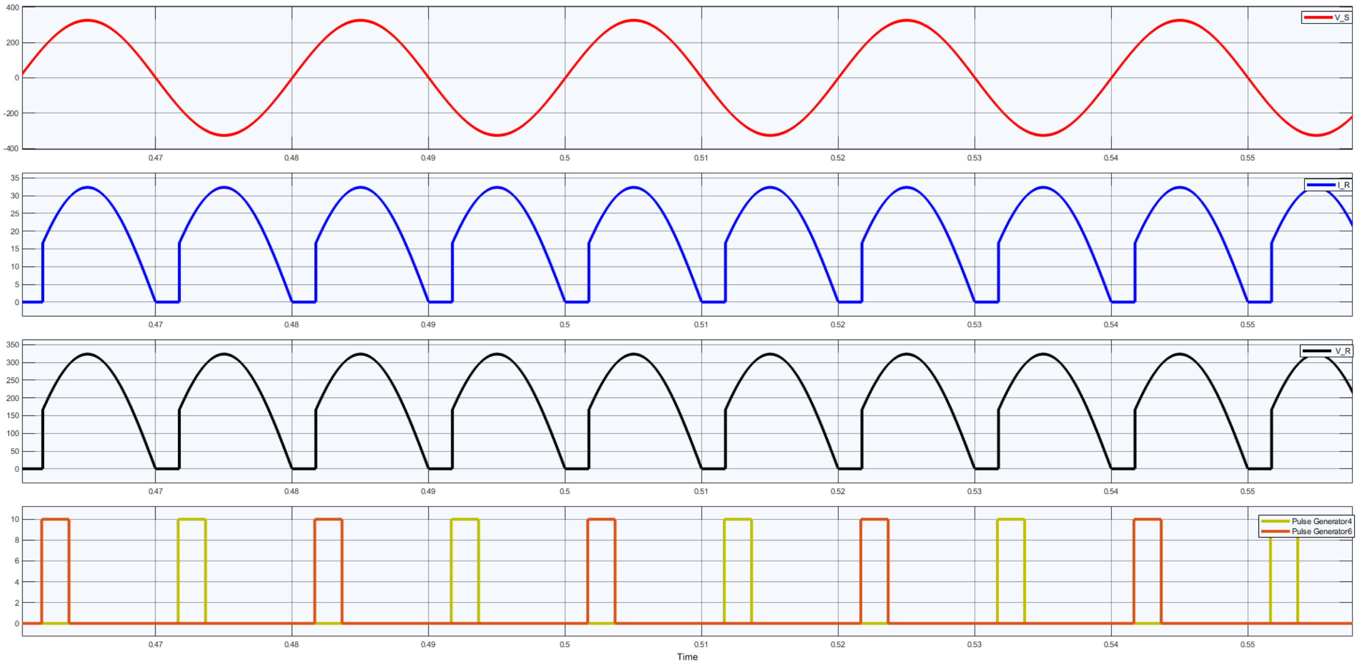


Figure 2.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

2.7 Single Phase Full Wave Controlled Rectifier with RL load

2.7.1 Circuit used for simulation

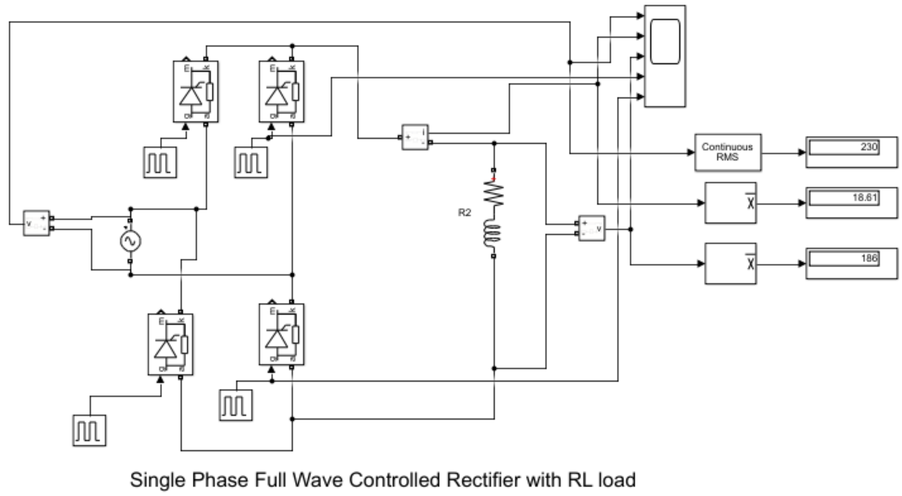


Figure 2.5: Circuit used for simulation

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

Theoretical values are corroborated by simulated values. When gate pulses are given, the full bridge rectifier with RL load provides output that is similar to the half-bridge rectifier with RL load, but with twice the frequency. The output current lags behind the output voltage due to the load's inductive nature, causing a delay in the thyristors' switching off. As a result, the thyristors in the rectifier legs briefly permit the negative half cycle of the AC voltage signal to conduct, leading to a momentary negative output voltage. 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

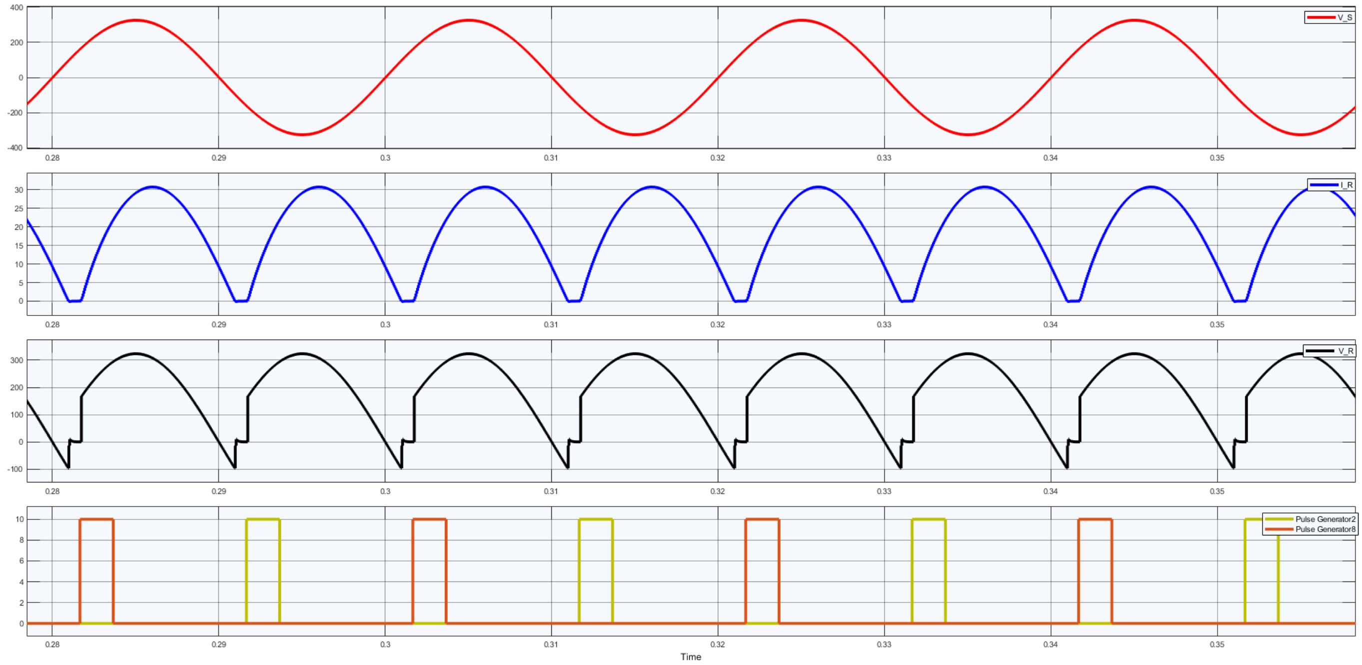


Figure 2.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

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.