Contents

List of Figures

List of Tables

Experiment 1

Half Wave Rectifier

1.1 Aim

Single Phase Half Wave Uncontrolled and Controlled Rectifier

1.2 Software Used

MATLAB R2020a

1.3 Theory

A rectifier is an electronic device that converts AC (alternating current) to DC (direct current). This is typically achieved using diodes, which allow current to flow in only one direction. In the case of a half-wave rectifier, only one half-cycle of an AC voltage waveform is permitted to pass, while the other half-cycle is blocked. By using a single diode, half-wave rectifiers are able to convert AC voltage to DC voltage.

There are two main types of single-phase half-wave rectifiers: uncontrolled and controlled. A single-phase half-wave uncontrolled rectifier is made up of an AC source, a diode, and a load. During the positive half-cycle of the AC source, the diode becomes forward biased and the circuit conducts, while during the negative half-cycle, the diode becomes reverse biased and blocks current. This type of rectifier is simple and inexpensive to construct, but it has limited applications due to its inability to control the DC output.

A single-phase half-wave controlled rectifier, on the other hand, includes a thyristor or SCR (Silicon Controlled Rectifier) in addition to an AC source and a load. The key difference between a controlled rectifier and an uncontrolled rectifier is the presence of the thyristor/SCR, which conducts only when gate pulses at a firing angle α are applied to it. Once the thyristor/SCR conducts, it continues to conduct even if the voltage across it becomes negative until the load current falls below the holding current level. The SCR automatically turns off when its voltage is reverse biased for a period longer than the SCR turn off time. This type of rectifier allows for better control of the DC output and is used in many applications, including power supplies, battery chargers, and DC motor drives.

In summary, rectifiers are important electronic devices that convert AC to DC voltage, and half-wave rectifiers are a type of rectifier that allows only one half-cycle of an AC voltage waveform to pass. While single-phase half-wave uncontrolled rectifiers are simple and inexpensive, they have limited applications due to their inability to control the DC output. Single-phase half-wave controlled rectifiers, which include a thyristor/SCR, allow for better control of the DC output and are used in many applications.

1.4 Theoretical Calculations

The theoretical calculations for a half-wave rectifier with an R load are given by the formulas:

$$V_{o,avg} = V_{phase}\sqrt{2(1+cos\alpha)2\pi} = V_m(1+cos\alpha)2\pi$$

$$I_{o,avg} = V_oR$$

In uncontrolled rectifiers, $\alpha = 0$, and the thyristor is replaced with a diode. For a single-phase half-wave uncontrolled rectifier with an RMS voltage of 230V and a resistive load of 10Ω, the output voltage is 103.53V, and the output current is 10.53A.

For a single-phase half-wave controlled rectifier with an RMS voltage of 230V and a resistive load of 10Ω and a firing angle of $\alpha = 30\circ$, the output voltage is 96.6V, and the output current is 9.66A.

1.5 Single Phase Half Wave Uncontrolled Rectifier with R load

1.5.1 Circuit used for simulation

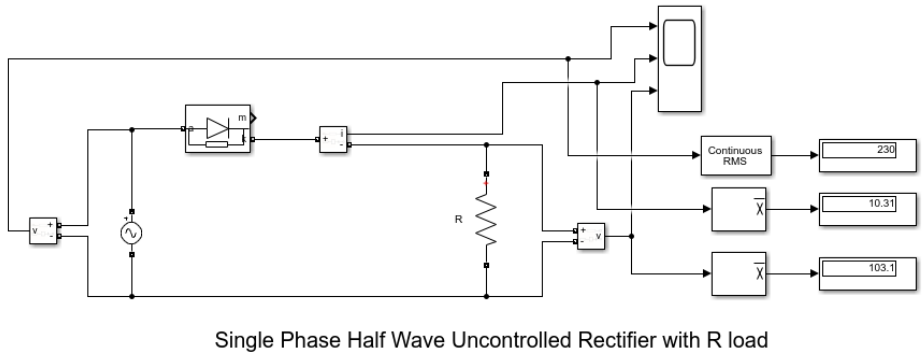


Figure 1.1: Circuit used for simulation

1.5.2 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 1.1: Components for Single Phase Half Wave Uncontrolled Rectifier with R load

1.5.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	103.53V	103.1V
Output Average Current ($I_{o,avg}$)	10.35A	10.31A
AC Input Power (P_{AC})	2389.5 W	2372 W
DC Input Power (P_{DC})	1071.53 W	1063 W
Efficiency (%)	44.84	44.84

Table 1.2: Observations for Single Phase Half Wave Uncontrolled Rectifier with R load

Upon observation, it is discerned that the simulated values coincide precisely with the corresponding theoretical values. Owing to the resistive nature of the load, the output current is in phase with the output voltage. Analysis of the output voltage and current waveforms reveals that the diode conducts during the positive half-cycle of the AC source, while it becomes reverse-biased during the negative half-cycle.

1.5.4 Resultant Waveforms

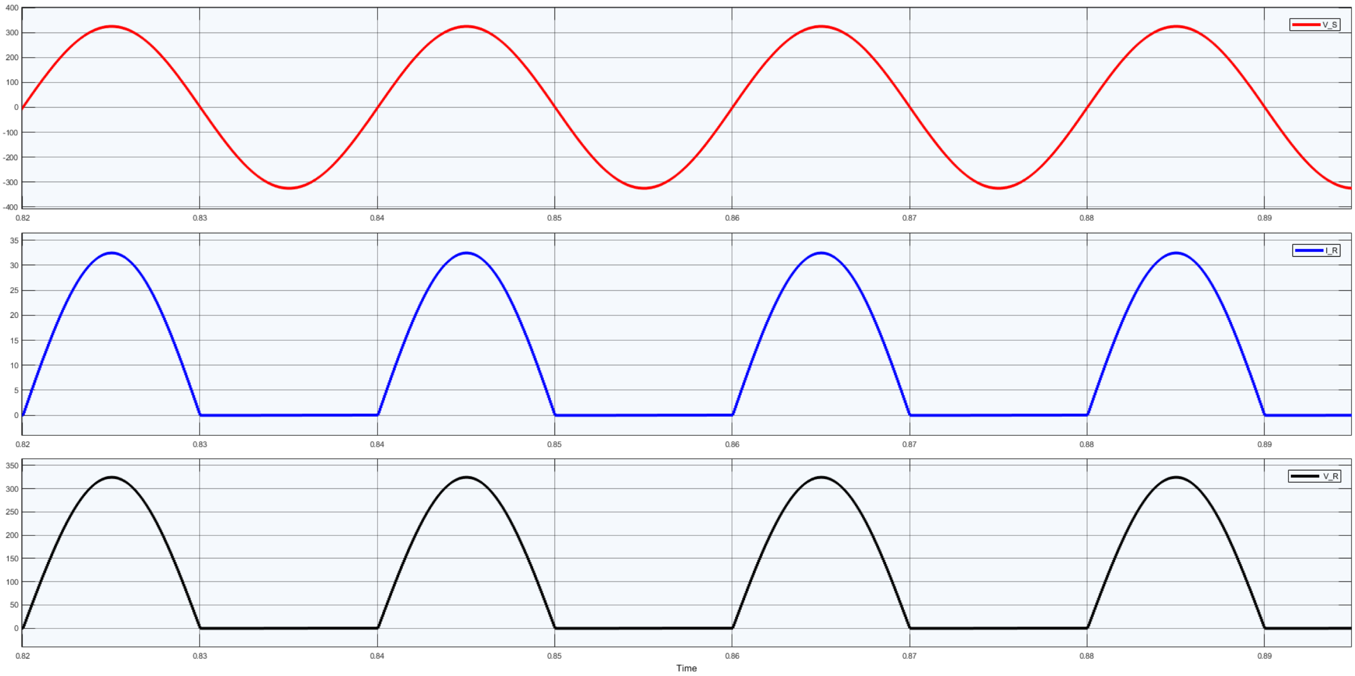


Figure 1.2: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with R load waveforms

1.6 Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.1 Circuit used for simulation

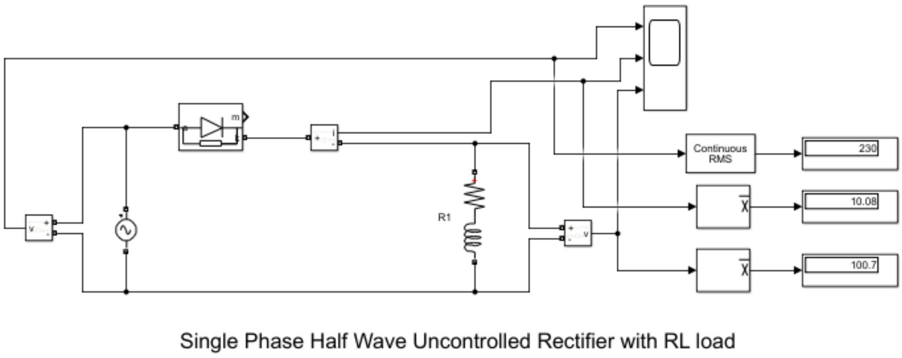


Figure 1.3: Circuit used for simulation

1.6.2 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 1.3: Components for Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	103.53V	100.8V
Output Average Current ($I_{o,avg}$)	10.35A	10.08A
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 1.4: Observations for Single Phase Half Wave Uncontrolled Rectifier with RL load

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%.

1.6.4 Resultant Waveforms

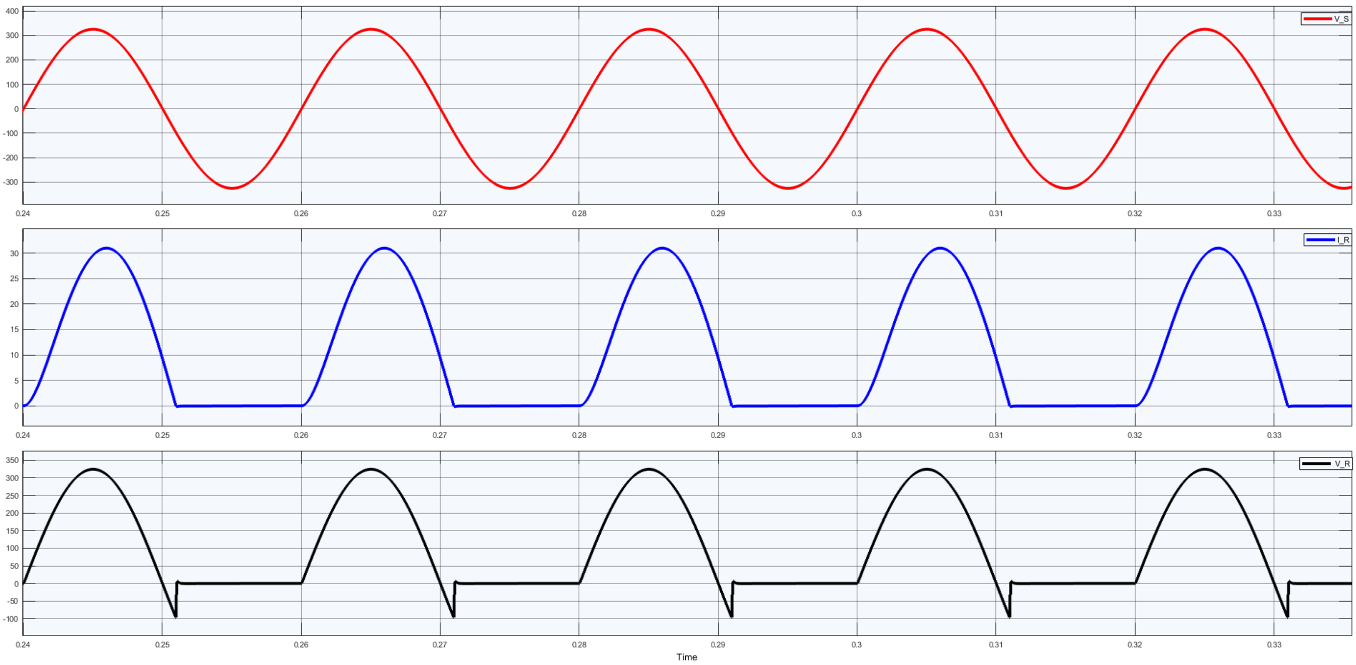
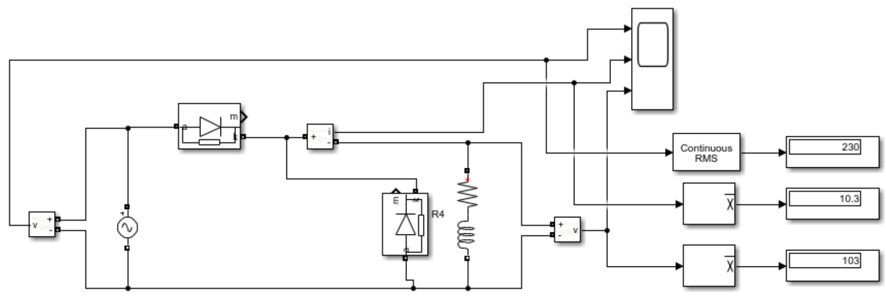


Figure 1.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

1.7 Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.7.1 Circuit used for simulation



Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

Figure 1.5: Circuit used for simulation

1.7.2 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 1.5: Components for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.7.3 Observations

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

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%.

1.7.4 Resultant Waveforms

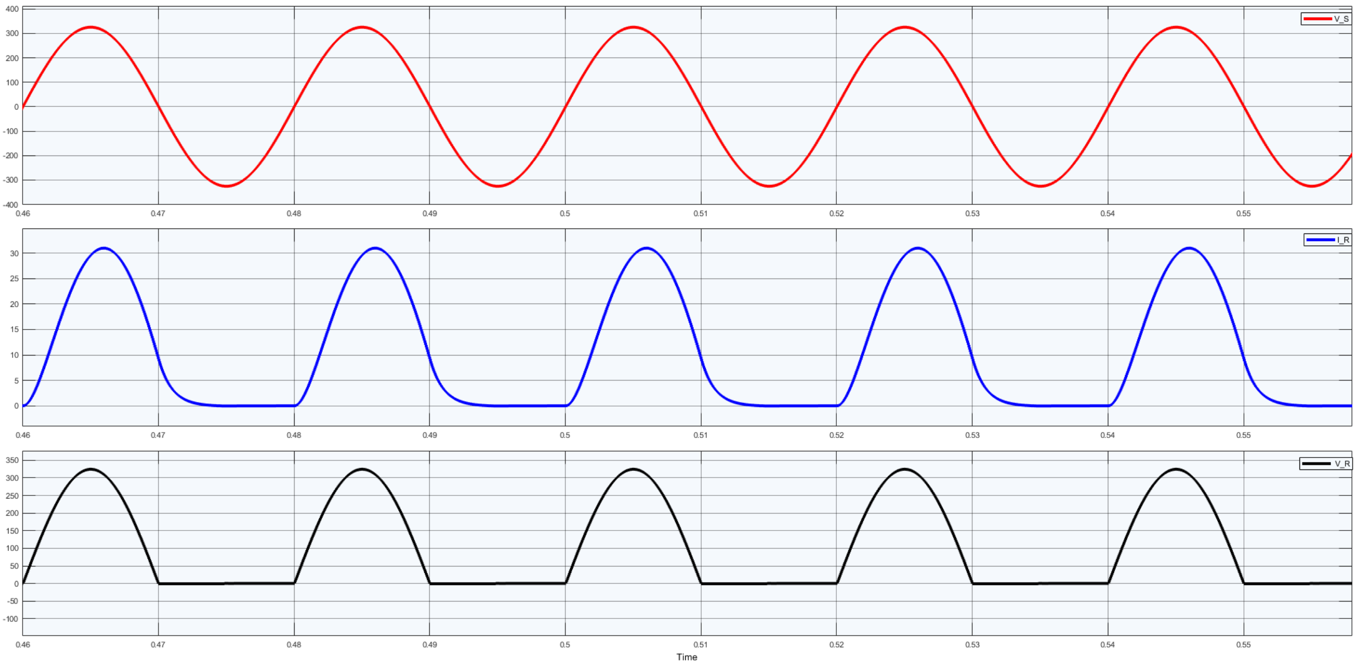


Figure 1.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.8 Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.1 Circuit used for simulation

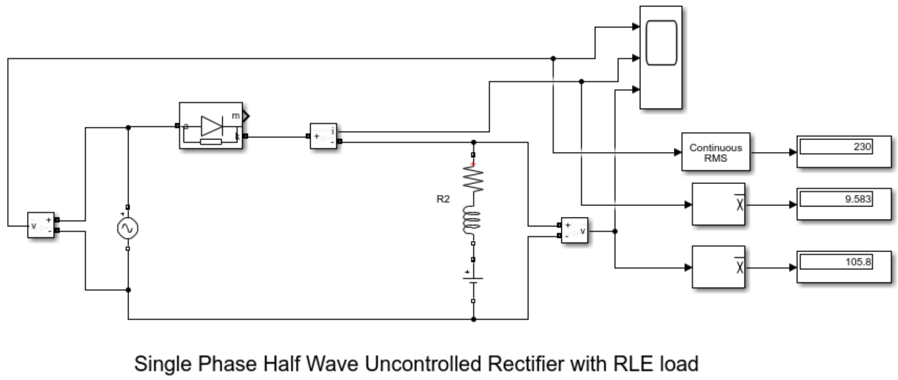


Figure 1.7: Circuit used for simulation

1.8.2 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	DC Source	100V	1
6	Voltmeter	-	2
7	Ammeter	-	1

Table 1.7: Components for Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	103.53V	105.8V
Output Average Current ($I_{o,avg}$)	10.35A	9.583A
AC Input Power (P_{AC})	2389.5 (W)	1290 (W)
DC Input Power (P_{DC})	1071.53 (W)	875.8 (W)
Efficiency (%)	44.84	67.88

Table 1.8: Observations for Single Phase Half Wave Uncontrolled Rectifier with RLE load

Upon observation of the simulation, it has been determined that the output voltage waveform of the single-phase half-wave rectifier mimics that of the RL load. However, it differs in that it always remains positive, and once the output current reaches zero, the diode ceases to conduct, and the output voltage becomes stabilized at 100V. The efficiency of uncontrolled rectifier with RLE load is 67.88

1.8.4 Resultant Waveforms

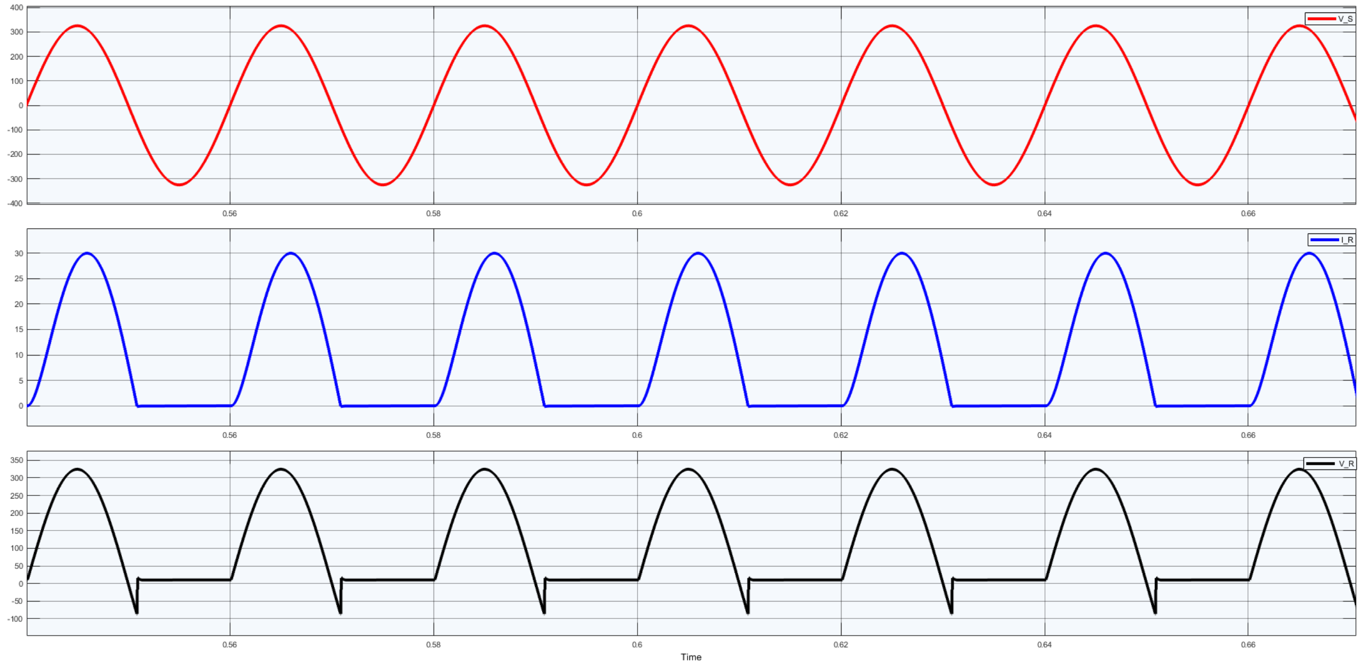


Figure 1.8: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RLE load waveforms

1.9 Single Phase Half Wave Controlled Rectifier with R load

1.9.1 Circuit used for simulation

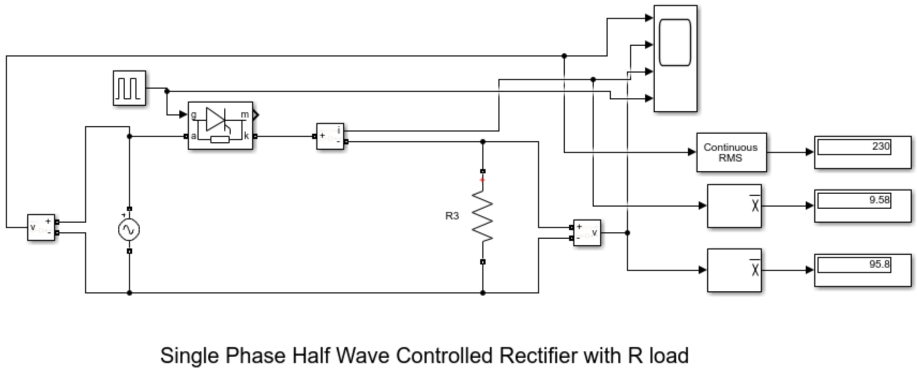


Figure 1.9: Circuit used for simulation (Firing Angle = 30°)

1.9.2 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
7	Thyristor	-	1

Table 1.9: Components for Single Phase Half Wave Controlled Rectifier with R load

1.9.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	96.6V	96.28V
Output Average Current ($I_{o,avg}$)	9.66A	9.628A
AC Input Power (P_{AC})	2214.44 (W)	2214 (W)
DC Input Power (P_{DC})	926.98 (W)	926.9 (W)
Efficiency (%)	41.86	41.86

Table 1.10: Observations for Single Phase Half Wave Controlled Rectifier with R load

The simulated values align closely with the theoretical values, indicating a high level of accuracy. Since the load is resistive, the output current is in phase with the output voltage. Additionally, it is evident that the application of the gate pulse to the thyristor initiates the rise of output voltage and current, which closely resembles the output waveforms of the uncontrolled rectifier. The efficiency of controlled rectifier with R load is 41.86

1.9.4 Resultant Waveforms

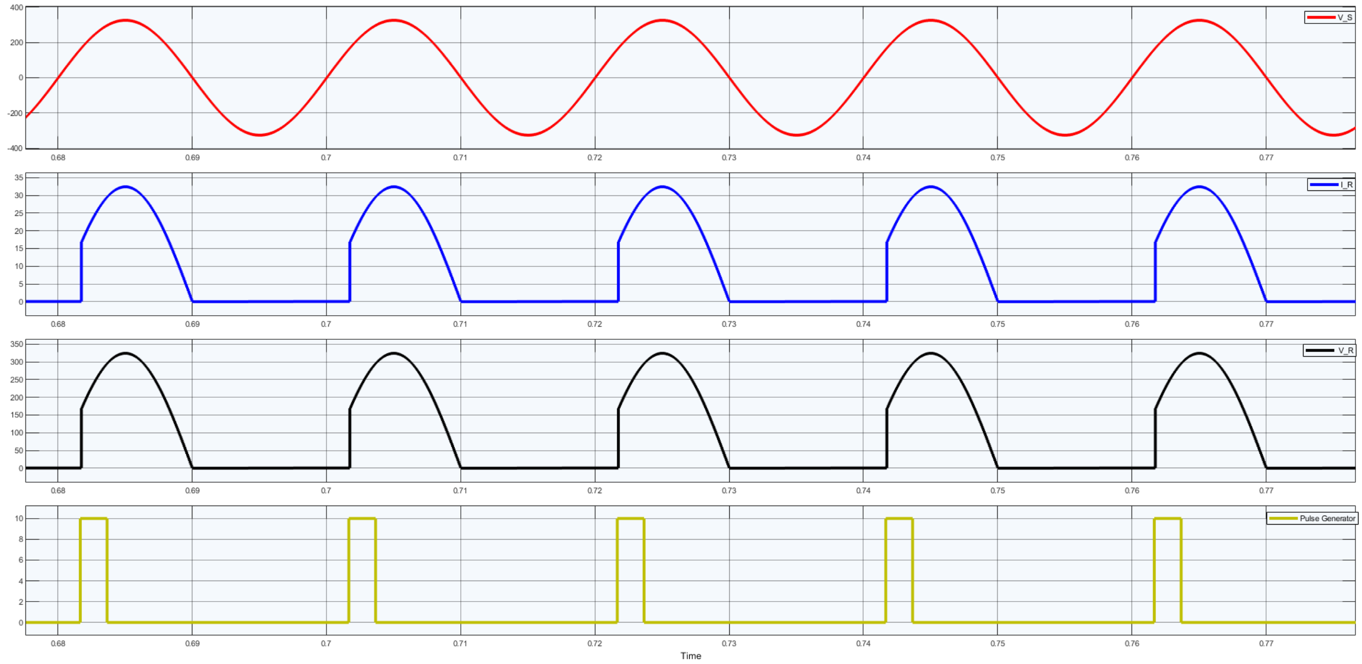


Figure 1.10: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with R load

1.10 Single Phase Half Wave Controlled Rectifier with RL load

1.10.1 Circuit used for simulation

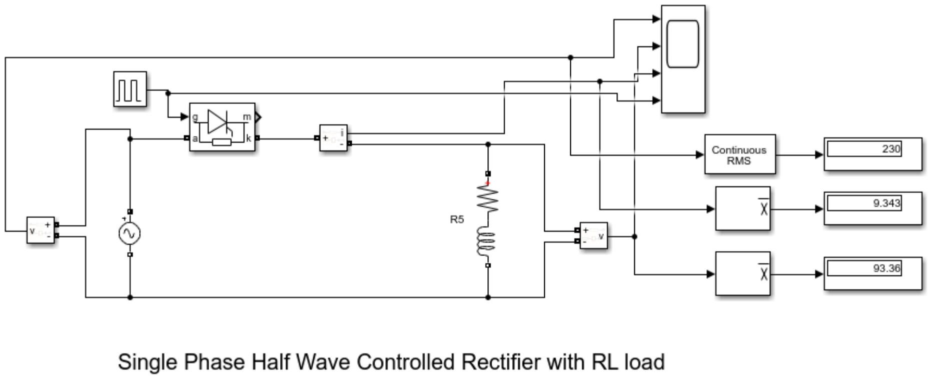


Figure 1.11: Circuit used for simulation (Firing Angle = 30°))

1.10.2 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
7	Thyristor	-	1

Table 1.11: Components for Single Phase Half Wave Controlled Rectifier with RL load

1.10.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	96.6V	93.96V
Output Average Current ($I_{o,avg}$)	9.66A	9.396A
AC Input Power (P_{AC})	2214.44 (W)	2161 (W)
DC Input Power (P_{DC})	926.98 (W)	882.8 (W)
Efficiency (%)	41.86	40.85

Table 1.12: Observations for Single Phase Half Wave Controlled Rectifier with RL load

Upon providing the firing gate pulse to the thyristor, it is observed that the circuit begins conducting. Due to the presence of an inductive component in the load, the output current lags behind the output voltage, leading to the conduction of the diode until the output current approaches zero. Consequently, the output voltage becomes negative during this duration. After the output current falls to zero, the thyristor ceases conduction, and the output voltage returns to zero as well. The efficiency of controlled rectifier with RL load is 40.85%.

1.10.4 Resultant Waveforms

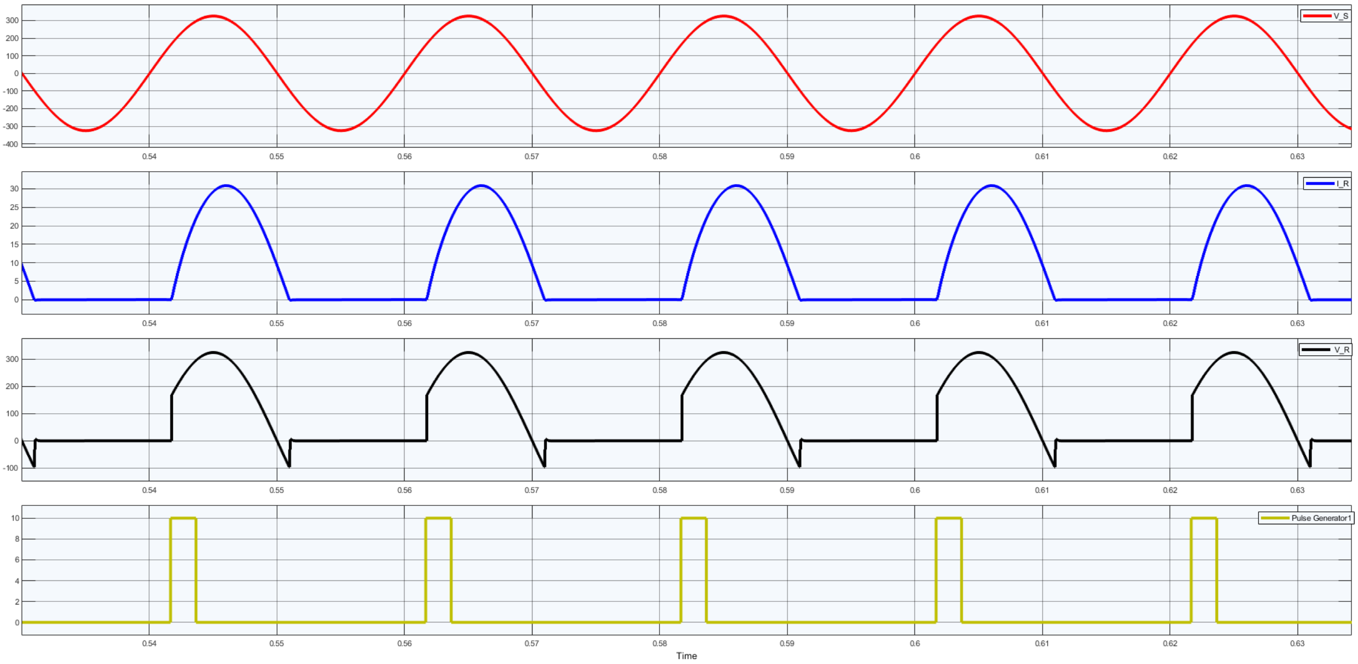
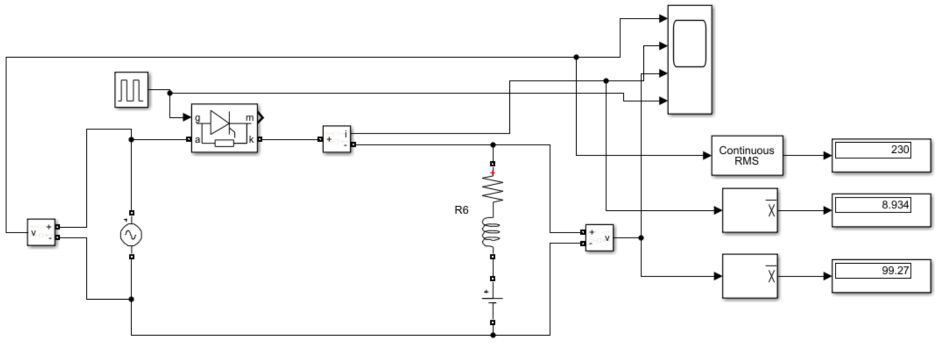


Figure 1.12: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RL load

1.11 Single Phase Half Wave Controlled Rectifier with RLE load

1.11.1 Circuit used for simulation



Single Phase Half Wave Controlled Rectifier with RLE load

Figure 1.13: Circuit used for simulation

1.11.2 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
7	Thyristor	-	1
8	DC Source	100V	1

Table 1.13: Components for Single Phase Half Wave Controlled Rectifier with RLE load

1.11.3 Observations

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	96.66V	155.1V
Output Average Current ($I_{o,avg}$)	9.66A	5.507A
AC Input Power (P_{AC})	2214.44 (W)	1266 (W)
DC Input Power (P_{DC})	926.98 (W)	853.9 (W)
Efficiency (%)	41.86	67.43

Table 1.14: Observations for Single Phase Half Wave Controlled Rectifier with RLE load

Upon giving the firing gate pulse to the thyristor, the circuit is observed to initiate conduction. Once the circuit initiates conduction, its characteristics resemble those of an uncontrolled half wave rectifier with RLE load. The efficiency of controlled rectifier with RL load is 67.43%.

1.11.4 Resultant Waveforms

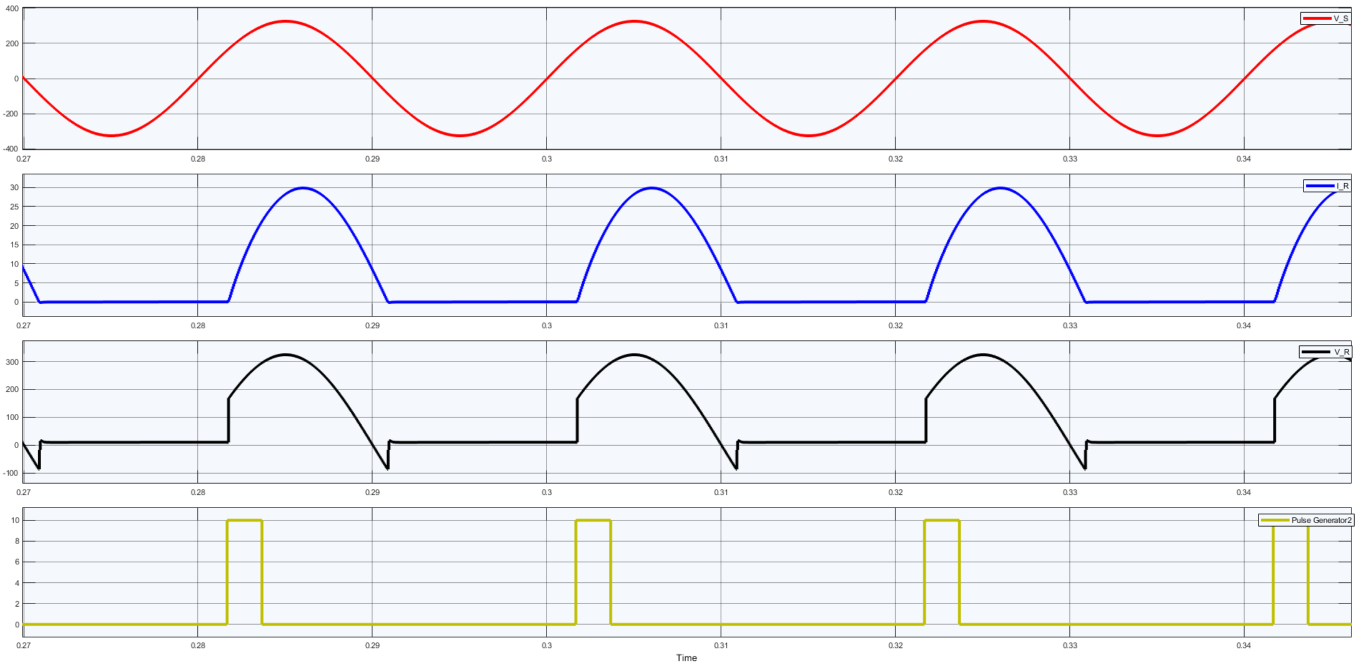


Figure 1.14: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RLE load

1.12 Conclusion

In this experiment, the implementation of single-phase half-wave rectifiers, both controlled and uncontrolled, with resistive, inductive, resistive-inductive and resistive-inductive with freewheeling diode loads were successfully accomplished using MATLAB's Simulink. The output waveforms for voltage and current were obtained in each case, and a comparative analysis between theoretically calculated and simulated output parameters was also performed.

Efficiency measurements were conducted on the half-wave uncontrolled rectifiers with R load, RL load, RL load with freewheeling diode, and RLE load, yielding efficiency values of 44.84%, 43.84%, 44.8%, and 67.88%, respectively. Thus, it can be concluded that the half-wave uncontrolled rectifier with RLE load has the maximum efficiency of 67.88%. Similarly, the efficiency values of half-wave controlled rectifiers with R load, RL load, and RLE load were measured as 41.86%, 40.85%, 44.8%, and 67.43%, respectively. Thus, the half-wave controlled rectifier with RLE load has the maximum efficiency of 67.43%.

Overall, the simulation results provided a clear indication of the efficiency of each type of rectifier with different loads. These results can be used as a guide to select the appropriate type of rectifier for a specific load in real-world applications. The implementation of these rectifiers has great practical significance in power electronics and can be used in a variety of applications, such as power supplies, motor drives, and lighting systems.