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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 single phase half wave uncontrolled rectifier circuit consists of an AC source, a diode, and a load. During the positive half cycle of the AC voltage, the diode is forward biased and conducts, allowing the current to flow through the load. During the negative half cycle, the diode becomes reverse biased and blocks the current flow. The output voltage of the circuit is unidirectional and pulsating. This circuit is used in applications where a low cost and simple design are important factors, such as in power supplies for household appliances.

1.4 Theoretical Calculations

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

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

$$I_{o,avg} = V_o R$$

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

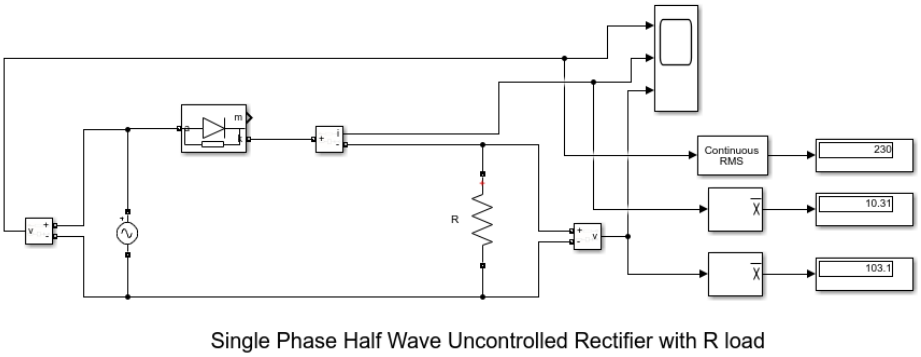

Figure 1.1: Circuit used for simulation

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	2636 W
DC Input Power (P_{DC})	1071.53 W	1063 W
Efficiency (%)	44.84	40.34

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

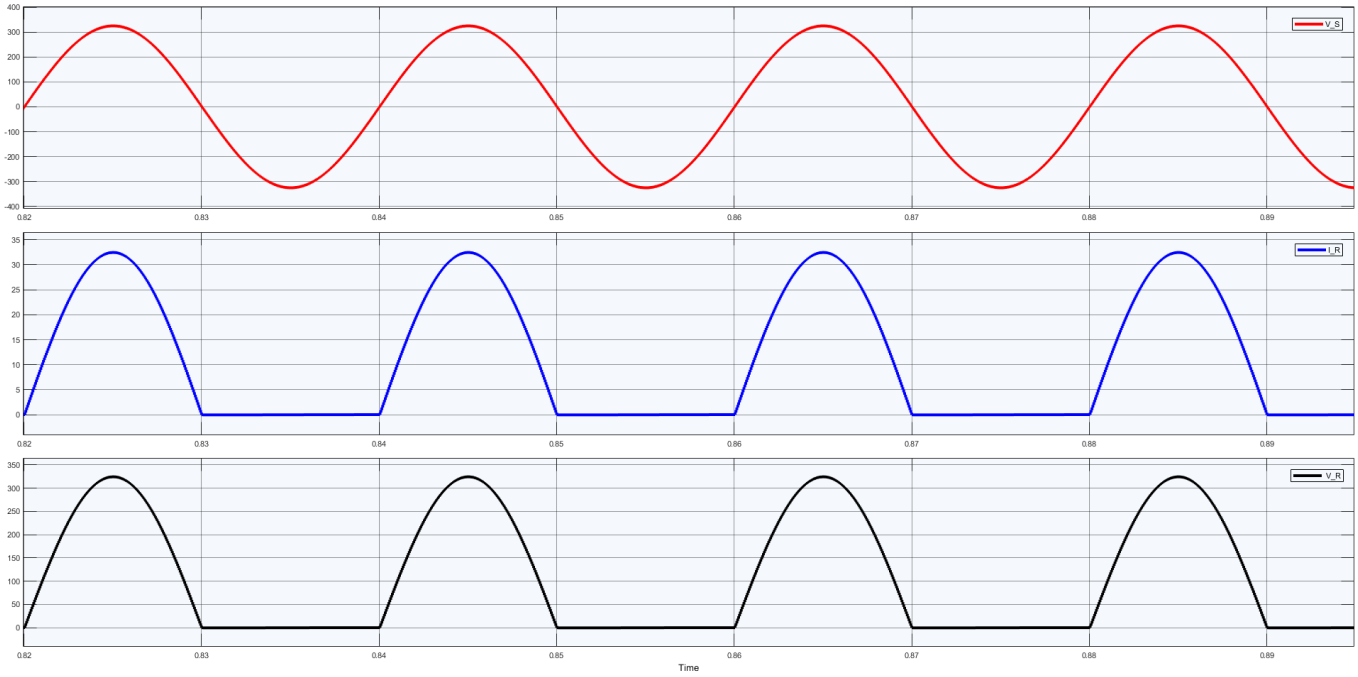

Figure 1.2: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with R load waveforms

1.6 Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.1 Circuit used for simulation

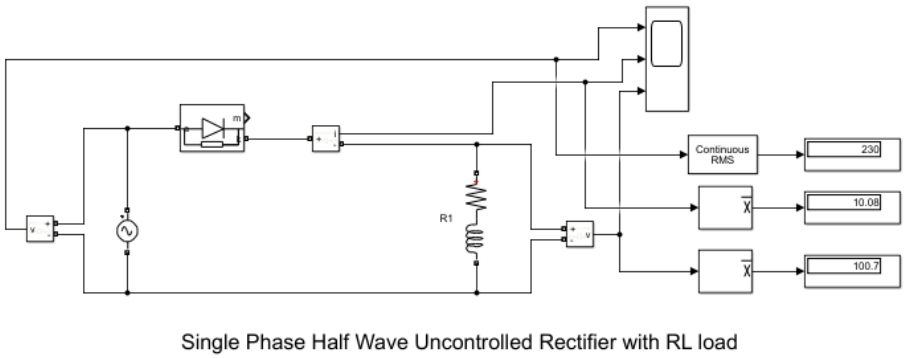

Figure 1.3: Circuit used for simulation

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	100.7V
Output Average Current ($I_{o,avg}$)	10.35A	10.08A
AC Input Power (P_{AC})	2389.5 (W)	2435 (W)
DC Input Power (P_{DC})	1071.53 (W)	1015 (W)
Efficiency (%)	44.84	41.66

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 41.66%.

1.6.4 Resultant Waveforms

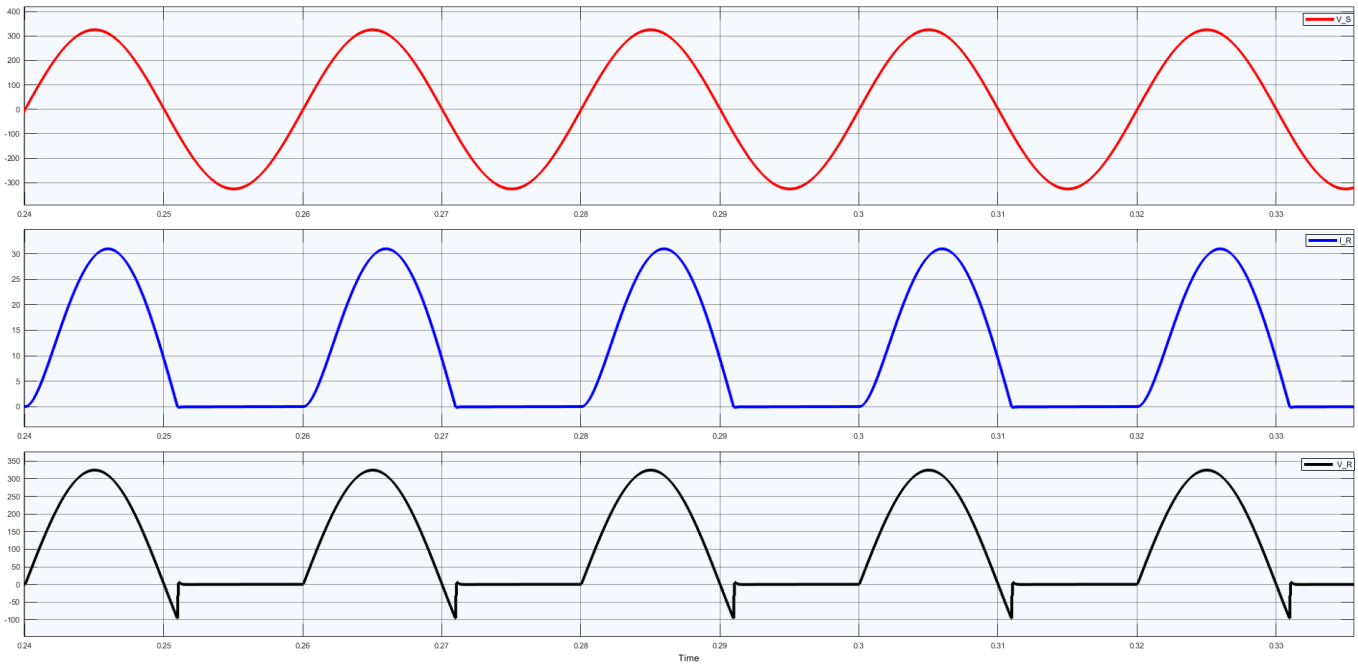

Figure 1.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

1.7.1 Circuit used for simulation

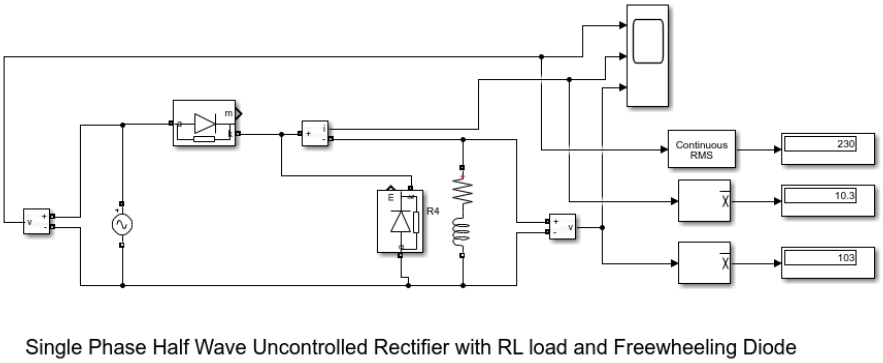

Figure 1.5: Circuit used for simulation

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)	2404 (W)
DC Input Power (P_{DC})	1071.53 (W)	1061 (W)
Efficiency (%)	44.84	44.13

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 44.13%.

1.7.4 Resultant Waveforms

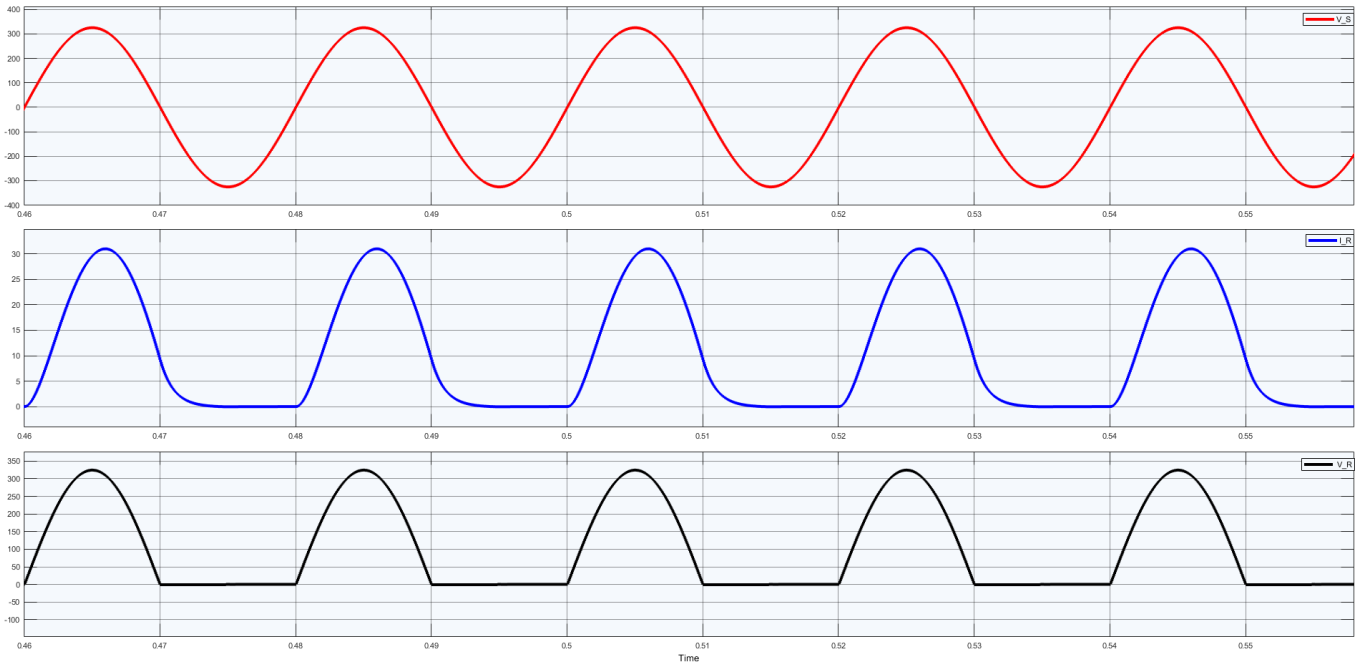

Figure 1.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.8 Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.1 Circuit used for simulation

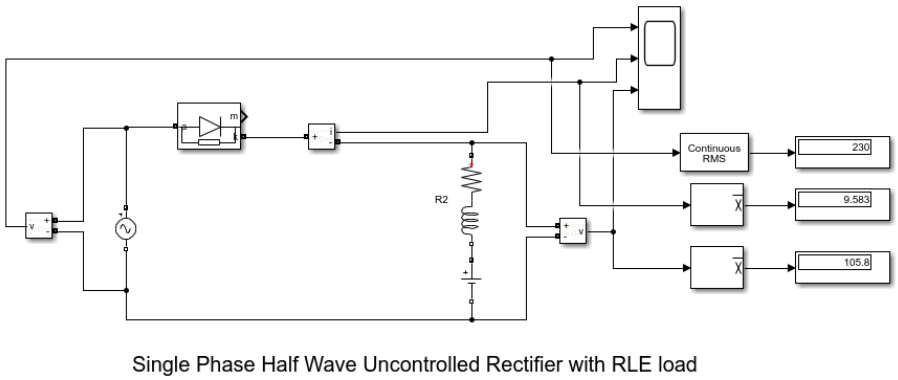

Figure 1.7: Circuit used for simulation

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

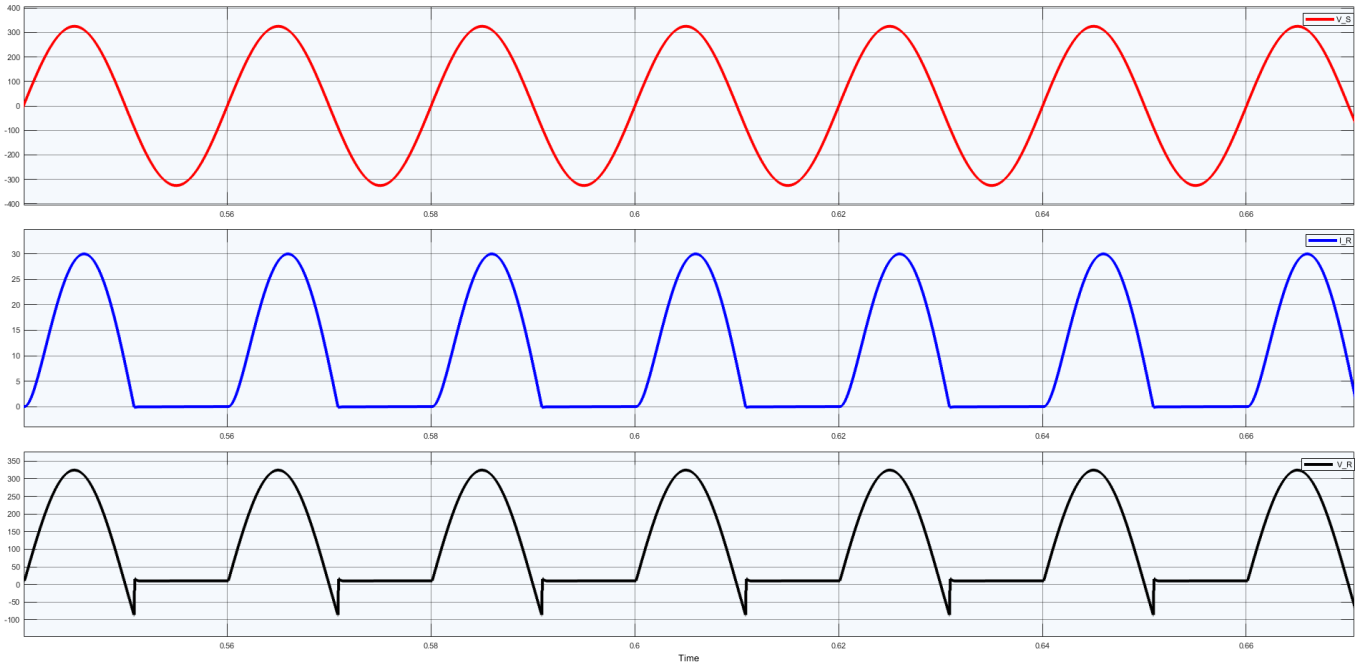

Figure 1.8: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RLE load waveforms

1.9 Single Phase Half Wave Controlled Rectifier with R load

1.9.1 Circuit used for simulation

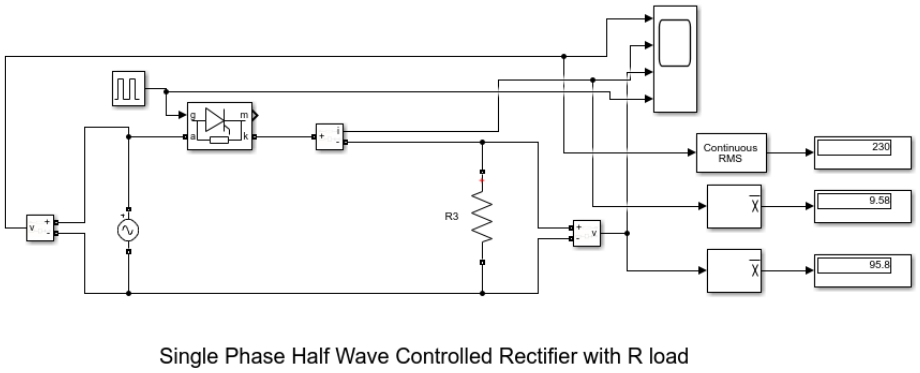

Figure 1.9: Circuit used for simulation (Firing Angle = 30°)

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	95.8V
Output Average Current ($I_{o,avg}$)	9.66A	9.58A
AC Input Power (P_{AC})	2214.44 (W)	2553 (W)
DC Input Power (P_{DC})	926.98 (W)	917.7 (W)
Efficiency (%)	41.86	35.95

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 35.95%.

1.9.4 Resultant Waveforms

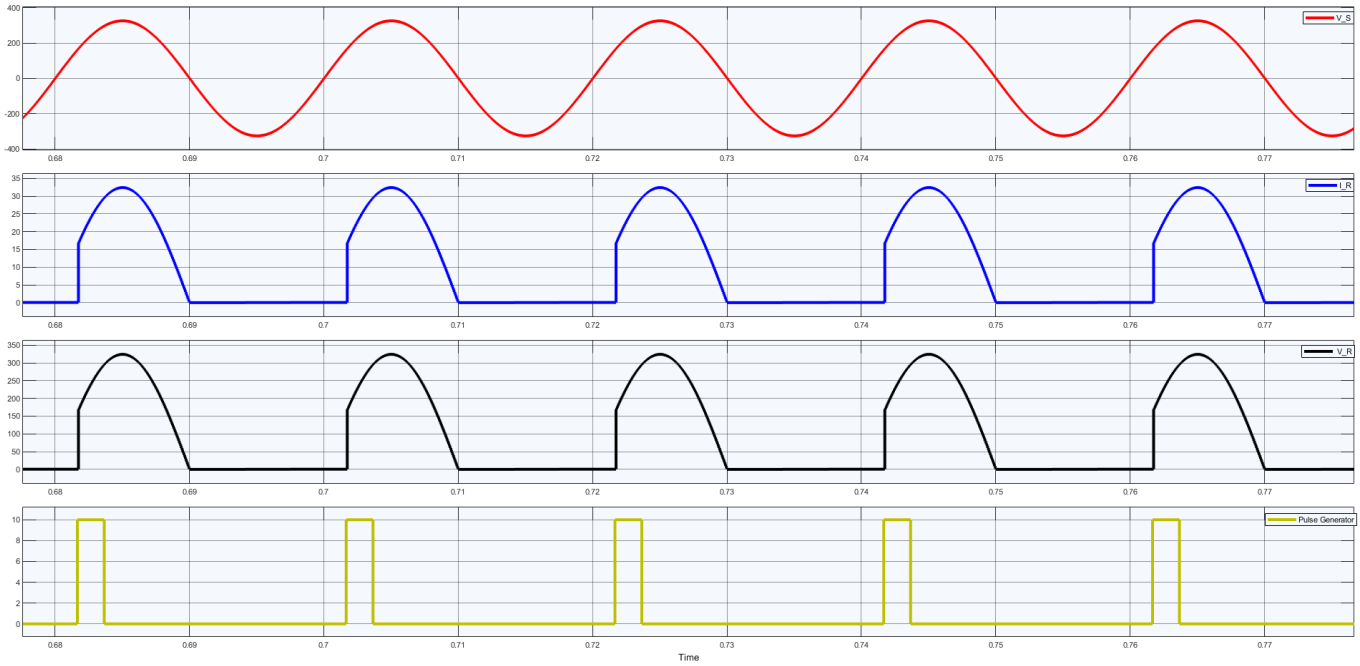

Figure 1.10: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with R load

1.10 Single Phase Half Wave Controlled Rectifier with RL load

1.10.1 Circuit used for simulation

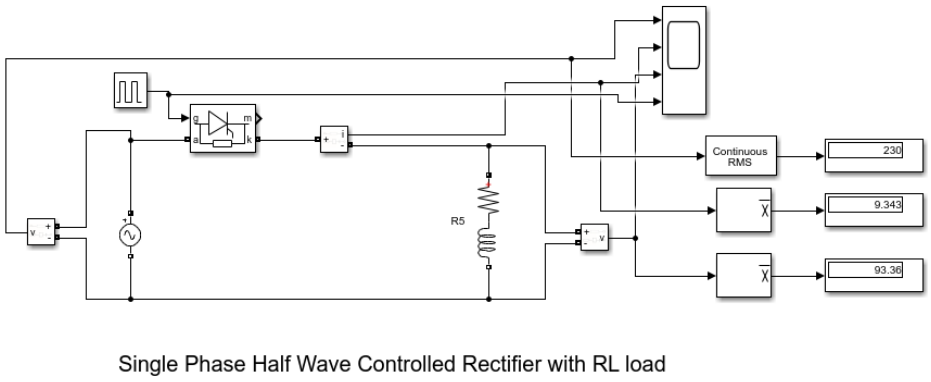

Figure 1.11: Circuit used for simulation (Firing Angle = 30°))

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	93.36V
Output Average Current ($I_{o,avg}$)	9.66A	9.343A
AC Input Power (P_{AC})	2214.44 (W)	2296 (W)
DC Input Power (P_{DC})	926.98 (W)	872.3 (W)
Efficiency (%)	41.86	37.99

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 37.99%.

1.10.4 Resultant Waveforms

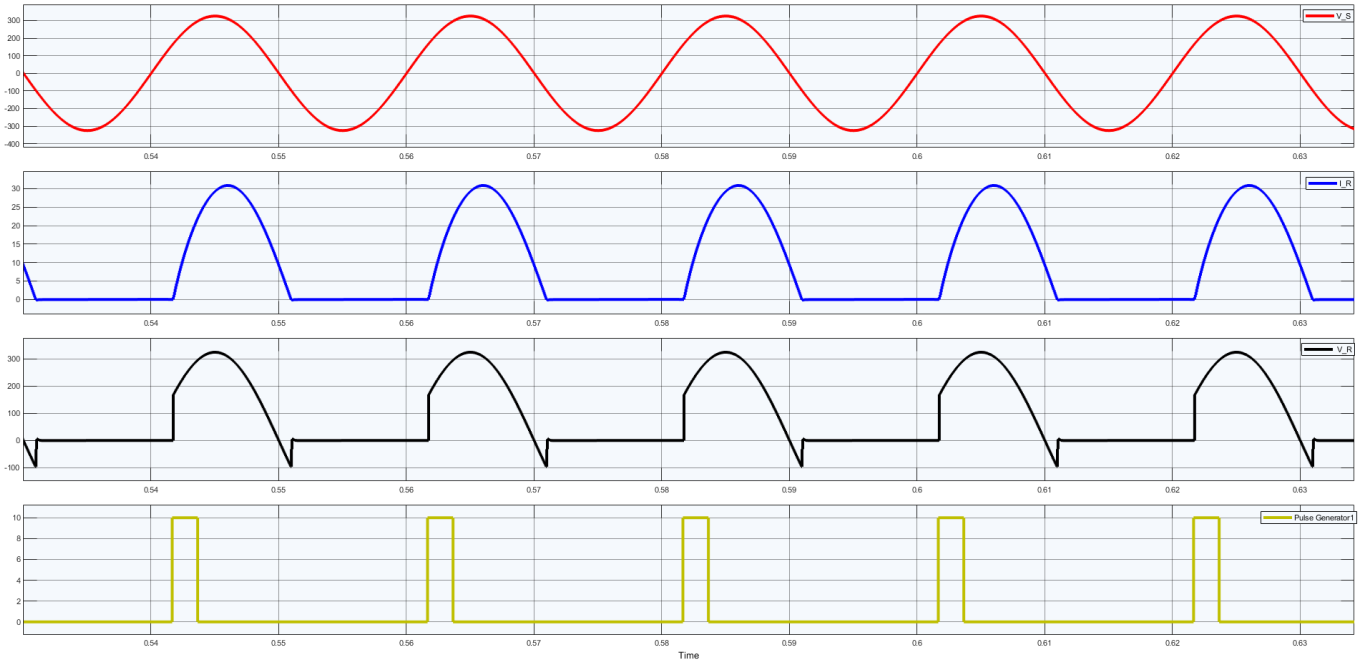

Figure 1.12: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RL load

1.11 Single Phase Half Wave Controlled Rectifier with RLE load

1.11.1 Circuit used for simulation

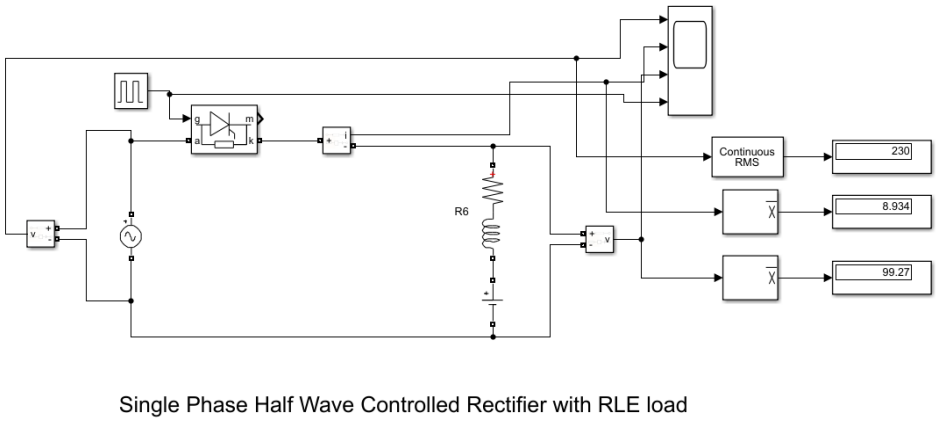

Figure 1.13: Circuit used for simulation

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	154.8V
Output Average Current ($I_{o,avg}$)	9.66A	5.483A
AC Input Power (P_{AC})	2214.44 (W)	1459 (W)
DC Input Power (P_{DC})	926.98 (W)	848.6 (W)
Efficiency (%)	41.86	58.18

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 58.18%.

1.11.4 Resultant Waveforms

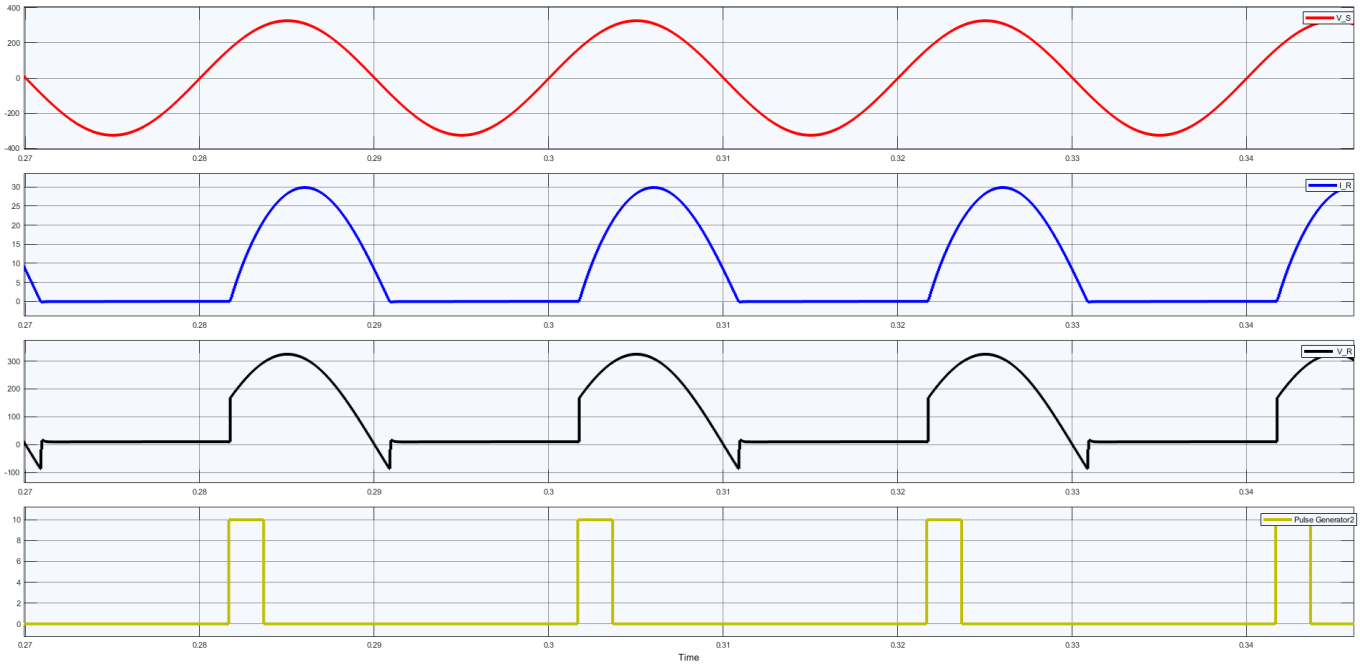

Figure 1.14: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RLE load

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.