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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

In a half wave rectifier, the diode is used to rectify the AC voltage into pulsating DC voltage. The diode is connected in series with the load, which allows only the positive half cycle of the AC waveform to pass through. During the negative half cycle, the diode becomes reverse biased and blocks the current flow. The output voltage of the rectifier is a pulsating DC voltage with only one polarity, which contains a large amount of ripple. The peak-to-peak voltage ripple of the output voltage is equal to the input voltage multiplied by 0.707. The half wave rectifier is simple and inexpensive, but it has a low efficiency and high ripple factor, which limits its applications to low-power and low-cost circuits

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

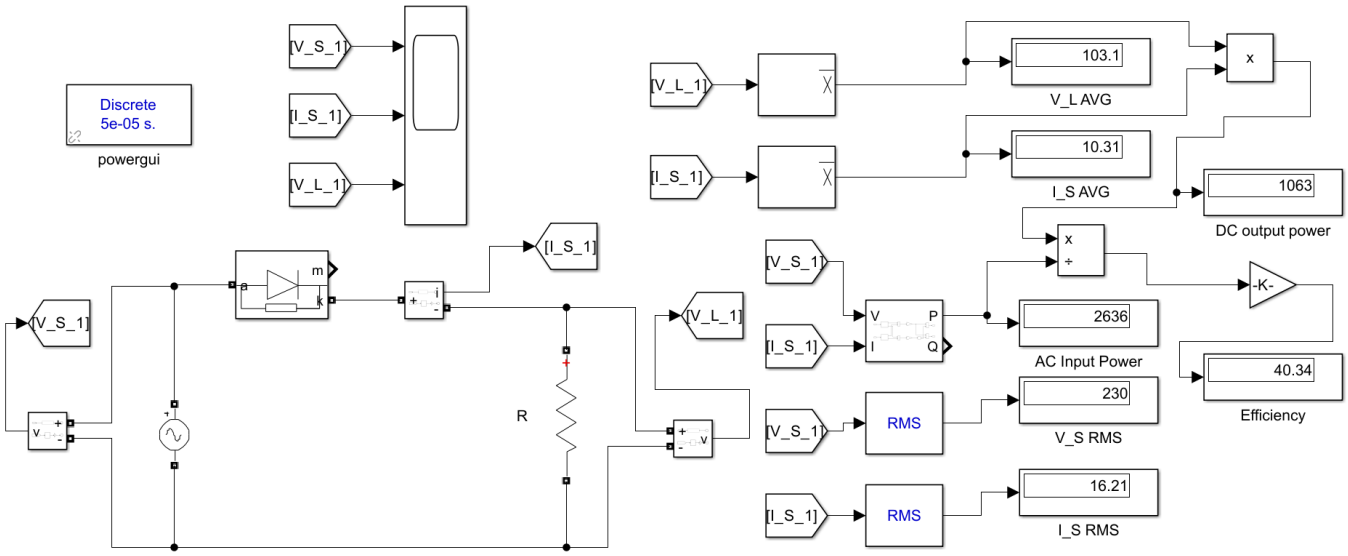

Figure 1.1: Circuit for Single Phase Half Wave Uncontrolled Rectifier with R load

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

The simulated values closely match the theoretical values, suggesting that the circuit is functioning correctly. Since the load is resistive, the output current is in phase with the output voltage. The output voltage and current waveforms indicate that the diode is forward-biased during the positive half-cycle of the AC source.

we obtain an efficiency of 40.34%

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

1.5.4 Resultant Waveforms

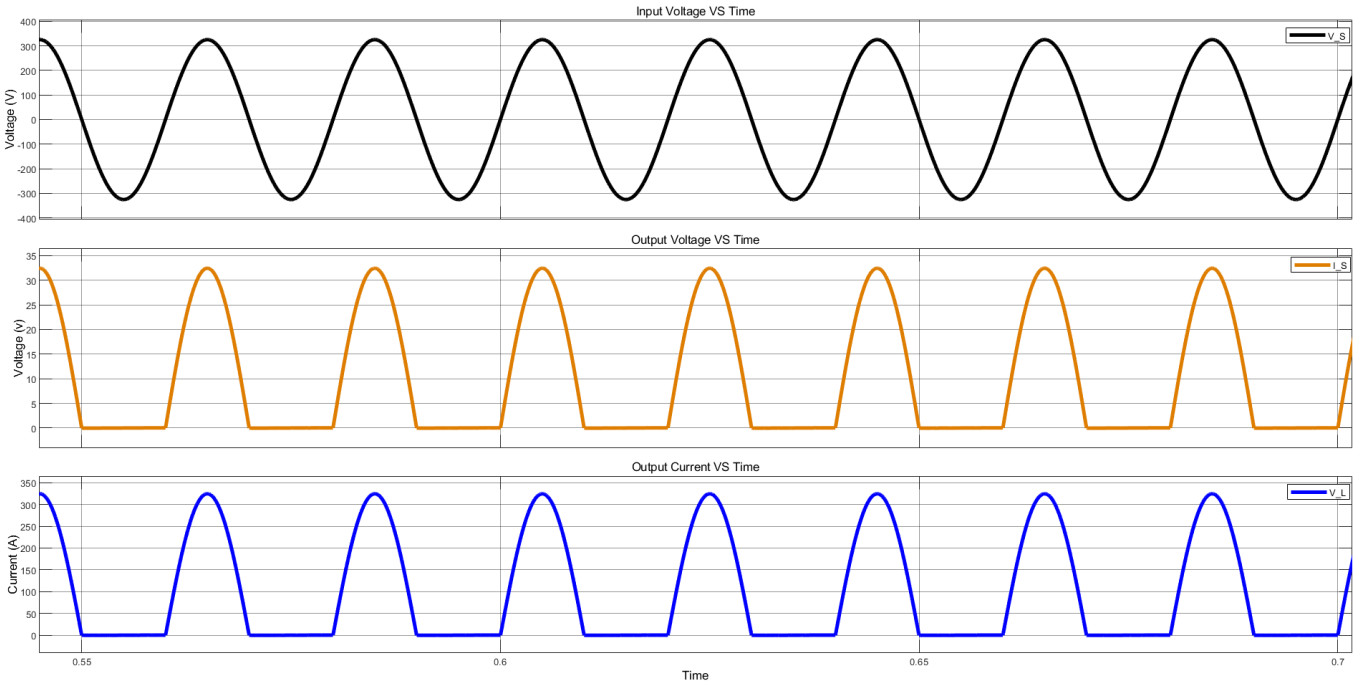

Figure 1.2: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with R load waveforms

1.6 Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.1 Circuit used for simulation

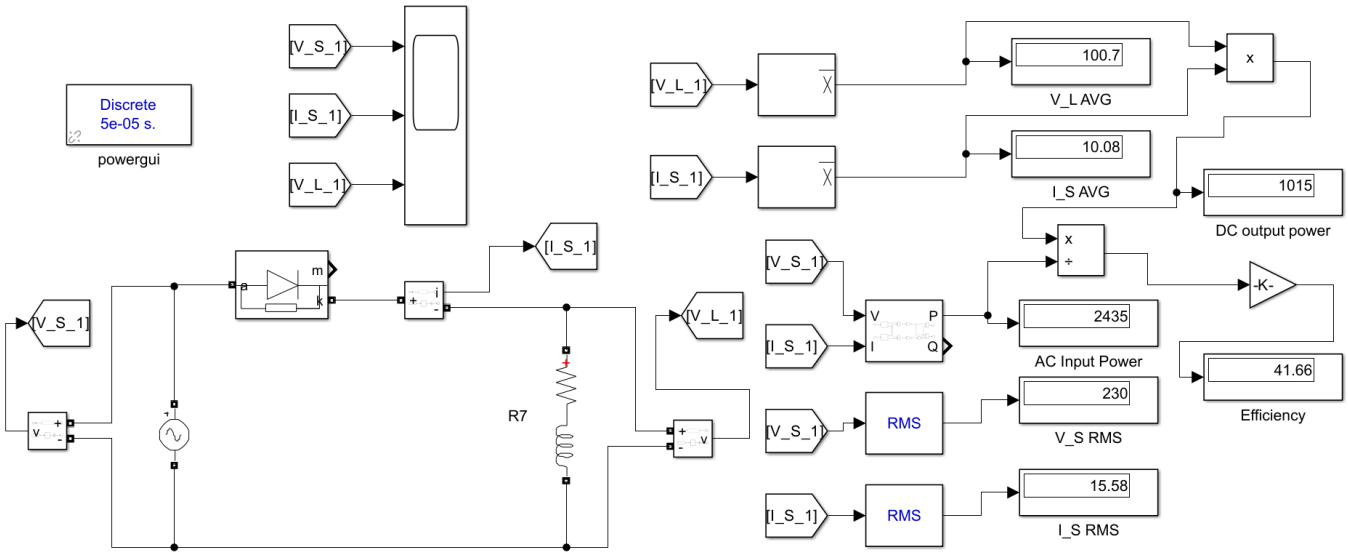

Figure 1.3: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

1. The simulated values agree with the theoretical values closely. However, the output current lags behind the output voltage due to the load's inductive component. The diode conducts until the output current reaches zero, causing the output voltage to be negative during this time period. The diode stops conducting once the output current reaches zero, and the output voltage returns to zero. The efficiency of uncontrolled rectifier with RL load is 41.66%.

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

1.6.4 Resultant Waveforms

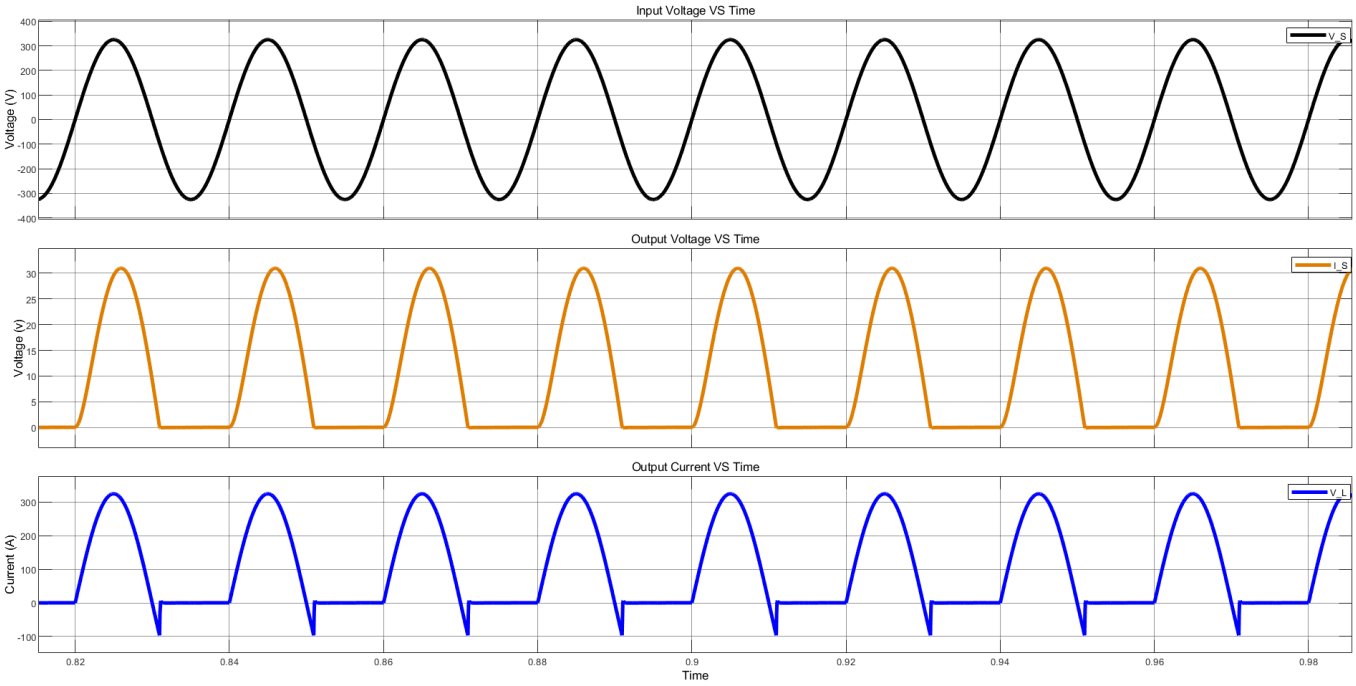

Figure 1.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

1.7.1 Circuit used for simulation

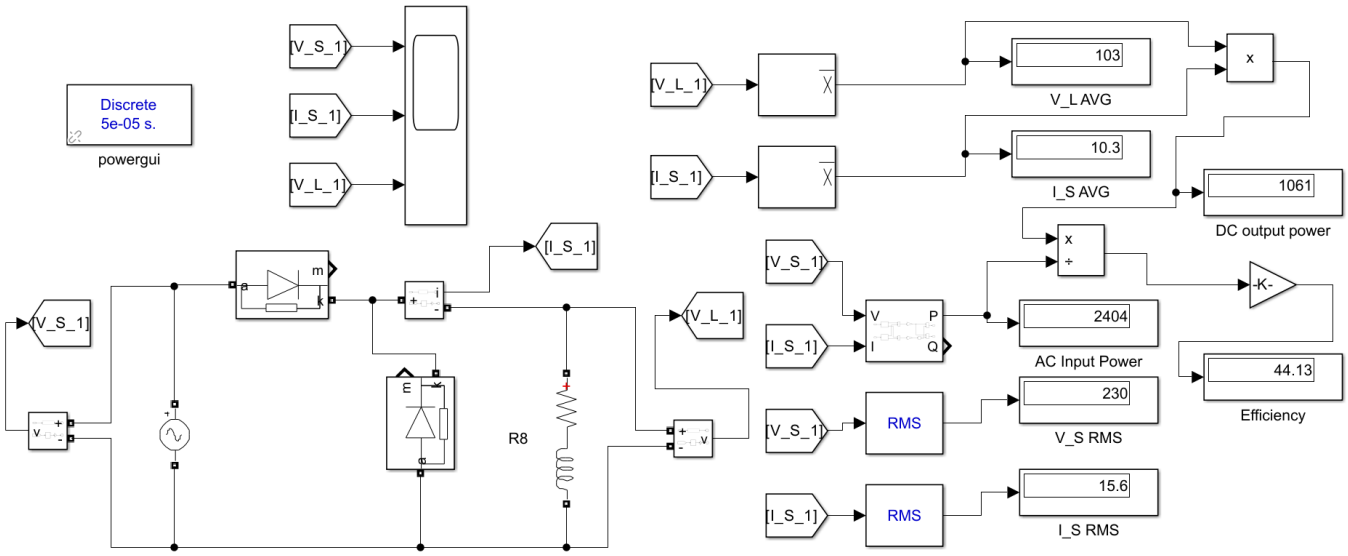

Figure 1.5: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

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

The simulated and calculated values demonstrate that the simulated output voltage is close to the calculated voltage, but the simulated output current varies from the calculated current. Additionally, the inclusion of the freewheeling diode causes the output current in the rectifier circuit to cut off abruptly when the source AC supply reaches zero volts, as the lagging current begins 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%.

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

1.7.4 Resultant Waveforms

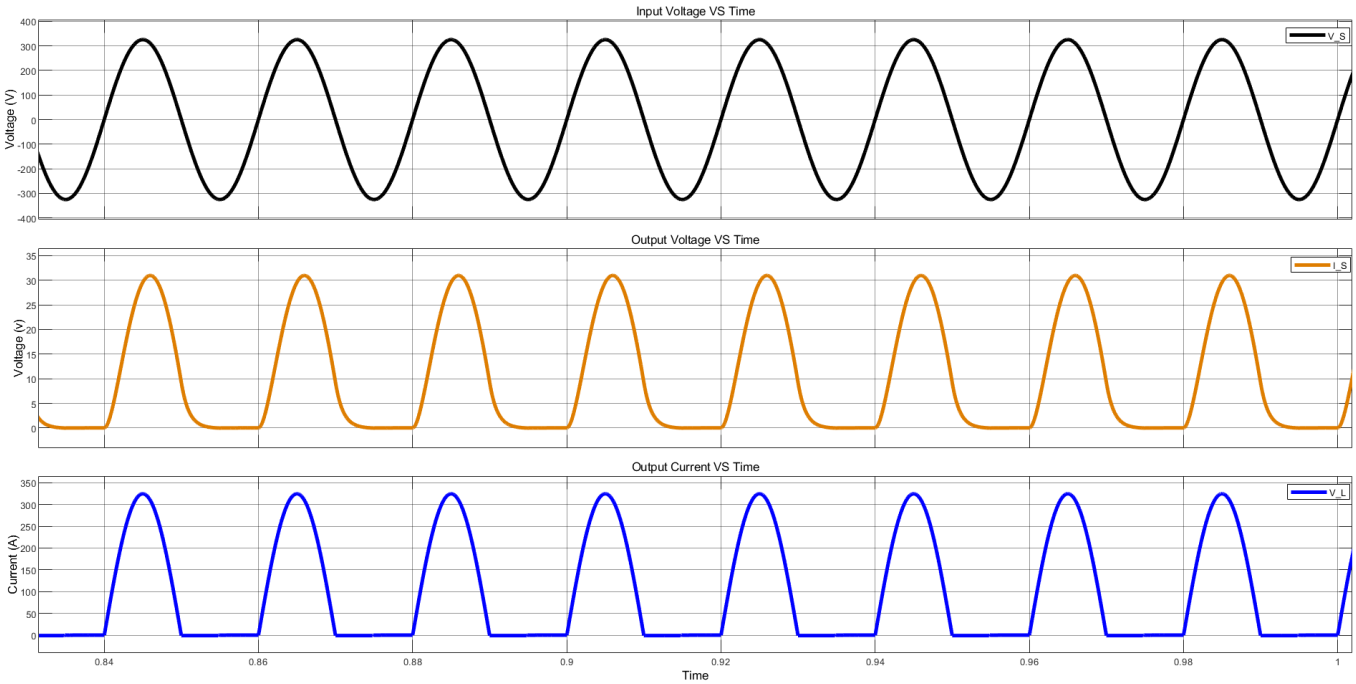

Figure 1.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.8 Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.1 Circuit used for simulation

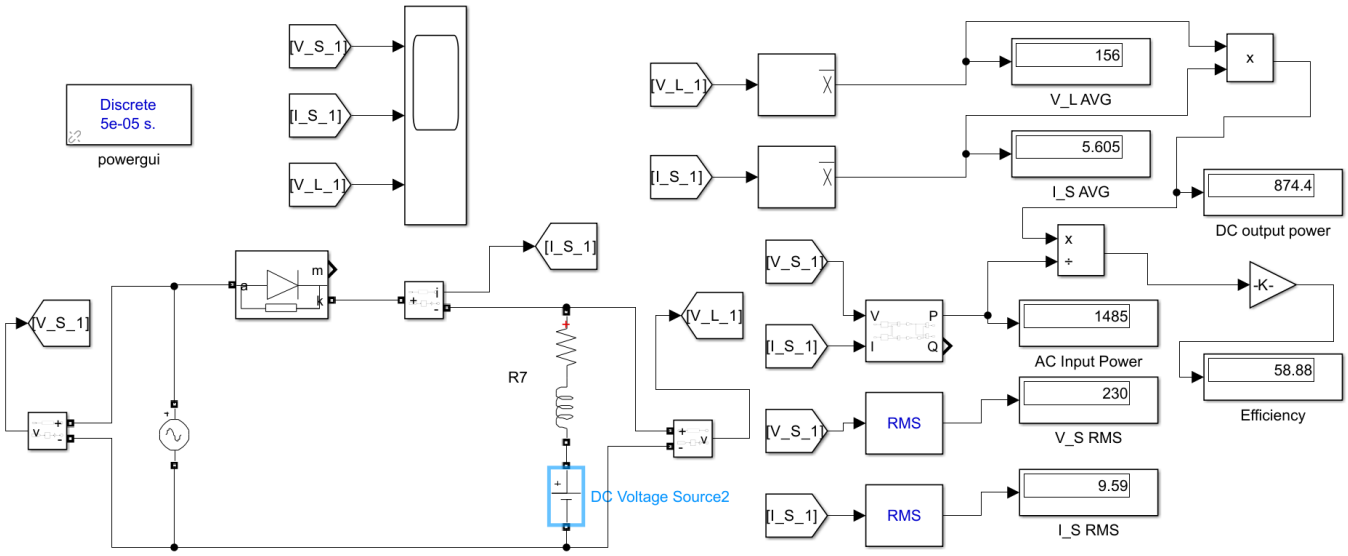

Figure 1.7: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RLE load

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

The simulation results demonstrate that the output voltage waveform for the RL load has the same shape as the input voltage waveform but with a positive DC offset. This is due to the rectification process that converts the negative half cycle of the input waveform into a positive voltage. When the output current falls to zero, the diode stops conducting, and the output voltage becomes a constant 100V, which is equivalent to the peak value of the input AC voltage. The efficiency of uncontrolled rectifier with RLE load is 58.88

Parameters	Theoretical Values	Simulation Values
AC Input Voltage ($V_{in,rms}$)	230V	230V
Output Average Voltage ($V_{o,avg}$)	148V	156V
Output Average Current ($I_{o,avg}$)	5.8A	5.605A
AC Input Power (P_{AC})	2389.5 (W)	1485 (W)
DC Input Power (P_{DC})	1071.53 (W)	874.4 (W)
Efficiency (%)	44.84	58.88

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

1.8.4 Resultant Waveforms

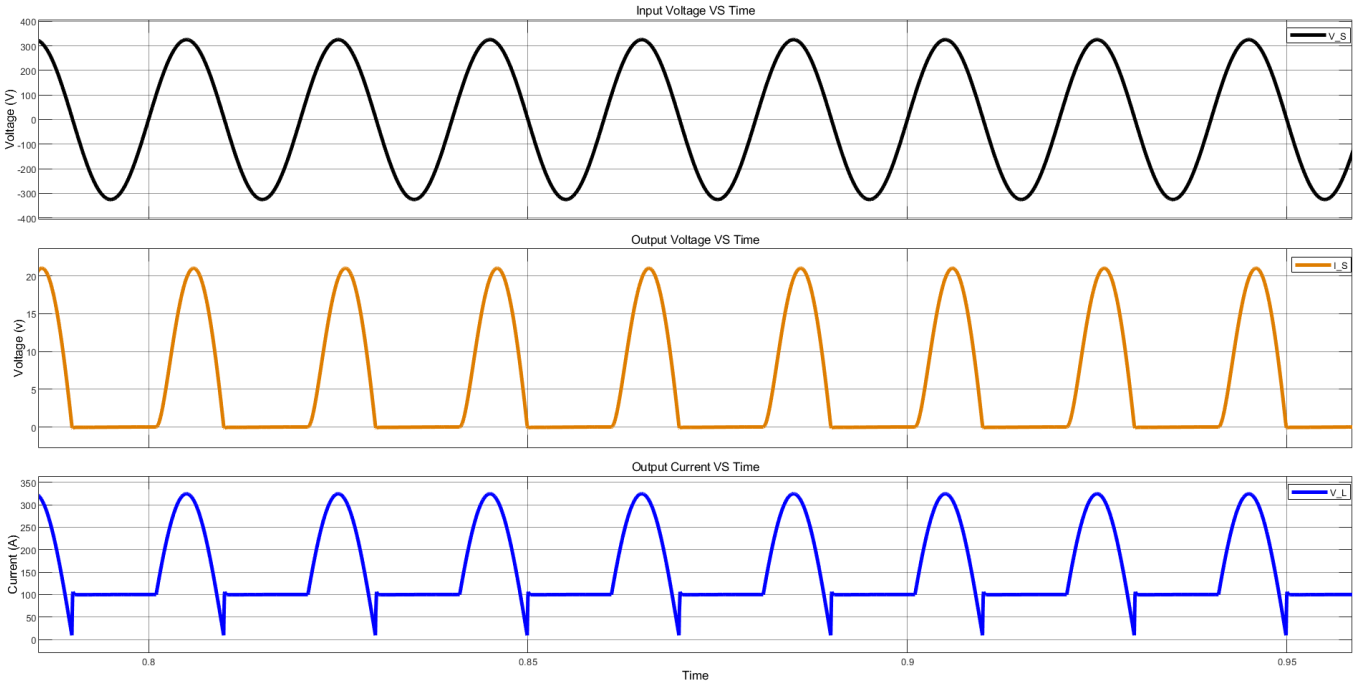

Figure 1.8: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RLE load waveforms

1.9 Single Phase Half Wave Controlled Rectifier with R load

1.9.1 Circuit used for simulation

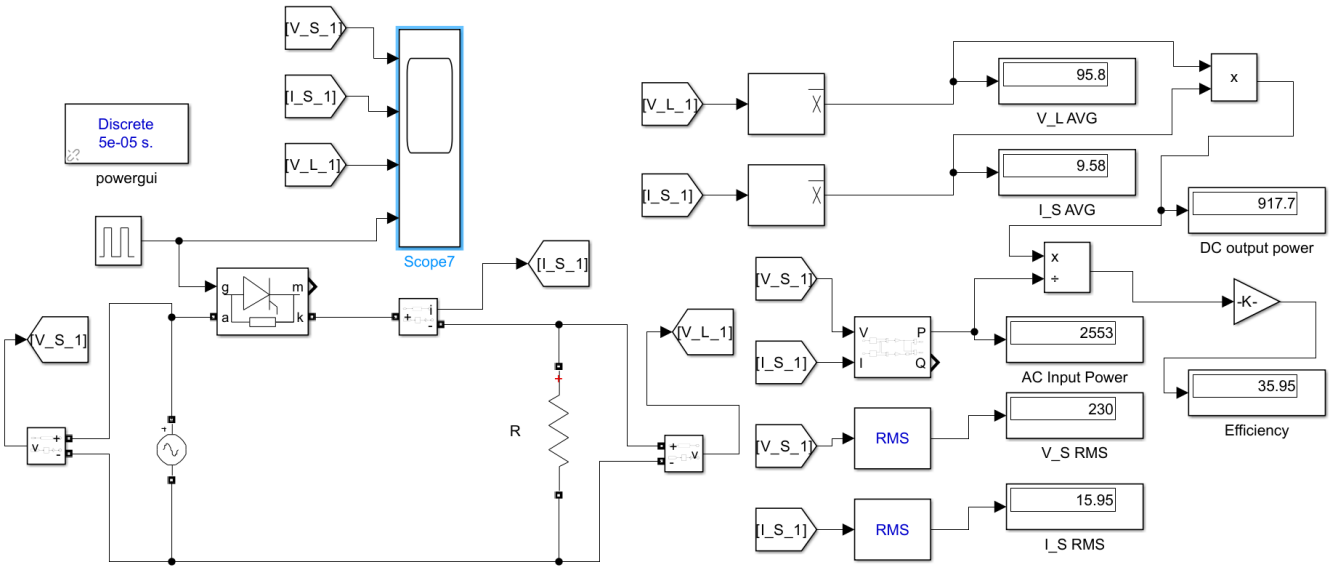

Figure 1.9: Circuit for Single Phase Half Wave Controlled Rectifier with R load (Firing Angle = 30°)

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

The simulation results show that the rectifier circuit is uncontrolled, and the output voltage follows the shape of the input voltage. As the load is resistive, the output current is in phase with the output voltage. The simulated values match the theoretical values accurately, indicating that the circuit is functioning correctly. However, the output voltage contains ripples due to the uncontrolled nature of the circuit. The efficiency of controlled rectifier with R load is 35.95%.

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

1.9.4 Resultant Waveforms

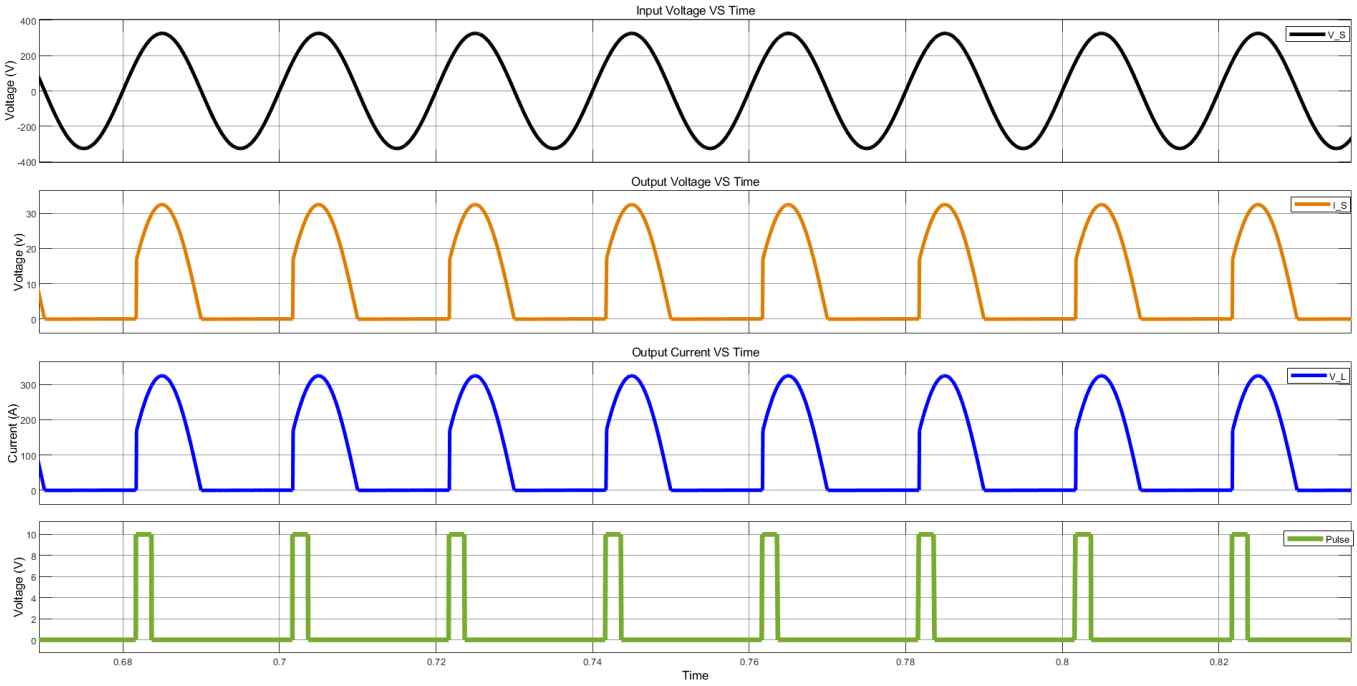

Figure 1.10: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with R load

1.10 Single Phase Half Wave Controlled Rectifier with RL load

1.10.1 Circuit used for simulation

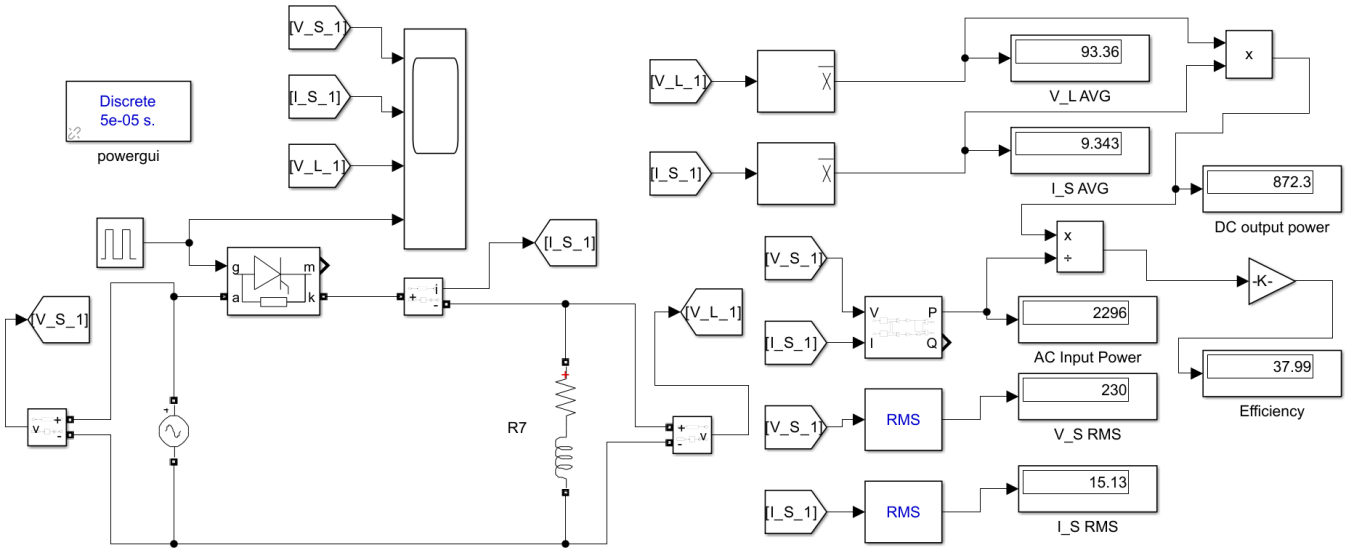

Figure 1.11: Circuit for Single Phase Half Wave Controlled Rectifier with RL load (Firing Angle = 30°)

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

The circuit does not conduct until a firing gate pulse is given to the thyristor. As the load has an inductive component, the output current lags the output voltage, causing the diode to conduct until the output current reaches zero. This results in the output voltage becoming negative during this period. When the output current becomes zero, the thyristor stops conducting, and the output voltage returns to zero. This type of circuit is commonly used in low power applications that require half-wave rectification. The efficiency of controlled rectifier with RL load is 37.99%.

1.10.4 Resultant Waveforms

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

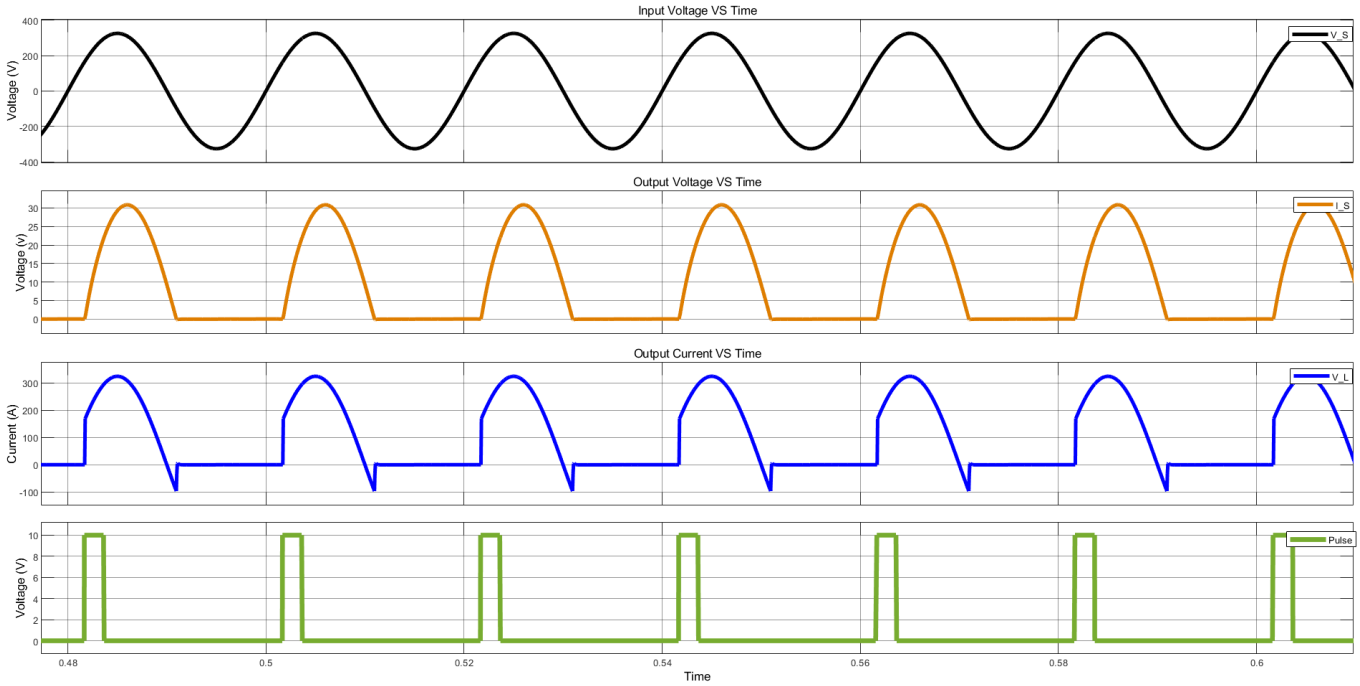

Figure 1.12: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RL load

1.11 Single Phase Half Wave Controlled Rectifier with RLE load

1.11.1 Circuit used for simulation

1.11.2 Components Required

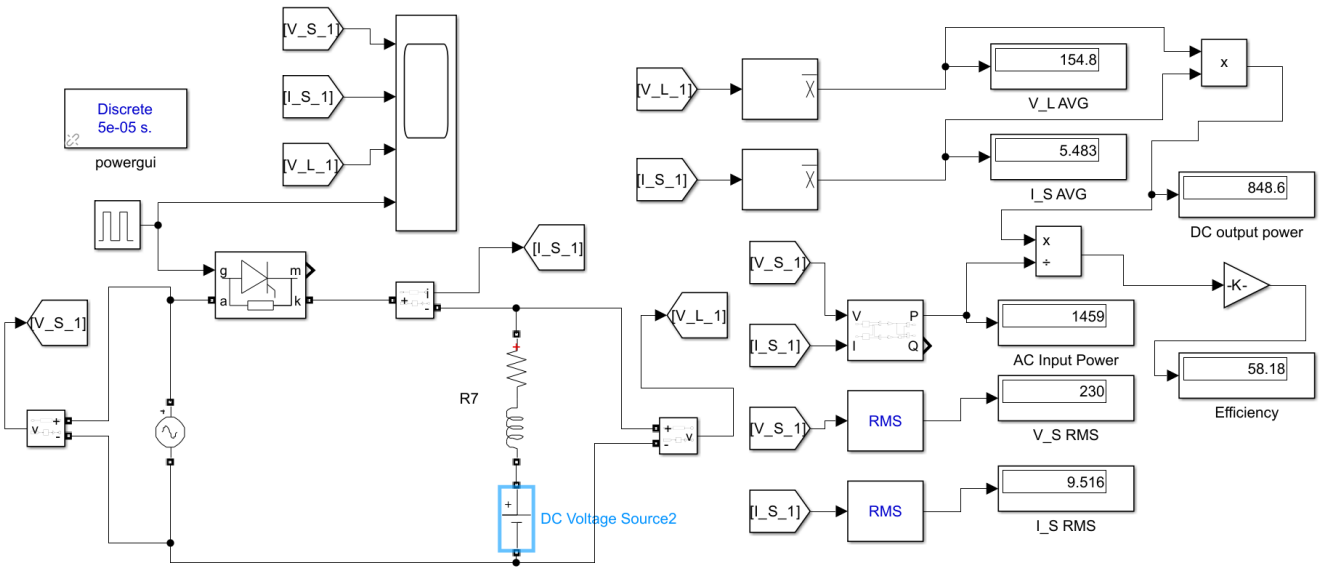

Figure 1.13: Circuit for Single Phase Half Wave Controlled Rectifier with RLE load (Firing Angle = 30°)

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

After giving the firing gate pulse to the thyristor, the circuit begins to behave like an uncontrolled half wave rectifier with an RLE load. The output voltage waveform follows the same shape as the RLE load waveform, and the output current lags the output voltage due to the inductive component of the load. The efficiency of controlled rectifier with RL load is 58.18%.

1.11.4 Resultant Waveforms

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

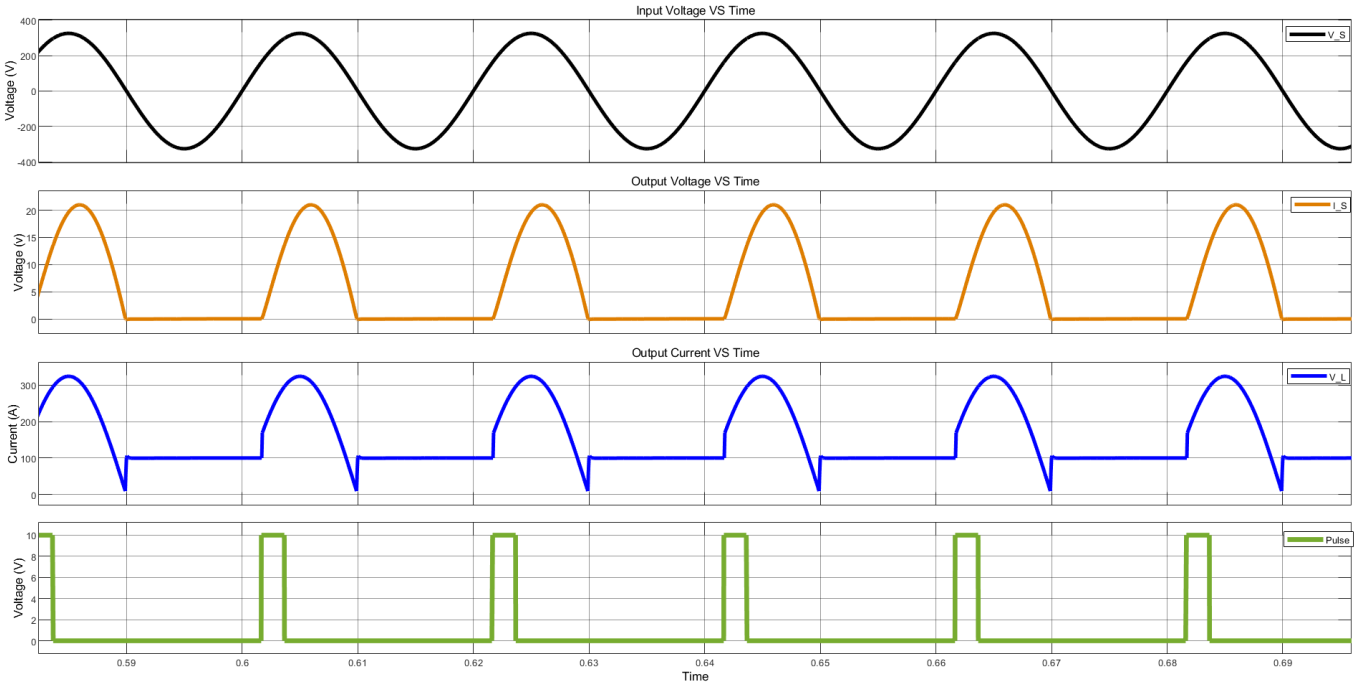

Figure 1.14: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RLE load

1.12 Conclusion

The experimental design employed MATLAB's Simulink to effectually implement single-phase half-wave rectifiers - both controlled and uncontrolled - with varying loads including resistive, inductive, resistive-inductive, and resistive-inductive with freewheeling diode. The ensuing simulation enabled waveform extraction for voltage and current, allowing for a comparative analysis of theoretical versus simulated output parameters. The assessment further entailed efficiency measurements for half-wave uncontrolled rectifiers operating on R load, RL load, RL load with freewheeling diode, and RLE load, culminating in respective efficiency values of 40.34%, 41.66%, 44.13%, and 58.88%. The experiment confirmed the half-wave uncontrolled rectifier with RLE load attaining maximum efficiency of 58.88%. Correspondingly, efficiency measurements of half-wave controlled rectifiers on R load, RL load, and RLE load were conducted, yielding efficiency values of 35.95%, 37.99%, and 58.18%, respectively. Hence, the half-wave controlled rectifier with RLE load obtained the highest efficiency of 58.18%, as per the evaluation.