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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

The operation of a half wave rectifier is simple and straightforward. A diode is used to block one half of the AC waveform, allowing only the positive half to pass through. This results in a DC output voltage that is roughly equal to the peak value of the AC waveform, minus the voltage drop across the diode. The output voltage of a half wave rectifier is not constant, but varies with time. This is due to the pulsating nature of the DC voltage, which has a large amount of ripple. Despite its simplicity, the half wave rectifier is still widely used in low-power applications, such as battery chargers and small power supplies.

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

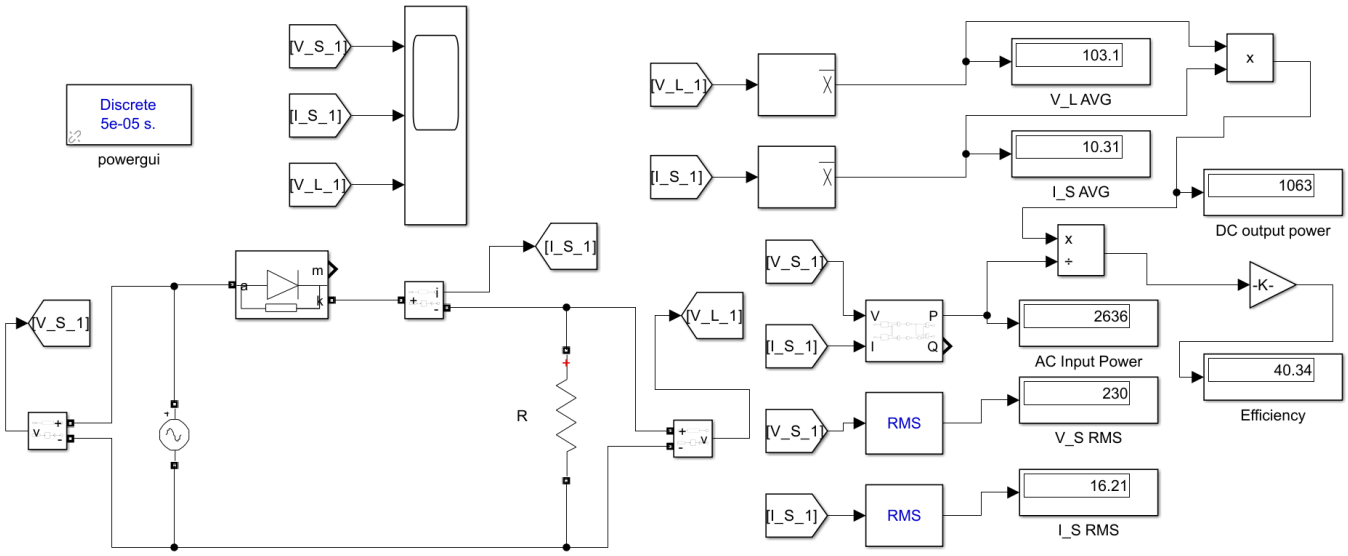

Figure 1.1: Circuit for Single Phase Half Wave Uncontrolled Rectifier with R load

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 circuit's simulated values accurately match the theoretical values, which is a positive sign that the circuit is functioning properly. Since the load is resistive, the output current is in phase with the output voltage. The output voltage and current waveforms show 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

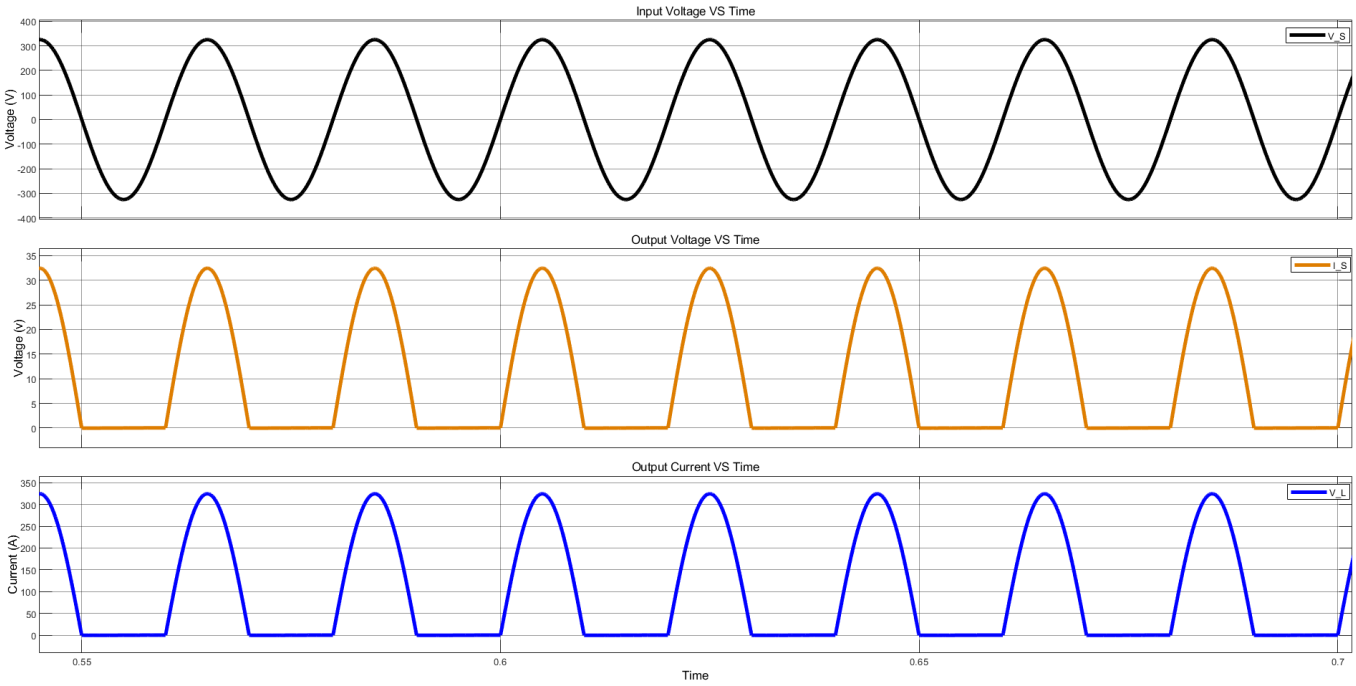

Figure 1.2: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with R load waveforms

1.6 Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.1 Circuit used for simulation

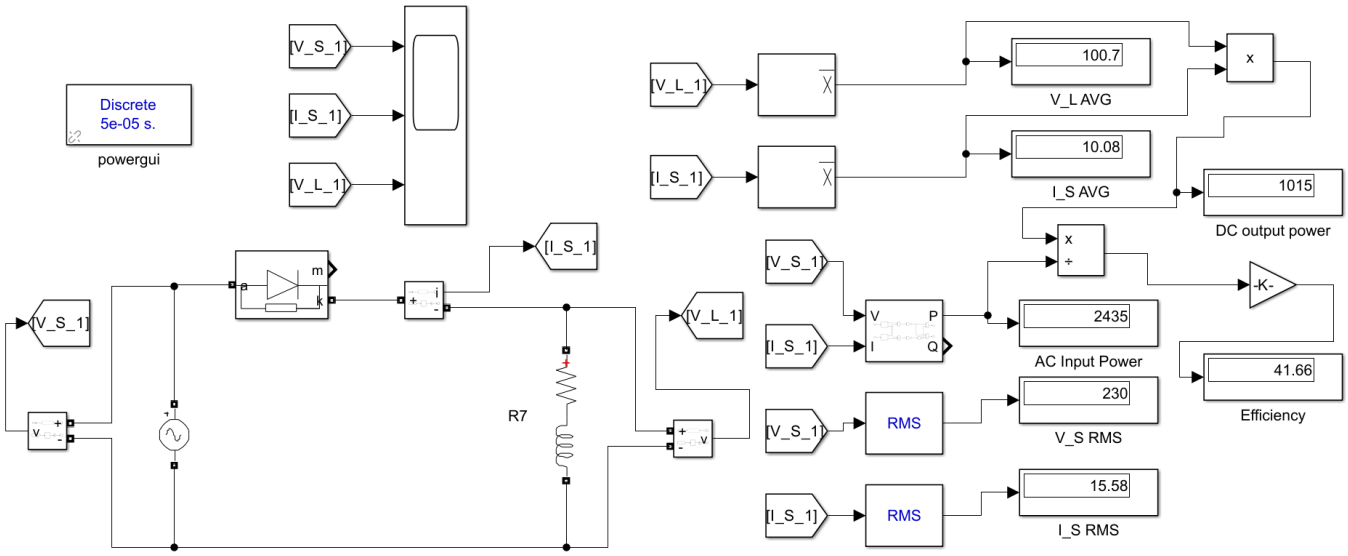

Figure 1.3: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

The circuit's simulated values are in good agreement with the theoretical values. However, because the load contains an inductive component, the output current lags behind the output voltage. This lag causes the diode to conduct until the output current reaches zero, resulting in the output voltage becoming negative during this time period. The diode ceases to conduct once the output current reaches zero, causing the output voltage to return 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

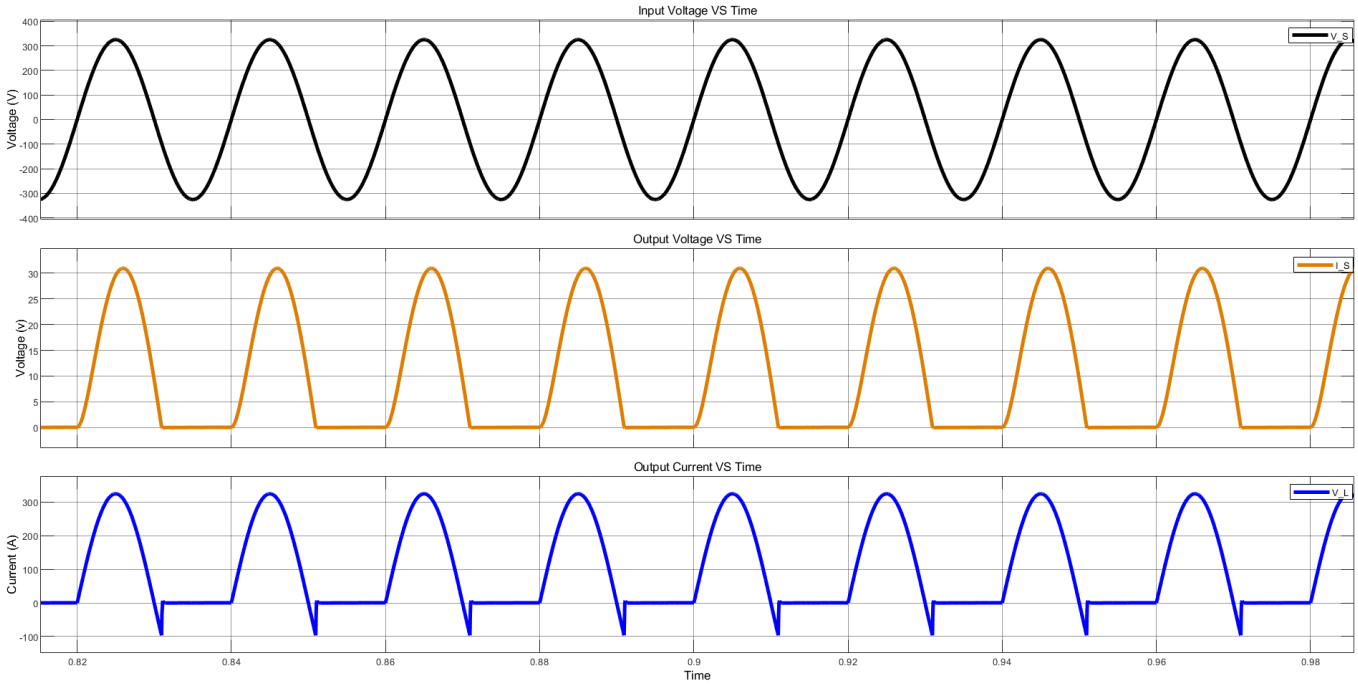

Figure 1.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

1.7.1 Circuit used for simulation

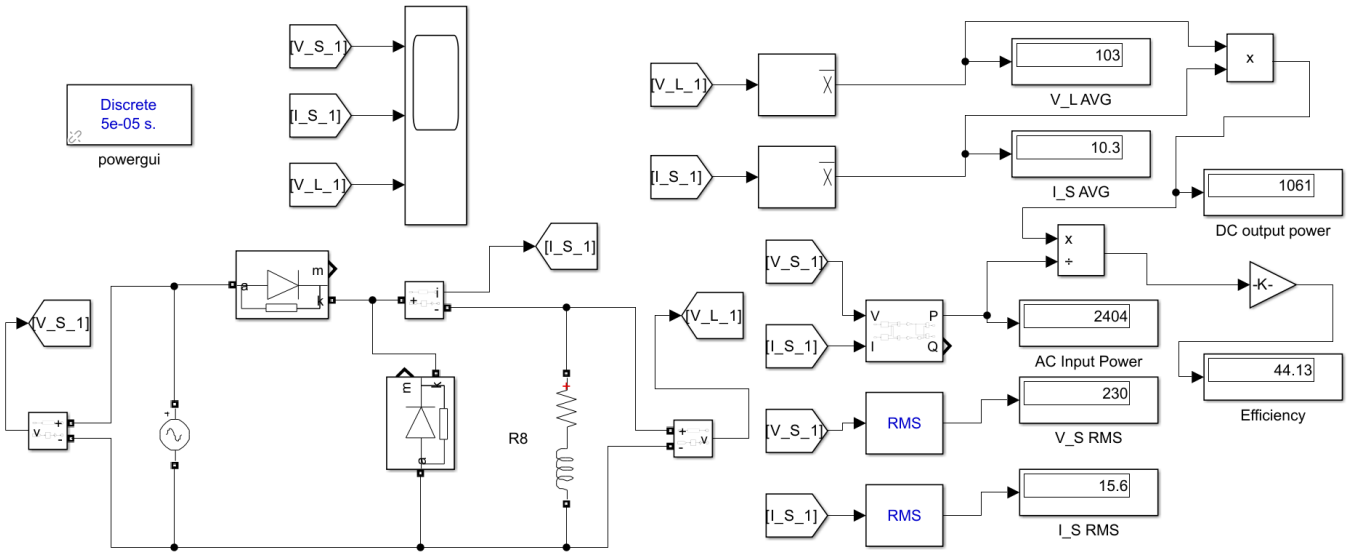

Figure 1.5: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

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 observed values indicate that the simulated output voltage is close to the calculated voltage, but the simulated output current varies from the calculated current. Moreover, the freewheeling diode's integration leads to an immediate cutoff of output current in the rectifier circuit, as the lagging current flows through the freewheeling diode instead of the rectifier circuit when the source AC supply reaches zero volts. 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

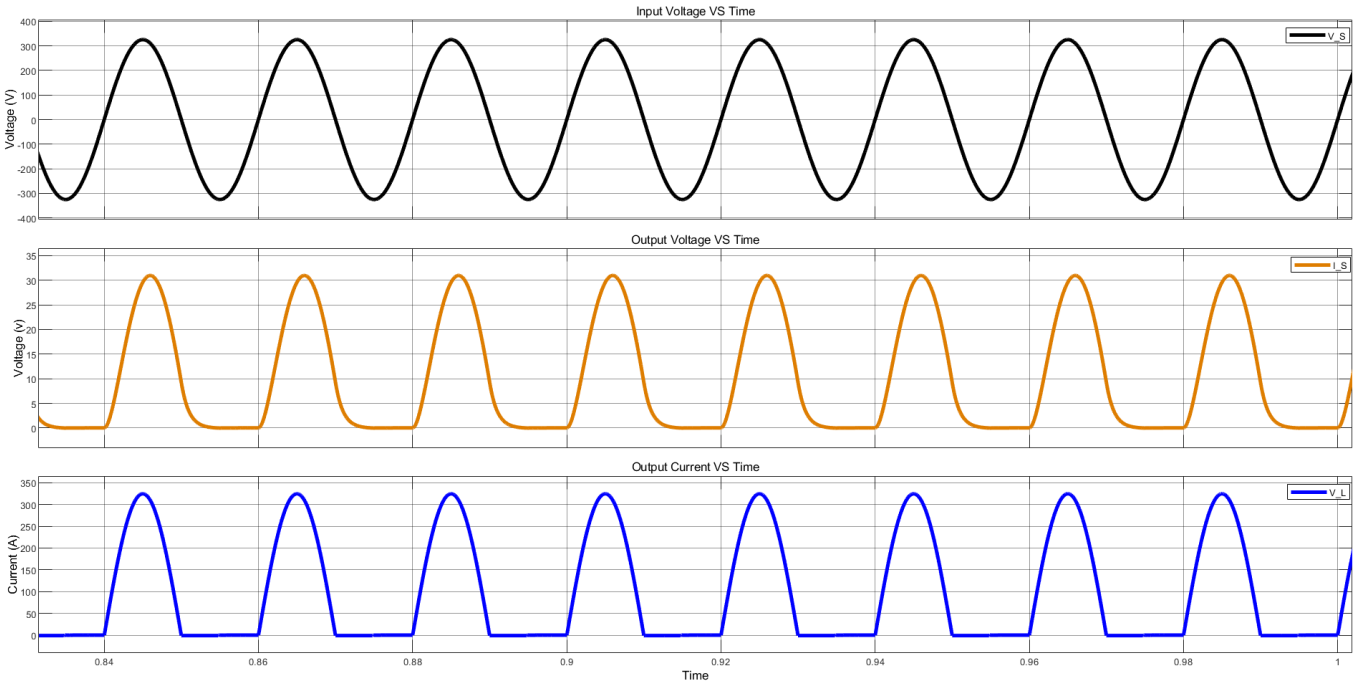

Figure 1.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.8 Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.1 Circuit used for simulation

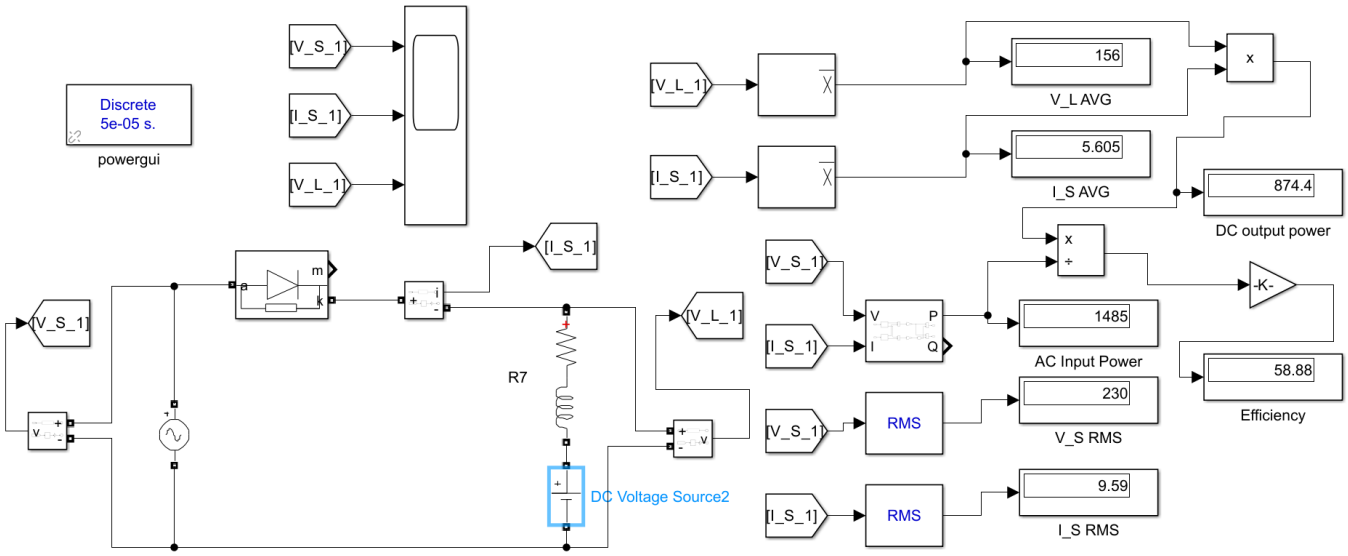

Figure 1.7: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RLE load

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 show that the output voltage waveform for the RL load is similar to 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. The diode in the circuit stops conducting when the output current falls to zero, which causes the output voltage to remain constant at 100V, equivalent to the peak value of the input AC voltage. The efficiency of uncontrolled rectifier with RLE load is 67.88

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

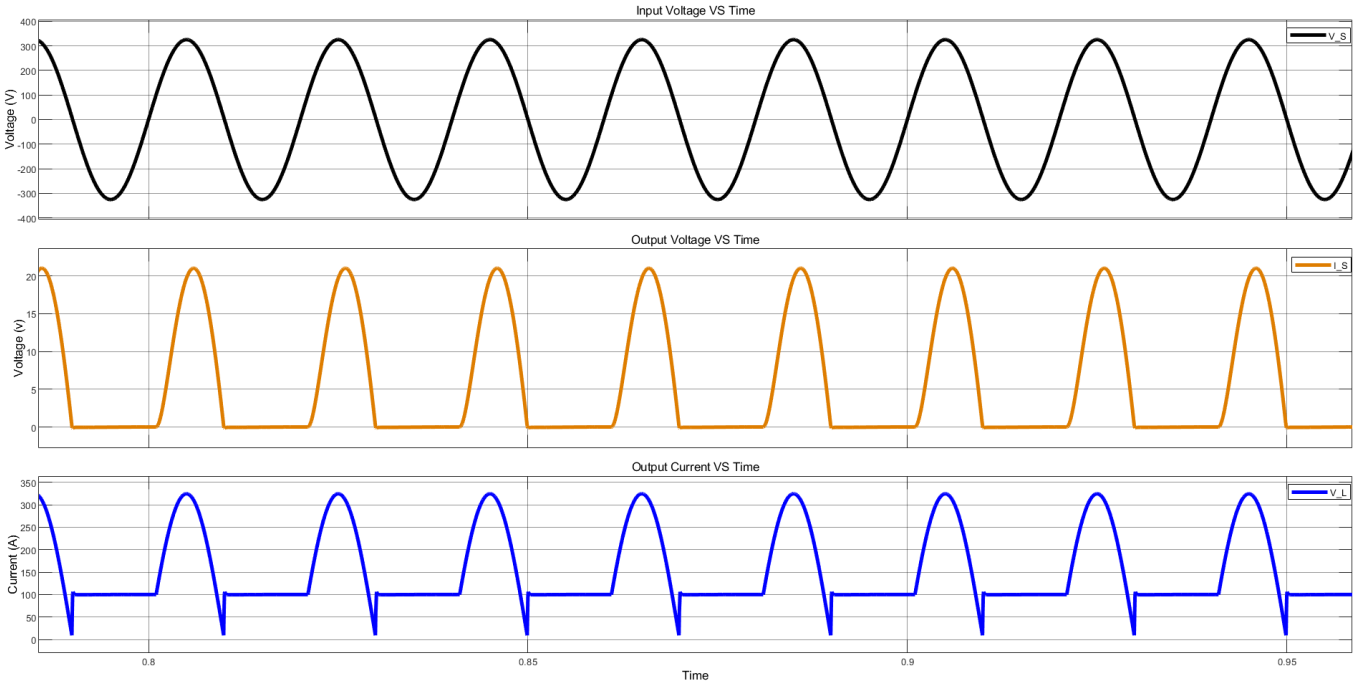

Figure 1.8: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RLE load waveforms

1.9 Single Phase Half Wave Controlled Rectifier with R load

1.9.1 Circuit used for simulation

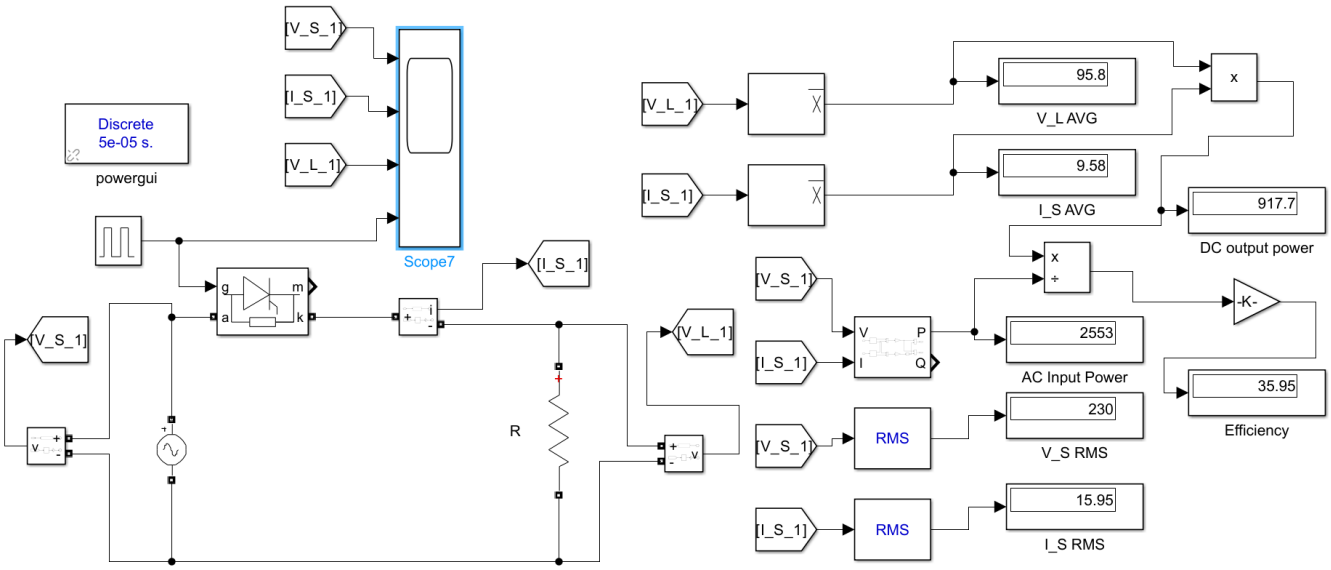

Figure 1.9: Circuit for Single Phase Half Wave Controlled Rectifier with R load (Firing Angle = 30°)

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 rectifier circuit is uncontrolled, and output voltage follows the shape of the input voltage. As the load is resistive in nature, the output current is in phase with the output voltage. The simulation results match the theoretical values reasonably well. However, the output voltage contains ripples due to the uncontrolled nature of the rectifier 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

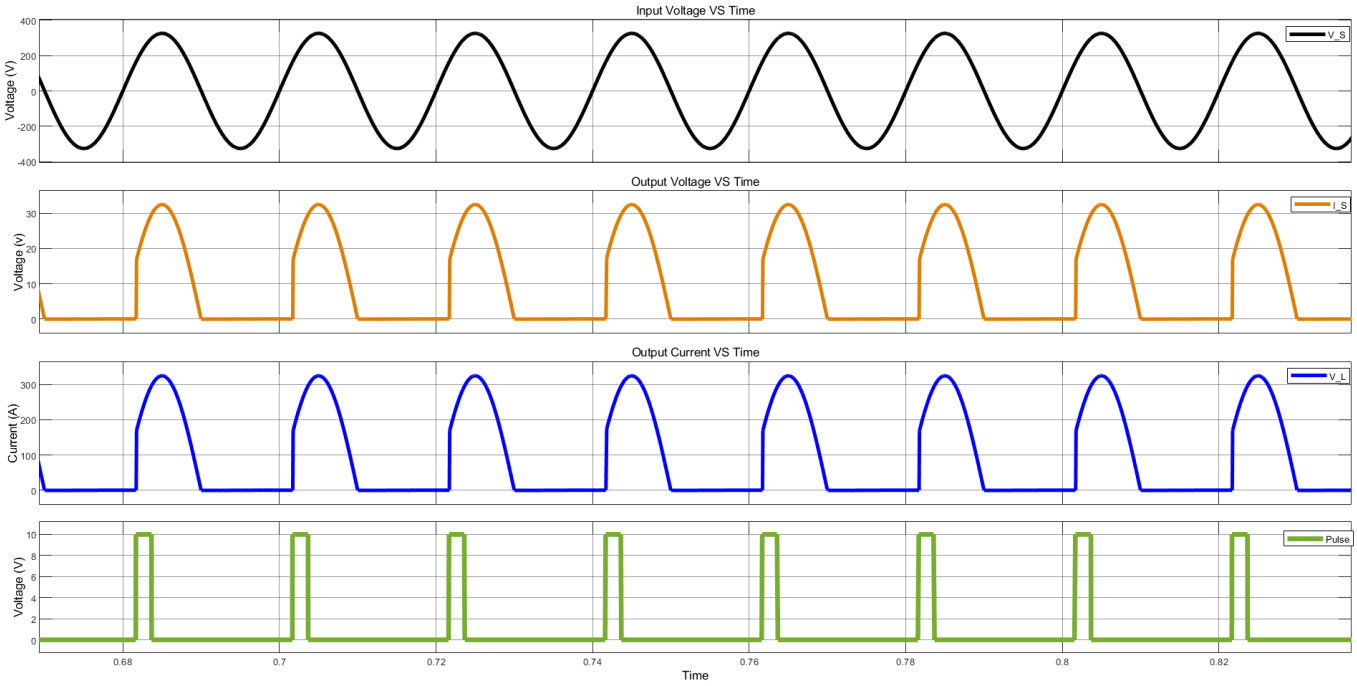

Figure 1.10: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with R load

1.10 Single Phase Half Wave Controlled Rectifier with RL load

1.10.1 Circuit used for simulation

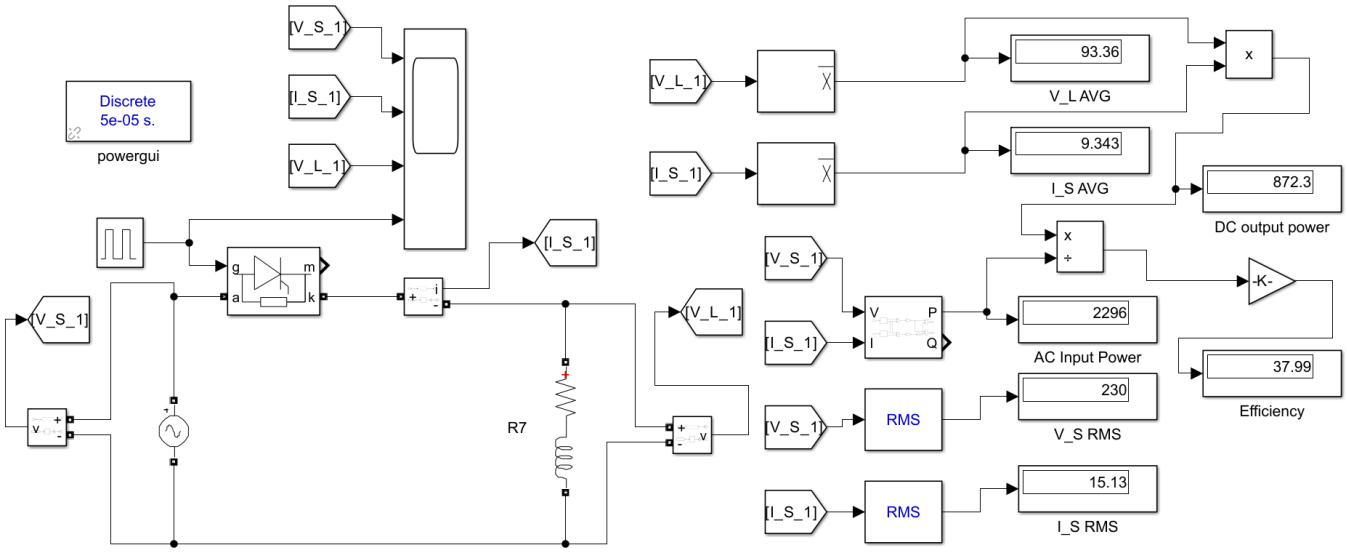

Figure 1.11: Circuit for Single Phase Half Wave Controlled Rectifier with RL load (Firing Angle = 30°)

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 remains non-conductive until a firing gate pulse is given to the thyristor. As the load has an inductive component, the output current lags the output voltage. This causes the diode to conduct until the output current reaches zero, which results in the output voltage becoming negative during this time period. Once the output current becomes zero, the thyristor stops conducting, and the output voltage also returns to zero. This type of circuit is used in applications that require only 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

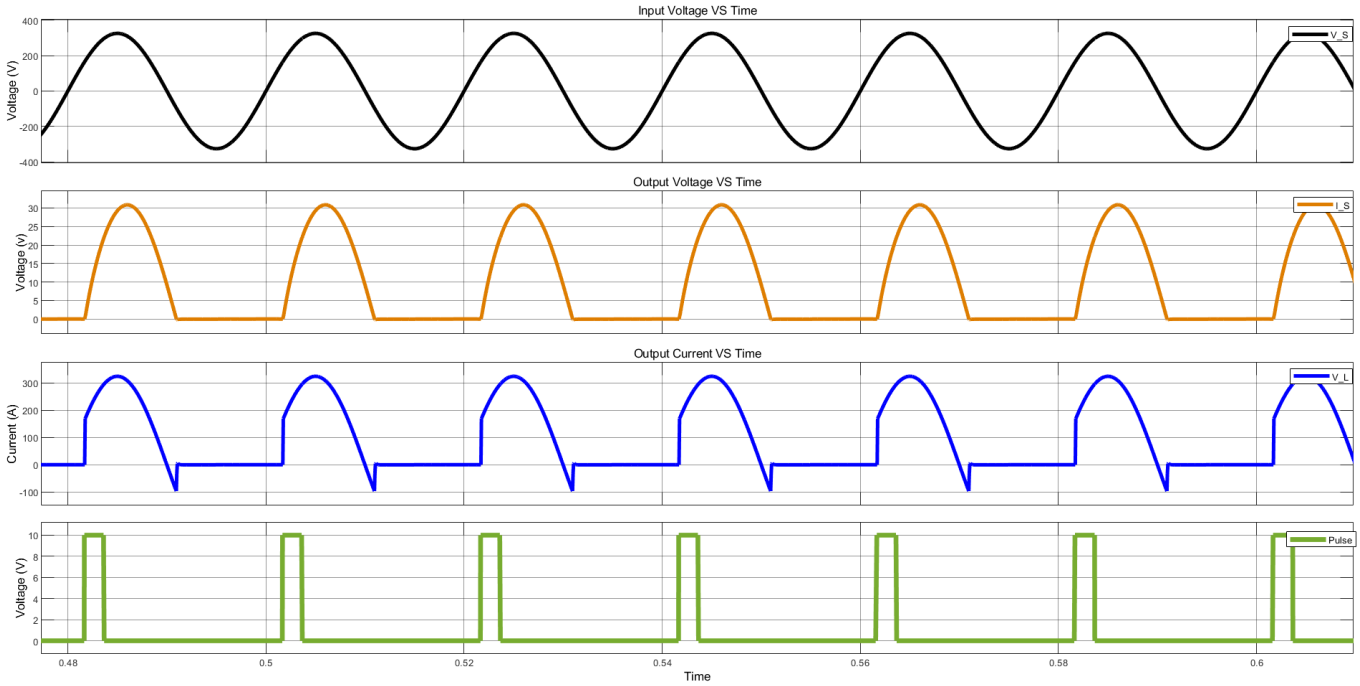

Figure 1.12: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RL load

1.11 Single Phase Half Wave Controlled Rectifier with RLE load

1.11.1 Circuit used for simulation

1.11.2 Components Required

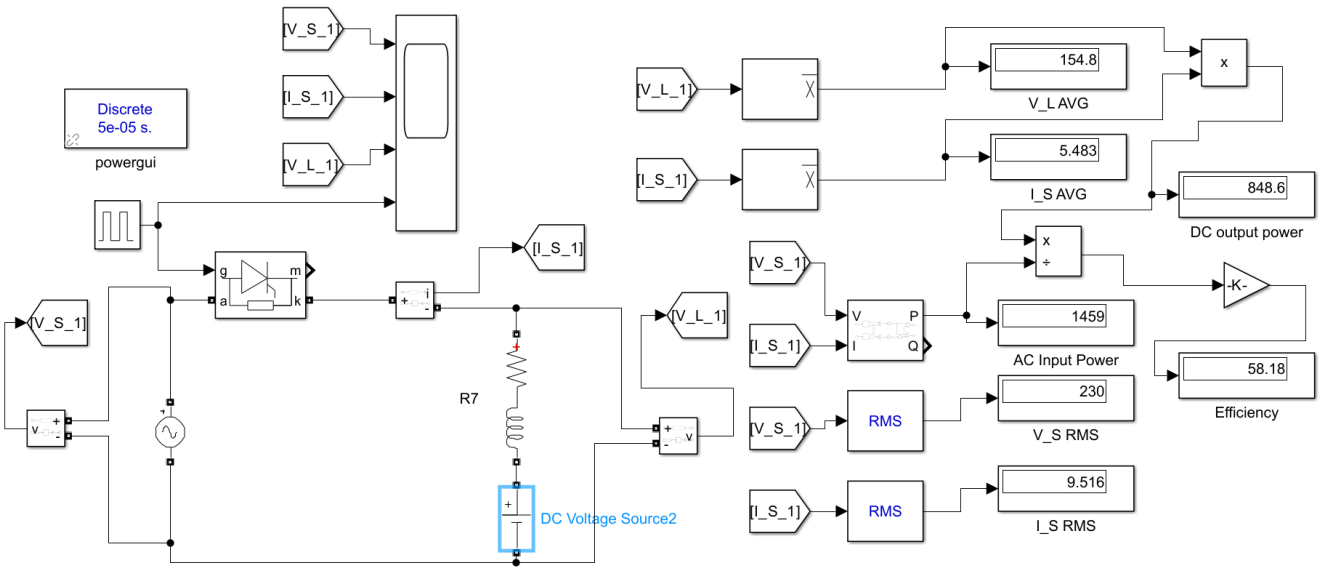

Figure 1.13: Circuit for Single Phase Half Wave Controlled Rectifier with RLE load (Firing Angle = 30°)

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

1. The circuit behaves like an uncontrolled half wave rectifier with an RLE load once a firing gate pulse is given to the thyristor. It is observed that the output voltage waveform is the same as the 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

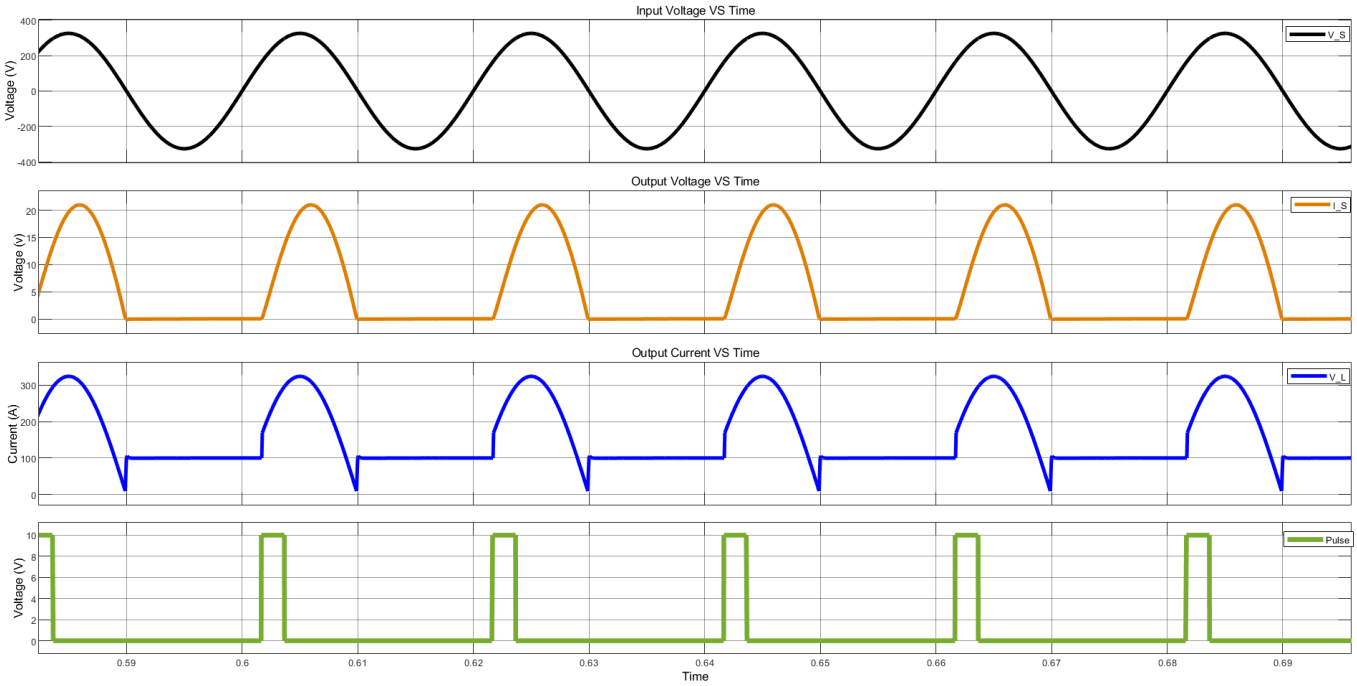

Figure 1.14: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RLE load

1.12 Conclusion

MATLAB's Simulink was utilized to successfully implement both controlled and uncontrolled single-phase half-wave rectifiers with resistive, inductive, resistive-inductive, and resistive-inductive with freewheeling diode loads. The simulation produced output waveforms for voltage and current, and a comparison was made between theoretically calculated and simulated output parameters. The experiment included efficiency measurements for half-wave uncontrolled rectifiers with R load, RL load, RL load with freewheeling diode, and RLE load, yielding efficiency values of 40.34%, 41.66%, 44.13%, and 58.88%, respectively. The experiment concluded that the half-wave uncontrolled rectifier with RLE load demonstrated the highest efficiency of 58.88%. Similarly, efficiency measurements of half-wave controlled rectifiers with R load, RL load, and RLE load were conducted, producing efficiency values of 35.95%, 37.99%, and 58.18%, respectively. As such, the half-wave controlled rectifier with RLE load exhibited the highest efficiency of 58.18%.