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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

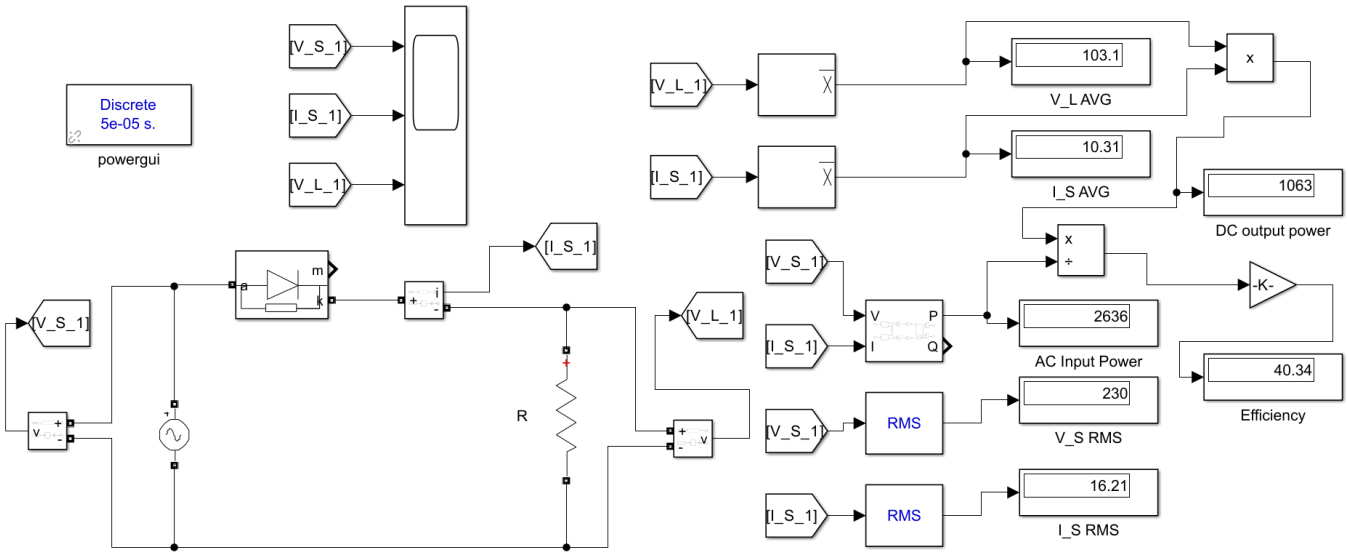

Figure 1.1: Circuit for Single Phase Half Wave Uncontrolled Rectifier with R load

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

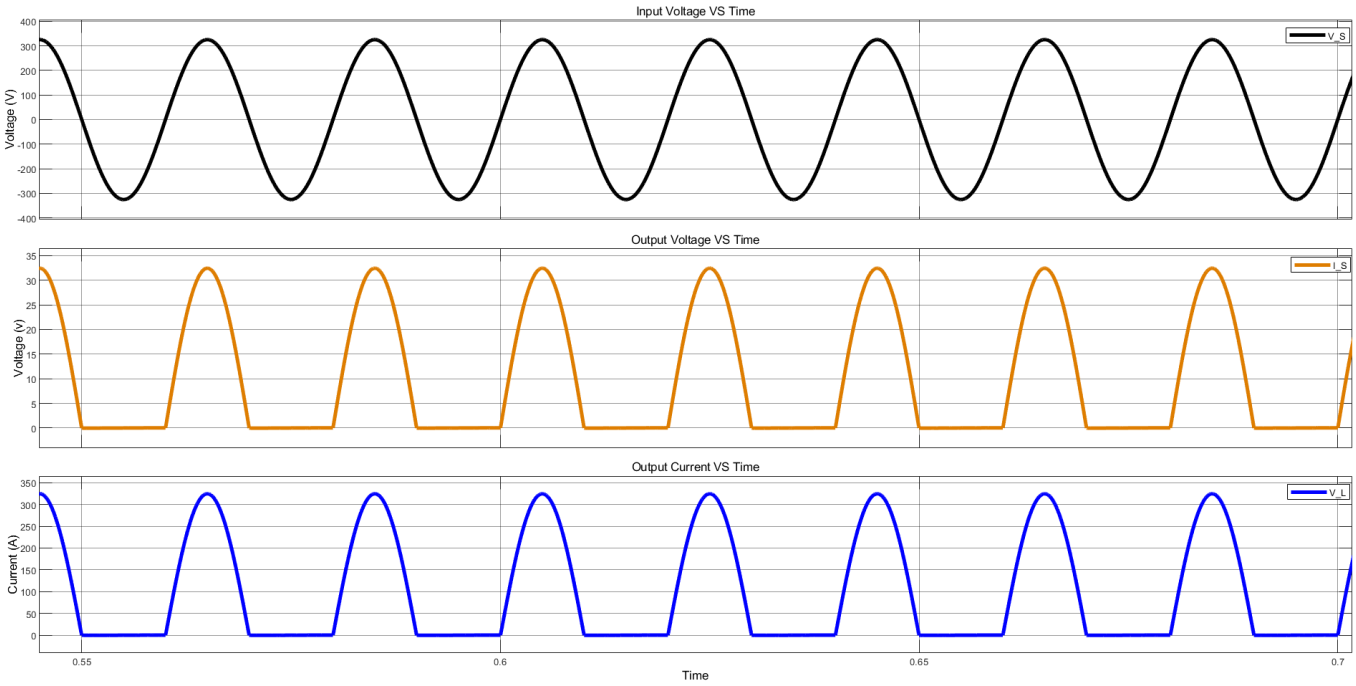

Figure 1.2: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with R load waveforms

1.6 Single Phase Half Wave Uncontrolled Rectifier with RL load

1.6.1 Circuit used for simulation

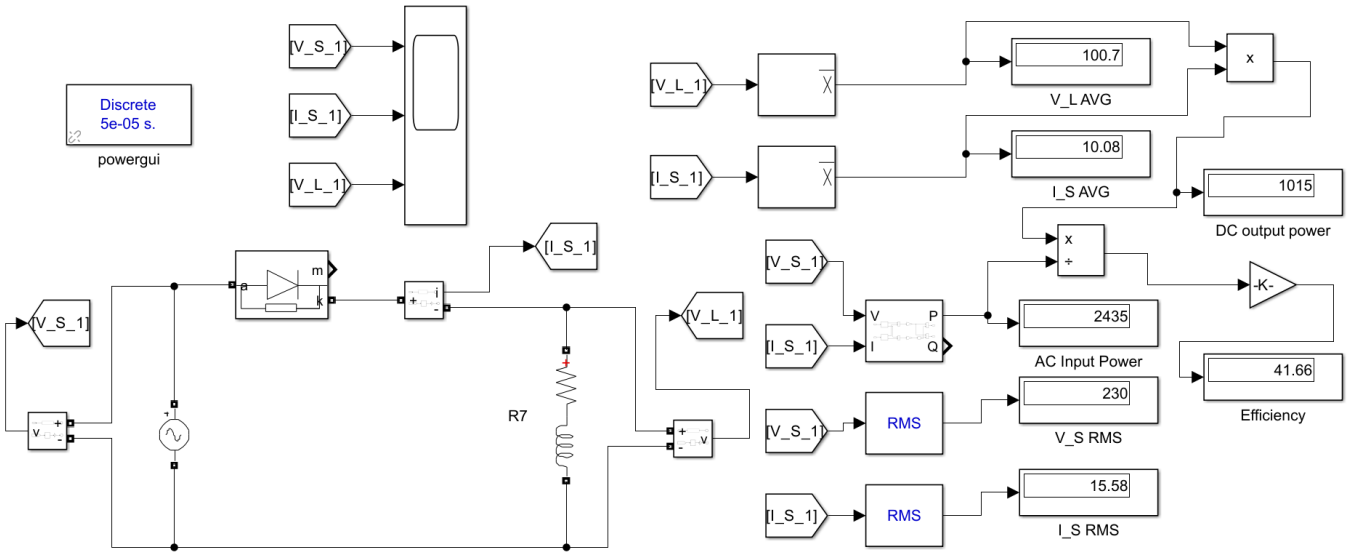

Figure 1.3: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load

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 simulated values match the theoretical values closely. However, because the load has an inductive component, the output current lags behind the output voltage. This lag causes the diode to conduct until the output current reaches zero, leading to a negative output voltage during this time. The diode stops conducting once the output current becomes 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

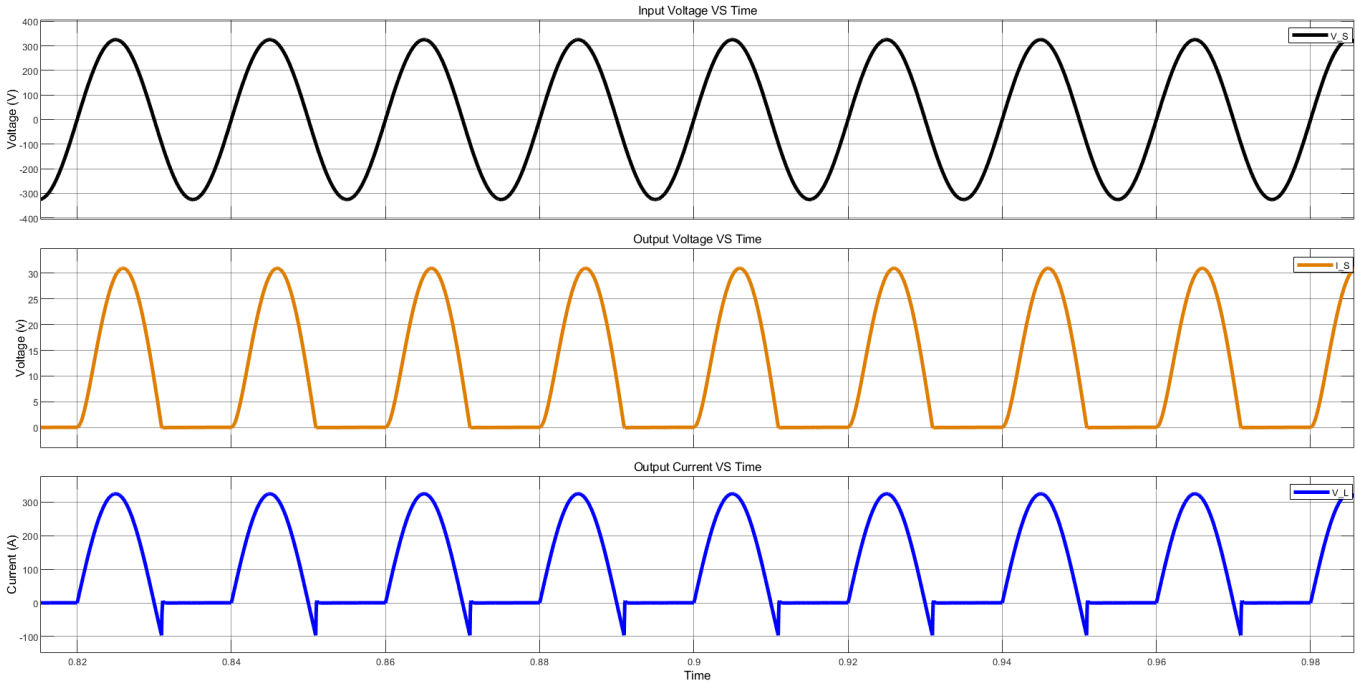

Figure 1.4: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load

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

1.7.1 Circuit used for simulation

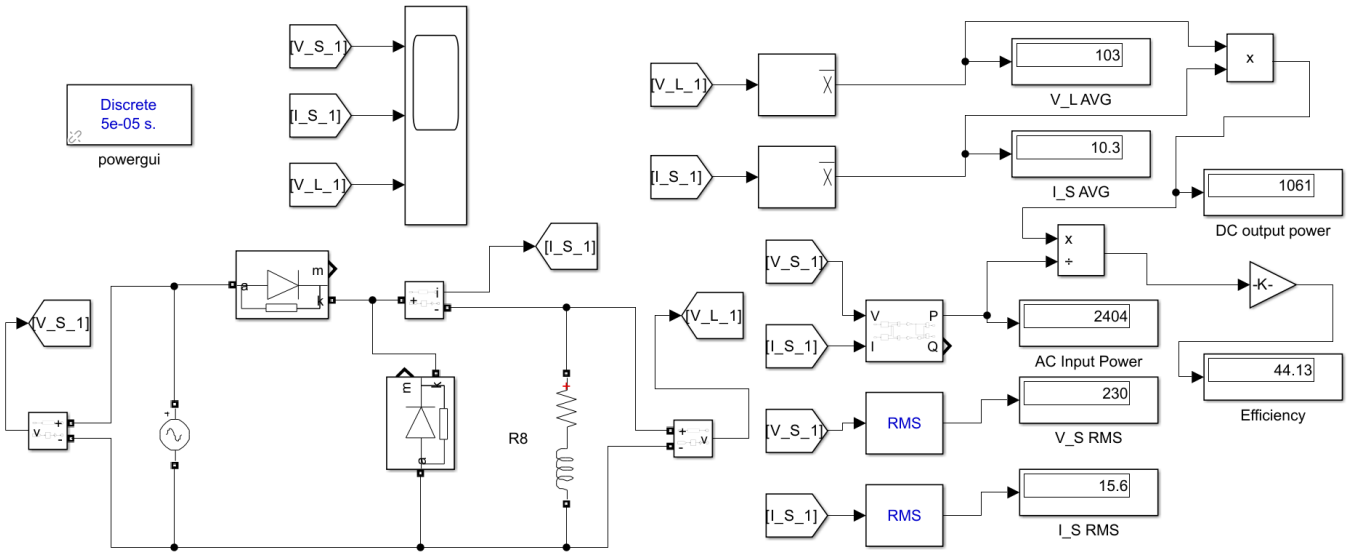

Figure 1.5: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

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 comparison between the simulated and calculated values reveals that the simulated output voltage is nearly equal to the calculated voltage, whereas the simulated output current deviates from the calculated current. The freewheeling diode's presence results in a sharp cutoff of output current in the rectifier circuit 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

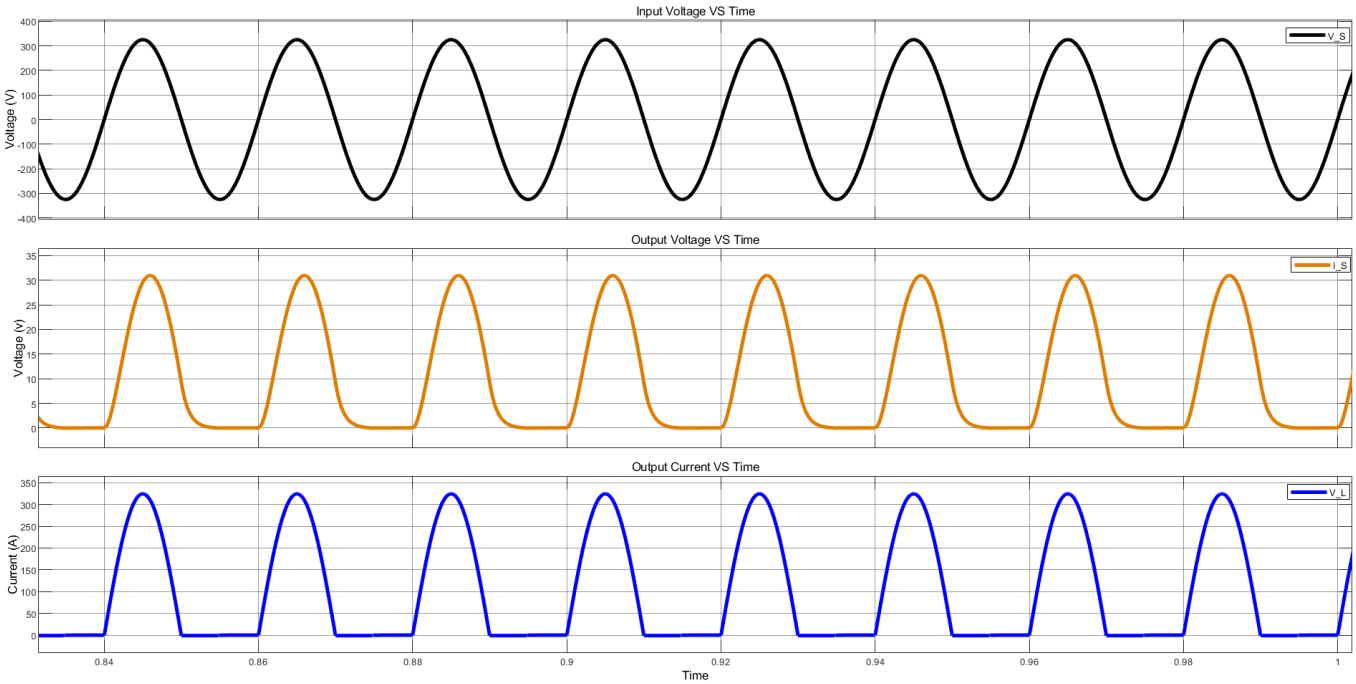

Figure 1.6: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RL load and Freewheeling Diode

1.8 Single Phase Half Wave Uncontrolled Rectifier with RLE load

1.8.1 Circuit used for simulation

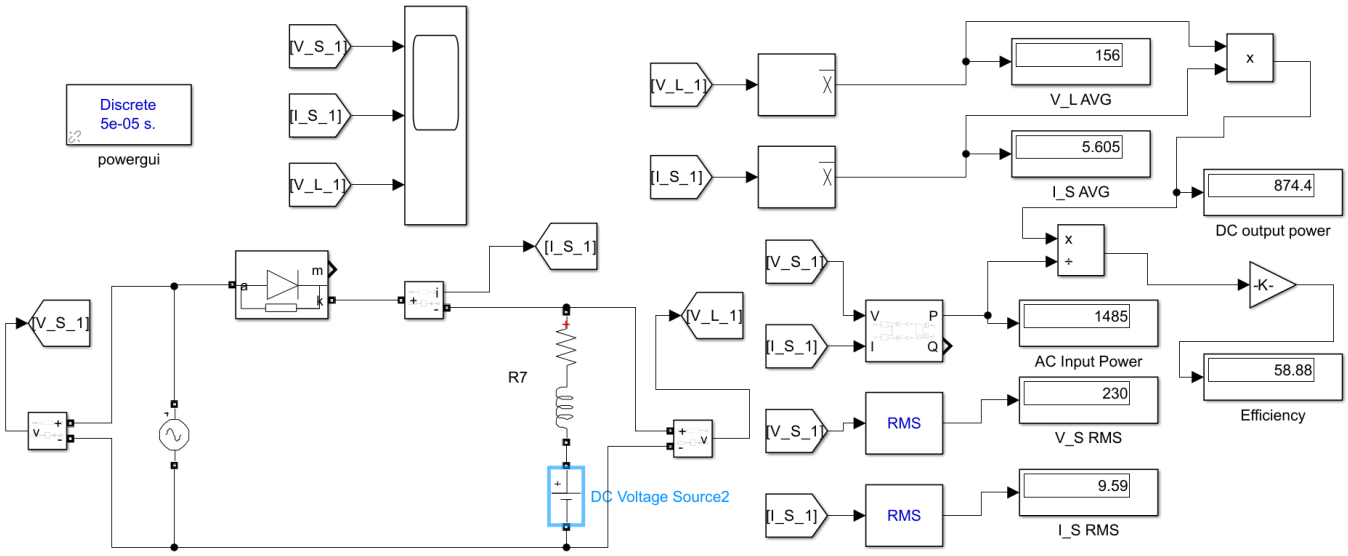

Figure 1.7: Circuit for Single Phase Half Wave Uncontrolled Rectifier with RLE load

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 reveal that the output voltage waveform follows the same shape as the RL load voltage waveform but with a positive DC offset. This is because of 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, equal 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

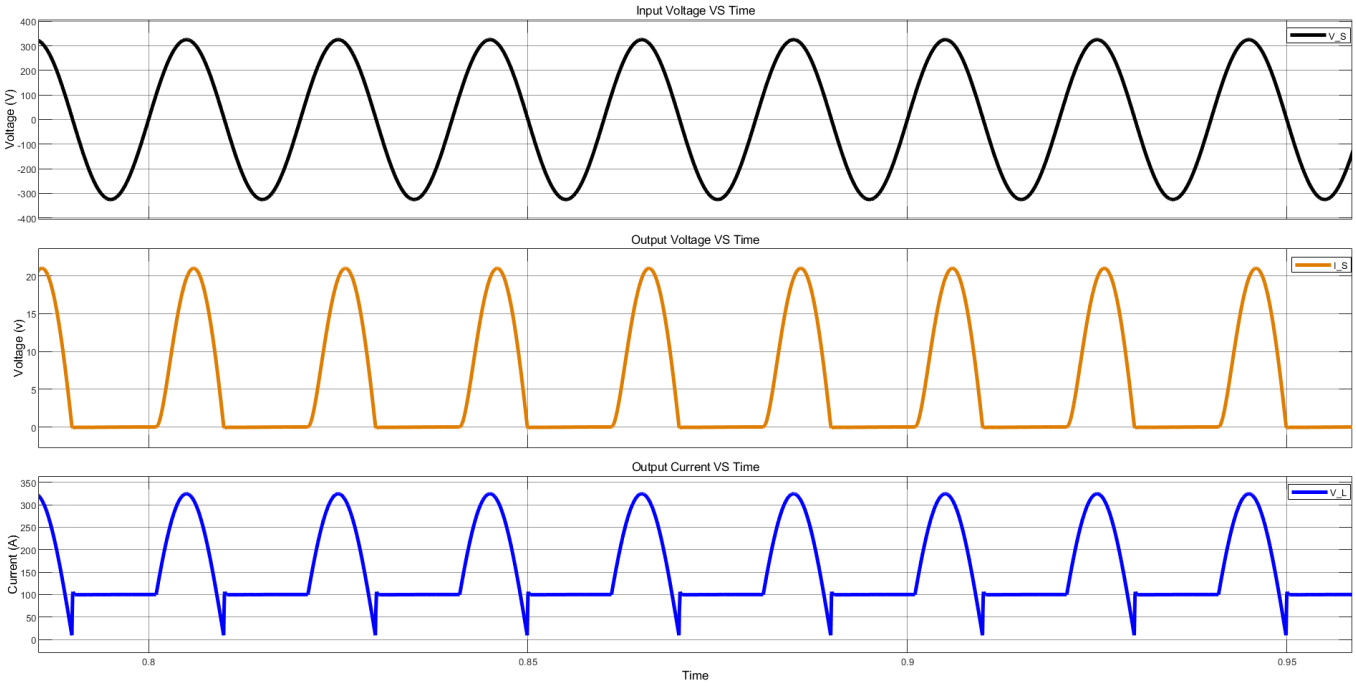

Figure 1.8: Scope Waveforms for Single Phase Half Wave Uncontrolled Rectifier with RLE load waveforms

1.9 Single Phase Half Wave Controlled Rectifier with R load

1.9.1 Circuit used for simulation

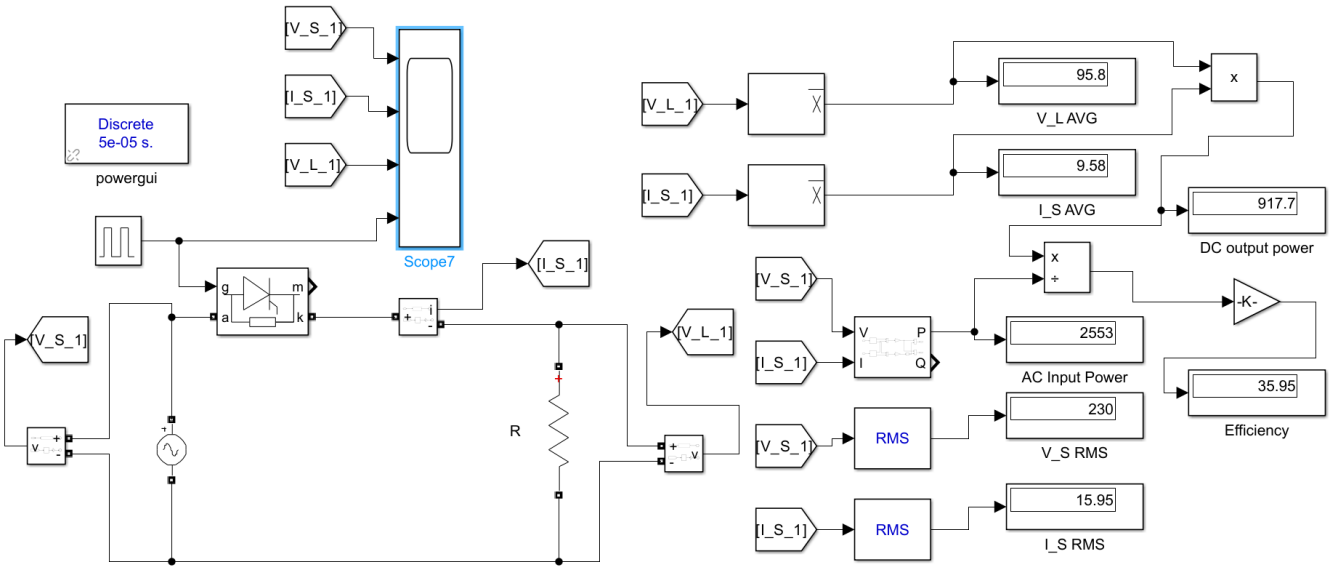

Figure 1.9: Circuit for Single Phase Half Wave Controlled Rectifier with R load (Firing Angle = 30°)

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 simulation results show that the rectifier circuit is functioning correctly, and the output voltage and current follow the theoretical values closely. As the load is resistive, the output current is in phase with the output voltage. The rectifier circuit is uncontrolled, and the output voltage contains a significant amount of ripple, which can cause problems for some applications. 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

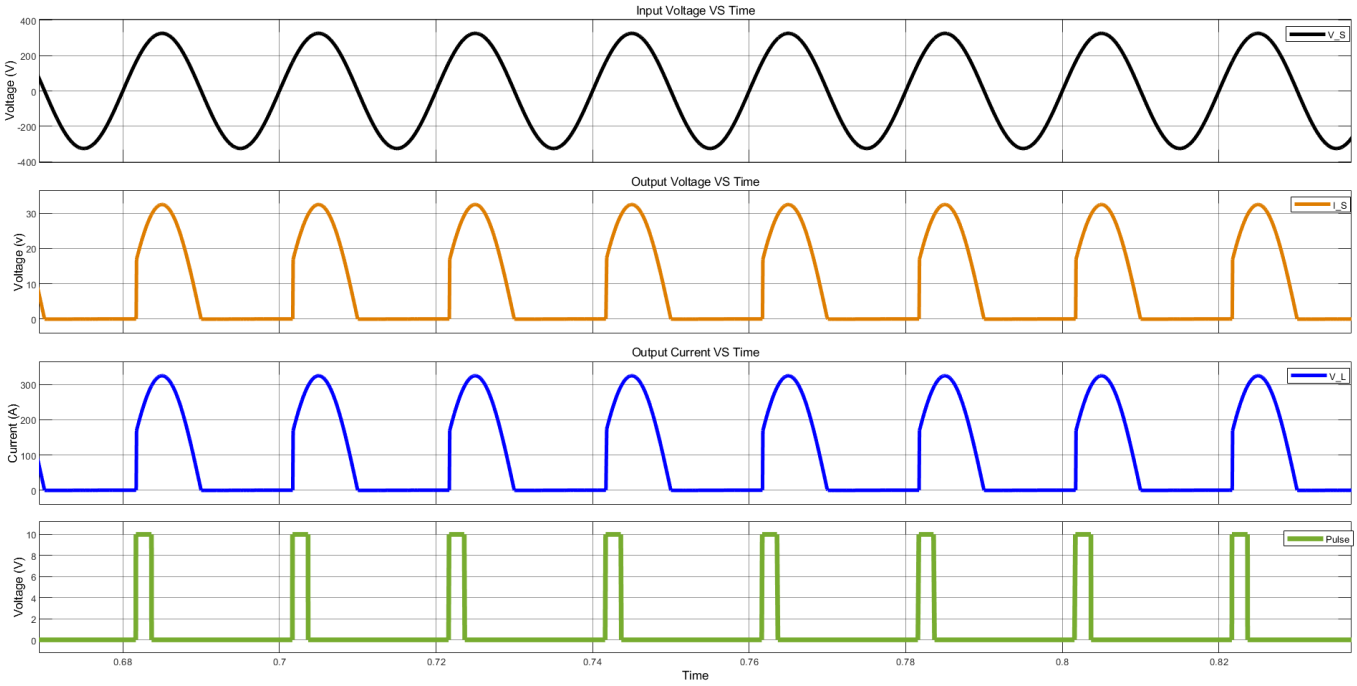

Figure 1.10: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with R load

1.10 Single Phase Half Wave Controlled Rectifier with RL load

1.10.1 Circuit used for simulation

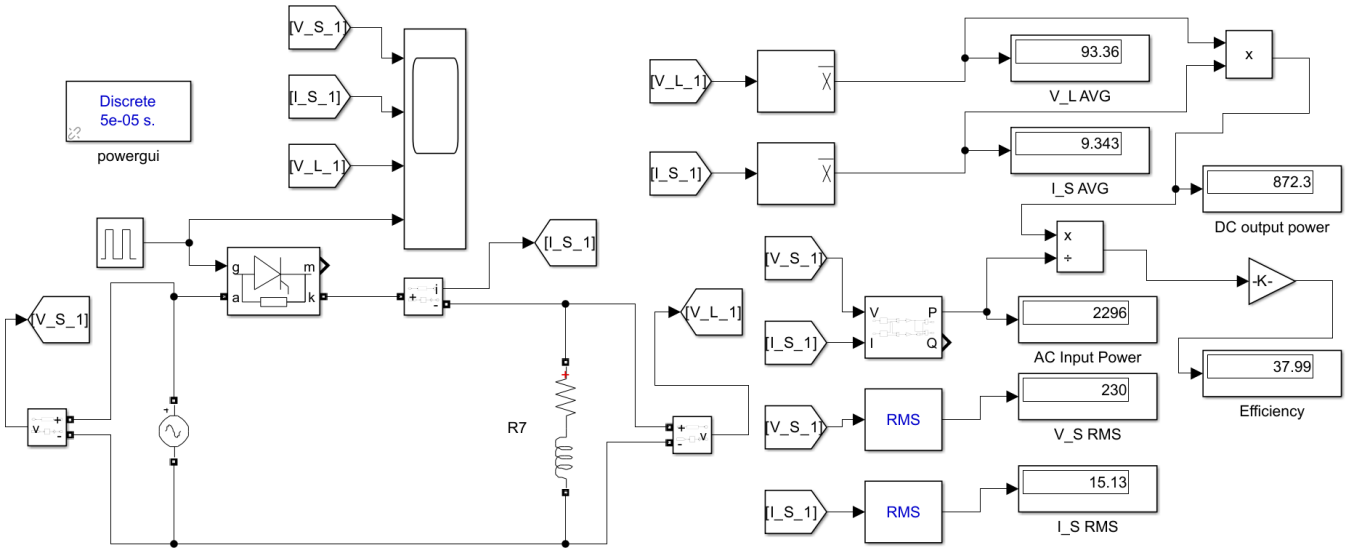

Figure 1.11: Circuit for Single Phase Half Wave Controlled Rectifier with RL load (Firing Angle = 30°)

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

It is observed that the circuit acts like an uncontrolled half wave rectifier only after the thyristor is triggered by a firing gate pulse. The output voltage waveform follows the shape of 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 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

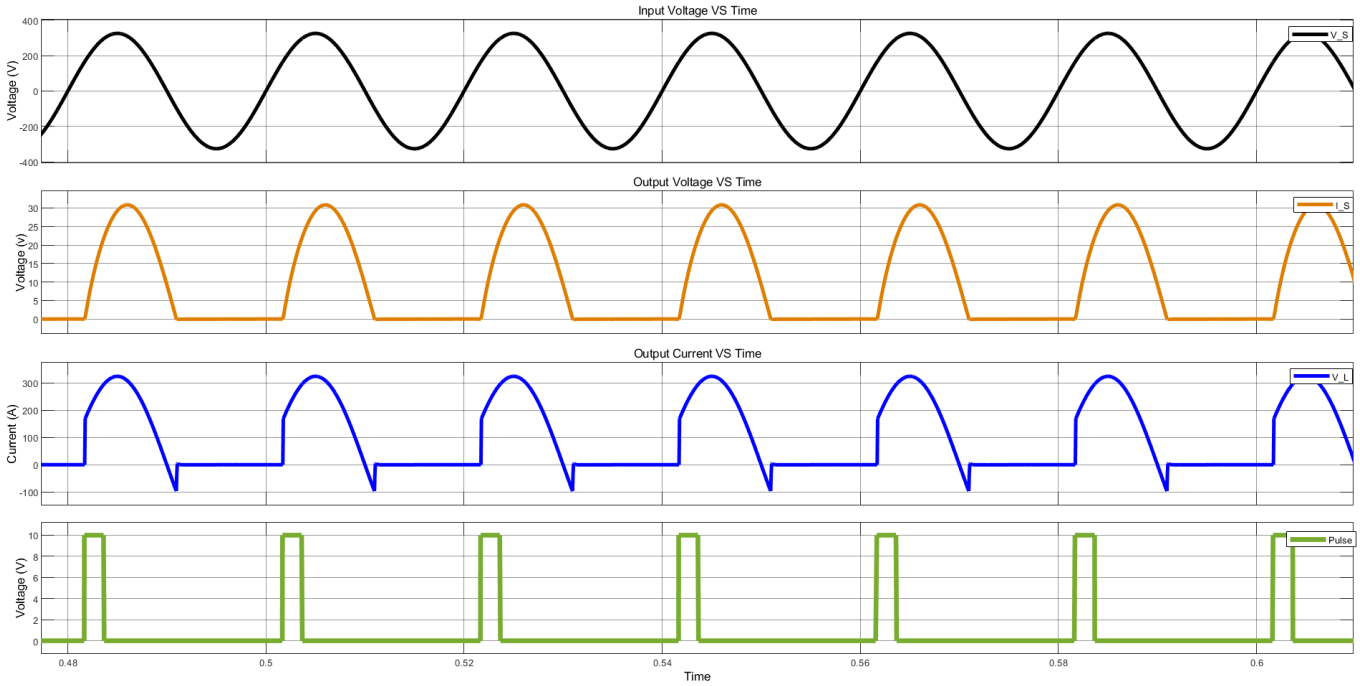

Figure 1.12: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RL load

1.11 Single Phase Half Wave Controlled Rectifier with RLE load

1.11.1 Circuit used for simulation

1.11.2 Components Required

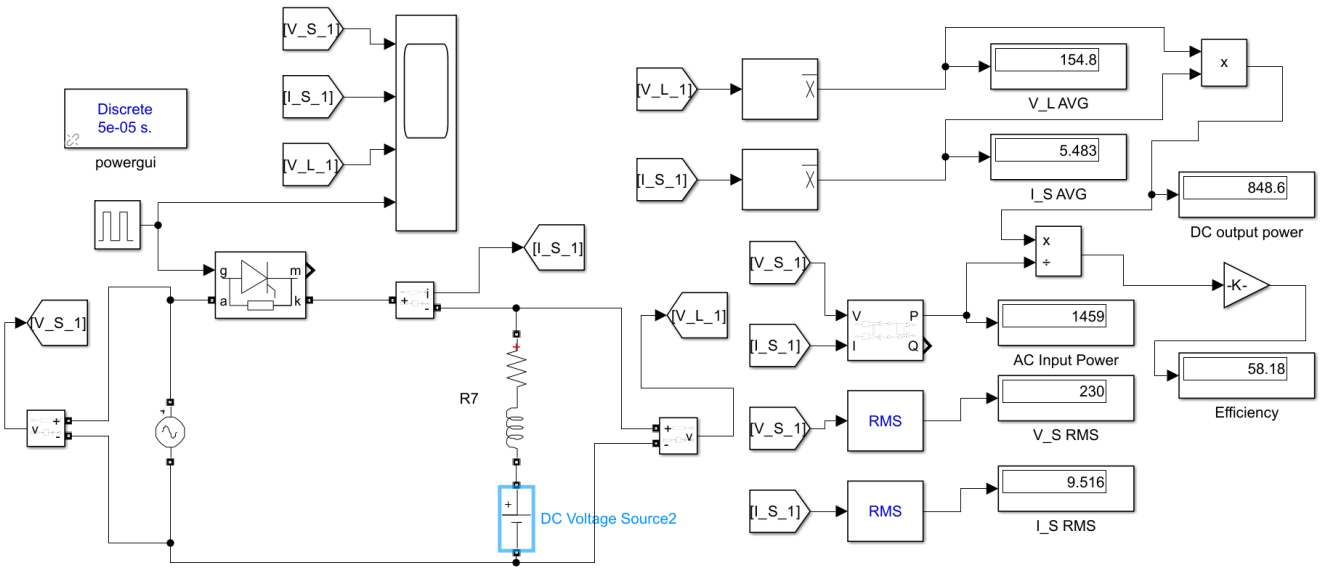

Figure 1.13: Circuit for Single Phase Half Wave Controlled Rectifier with RLE load (Firing Angle = 30°)

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

It is observed that the circuit acts like an uncontrolled half wave rectifier only after the thyristor is triggered by a firing gate pulse. The output voltage waveform follows the shape of 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

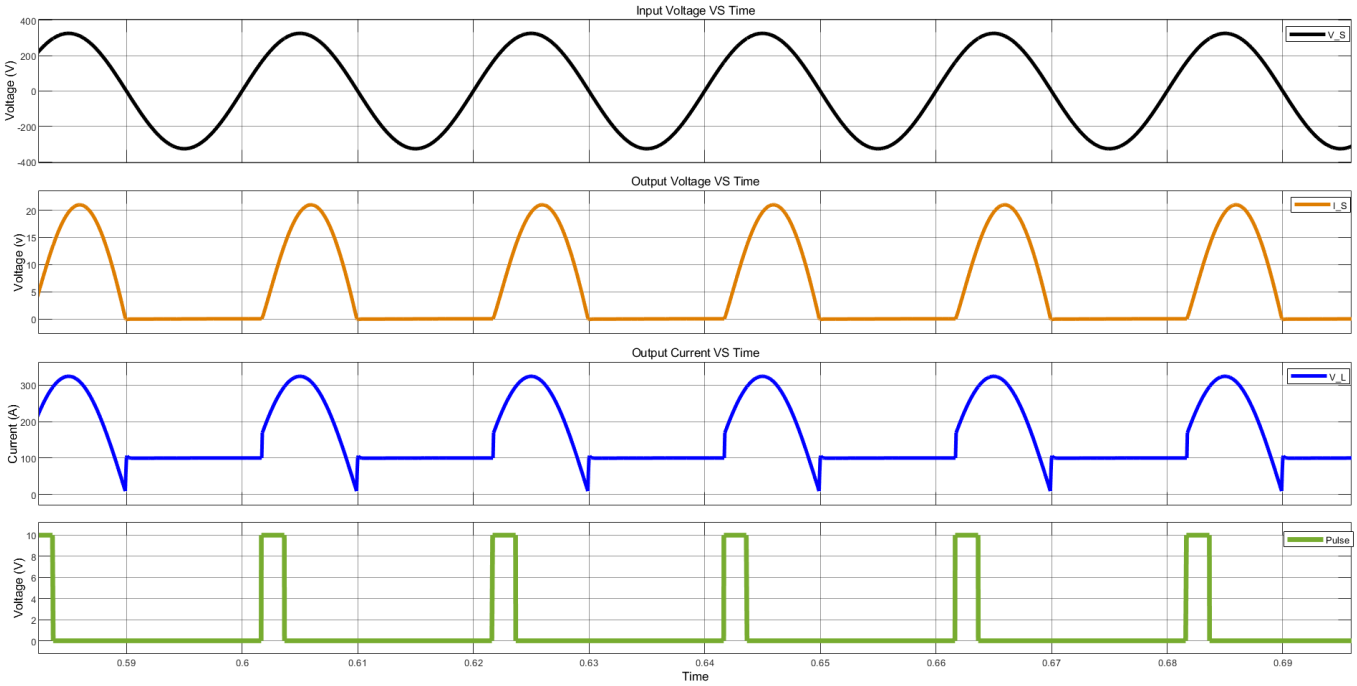

Figure 1.14: Scope Waveforms for Single Phase Half Wave Controlled Rectifier with RLE load

1.12 Conclusion

By leveraging MATLAB's Simulink, the study successfully implemented single-phase half-wave rectifiers - both controlled and uncontrolled - employing various loads, including resistive, inductive, resistive-inductive, and resistive-inductive with freewheeling diode. Subsequently, the simulation facilitated the extraction of output waveforms for voltage and current, allowing for a comparative analysis of theoretically calculated and simulated output parameters. Efficiency measurements were further taken for half-wave uncontrolled rectifiers operating on R load, RL load, RL load with freewheeling diode, and RLE load, resulting in efficiency values of 40.34%, 41.66%, 44.13%, and 58.88%, respectively. The investigation yielded a conclusion that the half-wave uncontrolled rectifier with RLE load possessed the highest efficiency of 58.88%. Efficiency measurements were also conducted for half-wave controlled rectifiers on R load, RL load, and RLE load, delivering efficiency values of 35.95%, 37.99%, and 58.18%, respectively. Consequently, the half-wave controlled rectifier with RLE load achieved the highest efficiency of 58.18%.

The present experiment effectively utilized MATLAB's Simulink to implement single-phase half-wave rectifiers - both controlled and uncontrolled - with various loads including resistive, inductive, resistive-inductive, and resistive-inductive with freewheeling diode. The resulting simulation enabled the derivation of output waveforms for voltage and current, allowing for a comparative assessment of theoretical versus simulated output parameters. Additionally, efficiency measurements were conducted for half-wave uncontrolled rectifiers operating on R load, RL load, RL load

with freewheeling diode, and RLE load, resulting in respective efficiency values of 40.34%, 41.66%, 44.13%, and 58.88%. The experiment established the half-wave uncontrolled rectifier with RLE load as possessing maximum efficiency of 58.88%. The efficiency measurements were similarly conducted for half-wave controlled rectifiers operating on R load, RL load, and RLE load, resulting in efficiency values of 35.95%, 37.99%, and 58.18%, respectively. Thus, the half-wave controlled rectifier with RLE load exhibited the highest efficiency of 58.18%.

The implementation of single-phase half-wave rectifiers - both controlled and uncontrolled - with varying