IGEE 401 Power Electronics

Lab Report 2

Group 213

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1.1 Objectives

The goal of this experiment is to become familiar with the Lab-Volt equipment used in the experimental procedure. Additionally, this lab focused on analyze the diode and thyristor three phase AC-DC converters.

1.2 Preliminary Calculations

For Diode Rectifier

$$I_{s-line-rms} = \sqrt{\frac{2}{3}} I_d$$

$$I_{s1-rms} = \frac{\sqrt{6}}{\pi} I_d$$

$$V_d = \frac{3}{\pi}\sqrt{6} V_s$$

$$I_d = \frac{V_d}{R}$$

$$P = \frac{3}{\pi}\sqrt{6} V_s I_d$$

For Thyristor Rectifier

$$V_d = \frac{3}{\pi}\sqrt{6} V_s \cos\alpha$$

$$P = \frac{3}{\pi}\sqrt{6} V_s I_d \cos\alpha$$

All the other calculations have the same equations as diode rectifiers.

Performance Indices	Diode Rectifier	Thyristor Rectifier
rms line voltage(v)	208	208
rms line current(A)	0.255	0.127
Rms fundamental line current (A)	0.244	0.122
Average load Voltage (V)	280.8	140.4
Average load current (A)	0.312	0.156
Real Power (W)	87.61	21.90

Table 1 Preliminary Calculations

1.3 Experimental Procedures and Results

1.3.1 Simulation-Diode three phase rectifier – Steady State

b. The waveform of the active and reactive power at the input of the AC-DC converter is shown below.

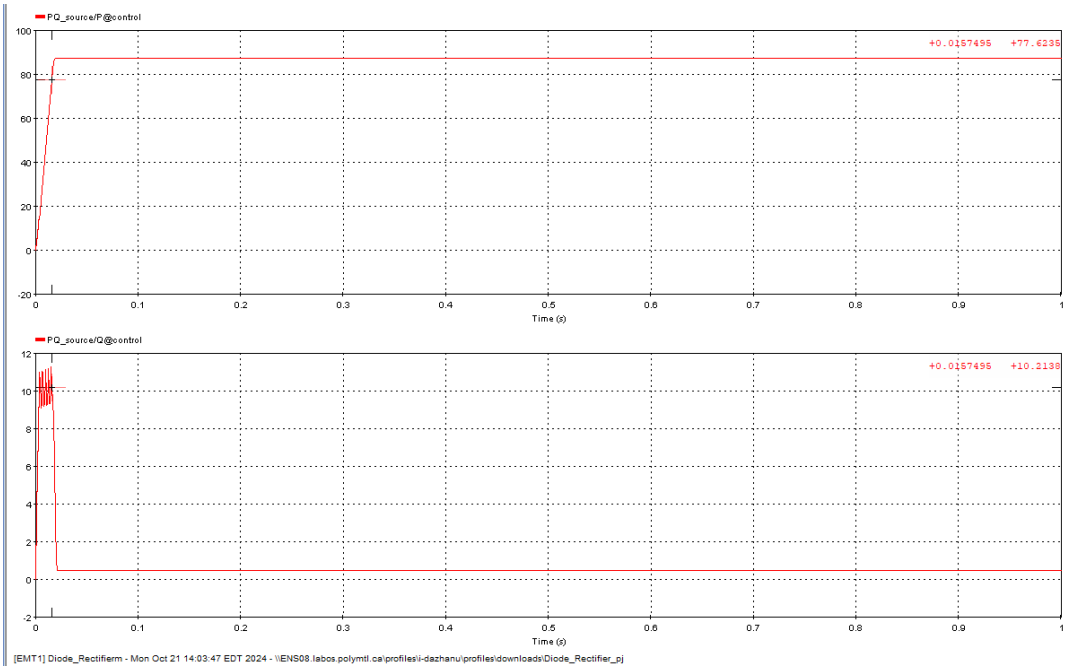

Figure 1 Active and Reactive power measurement of AC-DC converter

c. The waveform of the input current of the AC-DC converter and load voltage and load current are shown below.

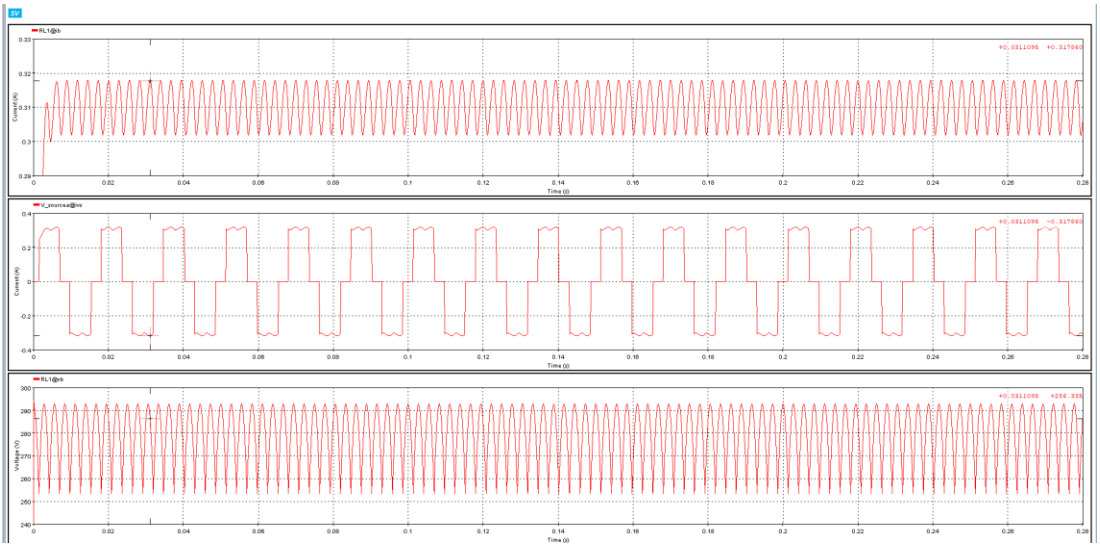

Figure 2 Waveform of input current, load voltage, and load current

d. The harmonic spectrum of input current, load voltage, and load current are shown below.

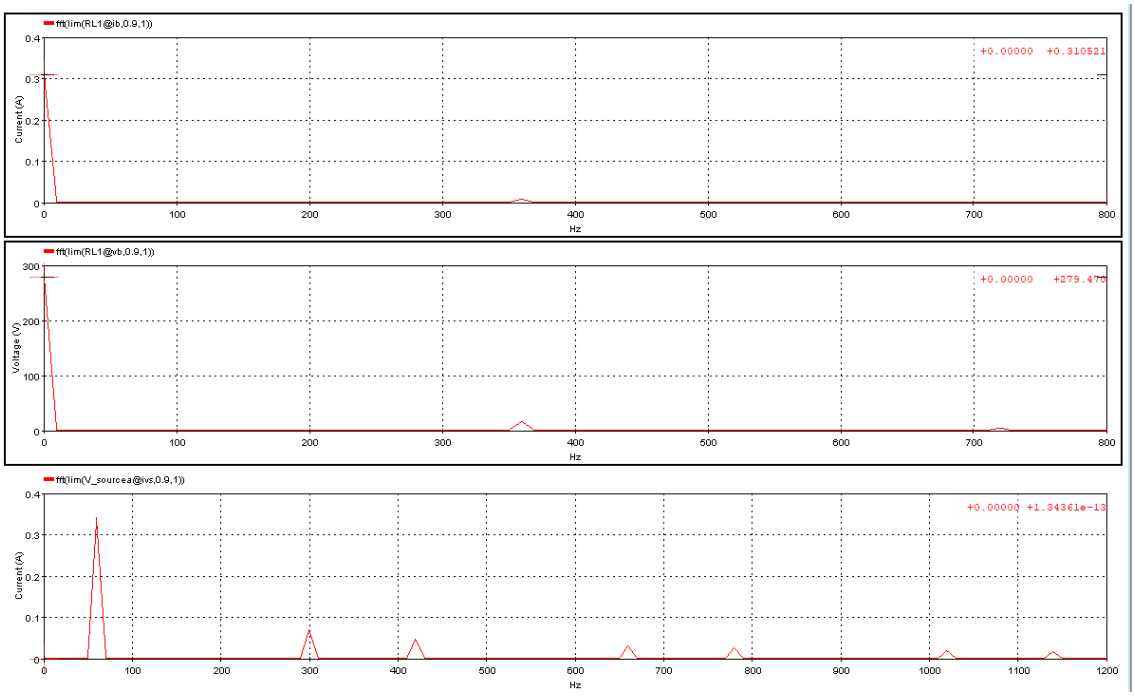

Figure 3 Harmonic spectrum of input current, load voltage, and load current

X Coordinate	Y peak of Input current
59.997	0.3425
299.99	0.0704237
419.998	0.0469384
659.997	0.030764
779.996	0.0258173

Table 2 Fundamental and Harmonic Components of Input current

X coordinate	Y peak of Load Current	Y peak of Load Voltage
DC	0.310521	279.47
359.99	0.00792418	16.0514
719.996	0.00105329	3.92901

Table 3 Fundamental and Harmonic Components of Load Current and Load Voltage

e. The waveforms of the current and voltage across one switch are shown below.

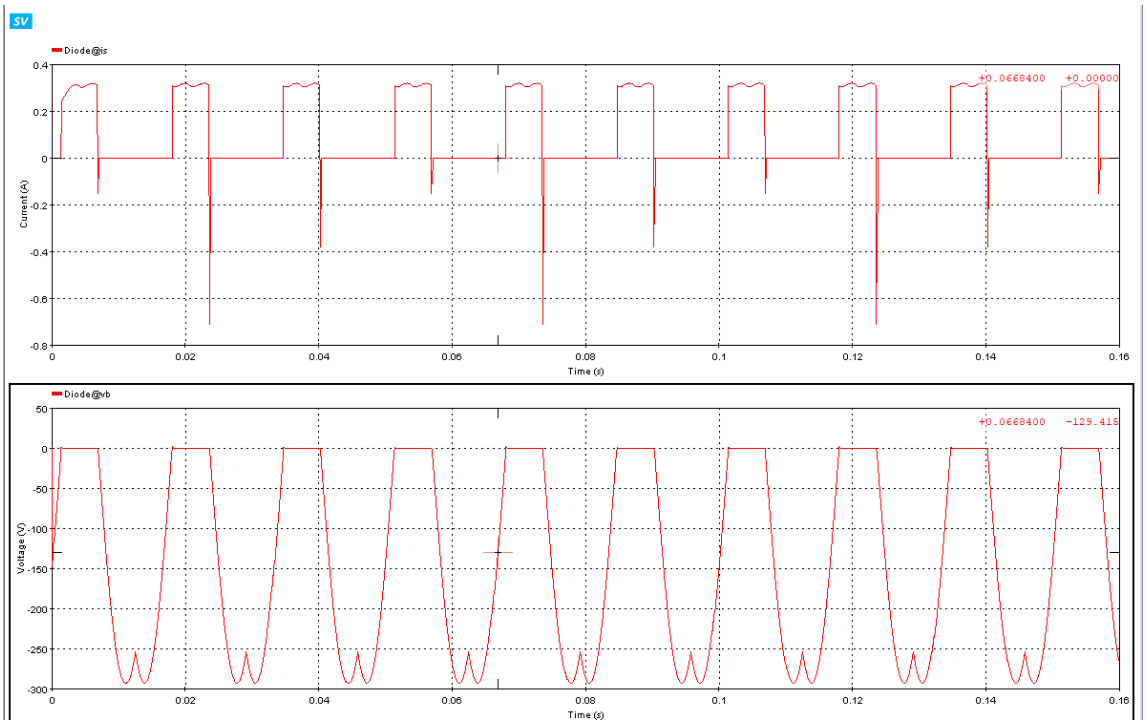

Figure 4 Waveform of current and voltage across one switch

f.

Performance indices	Diode Rectifier	Thyristor Rectifier	Thyristor Rectifier (60)
rms line voltage (V)	208	208	208
rms line current (A)	0.251	0.254	0.157
rms fundamental line current (A)	0.242	0.243	0.0415
Average load voltage (V)	279.47	280.885	139.601
Average load current (A)	0.3105	0.3121	0.1554
Real Power (W)	86.77	87.66	21.69

Table 4 Performance Indices-Simulation

1.3.2 Simulation - Steady State

For α = 0.01

c. The active and reactive powers at the input of the AC – DC converter is shown below.

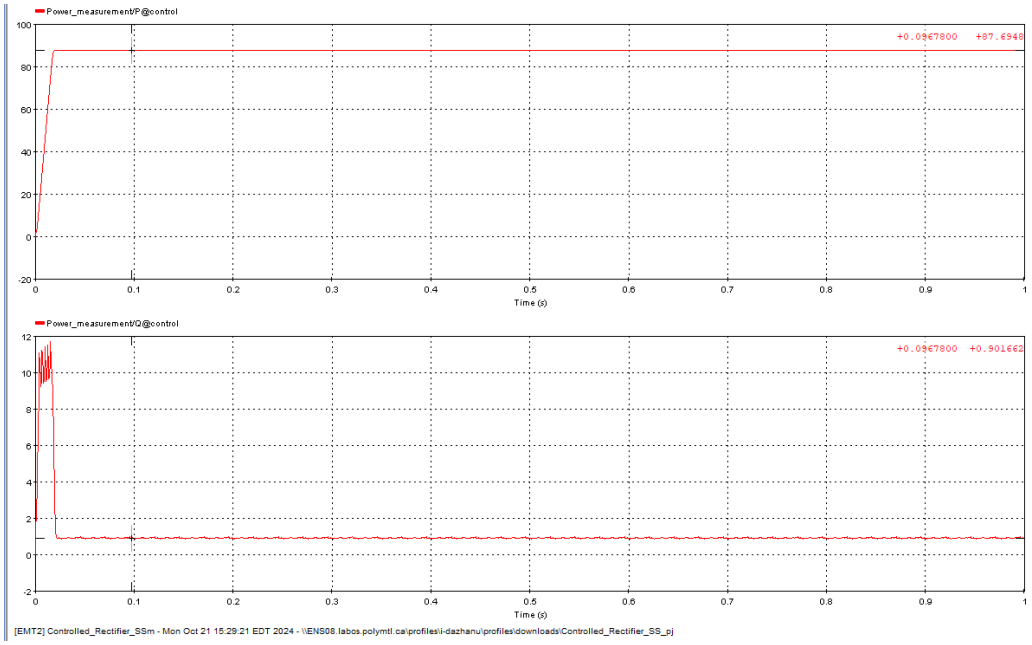

Figure 5 Active and Reactive power measurement of thyristor rectifier with firing angle of 0.1

d. The waveforms of the input current, load voltage and current are shown below.

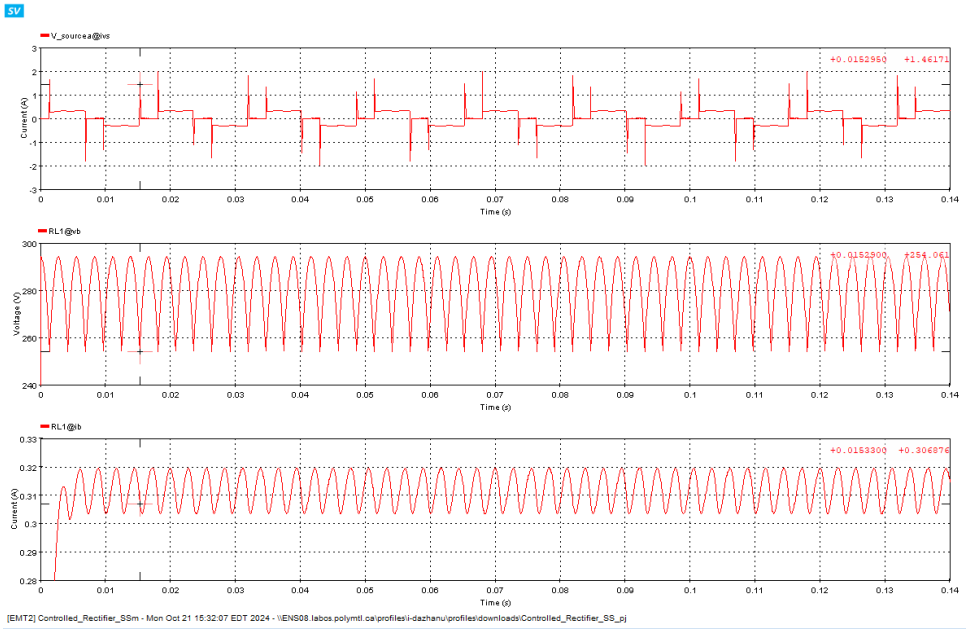

Figure 6 input current, load voltage and current waveforms

e. The required harmonic spectrums of the input current, load voltage, and current are shown below.

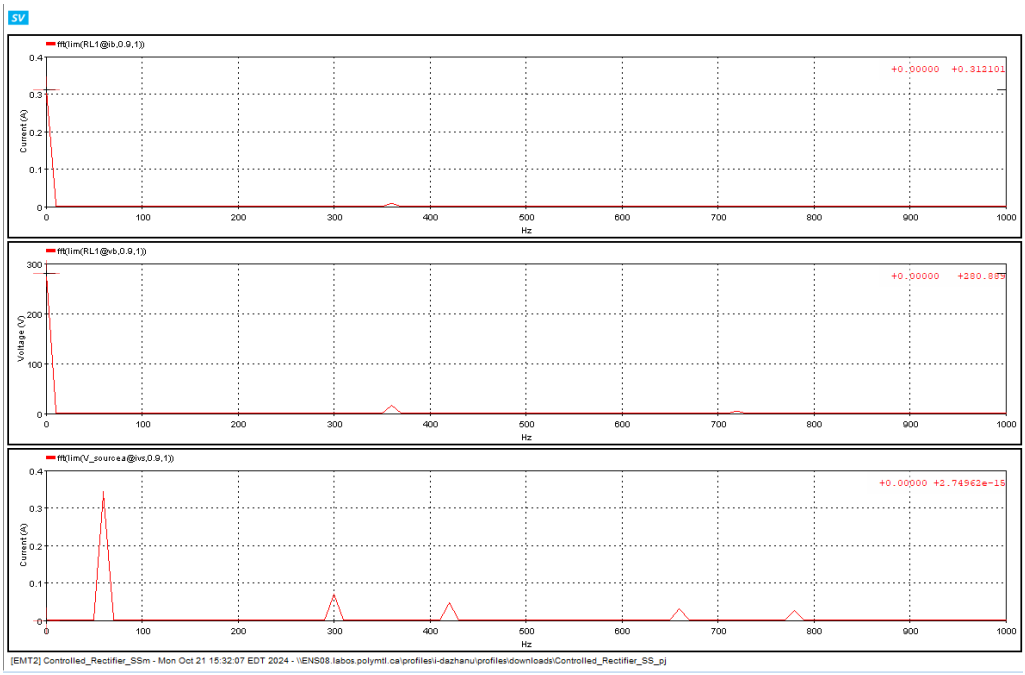

Figure 7 Harmonic spectrum of input current, load voltage and current

X Coordinate	Y peak of Input current
59.997	0.344231
299.99	0.079799
419.998	0.04736
659.997	0.031125
779.996	0.026167

Table 5 Fundamental and Harmonic Components of Input current

X coordinate	Y peak of Load Current	Y peak of Load Voltage
DC	0.312101	280.855
359.99	0.00794	16.0594
719.996	0.001055	3.93721

Table 6 Fundamental and Harmonic Components of Load Current and Load Voltage

f. Waveforms of current and voltage across one switch are shown below.

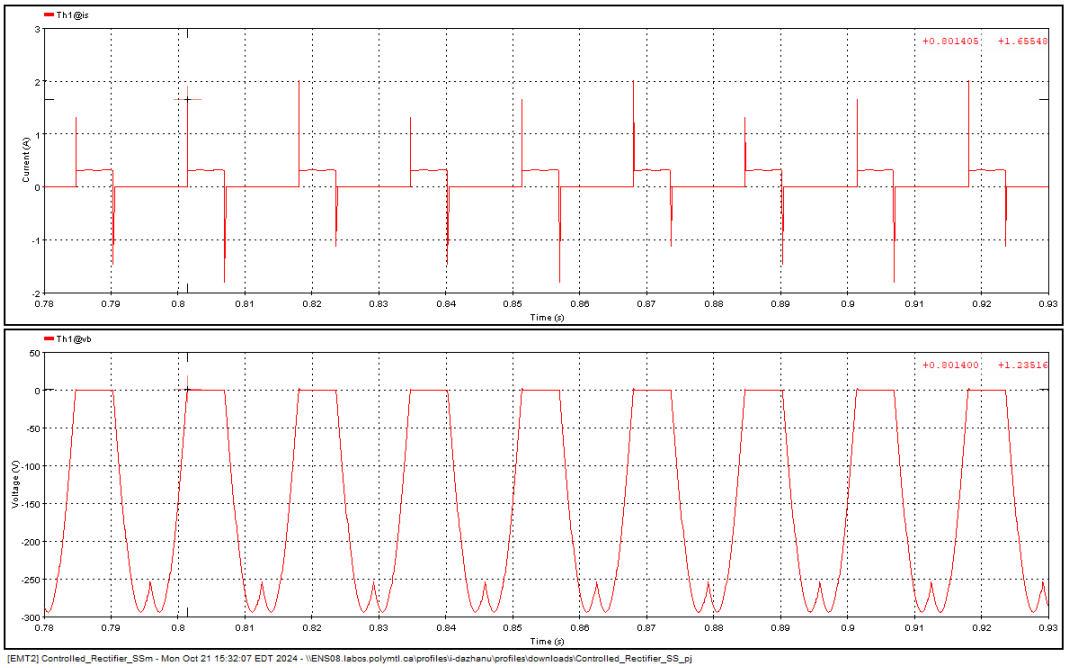

Figure 8 current and voltage across one switch

For α = 60

c. The active and reactive powers at the input of the AC – DC converter is shown below.

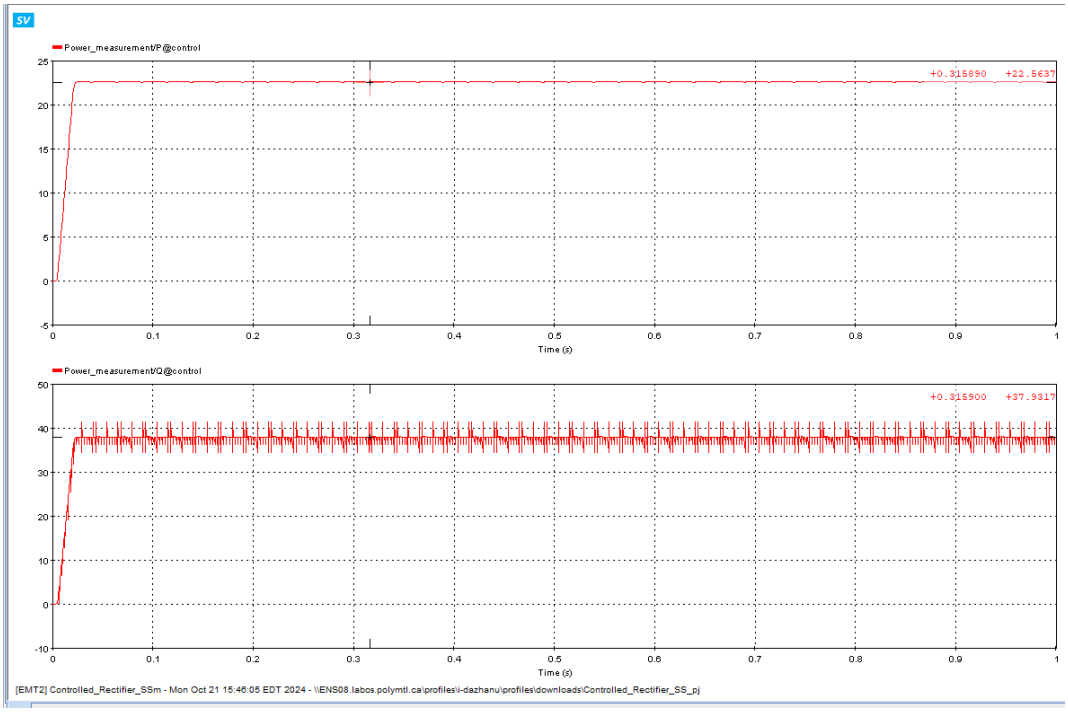

Figure 9 Active and Reactive power measurement of thyristor rectifier with firing angle of 60

d. The waveforms of the input current, load voltage and current are shown below.

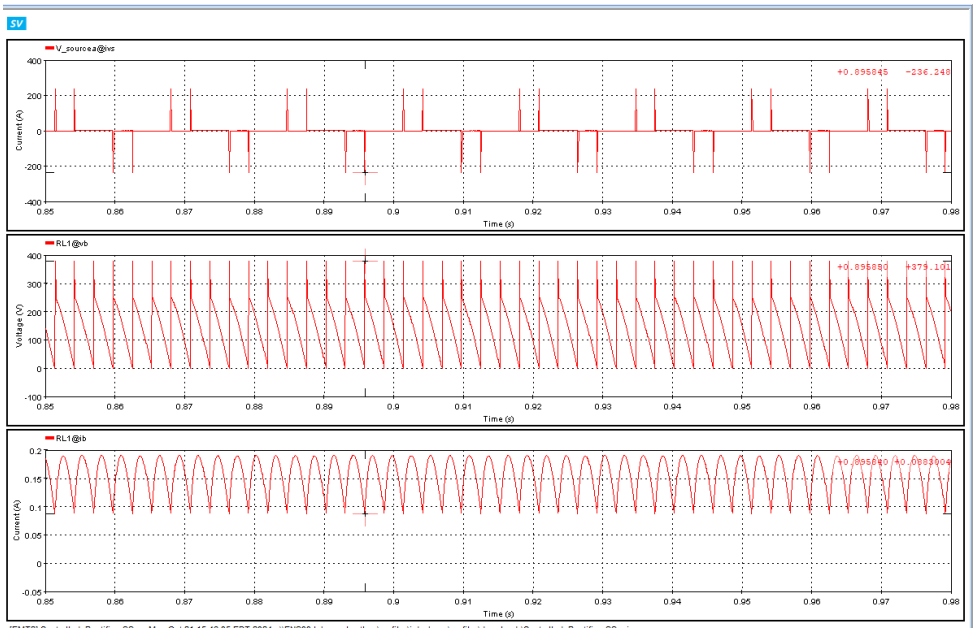

Figure 10 input current, load voltage and current waveforms

e. The required harmonic spectrums of the input current, load voltage, and current are shown below.

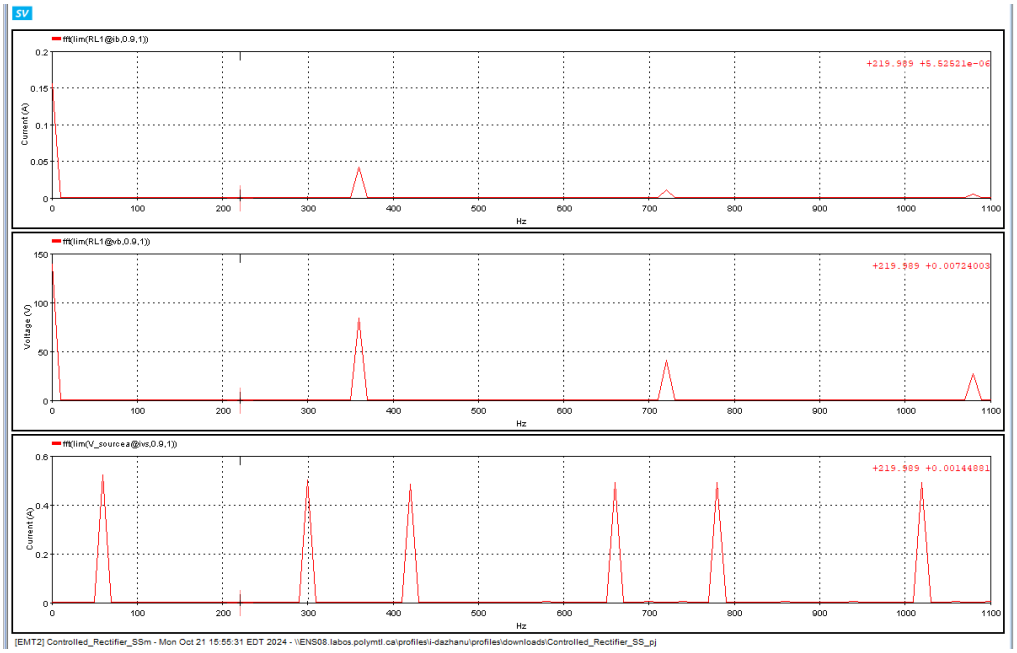

Figure 11 Harmonic spectrum of input current, load voltage and current

X Coordinate	Y peak of Input current
59.997	0.523544
299.99	0.503206
419.998	0.484044
659.997	0.490816
779.996	0.489912

Table 7 Fundamental and Harmonic Components of Input current

X coordinate	Y peak of Load Current	Y peak of Load Voltage
DC	0.155363	139.601
359.99	0.041519	83.9502
719.996	0.0109792	40.9644

Table 8 Fundamental and Harmonic Components of Load Current and Load Voltage

f. Waveforms of current and voltage across one switch are shown below.

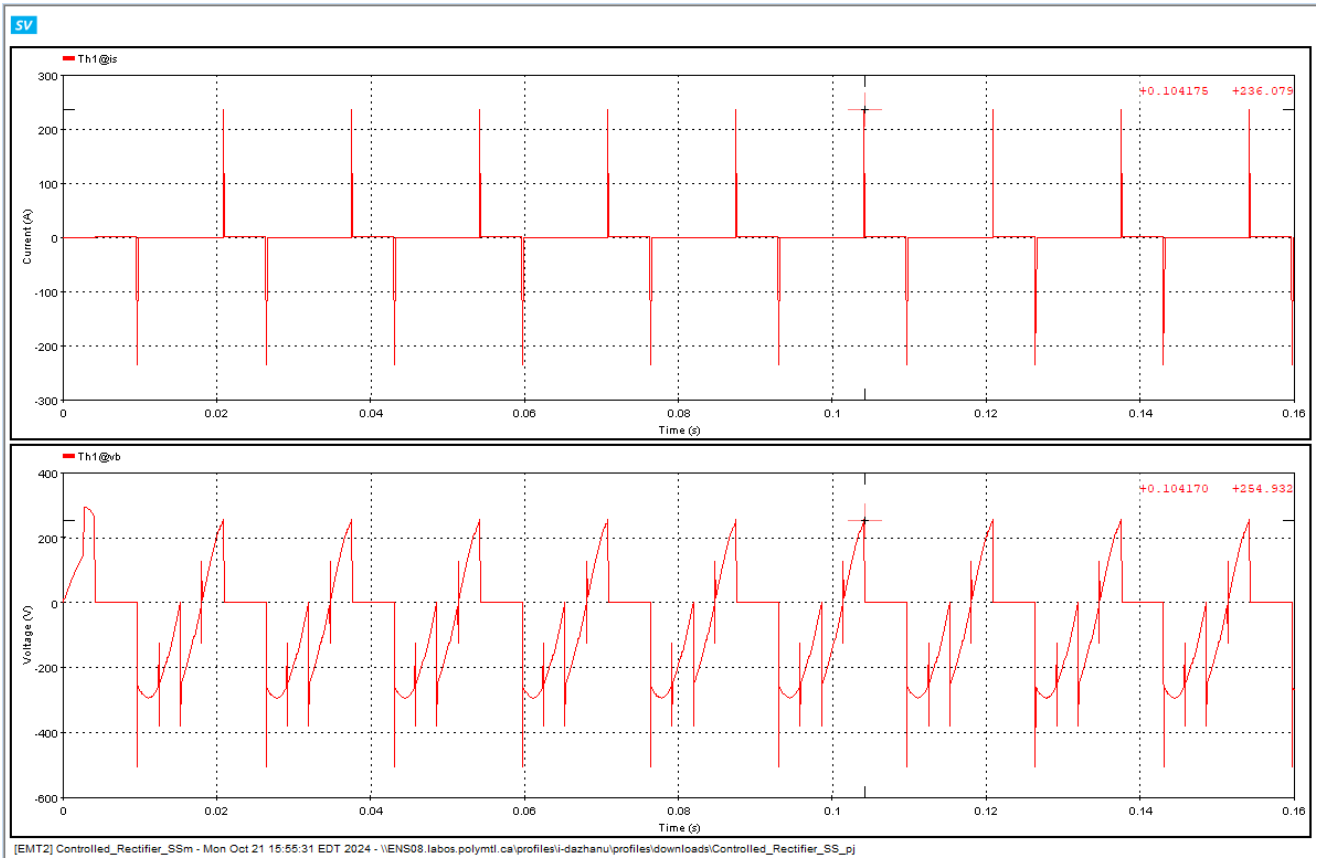

Figure 12 current and voltage across one switch

1.3.3 Simulation – Transient

c. The waveform of the input current of the rectifier, output current of the rectifier, and load voltage are shown below.

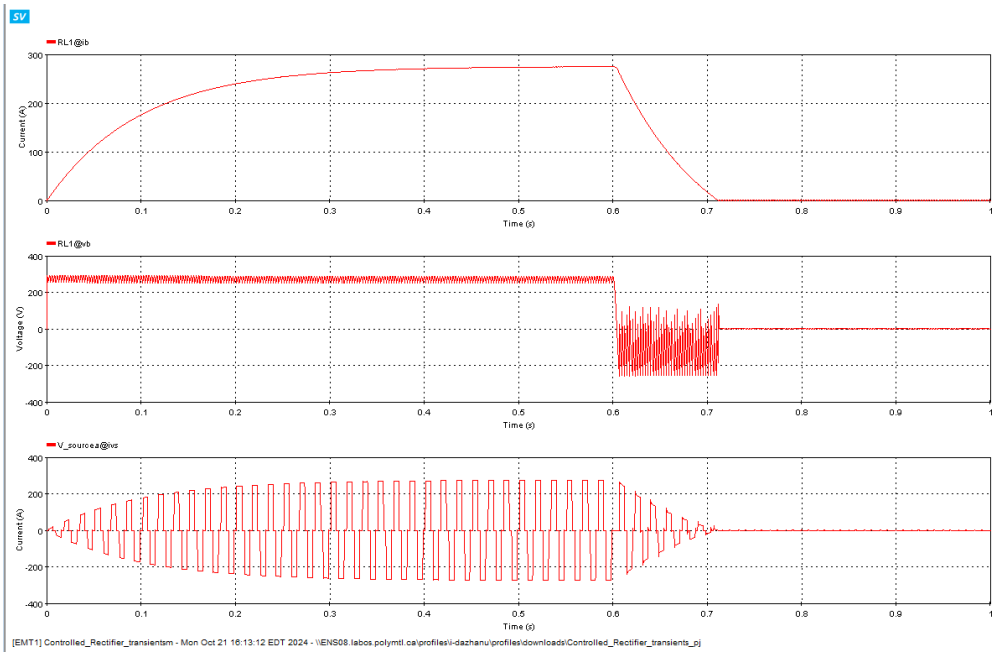

Figure 13 Input current of the rectifier, output current of the rectifier, and load voltage waveform

There are three operating modes in total.

Mode 1 happens from 0 to 0.6 seconds. The firing angle is 0.1 degrees, which is really close to zero. This allows maximum conduction of the thyristor, resulting in high average load voltage. During this period, both source current and load current steadily increase, reach its maximum value as it stabilizes to a steady-state condition. The rectifier is in forward power flow as it supplies power from AC source to the DC load.

Mode 2 is the period happens from 0.6 to around 0.7 seconds. The firing angle abruptly change from 0.1 to 120 degrees. This large change in firing angle causes a sudden reduction in load voltage and current since a large portion of the AC cycle is blocked by the thyristor. The voltage appear to be negative at this mode since the firing angle is bigger than 90 and the rectifier acts as an inverter.

Mode 4 is from 0.7 seconds onward, the rectifier essentially ceases to supply power to the load, causing the load voltage, load current, and input current to drop to zero. The power flow halts as the system enters a state of no conduction.

d. The harmonic spectrums of the load voltage in each of the operating modes are shown below.

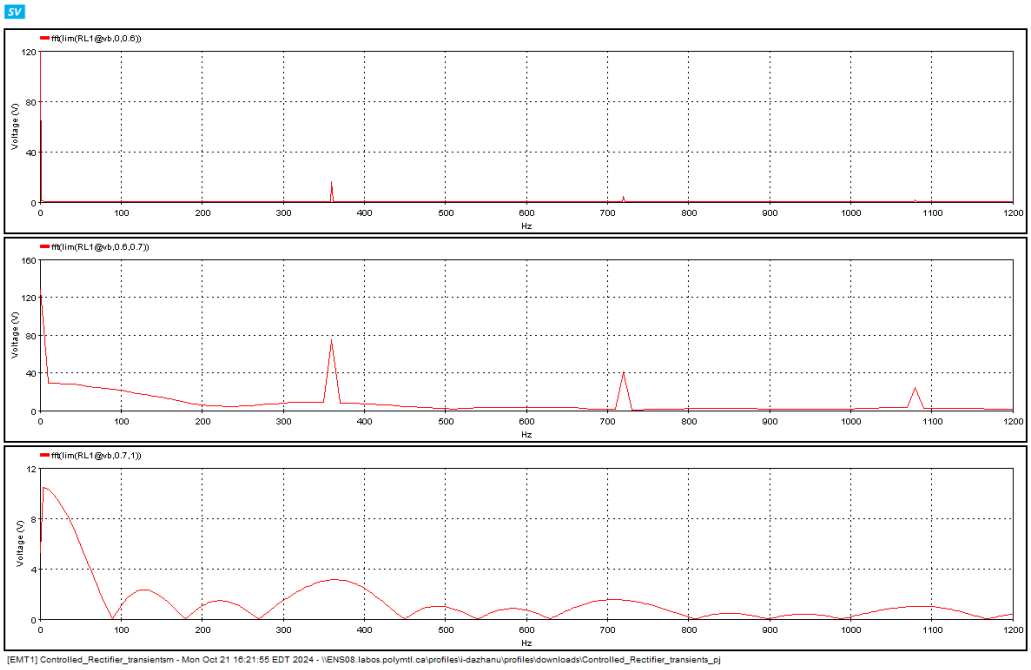

Figure 14 Harmonic Spectrum of Load Voltage in different operating modes

During Mode 1, with firing angle close to zero, allowing maximum conduction. The harmonic spectrum presents a strong DC component with minimal harmonic content. This indicates that the waveform is relatively smooth with minimal distortion.

During mode 2, the firing angle changes to 120 degrees, leading to sudden oscillations. The harmonic spectrum shows a noticeable increase in harmonic components at 360 Hz and 720 Hz. It has a higher level of distortion.

During mode 3, the firing angle remains at 120 degrees. The DC component is significantly reduced. It contains a substantial number of harmonics. The increase in harmonic content across various frequencies implies that the waveform is highly distorted, and that little effective power transfer occurs, as seen in the zero-current state in the time-domain waveform.

1.4 Questions and Discussions

1). The table is shown below

$$THD = 100 \cdot \frac{I_{dis}}{I_{s1}}$$

$$S = \sqrt{3}\, V_{LL} I_s$$

$$P = \sqrt{3} V_{LL} I_{s1} cos\alpha$$

$$pf = \frac{P}{S}$$

Performance Indices	Diode Rectifier		Thyristor Rectifier	
	Theo	Sim	Theo	Sim
Line Current THD	30.36	27.53	31.1	30.349
Apparent Power Input Power (VA)	91.87	90.43	45.75	56.56
Real Power (W)	87.91	87.19	21.98	25.6141
Input Power Factor	0.955	0.955	0.478	0.453

Table 9 Performance Indices Evaluation - Three Phase Full Bridge Rectifier

2). Compare the results and comments

The results from the simulation and theoretical calculations match for both the diode rectifier and the thyristor rectifier, with minor differences. These differences can be attributed to the idealized conditions in which the theoretical calculations were done.

3). Why the negative voltage across the load cannot be sustained indefinitely in (3.3.b)

The inverter mode operation of the thyristor can only be sustained if there is a power source on the DC side of the converter. However, in this circuit, there is no such power, and negative voltage cannot last.

1.5 Conclusion

This lab provided hands-on experience and insights into the operation and performance of three-phase diode and thyristor AC-DC converters. Through simulations and harmonic analysis, we observed the differences in performance indices between the diode and thyristor rectifiers, particularly in terms of average load voltage, current, and real power. The diode rectifier demonstrated a higher average load voltage and current compared to the thyristor rectifier at a firing angle of 60°, which aligns with theoretical expectations due to the control introduced by the thyristor's firing angle. Additionally, the transient response of the thyristor rectifier was analyzed by adjusting the firing angle during operation. This analysis revealed three distinct modes of operation: full conduction with forward power flow, a transition period with oscillations, and a reduced conduction mode.