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EE 463 Term Project Fall 2018

Single Phase Diode Rectifiers

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1. Introduction

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. In this project I will analyse single phase and three phase rectifiers with different loads and line inductances. I will simulate the circuits in Simulink. Then, I will comment about them by using theoretical background from EE463.

2. Test Results

a. 1st Question

Since it is a full wave rectifier, we should see a fully rectified sinusoidal signal. However, we can only see a sinusoidal signal if we take enough samples. Input voltage's frequency is 50 Hz, so the period is 20ms. If we make the step size 1.5ms, we only take 13 samples in a period which makes the signal not smooth as it should be. On the other hand, if we make the step size 1us and 10us, we see a sinusoidal signal. For a faster processing, 1us is enough for 50 Hz signal.

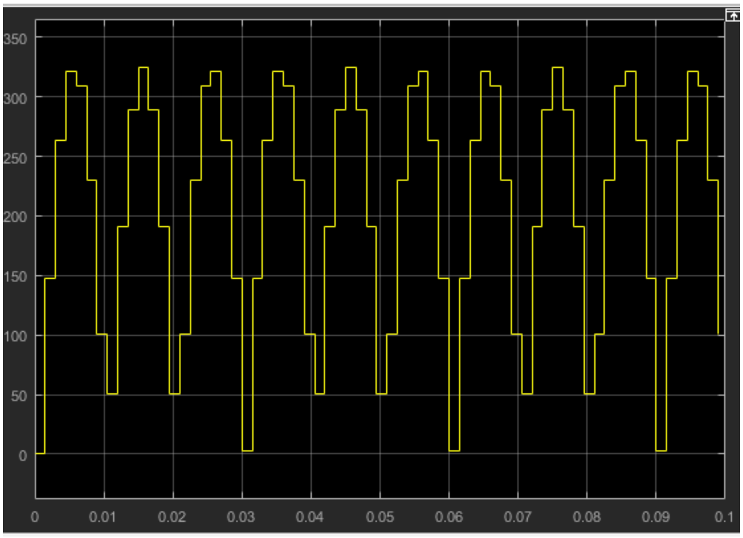

Figure 1: Vout Characteristics for 1.5ms Step Size

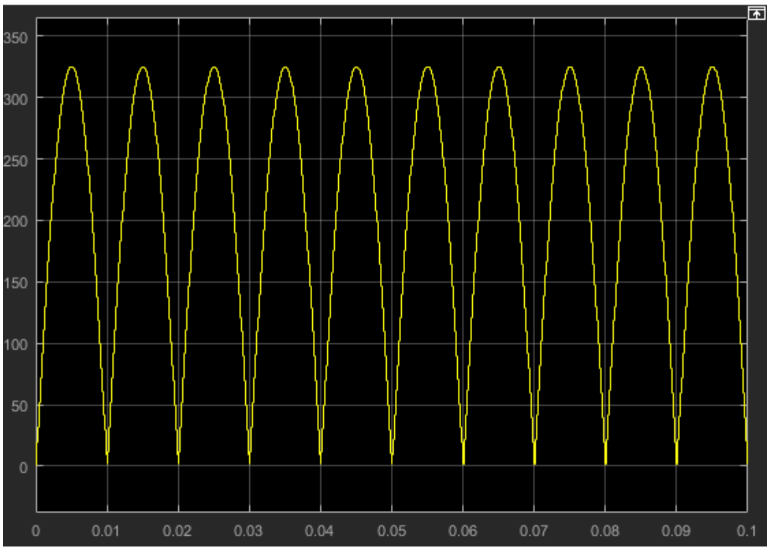

Figure 2: Vout Characteristics for 1us Step Size

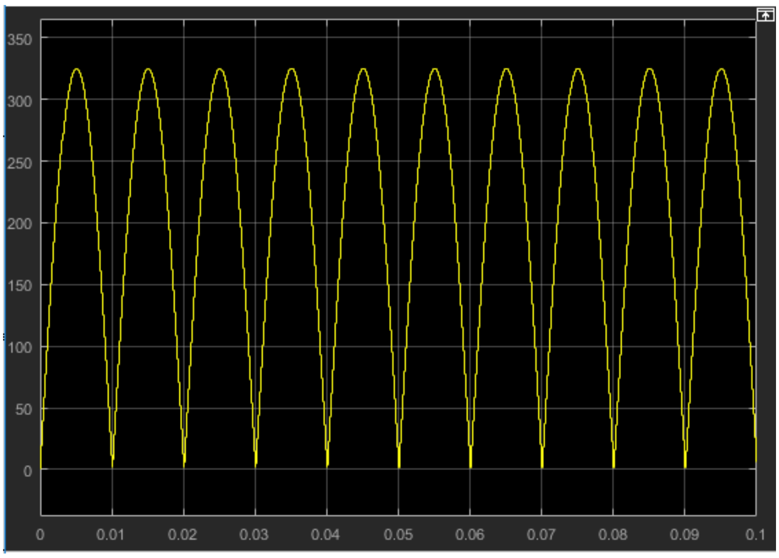

Figure 3: Vout Characteristics for 10us Step Size

b. 2nd Question

i. 2.1Part

If we have an inductance at the load, there would be no difference in voltage characteristics because output voltage is related to input voltage. However, there will be a difference in current characteristics. There is the relationship between current and voltage as given: Vout = i*R + L*di/dt. Then, the current becomes $\boldsymbol{i = e^{-Rt/L} + \frac{Vout}{R} = e^{-25t/L} + \frac{Vout}{25}}$. Thus, if we make L=0, we would see a sinusoidal current characteristics. If we make L=10mH, again we would see almost a sinusoidal signal, since it is a small inductance value. On the other hand, if we make L=1H, we wouldn't see a sinusoidal signal. The total harmonic distortion (THD) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. If a load is purely resistive, we wouldn't see a distortion. However, if it is a capacitive or inductive load, we would see distortions. As we convert the resistive load to inductive load, we would see more distortions. We would see the biggest distortion in third harmonic.

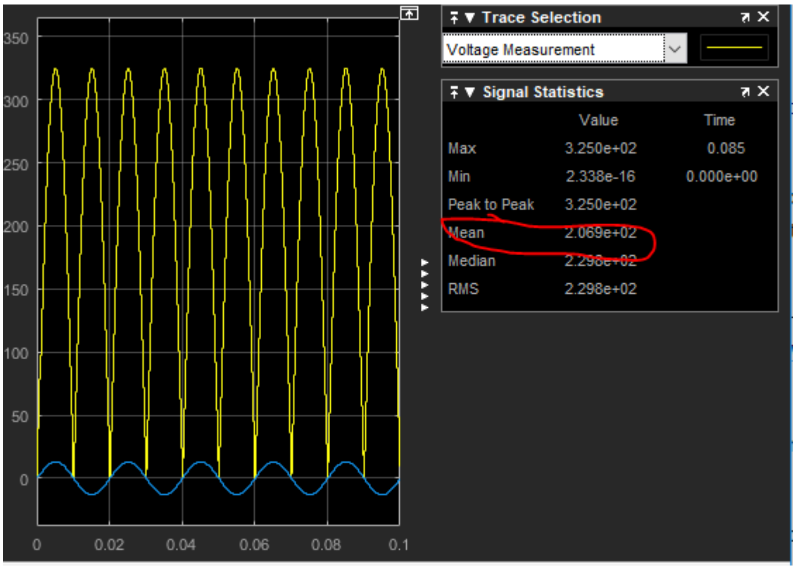

Figure 4: Voltage and Current Characteristics for R=25ohm Load

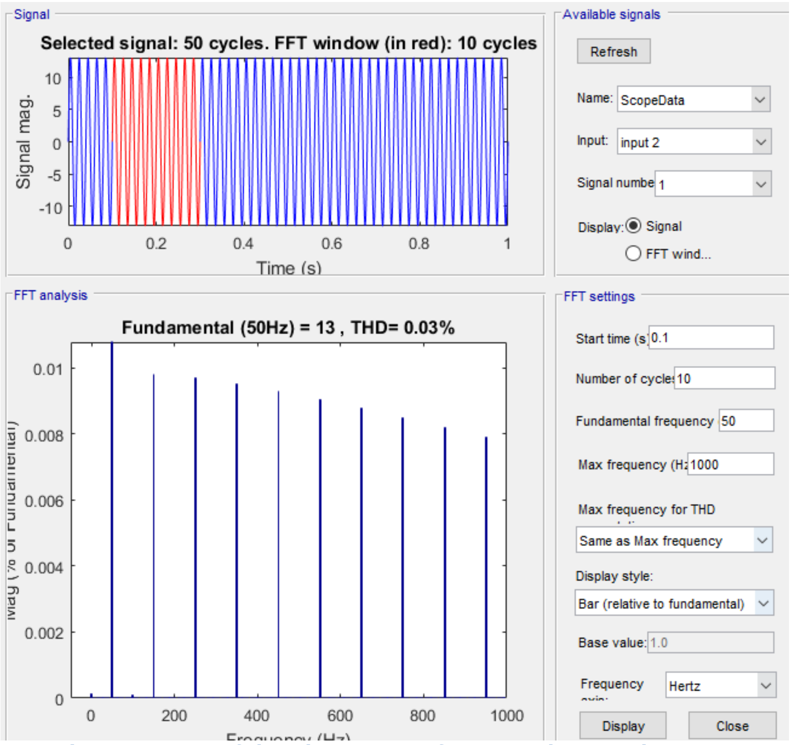

Figure 5: THD of the Line current for R=25ohm Load

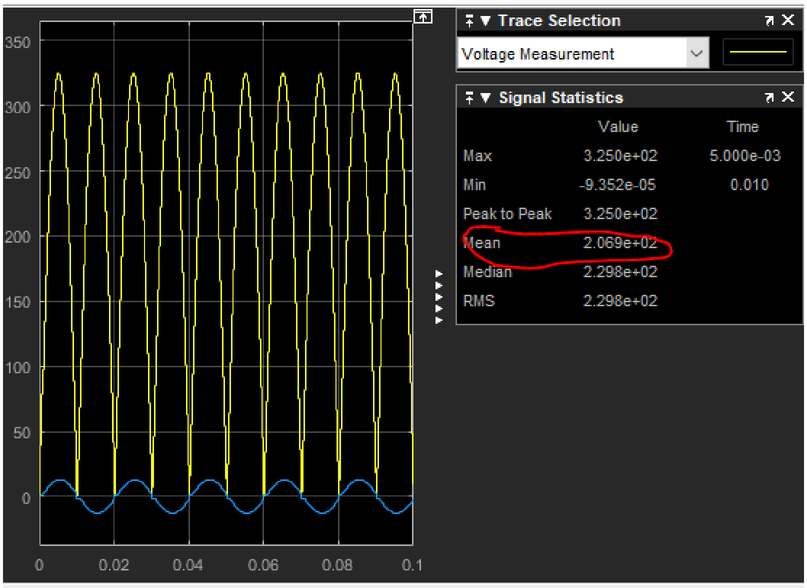

Figure 6: Voltage and Current Characteristics for R=25ohm L= 10mH Load

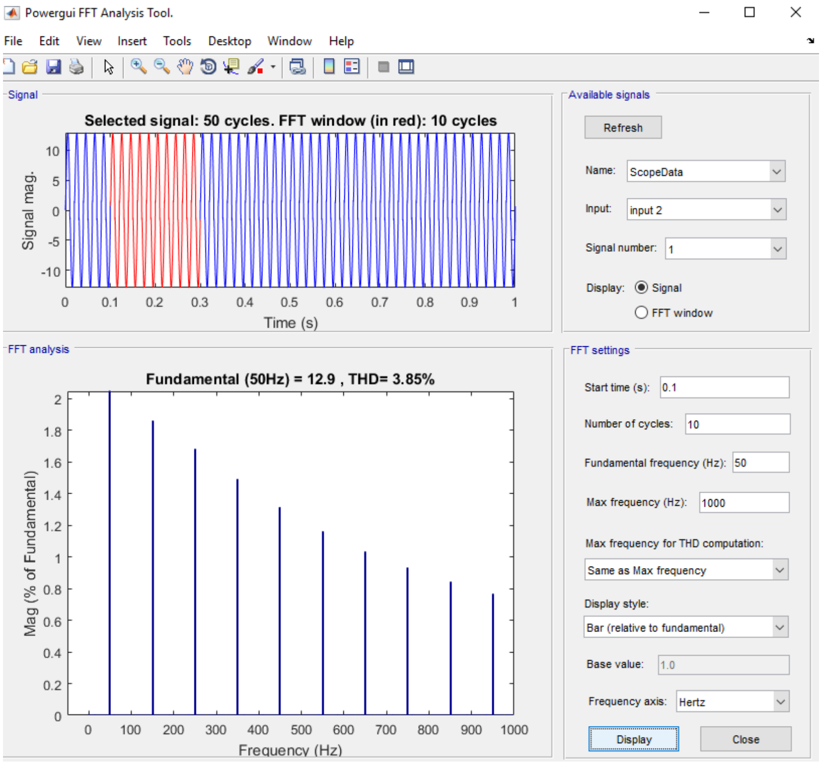

Figure 7: THD of the Line current for R=25 L=10mH Load

Figure 8: Figure 6: Voltage and Current Characteristics for R=25ohm L= 1H Load

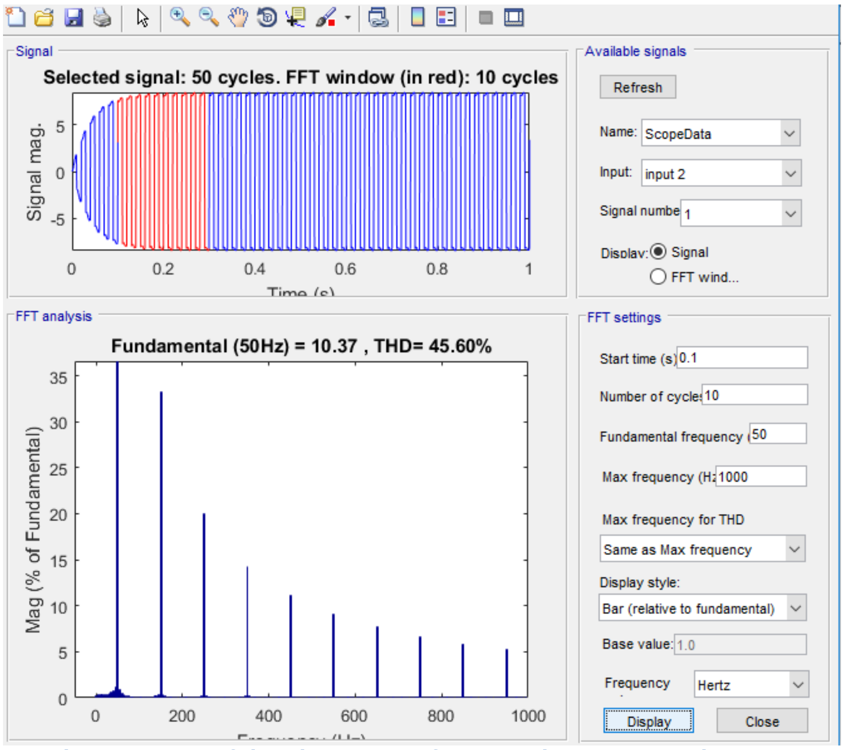

Figure 9: THD of the Line current for R=25ohm L=1H Load

ii. 2.2 Part

We have two main conditions to choose the diode. Firstly, it should be capable of working at 4A average current. Secondly, maximum DC reverse voltage must be greater than 325V. I took maximum DC reverse voltage as 400 V, and average current 6A for discrete diode and 15A for single phase diode rectifier module. I have chosen both types of diodes from Taiwan Semiconductor Corporation to make a comparison. Thus, I have chosen TPMR6G for discrete diode. Its price is 0.65$ at Digikey which makes 4*0.65=2.60$ for full wave rectifier. I have chosen GBPC1504 for single phase diode rectifier module. Its price is 2.33€=2.60$ at Farnell. Important parameters:

TPMR6G Digikey & Datasheet:

- https://www.digikey.com/product-detail/en/taiwan-semiconductor-corporation/TPMR6G-S1G/TPMR6GS1GDKR-ND/7359695
- https://www.taiwansemi.com/products/datasheet/TPMR6G%20SERIES_A1512.pdf

GBPC1504 Farnell & Datasheet:

- https://tr.farnell.com/taiwan-semiconductor/gbpc1504/diode-bridge-rect-1-ph-400v-module/dp/2677234?st=single%20phase%20diode%20rectifier%20module
- https://eu.mouser.com/datasheet/2/395/GBPC%2015005%20SERIES_K14-523399.pdf

	TPMR6G	GBPC1504
Max Reverse Voltage (V)	400	400
Max Average Rectified Current (A)	6	15
Max Forward Voltage (V)	1.2	1.1
Operating Temperature Range (°C)	- 55 to +175	- 55 to +150
Price ($)	2.60	2.60

If we look at the important parameters, we could easily see that module is better than discrete in max forward voltage and average rectified current parameters. (15/2=7.5V>6V; 1.1<1.2V). However, the prices are similar. Also, it takes up less space than discrete diodes on the PCB board. These make the module the best option for full wave rectifier circuit.

iii. 2.3 Part

I have chosen 4.7uF capacitor value to make the output voltage ripple smaller than 20% of the average output voltage as seen in the following graph:

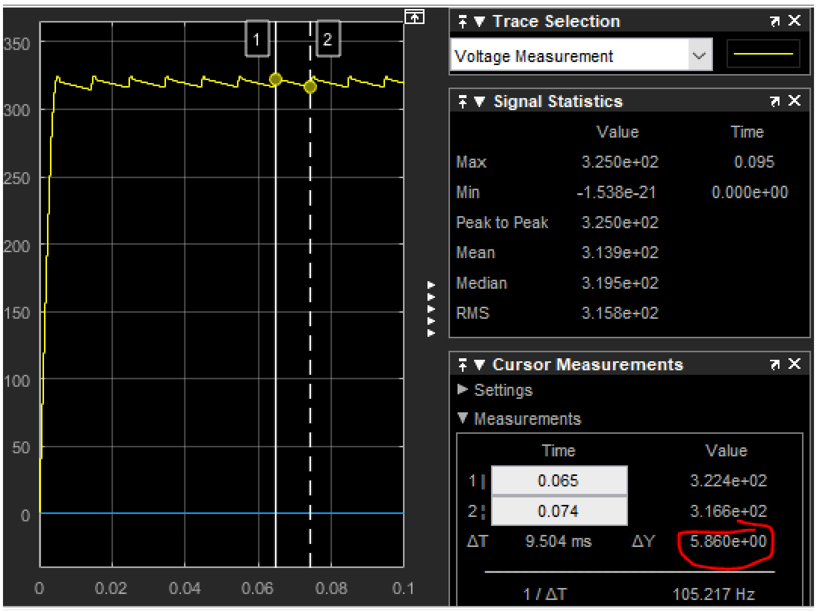

Figure 10: Output Voltage Ripple with R=25 C=4.7uF Load

I have chosen commercial capacitor as below:

https://www.digikey.com/product-detail/en/nichicon/ULR2G4R7MNL1GS/493-6709-2-ND/3664129

iv. 2.4 Part

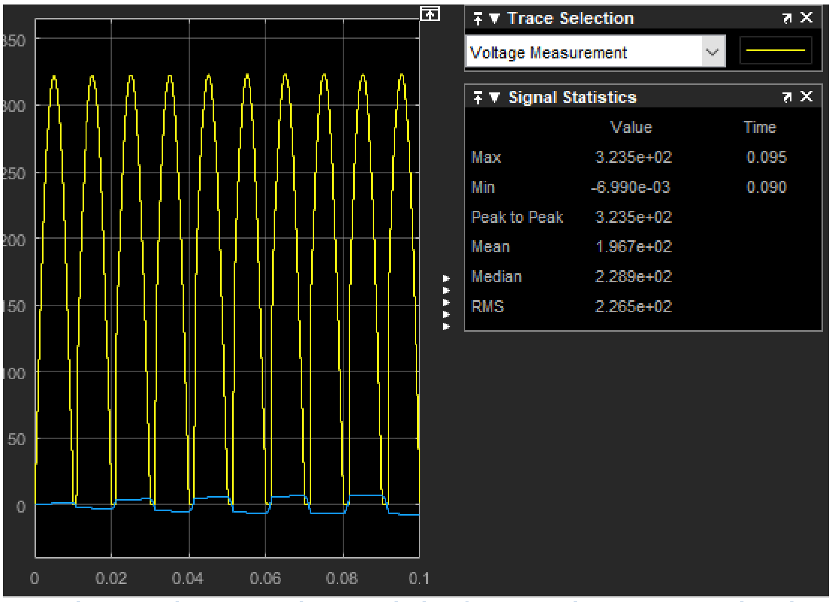

Figure 11: Voltage and Current Characteristics for R=25ohm L= 1H Load and Ls=10mH

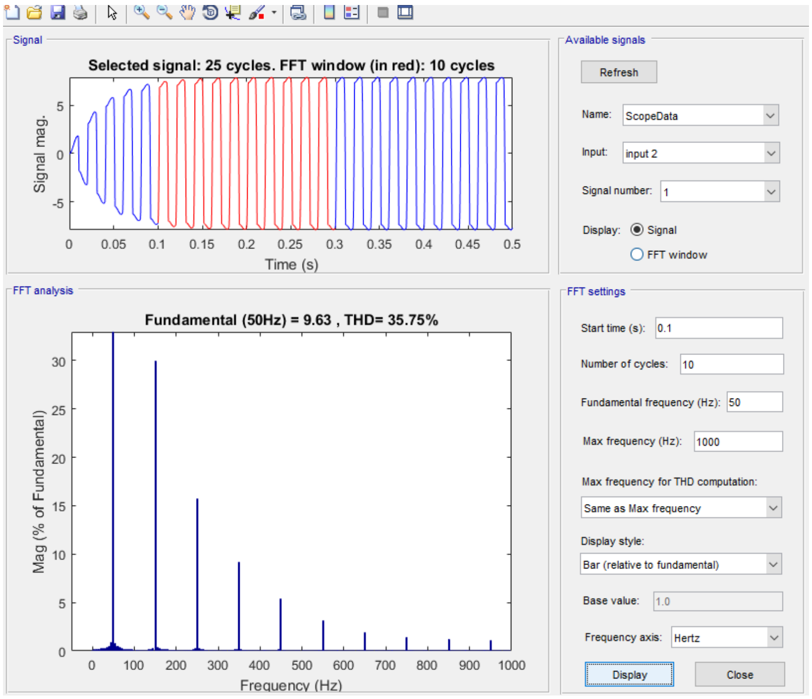

Figure 12: THD of the Line current for R=25ohm L=1H Load and Ls=10mH

As seen above, there is a drop in mean output voltage from 207V at Ls=0 to 197 V at Ls=10mH. Also, there is a drop in THD of line current from 45.60 to 35.75. As a comment, line inductance causes a voltage drop which is bad for the power circuit. On the other hand decreasing the THD is good for the same circuit. It is trade-off.

v. 2.5 Part

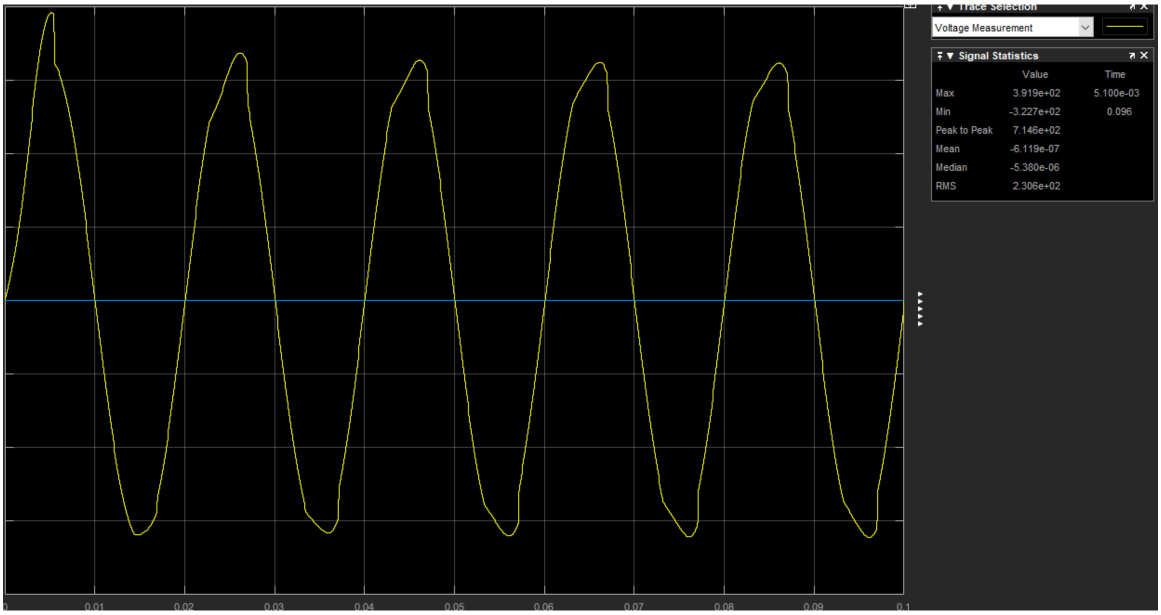

Figure 13: Voltage Characteristic of common coupling (PCC) at Figure 5.25 of textbook(Mohan)

As seen above, the voltage characteristic is not a purely sinusoidal signal because of the line inductance.

c. 3rd Question

i. 3.1 Part

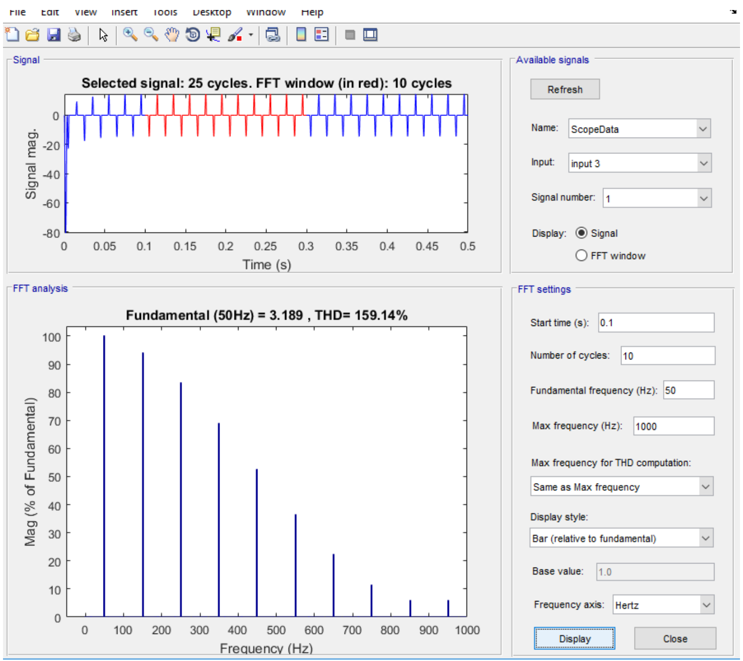

Figure 14: THD of Input Current for Figure 1 Circuit

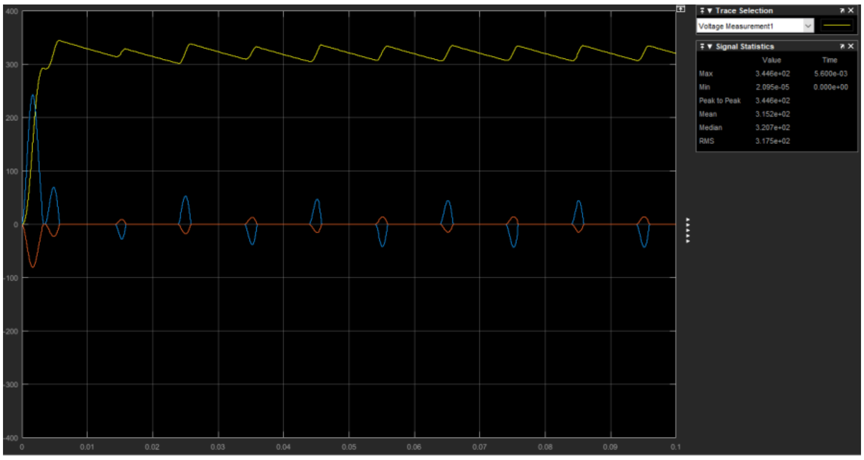

Figure 15: Waveforms for Phase A Current (Red), Neutral Wire Current (Blue) and "Diode Bridge 1" Output Voltage (Yellow)

ii. 3.2 Part

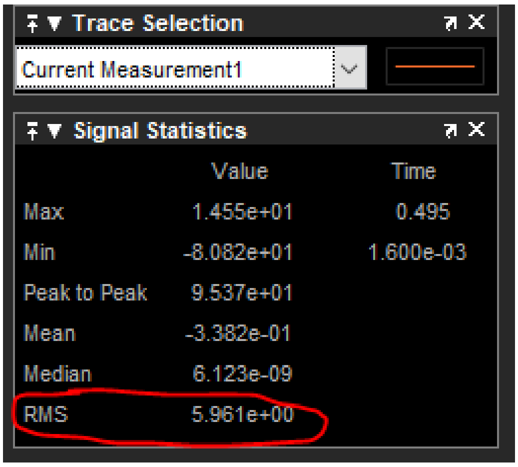

Figure 16: RMS Value of Line Current

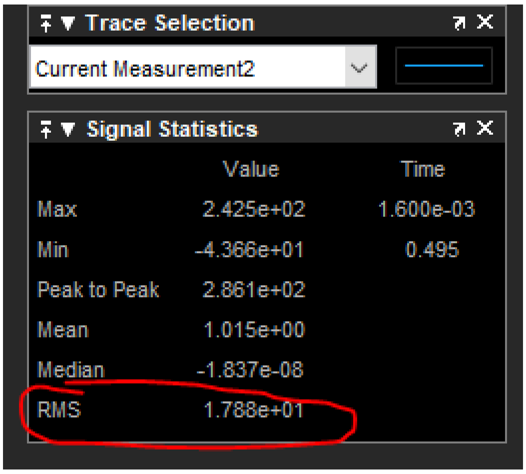

Figure 17: RMS Value of Neutral Wire Current

iii. 3.3 Part

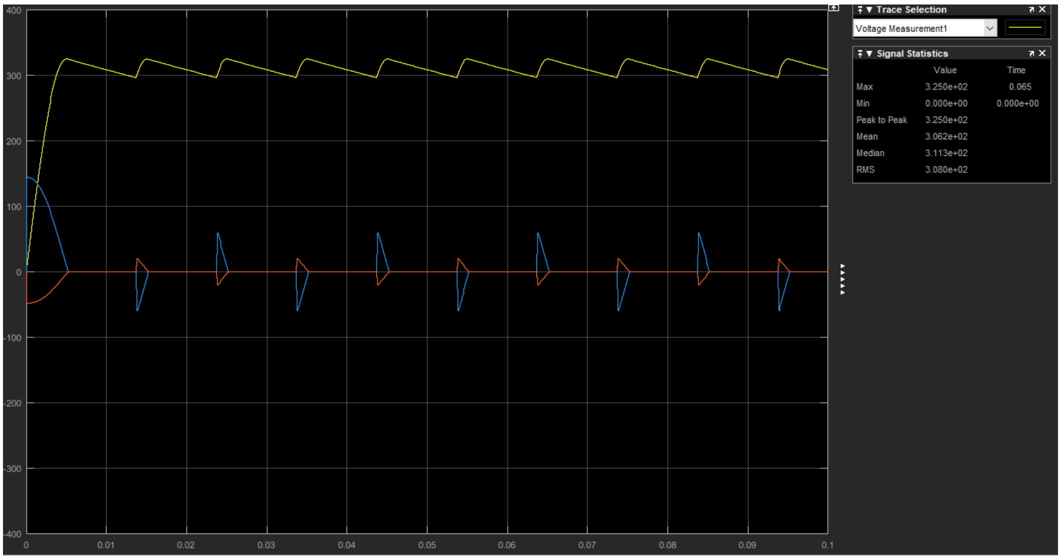

Figure 18: Waveforms for Phase A Current (Red), Neutral Wire Current (Blue) and “Diode Bridge 1” Output Voltage (Yellow) for Ls=0

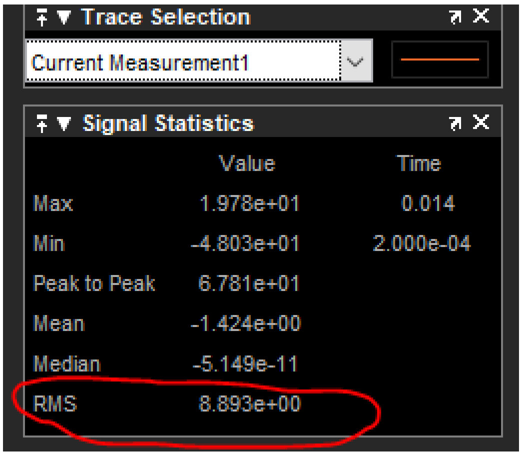

Figure 19: RMS Value of Line Current for Ls=0

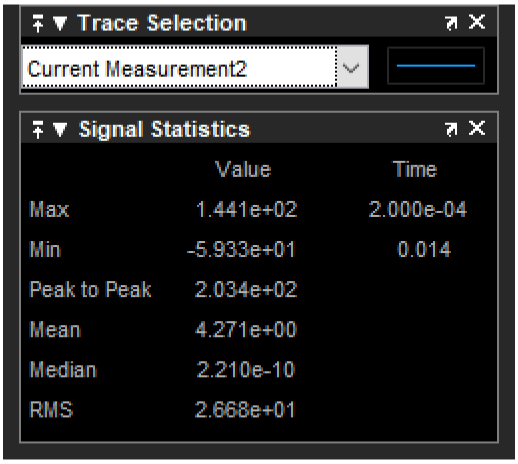

Figure 20: RMS Value of Neutral Wire Current for Ls=0

If we decrease line inductance we could increase the RMS value of currents. Also, that decreases the RMS value of RMS value of output voltage.

3. Conclusion

In this project, I have designed both single phase and three phase full wave rectifiers with different type loads and line inductances in Simulink environment. Thanks to that I learned to use Simulink. I have become familiar with rectifiers. I have understood the importance of line inductance and different type loads for rectifying. Also, I researched proper diodes and capacitors for power circuits. Thanks to that, I will be able to understand datasheet better. I have discovered the difference between power components and standard components. Until this project, I couldn’t imagine what THD means in a circuit, but now I know what it means exactly.