MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

5670463 – Project-1
Single Phase Diode Rectifiers

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Table of Contents

INTRODUCTION

Electricity is a key of development in the modern era. Since electricity is a kind of energy that people need, it is a must to transform this pure electricity into the form that the people can use in both their industries and their daily life.

Power Electronics is a working discipline under Electrical and Electronics Engineering by which the electricity is transformed into the needed form where it is desired to be used. The very basic components of Power Electronics is the "Diode Rectifiers" by which the AC voltages can be converted into DC voltages to make the machines, other DC voltage-configurated components be able to operate.

The "Diode Rectifiers" are generically divided into two parts which are the single phase and the three phase diode rectifiers. The Three Phase Diode Rectifiers are more general because the general concept of both transmission and the distribution systems designed to operate under 3 Phase AC Voltages.

The Diode Rectifiers are the sort of elements that consists of simply four (in single phase AC voltages) and mainly six (in three phase AC voltages) diodes in order to eliminate the negative part of the voltages and transform the AC voltages into DC voltages. The working principle of those diodes are very simple, but the general concept and the principle of the phase diode rectifiers are complicated because they operate similarly but give different results at the output stage of them. For instance, under an R-Load, RL-Load, RC Load and RLC-Load it gives different voltage waveforms at the output stage.

This project is mainly about investigating the working principles and the outputs of the single-phase diode rectifiers under different load conditions and with/without line inductances. This report is consisted of the simulation results of the given conditions of Project Definition Report and the results' analysis of those conditions.

It was asked to get the simulation results on MATLAB-Simulink by using a special tool whose name is Simscape.

QUESTION-1

In this question it was asked to simulate a single-phase diode rectifier under different step sizes which are 1.5ms, 1us, 10us with an R load of 100 Ohms.

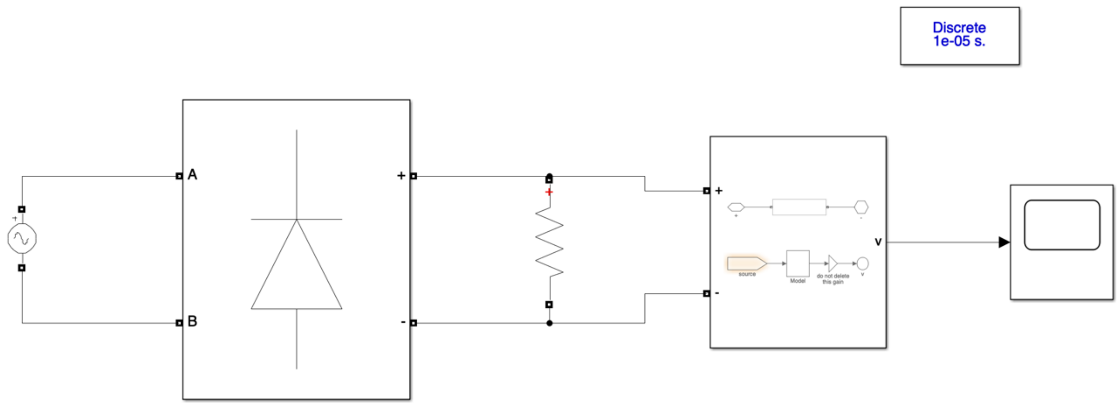

Figure 1: Schematic of Question 1 on Simulink

The students were conducted the process. It was desired to obtain a smooth-sinusoidal wave at the output stage. However, under 1.5ms, the obtained output waveform was not a pure sine-wave because the period/frequency of the voltage is so smaller than the normal system frequency. The most accurate result was obtained under 1us step-size, because 1us period is equal to 50Hertz which is operating frequency of our system. The simulation results are given below.

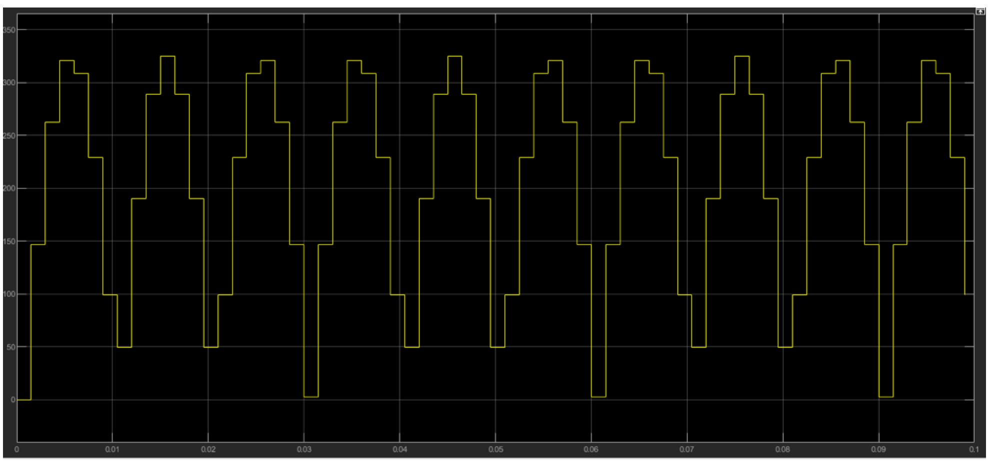

Figure 2: The Graph of 1-Ph. Diode Rectifier under 1,5ms Step-Size

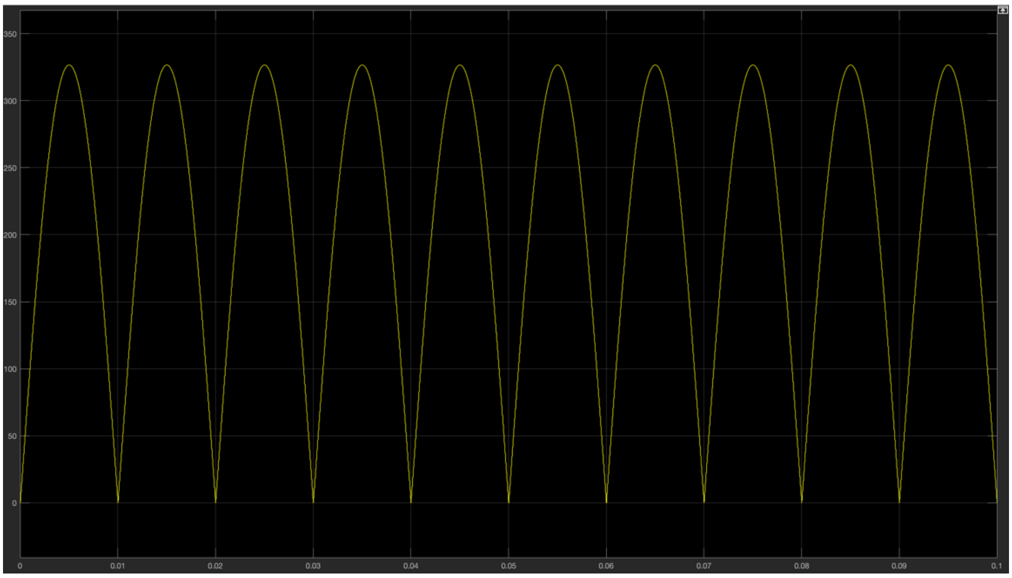

Figure 3: The Graph of 1-Ph. Diode Rectifier under 10us Step-Size

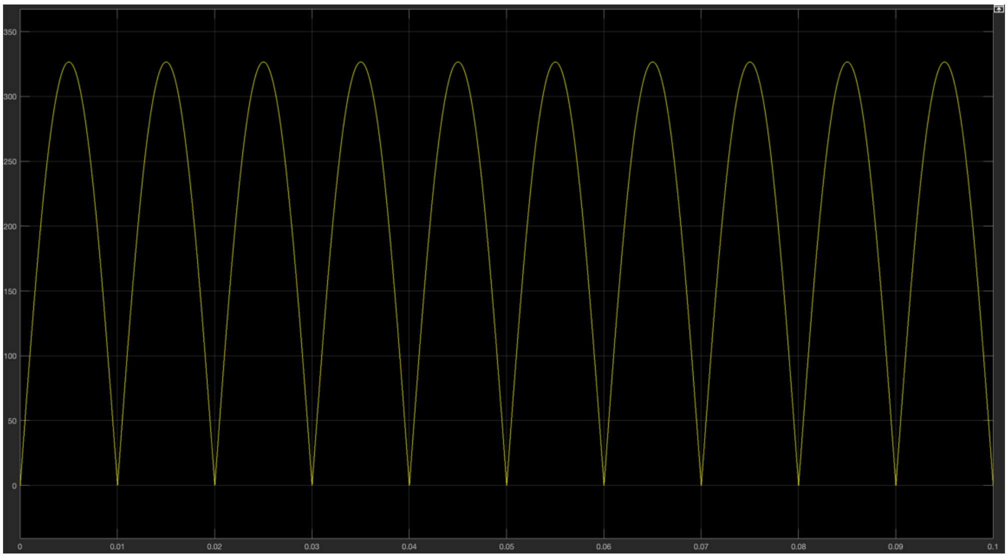

Figure 4: The Graph of 1-Ph. Diode Rectifier under 1us Step-Size

QUESTION 2

In this question it was asked to simulate a single-phase rectifier under different conditions such as different load and line impedances, the average voltage value at the output stage, the THD of the line current and the output graphs of those simple circuits.

QUESTION 2.1

It was asked to simulate a single-phase diode rectifier R=25Ohms and RL Loads in which the L=10mH and L=1H.

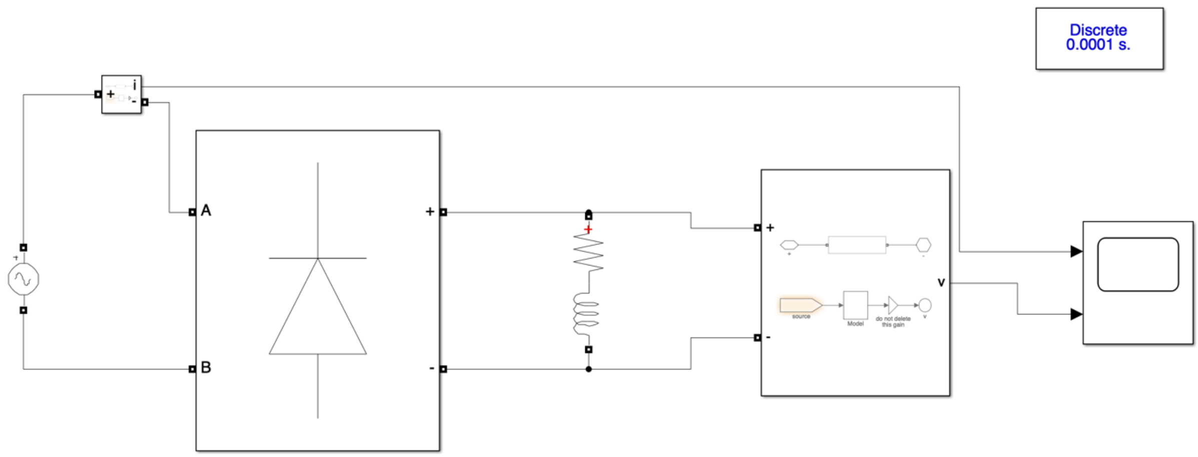

Figure 5: The Schematic of Question 2.1

The output voltage waveforms are not affected by the varying inductances since the resistance is constant. However, different inductance values at the load-side, affects the line current characteristics. As the value of the L increases, the THD of the line current increases and the shape of the line current waveform changes.

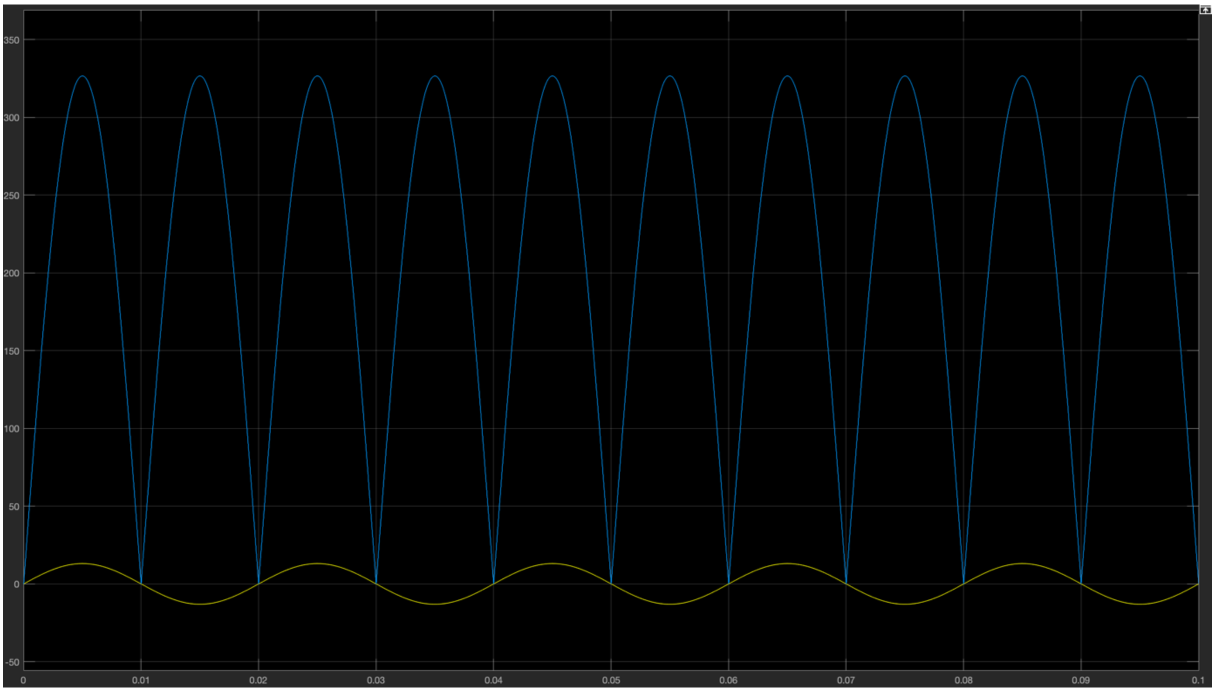

Figure 6: The Output Voltage and Line Current Waveforms with R-Load

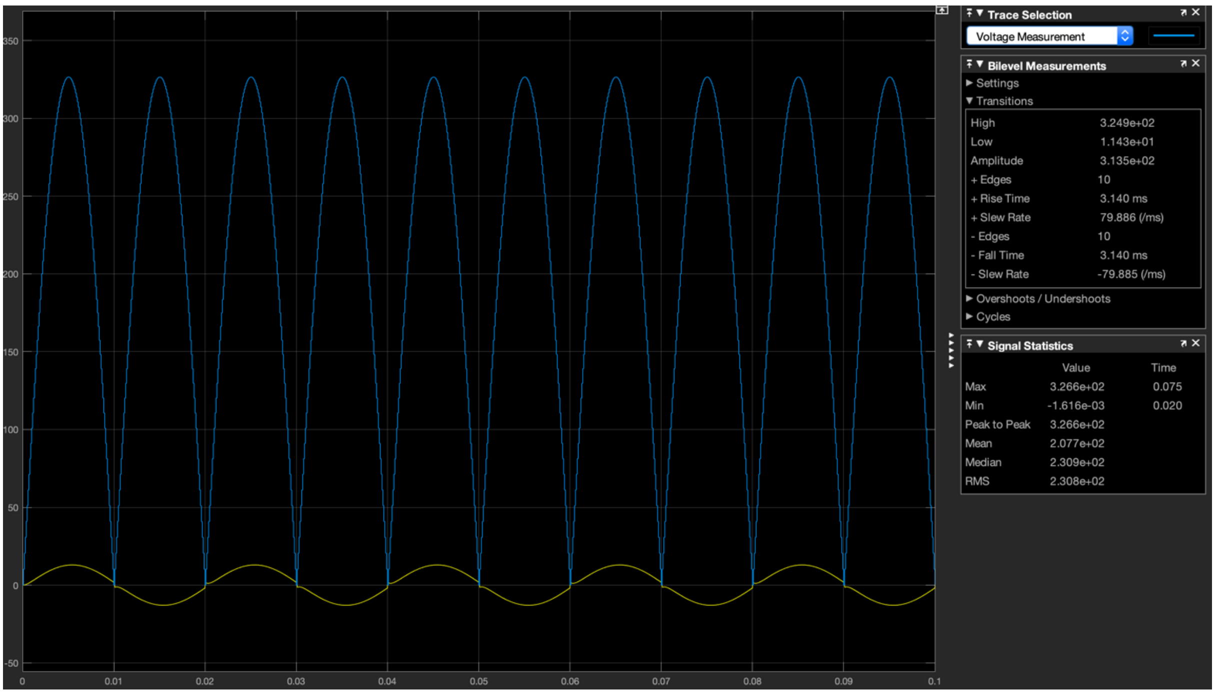

Figure 7: The Output Voltage and Line Current Waveforms with RL-Load(10mH)

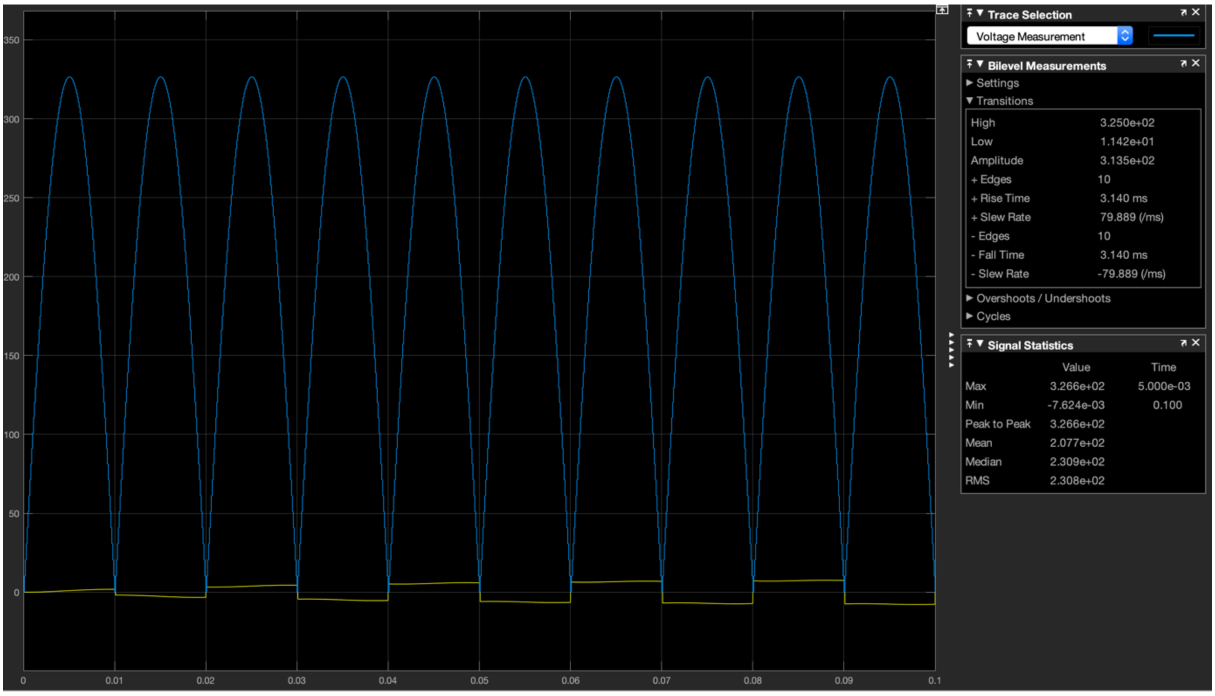

Figure 8: The Output Voltage and Line Current Waveforms with RL-Load(1H)

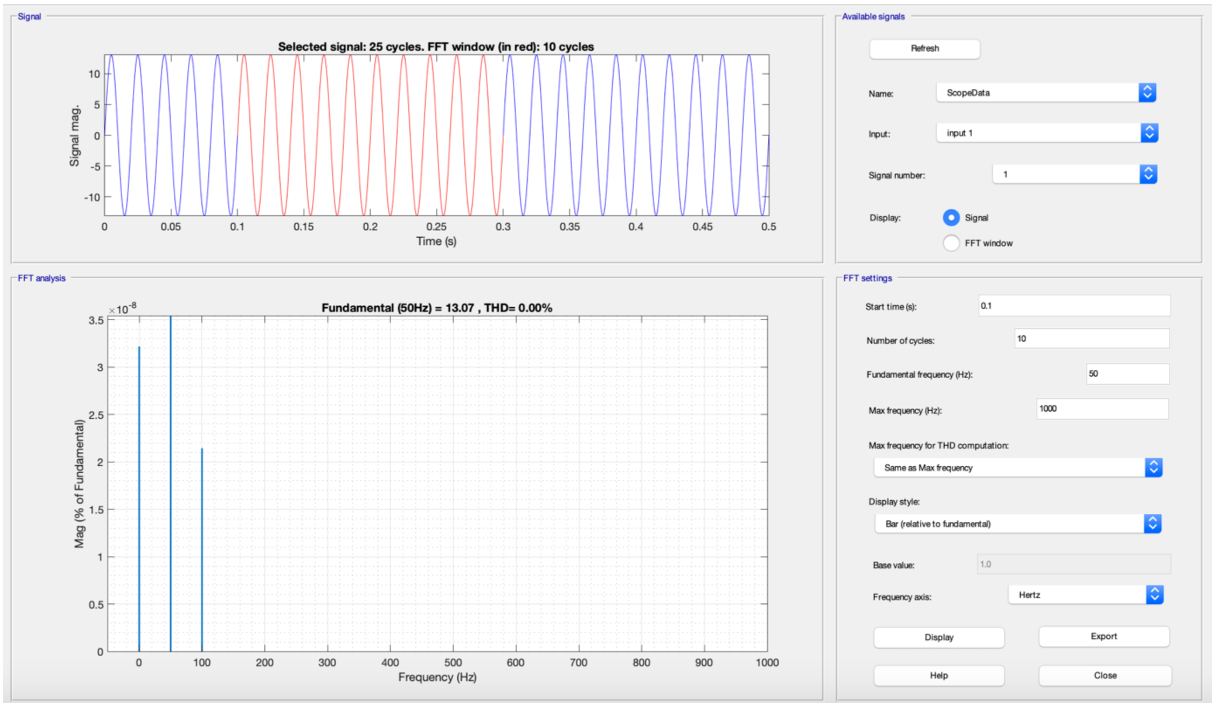

Figure 9: The THD Graph of the Line Current in the Given R-Load Circuit

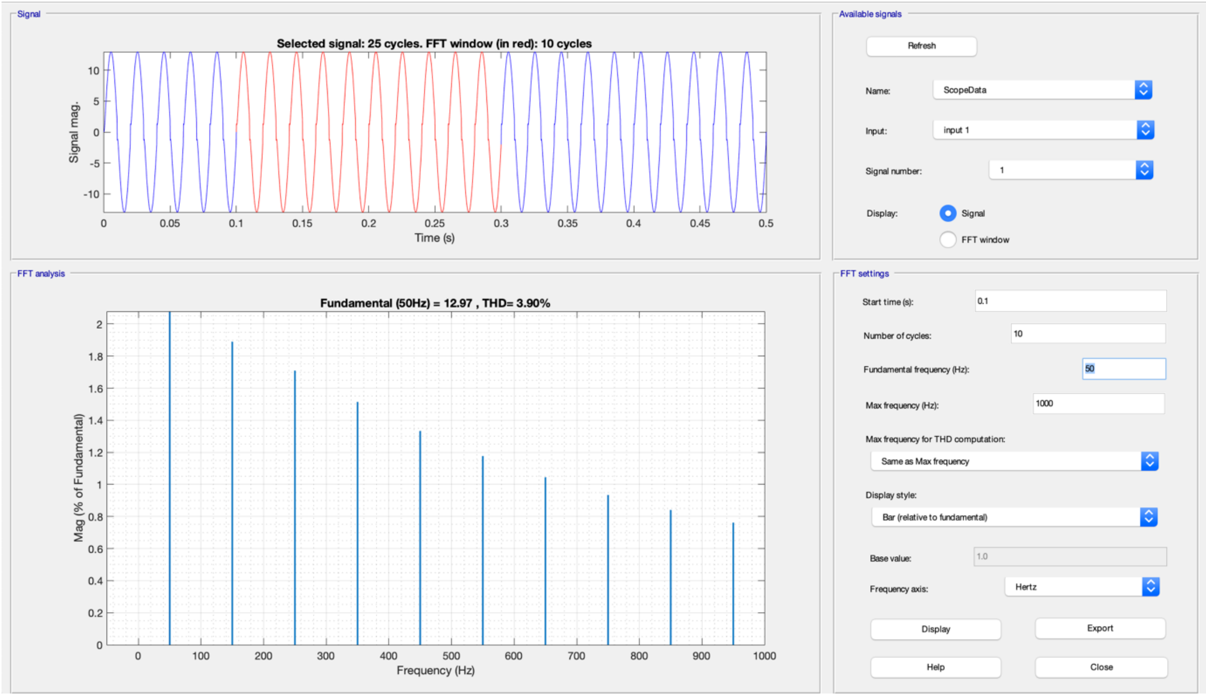

Figure 10: The THD Graph of the Line Current in the Given RL-Load (10mH) Circuit

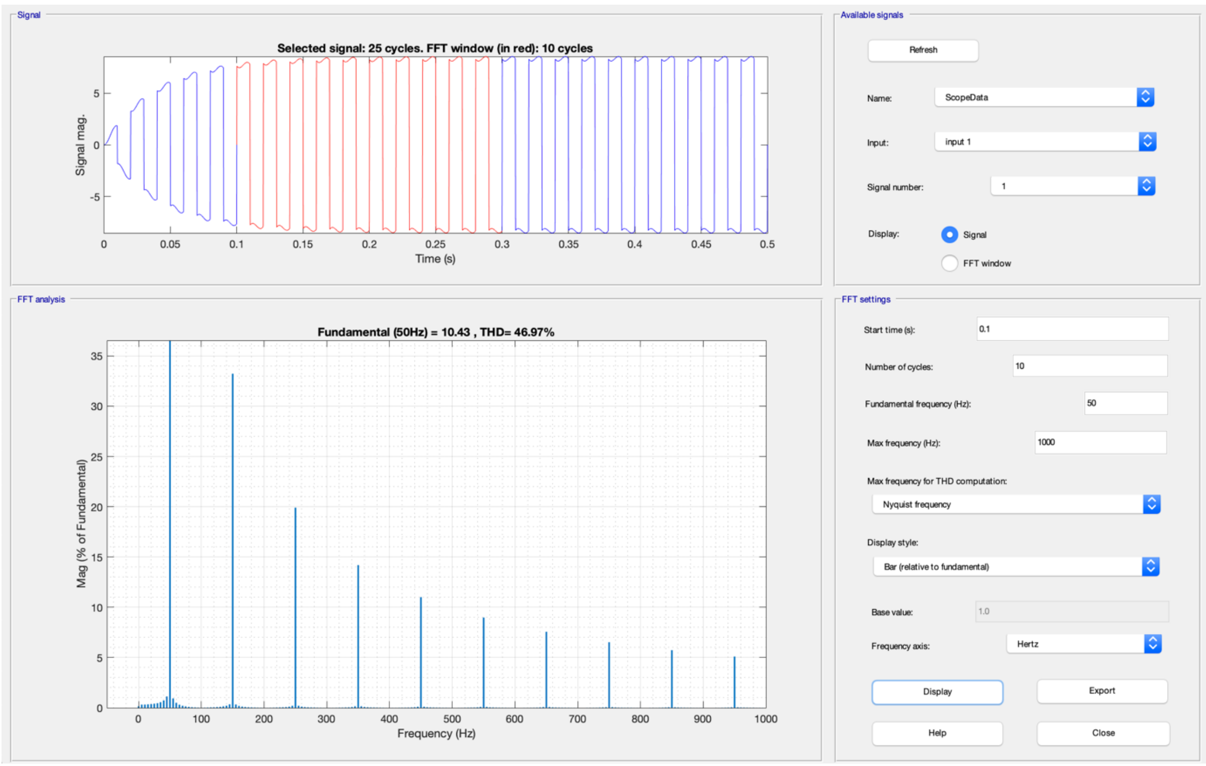

Figure 11: The THD Graph of the Line Current in the Given RL-Load (1H) Circuit

QUESTION 2.2

To choose commercial diodes, some conditions need to be taken into considerations such as reverse voltage and average current value. According to our design specifications that is done in Simulink the specification values must be higher than 326.6 V and 4A.

Digikey and Farnell websites are chosen to research these diodes.

P600G-E3/73GITB-ND is chosen from Digikey for single diode because of its 400V reverse voltage value and 6A current value and its price is 0.76 x 4=3.04 USD.

GBPC604-E4/51 is chosen from Farnell for rectifier because 400V reverse voltage value and 6A current value and its price 2.63 USD. The Websites and Datasheet Links are mentioned below.

P600G-E3/73GITB-ND
https://www.digikey.com/product-detail/en/vishay-semiconductor-diodes-division/P600G-E3-73/P600G-E3-73GITB-ND/2141431
http://www.vishay.com/docs/88692/p600a.pdf

GBPC604-E4/51
https://tr.farnell.com/vishay/gbpc604-e4-51/bridge-rectifier-single-phase/dp/2300533
http://www.farnell.com/datasheets/2046652.pdf?_ga=2.148937011.483478022.1543180687-1436260467.1543180687

After the analyzing their datasheets and considering conditions(Price, Voltage, Current, Recovery Times), the rectifier module is more preferable than one diode.

QUESTION 2.3

In question 2.3, it was asked to analyze the RC Load design and determine a capacitance value which is commercially used that makes the ripple voltage 20% of the average output voltage.

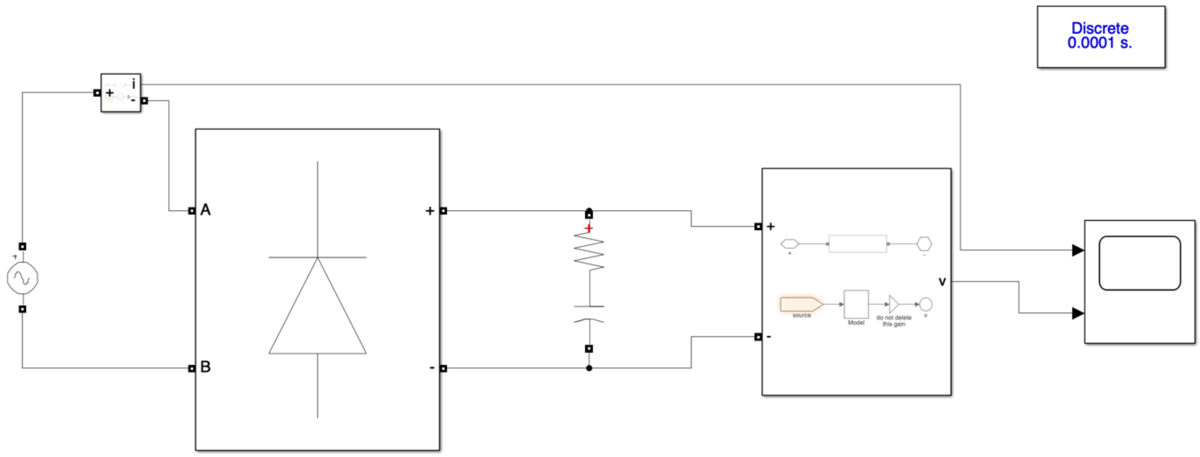

Figure 12: The Schematic of RC Load Circuit

When a capacitor is connected to an R-Load, it causes a ripple effect at the output stage and as the capacitance value is increased, the ripple effect is decreased. When a capacitor whose value is 680pF is connected to the R-Load in series, the ripple voltage reaches to the 20% of the average voltage. The output voltage waveform is given below.

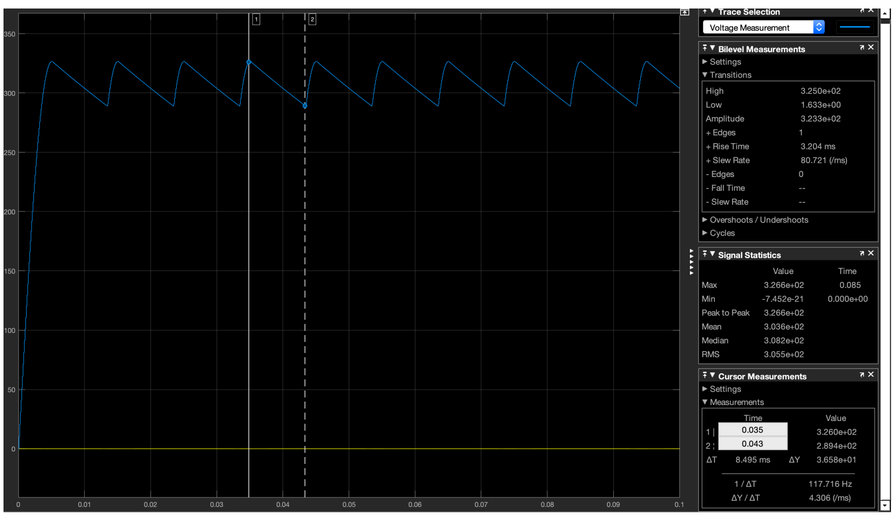

Figure 13: The Output Ripple Voltage of the Circuit given in Figure 12

QUESTION 2.4

In this question, it was asked to simulate a-the same circuit given in question 2.1 with a line inductance whose value is 10mH.

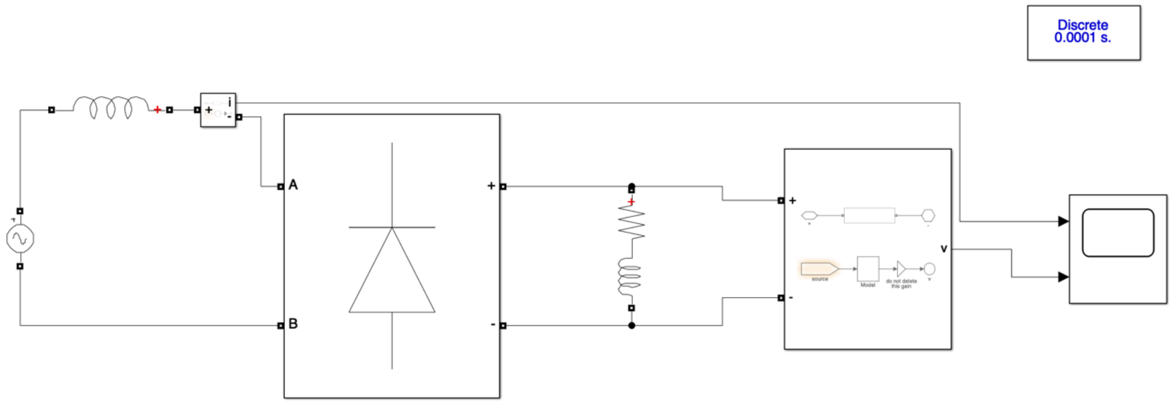

Figure 14: The Schematic of the Given Circuit in Q2.1 with a Line Inductance (10mH)

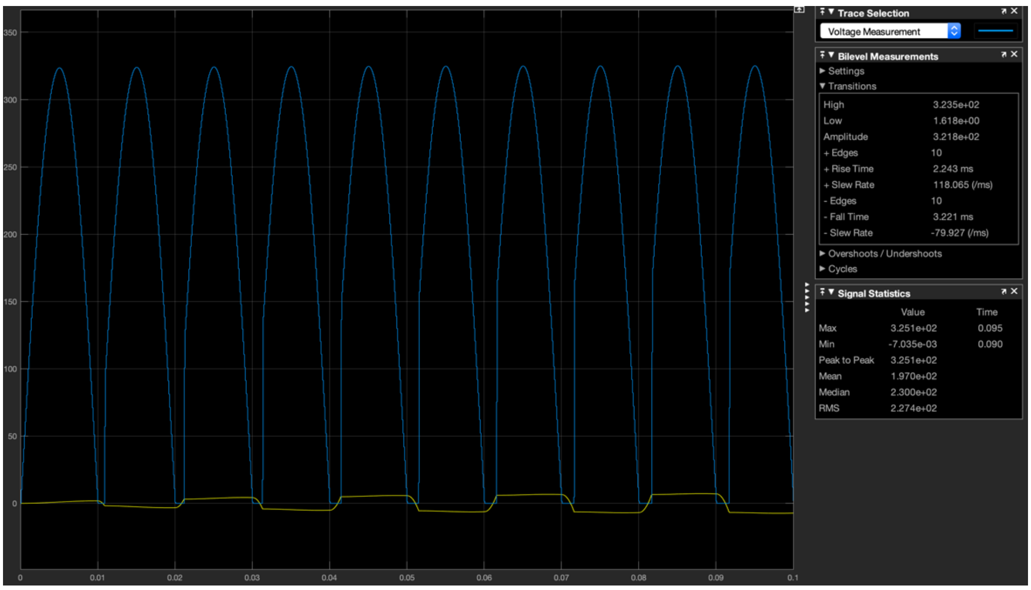

Figure 15: The Output Voltage and Line Current Waveforms of Figure 14

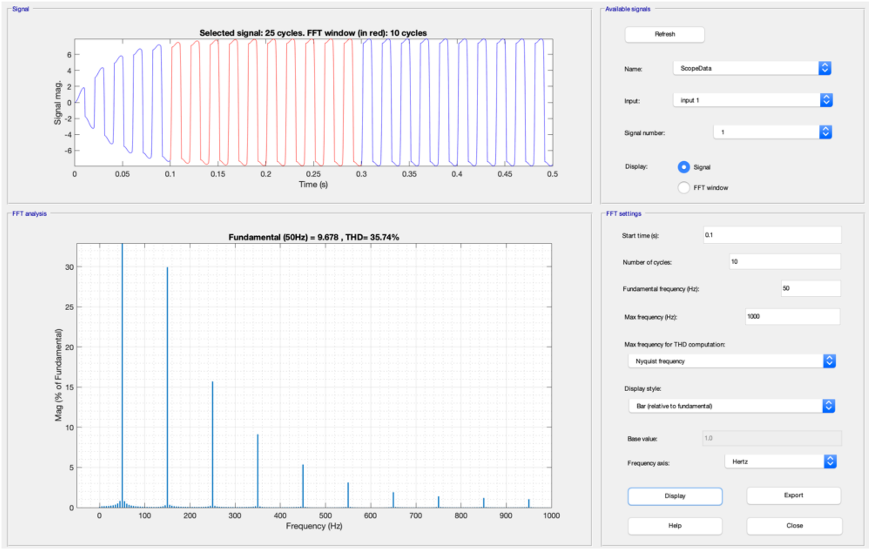

Figure 16: The THD Graph of the Line Inductance in Figure 14

If one compares the results with and without the line inductance, two results are obtained. The first result is the average voltage value is decreased which means as a power loss in the system and the second result is the THD of the line current is decreased which is a good thing for the system.

QUESTION 2.5

In this question it is asked to configure a model which is given in the textbook of Mohan with an R-Load R=25Ohms and the Line inductances L=600uH.

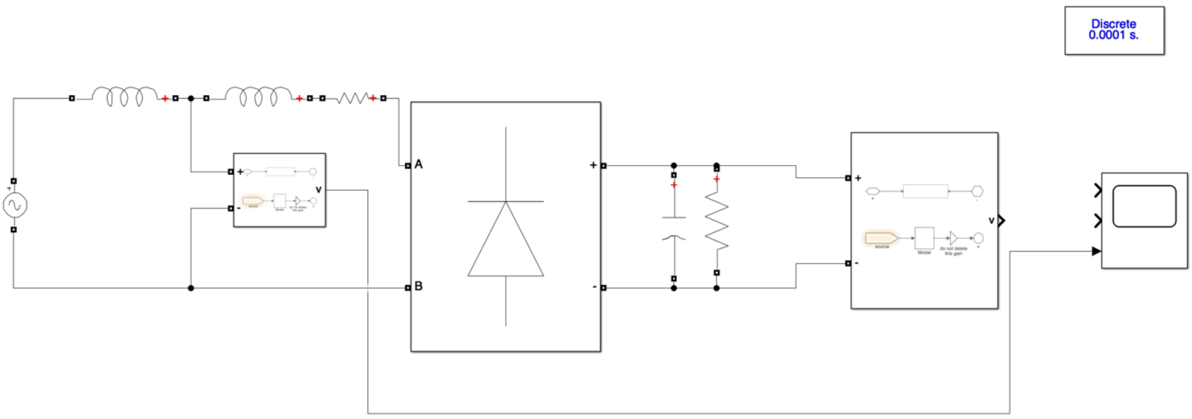

Figure 17: The Schematic of the Model in the Textbook of Mohan

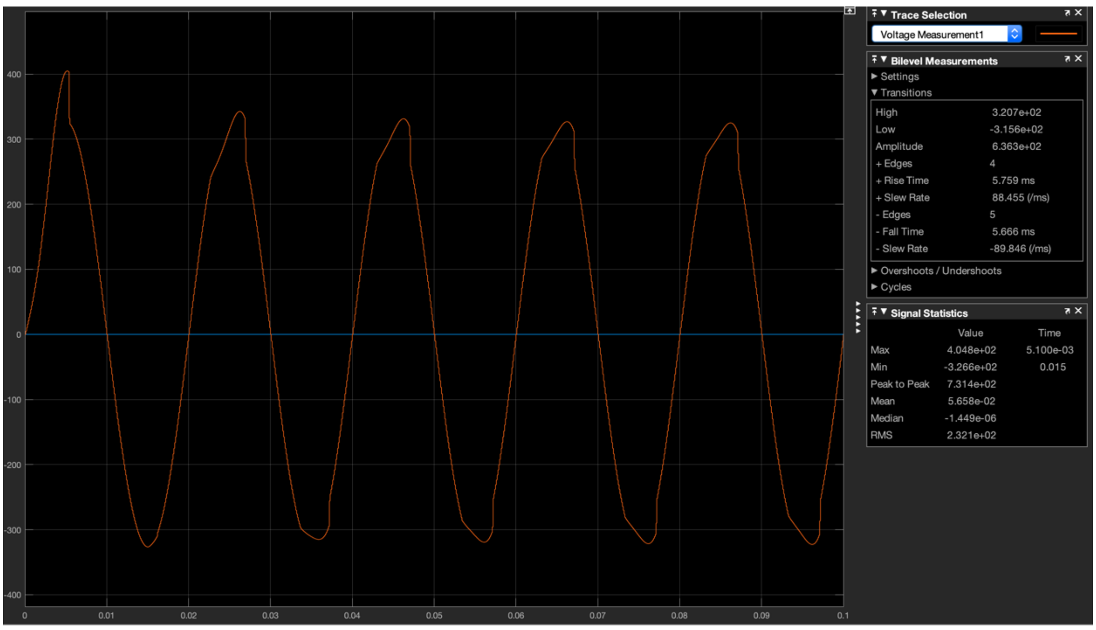

Figure 18: The PCC[1] Waveform of the Given Circuit

As it is seen in the figure, even a very small line inductance can create changes on the purity of the sinusoidal input voltage waveform.

[1] Point of Common Coupling

QUESTION 3

In this question it was asked to obtain the THD of the input current, the Phase-A and Neutral Wire current waveforms and the RMS values of these and the output voltage waveform with/without line inductance of a 3 Single Phase Diode Bridge Rectifier with a constant RC-Load that are R=200Ohms and C=470uF.

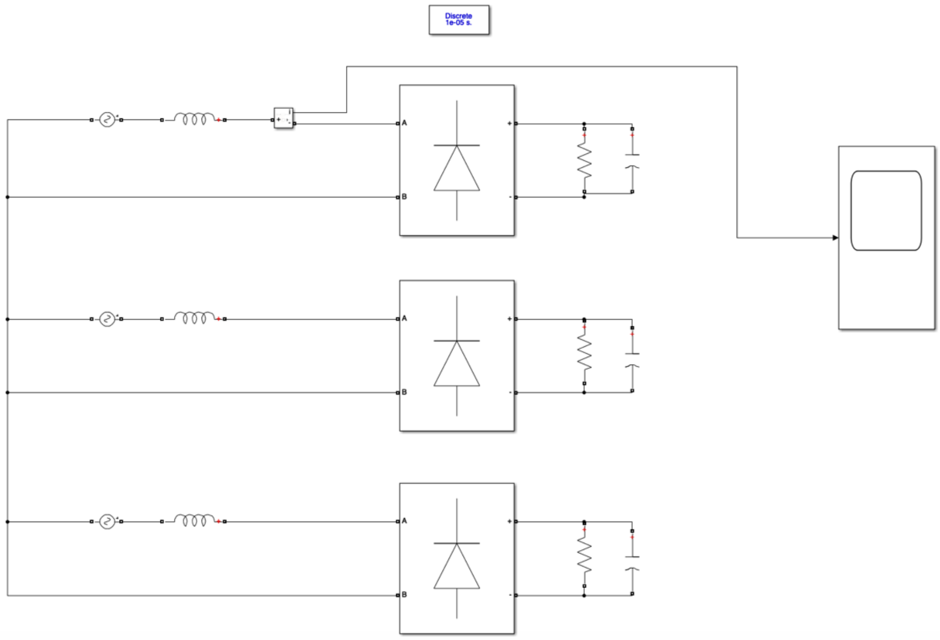

Figure 19: The Schematic of 3 Single Phase Diode Bridge Rectifiers with Line Inductance

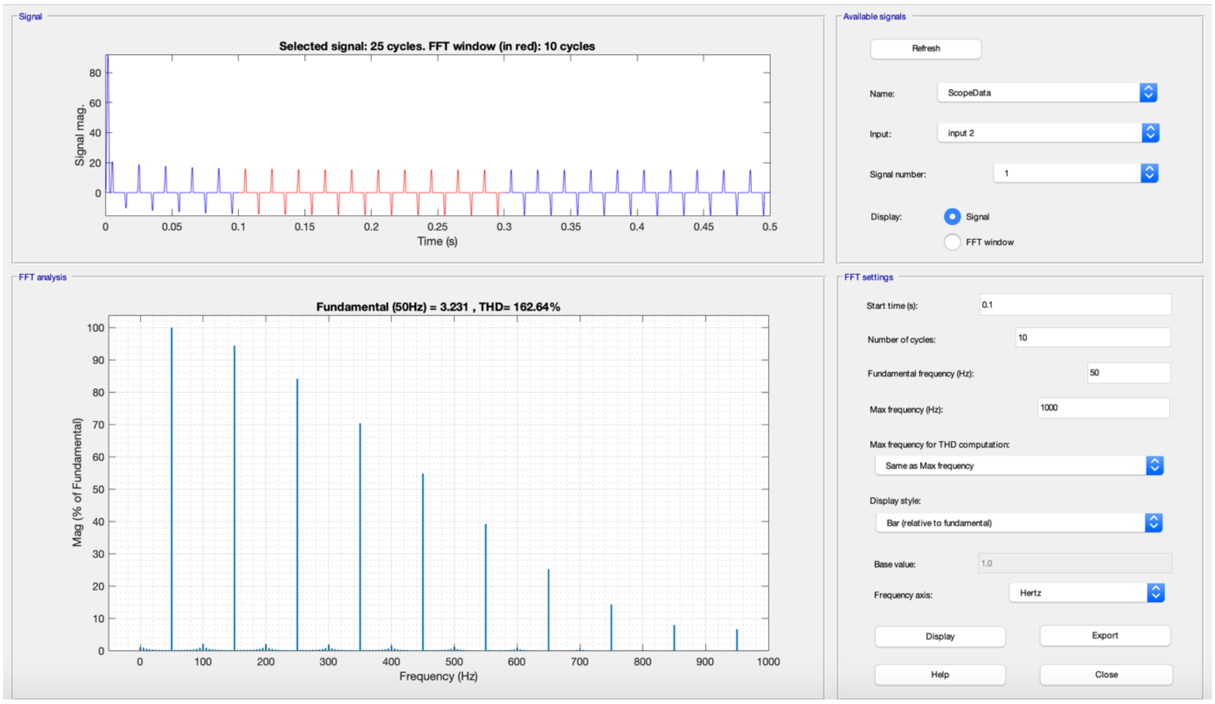

Figure 20: The THD Graph of the Given Circuit

In this graph, as it can be seen, due to the capacitance a very high THD value is obtained in the Line Current.

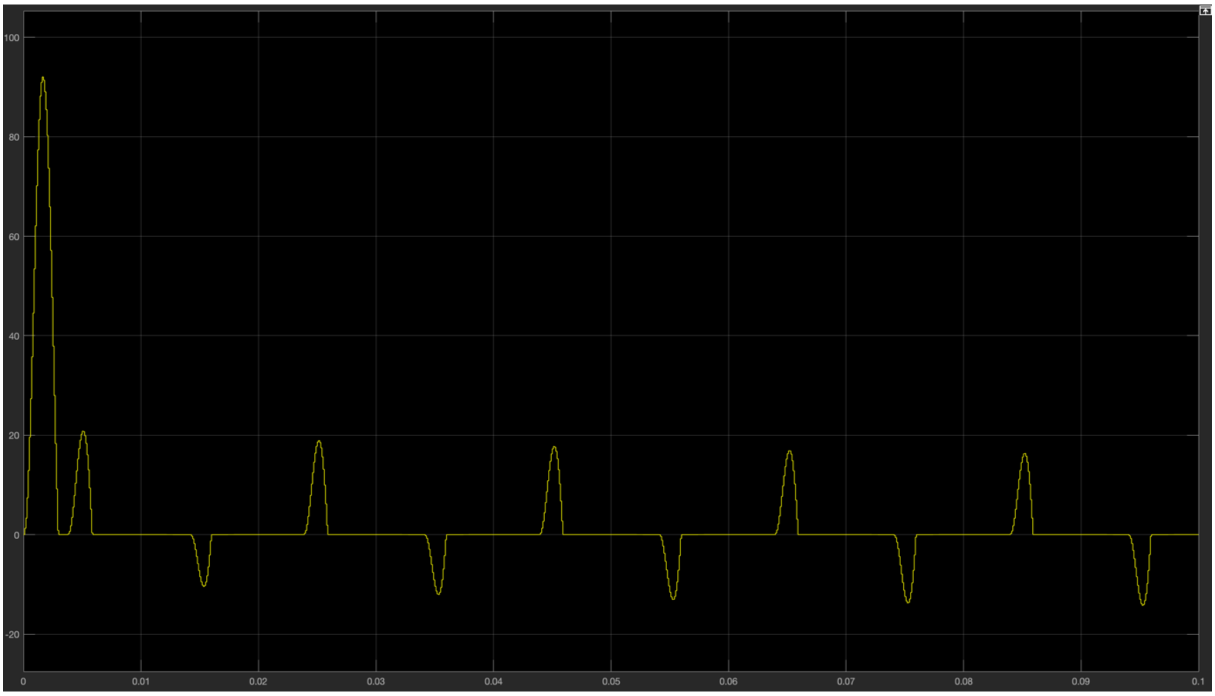

Figure 21: The Graph of the Input Current Waveform

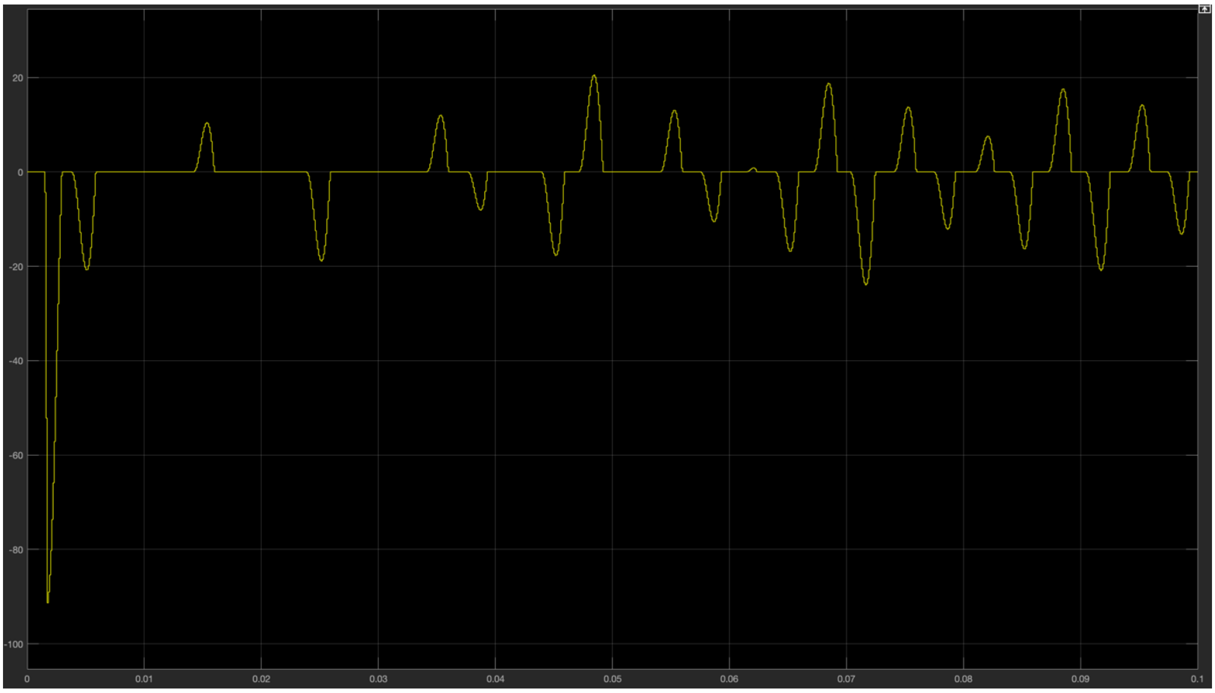

Figure 22: The Graph of Neutral Wire Current Waveform

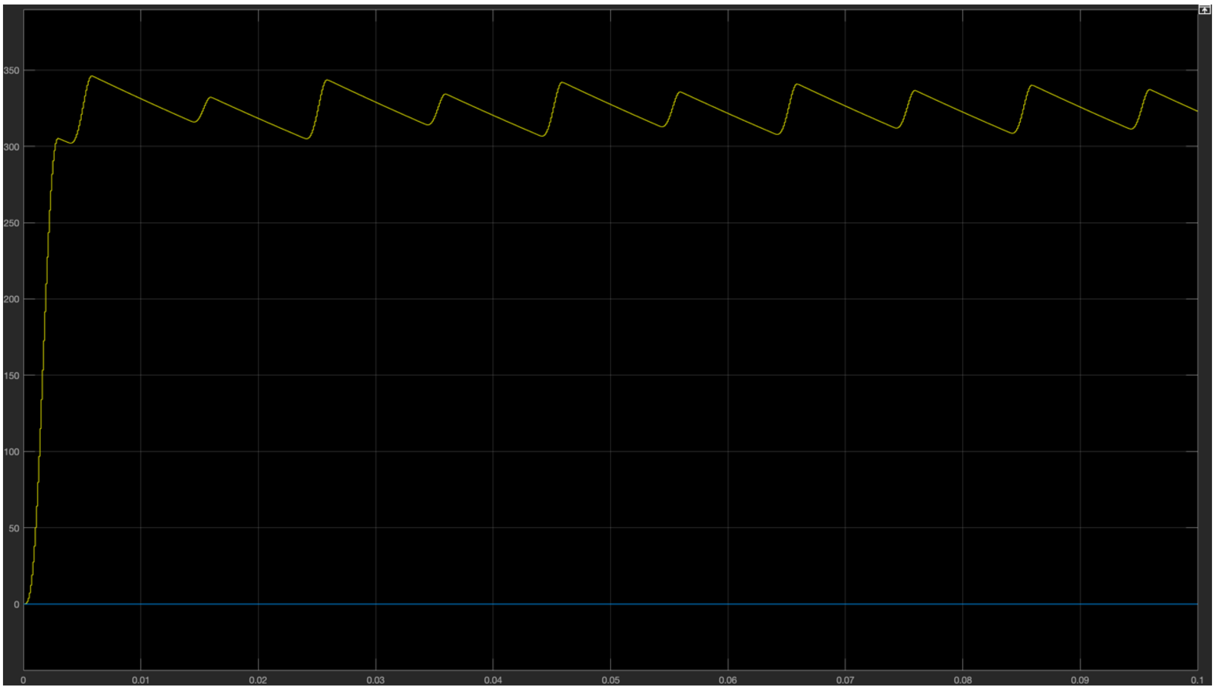

Figure 23: The Output Graph of the Rippled Voltage Waveform

Signal Statistics

	Value	Time
Max	2.053e+01	0.048
Min	-9.136e+01	1.700e-03
Peak to Peak	1.119e+02	
Mean	-1.347e+00	
Median	-7.558e-12	
RMS	9.692e+00	

Signal Statistics

Minimize	Value	Time
Max	2.396e+01	0.072
Min	-2.657e+02	8.000e-04
Peak to Peak	2.897e+02	
Mean	-2.472e+00	
Median	-3.419e-05	
RMS	2.487e+01	

Figure 24: The RMS Values of Line and Neutral Currents

The very different values between the current RMS values are caused because of the Line inductance of each phases. Since there is no line inductance in the neutral wire, the RMS values are different than the line current RMS values.

The last part of the Question three asked to conduct the same simulation processes without the line inductances. The graphs are given below.

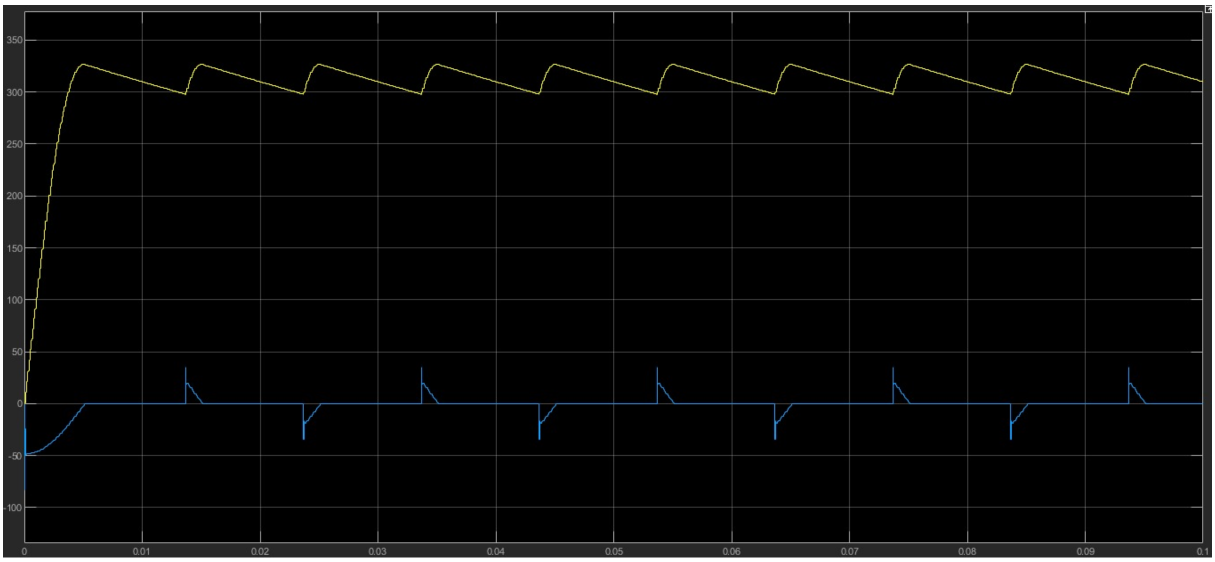

Figure 25: The Output Graph of the Rippled Voltage Waveform

The output rippled voltage waveform is closed to the DC voltage waveform due to the absence of the line inductances.

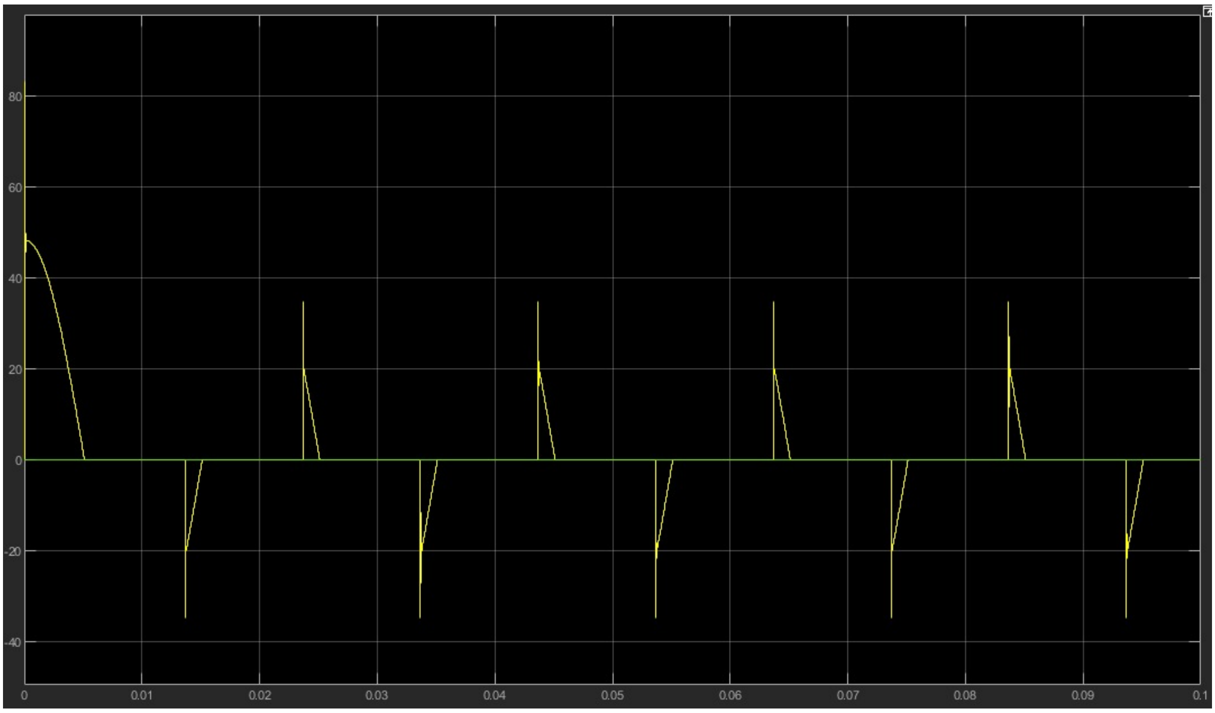

Figure 26: The Graph of the Input Current Waveform

The input current waveform is swifter because there is no commutation due to the line inductances. As it was mentioned above the THD of the input phase current is increased.

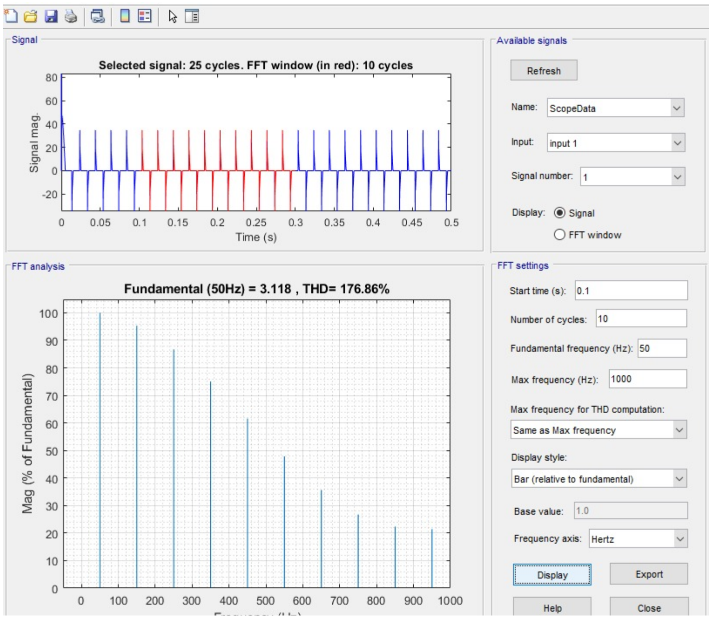

Figure 27: The THD Graph of the Input Current Waveform

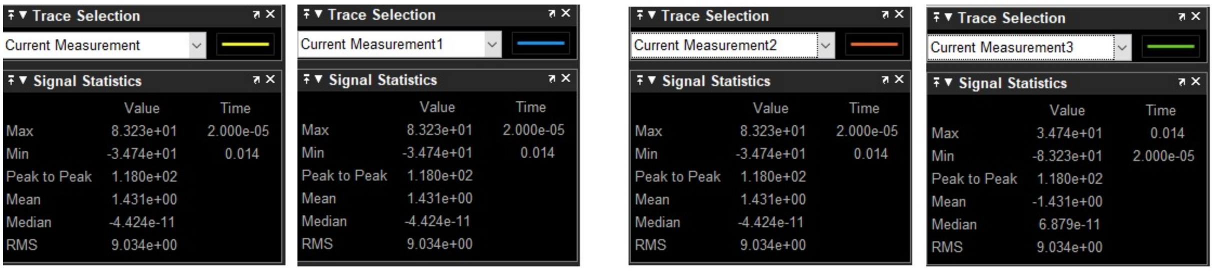

Figure 28: The RMS Current Values of both Line and Neutral Wires

The RMS values are became equal except for the phase shift between them because since there is no line inductance.

CONCLUSION

In this project, the working principles of the single-phase diode rectifiers are analyzed by the usage of MATLAB-Simulink.

Students found the chance of learning, investigating and using the Simulink which is a useful program for the designs and the analyses in Power Electronics Area.

Thanks to this project, the theoretical knowledge was transformed and investigated in the simulations.