MIDDLE EAST TECHNICAL UNIVERSITY

Department of Electrical and Electronics Engineering

EE463 Project-2 Report

Controlled Rectifiers

Hikmet Murat Çolakoğlu
Mert Elmas

Table of Contents

Introduction

The main objective of this report is to document the procedures and observations made throughout the Software project 2 which is mainly about controlled rectifiers. It begins with ıntroducing the results in a systematic manner and explaining these obtained data as the reader proceeds forward. It is assumed that the rectifiers are connected to the Turkish grid (400 V l-l, 50 Hz) for this project.

Results

Part 1

In order to see the correct steady state mean current value, it was necessary to pick a right interval of the graph. However it should be noted that the current waveform took some time to built up its steady state form for both topologies.

Part 1.a

The relationship between the $V_o(t)$ and the $I_o(t)$ as $V_o(t) = R_o * I_o(t) + L\frac{dI_o(t)}{dt}$ (1)

If the both sides of this equation are integrated with respect to time and taken its mean over the period which is taken as the integral interval the new equation would be as follows:

$\frac{1}{T}\int_0^T V_o(t) = \frac{1}{T}R_o\int_0^T I_o(t)dt + L\int_{I_o(0)}^{I_o(T)} d\,I_o(t)$ (2) which is equivalent to this equation $V_{av} = R_o I_{av}$ (3)since in steady state the last integral will be equal to zero in an RL circuit. There is also a relationship between V_{av} and the firing angle α as follows: $V_{av} = \frac{2\sqrt{2}}{\pi} Vs\,cos(\alpha) - \frac{2wL_S I_O}{\pi}$ (4)

If the second term is ignored than the relationship between the firing angle and the I_{av} would be as $I_{av} = \frac{2\sqrt{2}}{\pi}\frac{Vs}{R_O}cos(\alpha)$ (5)

For an average current of 40A this equation 5 would yield a firing angle of 37° which is consistent with the simulation results.

Part 1.a.1

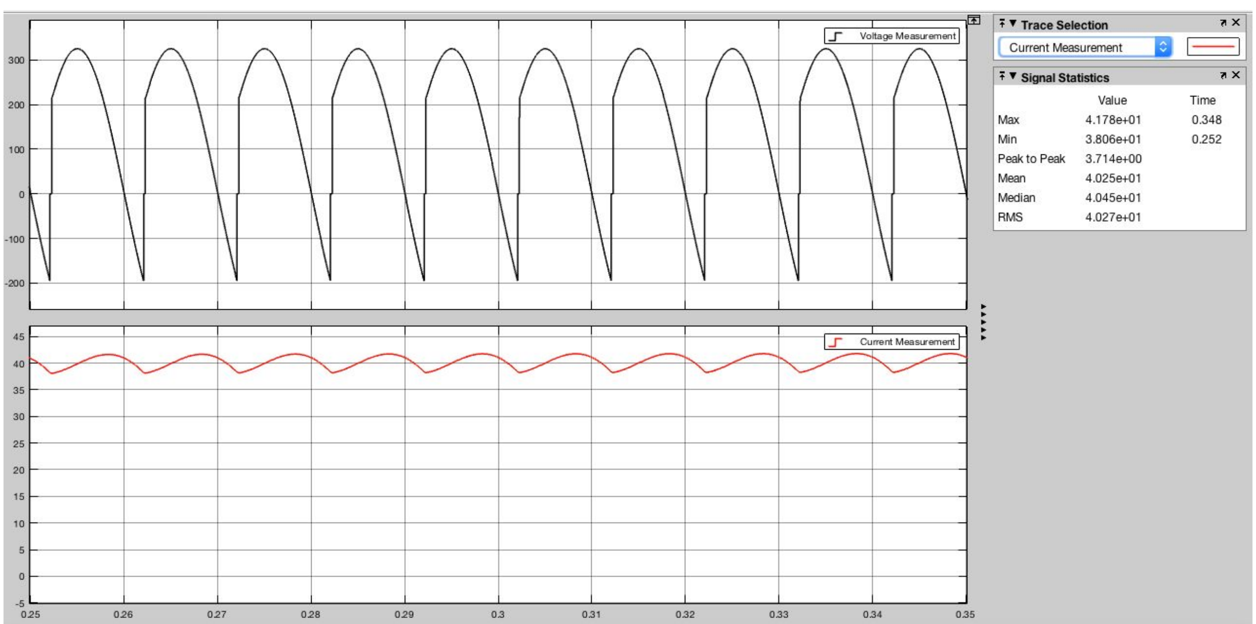

Figure 1: Output voltage and output current waveforms for case a of part 1.

From the figure the effect of the inductance in the circuit can be seen it the output voltage waveform as commutation.

Part 1.a.2

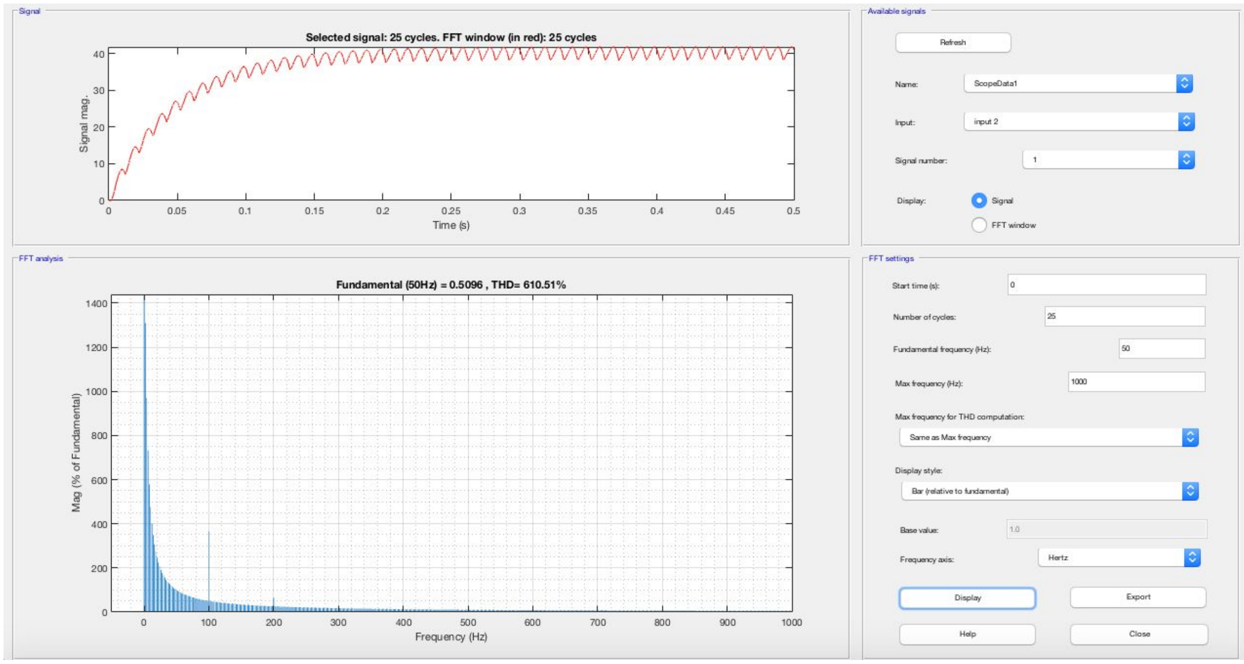

Figure 2: THD analysis of the case-a of part 1

From figure 2, percentage wise THD value of the output current of case-a part1 can be found to be 610%.

Part 1.b

Part 1.b.1

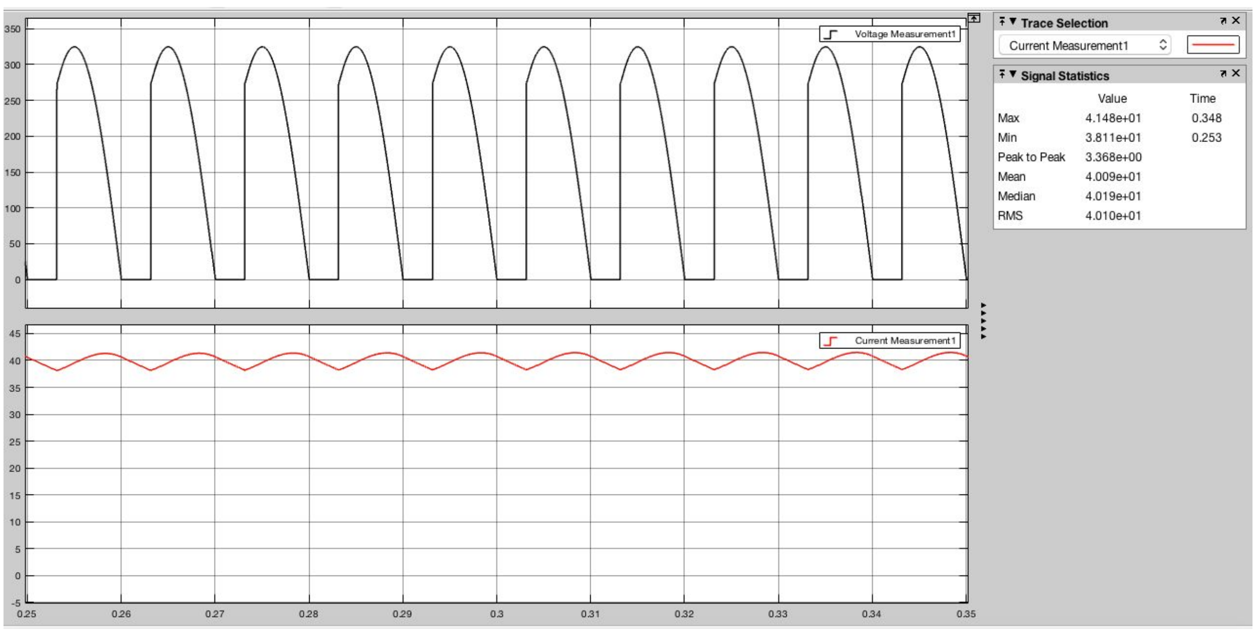

Figure 3: Output voltage and output current waveforms for case-b of part 1.

Part 1.b.2

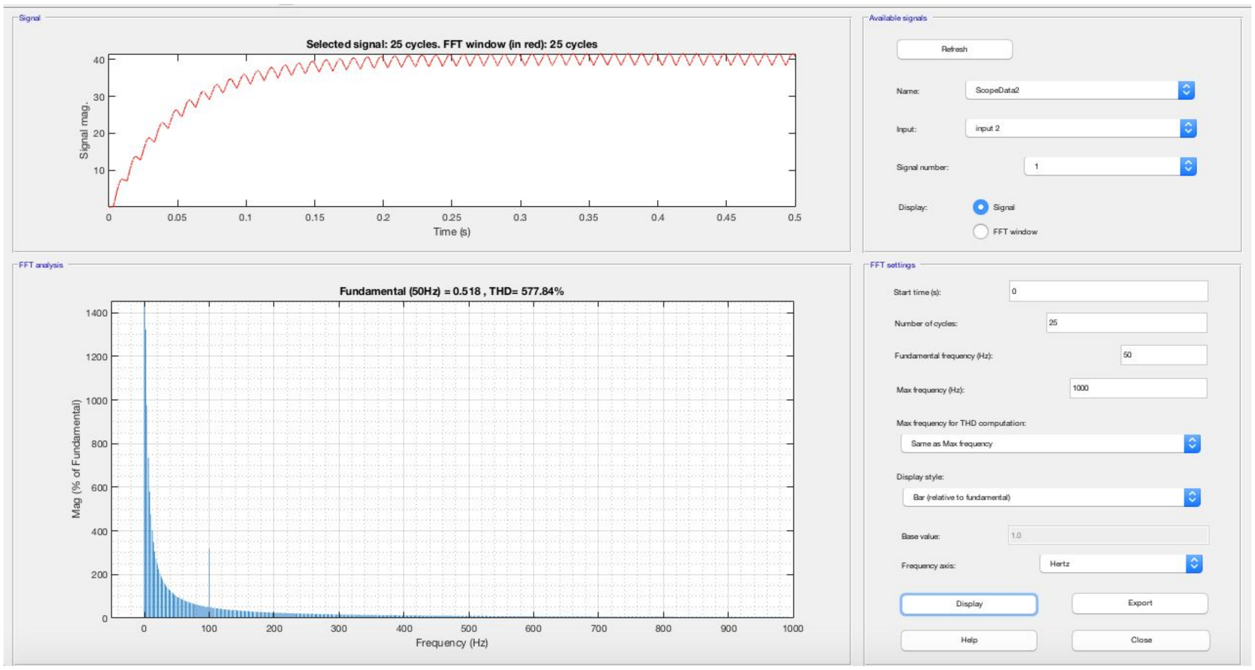

Figure 4: THD analysis of the case-b of part 1

From figure 4, percentage wise THD value of the output current of case-a part1 can be found to be 577%. With the results of the previous topology it can be concluded that these two topologies do not have notable differences in their resultant THD values.

Part 1.c

Compare the topologies wrt to their advantages, disadvantages and their application areas. Discuss their operational similarities and differences.

Even though the THD values and the output current waveforms are found to be very similar with each other the main difference was in the output voltage waveforms where the first topology yielded a waveform with negative values and the second topology yielded a non-negative valued waveform This is due to the freewheeling diode which would not alove negative current through itself.
Also, having an only positive voltage waveform is an advantage comes with the second topology because the higher mean value for the same input voltage is better when considering power delivery.

Part 2

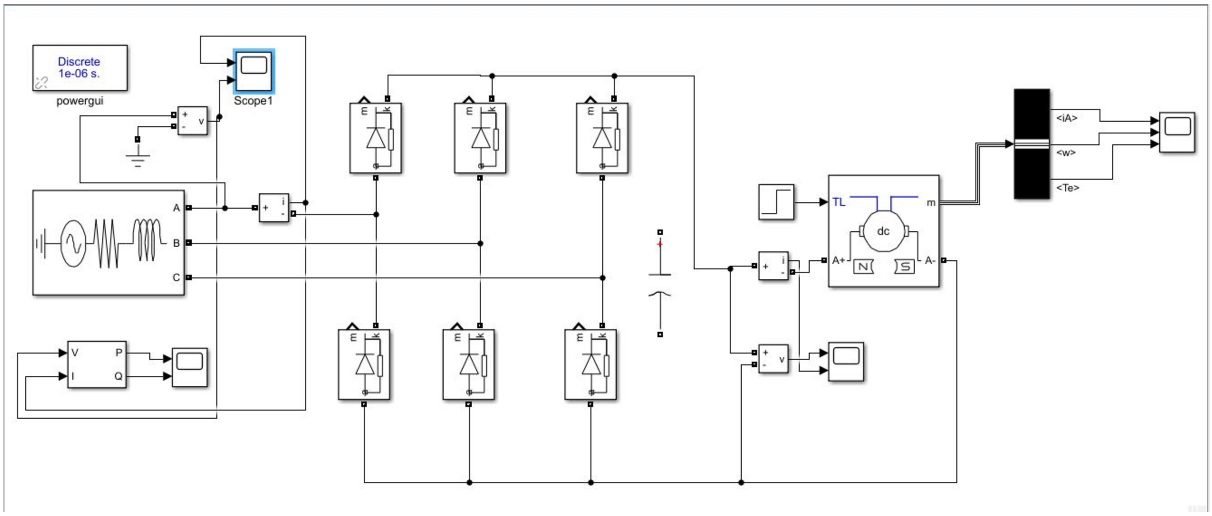

Figure 5 : Schematic for the DC motor driver.

Part 2.a

Part 2.a.1

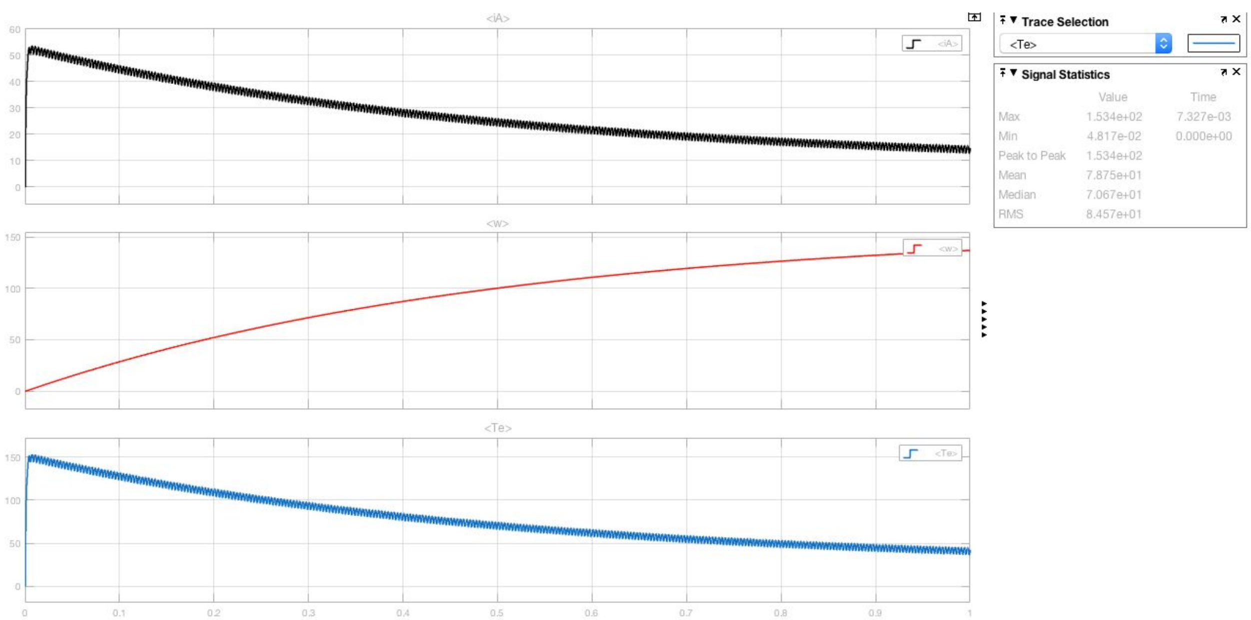

Figure 6 : Waveforms of armature current (Ia), rotational speed(w) and torque (Te) of the motor

Part 2.b

Frequency of torque ripple is 300 Hz which is same with frequency of output voltage of 3 phase-full-bridge rectifier. It shows us cause of ripple in torque is ripple of output voltage. Magnitude of torque is changing between 22 and 31 N.m because of the same reason.

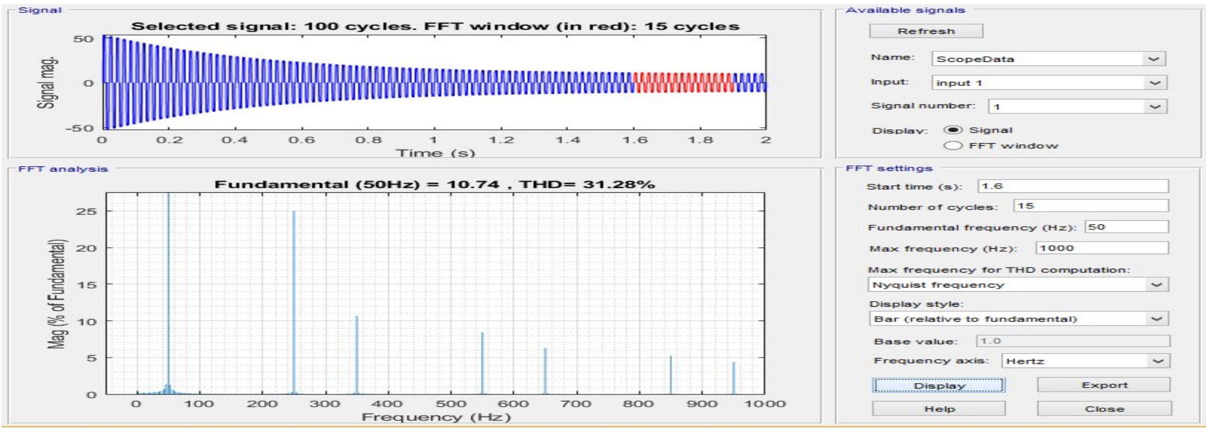

Figure 7: THD of line current

Part 2.c.1

One method of reducing torque ripple is connecting a capacitor at the output of rectifier.

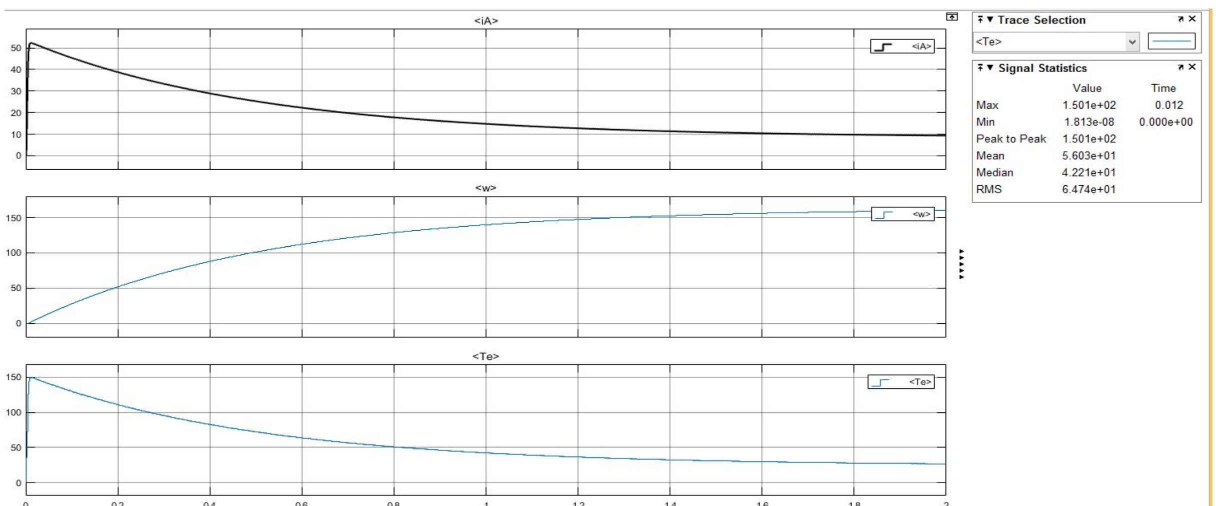

Figure 8: Waveforms of armature current, speed and torque of the motor with 10mF capacitor

Magnitude of torque ripple is reduced to 1.7 N.m with this method which is below 10 % of average torque. The main advantage of connecting capacitor is reducing torque ripple but it has several disadvantages. One disadvantage is increasing THD of line current to 123.52. Other disadvantage is increasing power loss due to capacitor and decreasing power quality.

Part 2.d

Input electrical power and output mechanical power is calculated via formulas which is given below or simulated via power block.

$$P_{in} = 3 * V_{phase} * I_{phase} * p.f$$

$$P_{out} = T * w$$

$$P_{loss-R} = I^2 * R * 3$$

P_{in}=5150 W P_{out}=27*154.3=4166 W P_{loss-R}=7.7*7.7*3*0.1=18 W $P_{rec-out}$=5037 W

Therefore, motor loss is found by subtracting output power of rectifier from output power of motor which is 870 W and rectifier loss is found by subtracting input power of rectifier from output power of rectifier which is 113 W

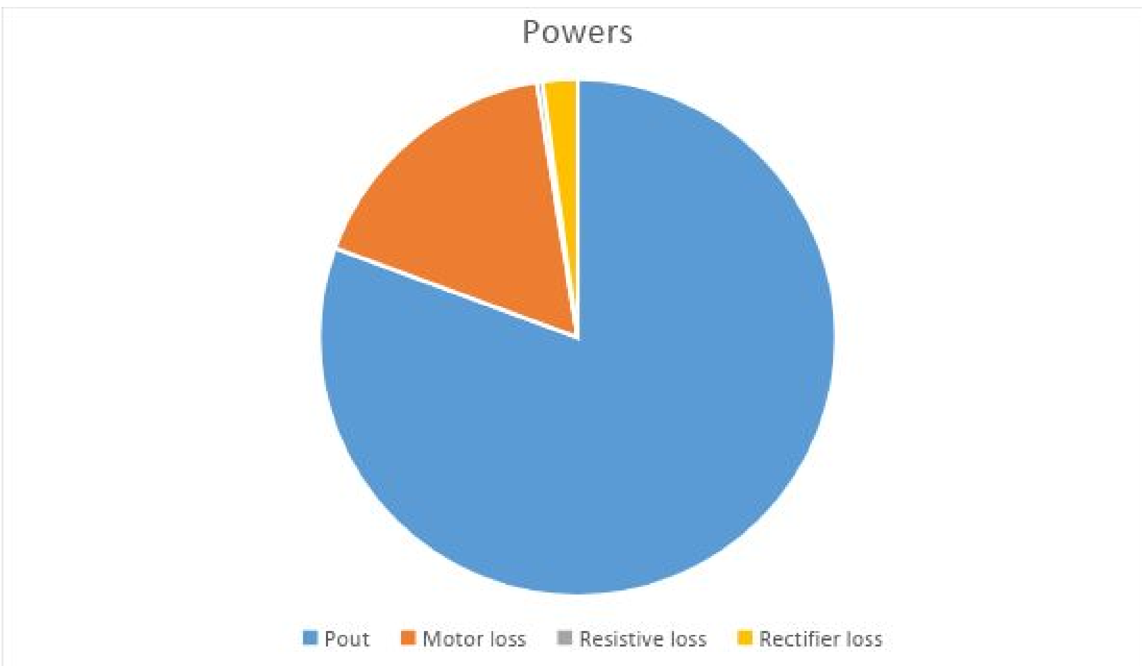

Figure 9 : Pie chart for the power distribution

Efficiency of motor is $\frac{P_{in}}{P_{out}} * 100 = \frac{4166}{5037} * 100 = 82.7$ %

Part 3

Part 3.a

This topology is called 12 pulse rectifier topology which is also evident from the output voltage waveform in Part 3.a, figure 12. There is other 12 pulse rectifier topologies with different winding combinations where primary is Y and the secondaries has Y and Delta connections as in figure 10.

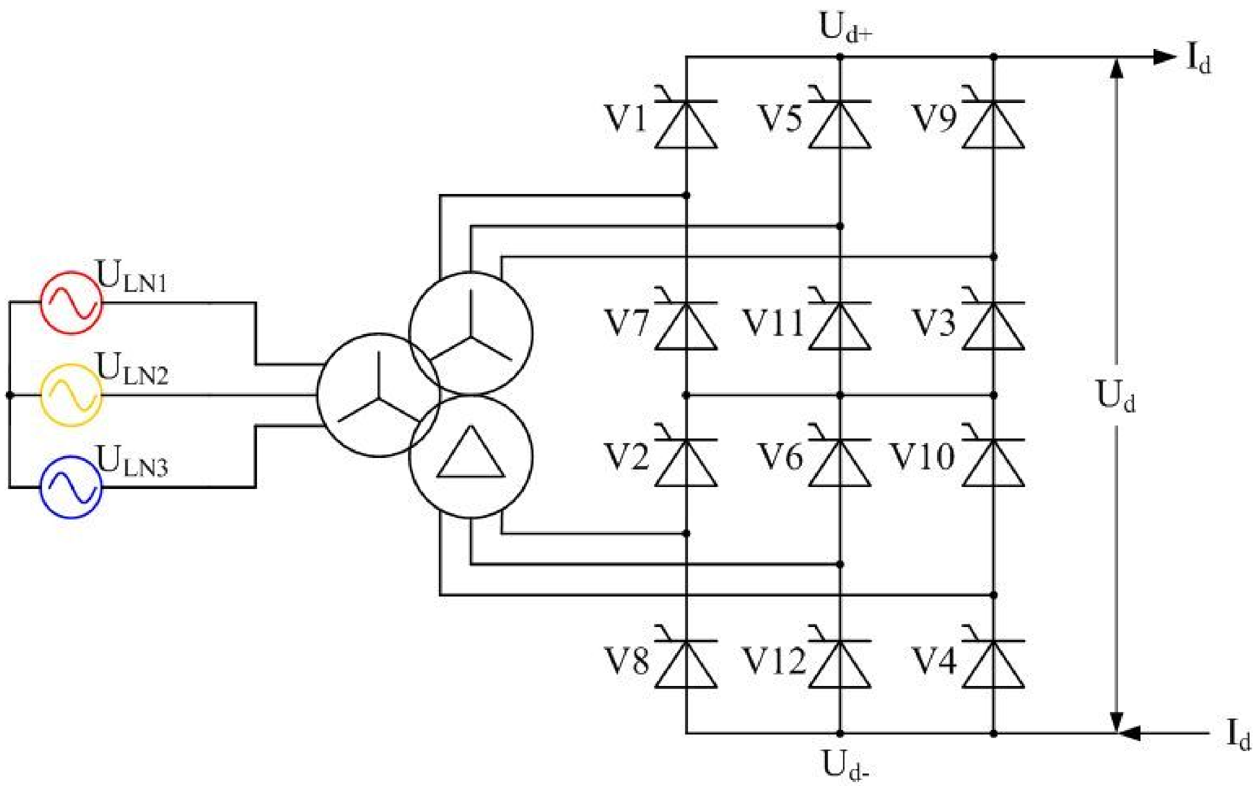

Figure 10 : Another 12 pulse rectifier topology.

Part 3.b

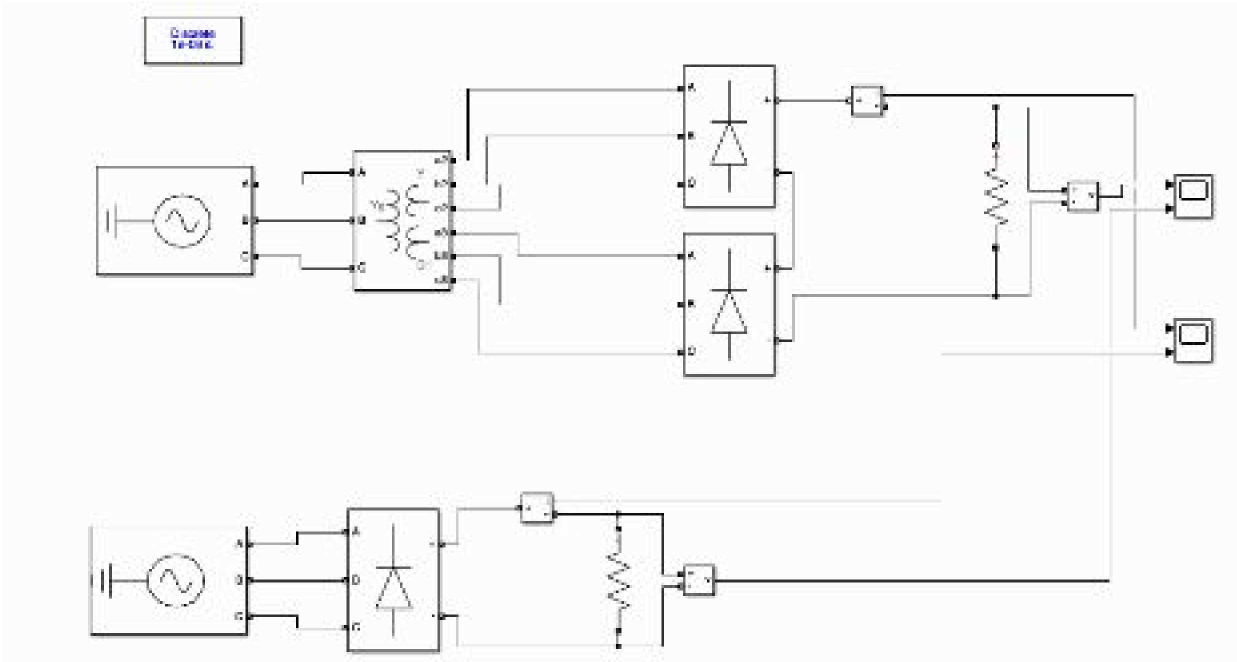

Figure 11: Circuit schematics for the comparison of the given topology and the full bridge diode rectifer.

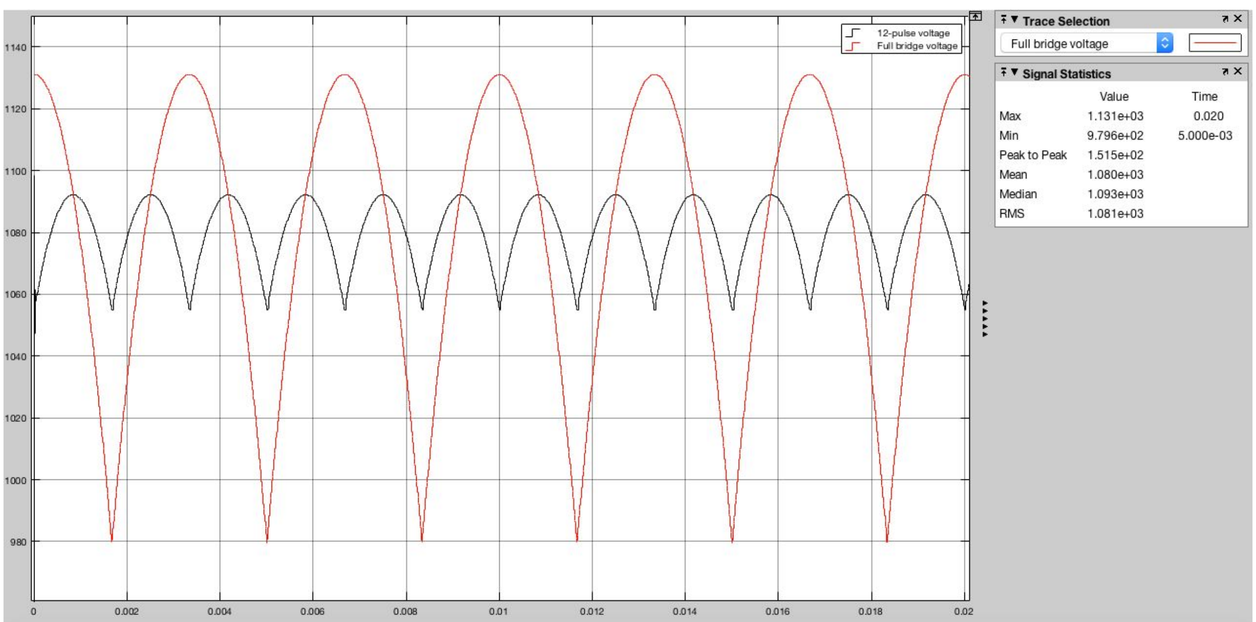

Figure 12: Waveforms generated by the assumed to be the 12 pulse rectifier topology and full bridge diode rectifier.

The resulting waveforms of both of the topologies can be seen in the figure 11. Even though they produce voltages with the same mean value, 12-pulse rectifier topology has less ripple in its output waveform which is something desired. However the 12 pulse rectifier topology requires more hardware source which means it will increase the cost. Also it should be noted that in order to achieve the same mean value for the output voltages diode rectifier requires twice the input line to line voltage that of the 12 pulse rectifier. This fact can be considered as the biggest “pro” for this rectifier.