MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE463 Project-2 Report

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1.

a.

$$|Z_{Load}| = \sqrt{4^2 + 0{,}200^2} = 4{,}004 \ \Omega$$

$$V_{av} = I_{av} \cdot |Z_{load}| = 40 \cdot 4{,}004 = 160{,}16 \text{ Volt}$$

Formula For Fully-Controlled : $V_{av} = \dfrac{2\sqrt{2}}{\pi} \cdot V_d \cdot \cos(\alpha) - \dfrac{2 \omega L_s I_{d_{min}}}{\pi}$

Let's take $I_{d_{min}} = I_{d_{av}} = 40$ A for simplicity

$$\Rightarrow 160{,}16 = \frac{2\sqrt{2}}{\pi} \cdot 230 \cdot \cos(\alpha) - \frac{\cancel{2} \cdot 2 \cancel{\pi} \cdot 50 \cdot 0{,}\cancel{5} \cdot 10^{-3} \cdot 40}{\cancel{\pi}}$$

$$\Rightarrow \cos(\alpha) = 0{,}793 \Rightarrow \alpha = 37{,}53 \text{ degrees}$$

Formula For Half-Controlled : $V_{av} = \dfrac{\sqrt{2}}{\pi} \cdot V_d \cdot \left(1 + \cos(\alpha)\right) - \dfrac{2 \cdot \omega \cdot L_s \cdot I_{d_{min}}}{\pi}$

$$\Rightarrow 160{,}16 = \frac{\sqrt{2}}{\pi} \cdot 230 \cdot \left(1 + \cos(\alpha)\right) - \frac{\cancel{2} \cdot 2 \cancel{\pi} \cdot 50 \cdot 0{,}\cancel{5} \cdot 10^{-3} \cdot 40}{\cancel{\pi}}$$

$$\Rightarrow \cos(\alpha) = 0{,}586 \Rightarrow \alpha = 54{,}16 \text{ degrees}$$

Figure 1 Analytical Calculation of the Firing Angles

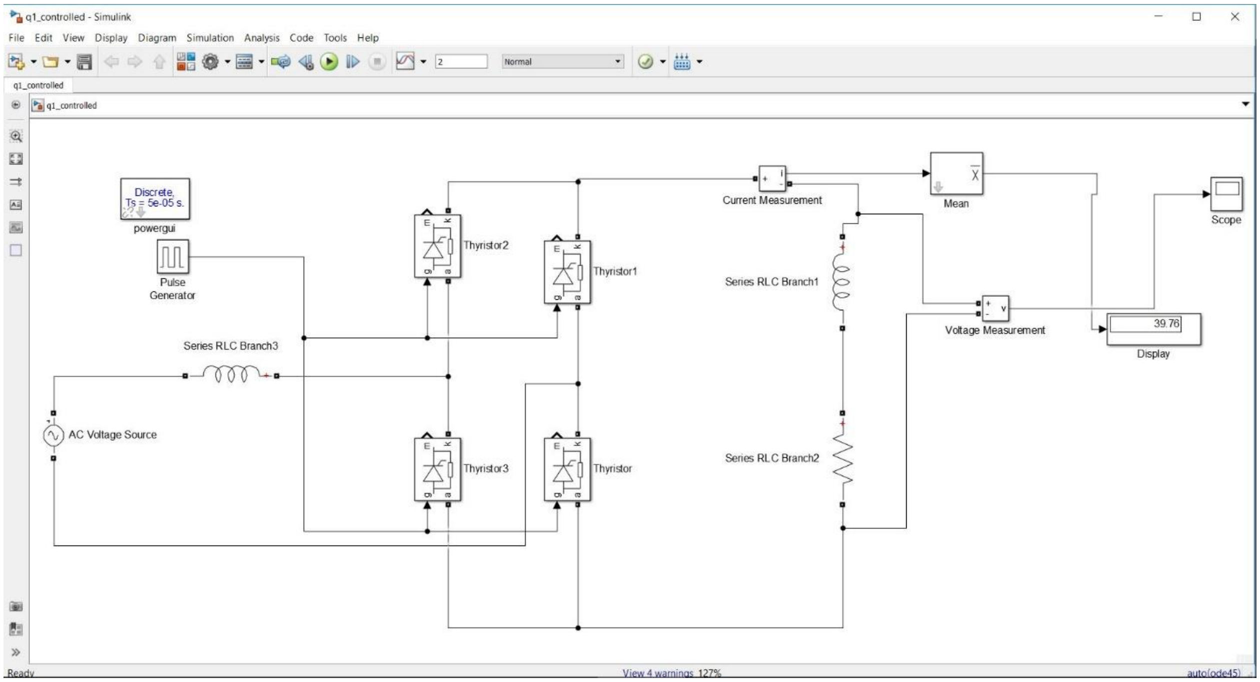

Figure 2 the Schematic of the Full-Controlled Rectifier

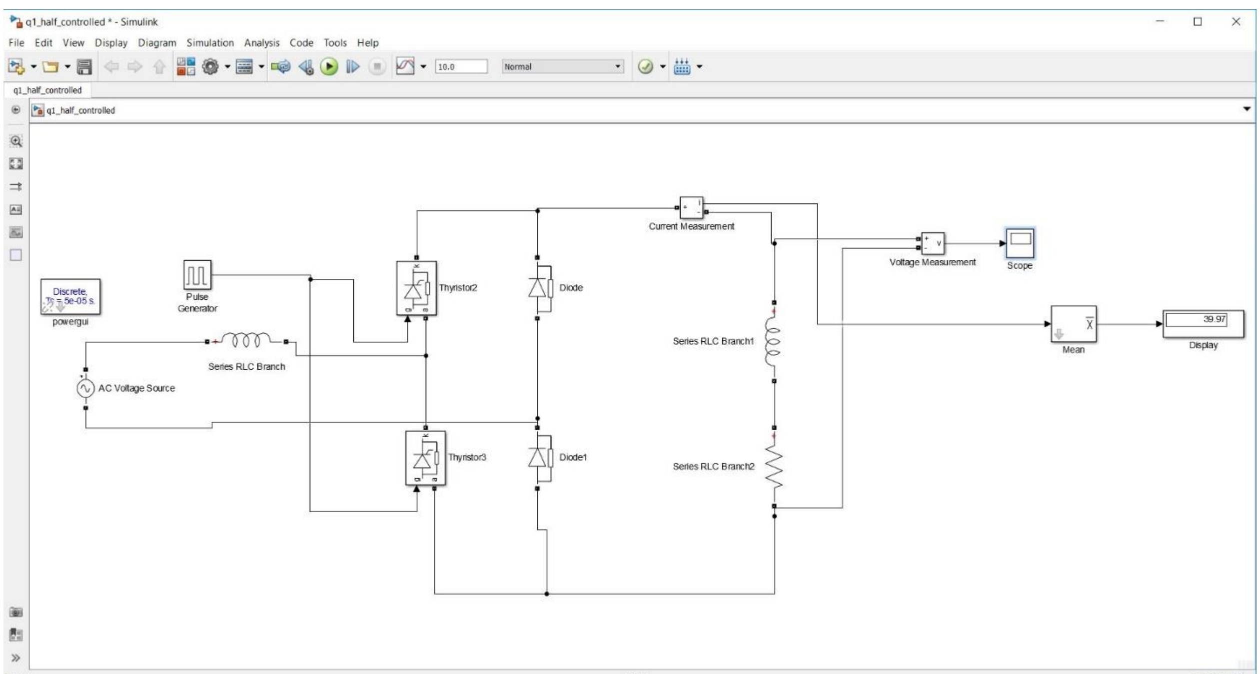

Figure 3 the Schematic of the Half-Controlled Rectifier

Figure 4 the Waveform of the Full-Controlled Rectifier for Calculation of the Firing Angle

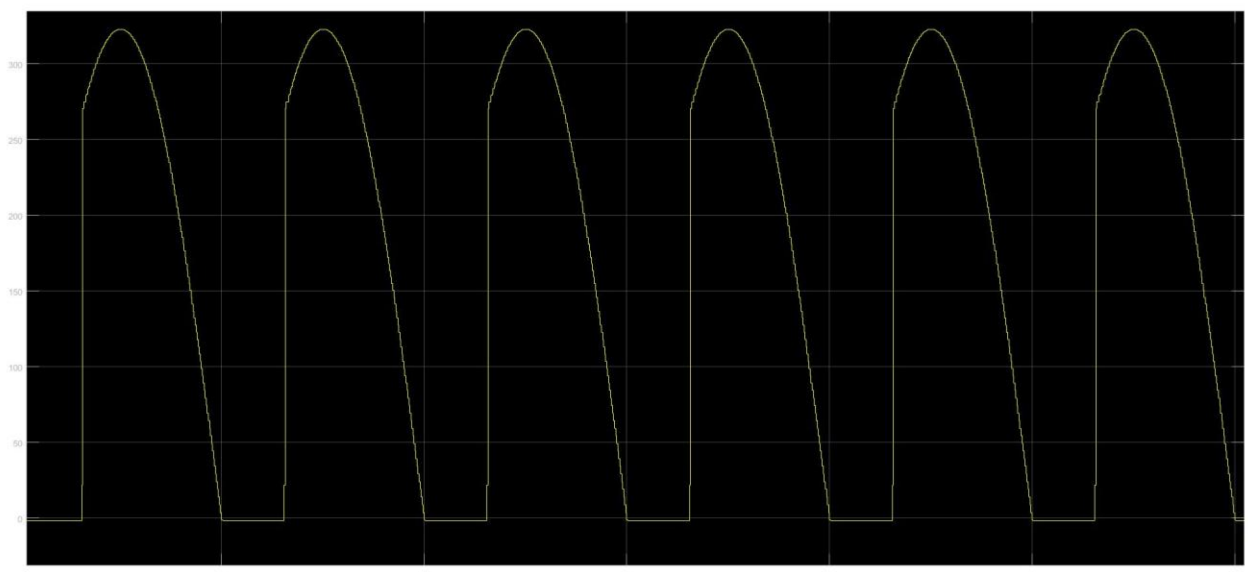

Figure 5 the Waveform of the Half-Controlled Rectifier for Calculation of the Firing Angle b.

Figure 6 the Harmonics of the Source Current (Is) of the Full-Controlled Rectifier

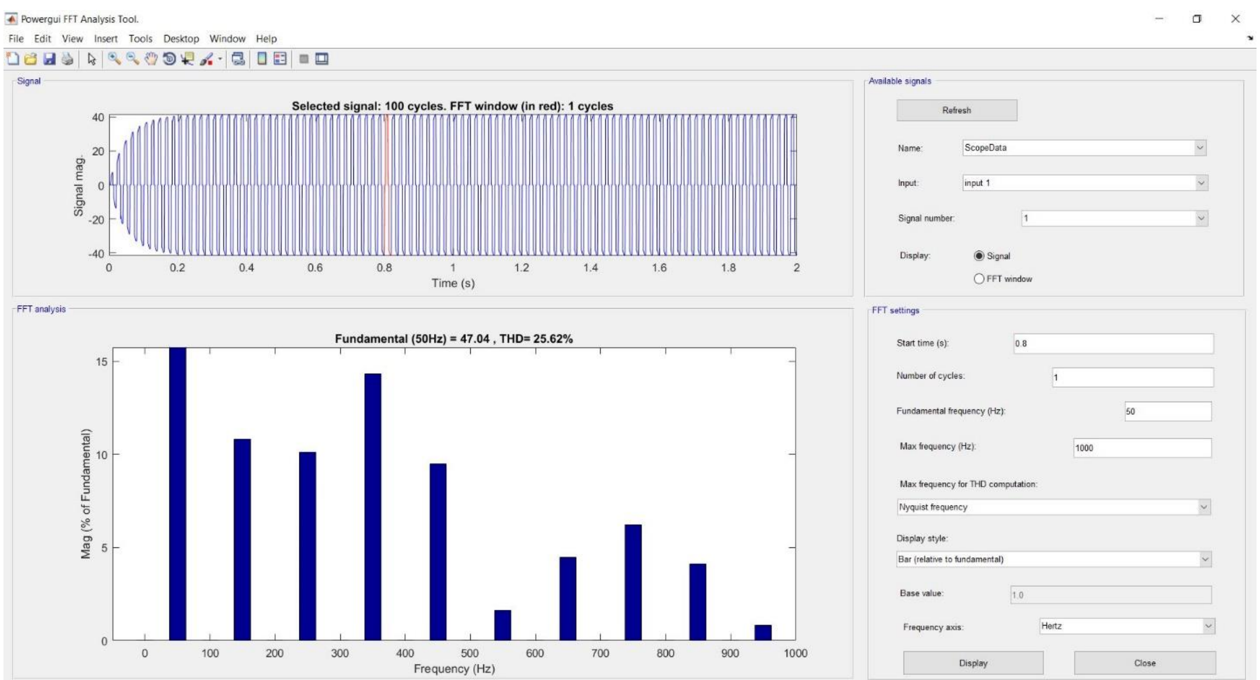

Figure 7 the Harmonics of the Source Current (Is) of the Half-Controlled Rectifier

As shown in the figures which are above, THD of the source current of the full-controlled rectifier is higher than half-controlled one because in first case, current seem like a square wave however in second case, current seem like more sinusoidal. Reason of this is that in second case current cannot pass some time due to the free-wheeling diodes. These destroy the current waveform.

c.

The difference between the topologies, output voltage cannot be negative in half-controlled rectifier. However, output voltage can be negative in fully-controlled. Because of that, average output voltage of the half-controlled rectifier is higher than fully-controlled one in same case. Moreover, negative output voltage is a big disadvantage of the fully-controlled rectifier because some loads are sensitive to negative voltage.

The similarities of these are that if thyristors are fired at the same time for both cases, starting of the output voltage is same.

2.

a) The schematic of the question which is shown in Figure 8 is created by using Simulink. Sample time is selected 1 us because simulation time selected long time such as 20seconds.

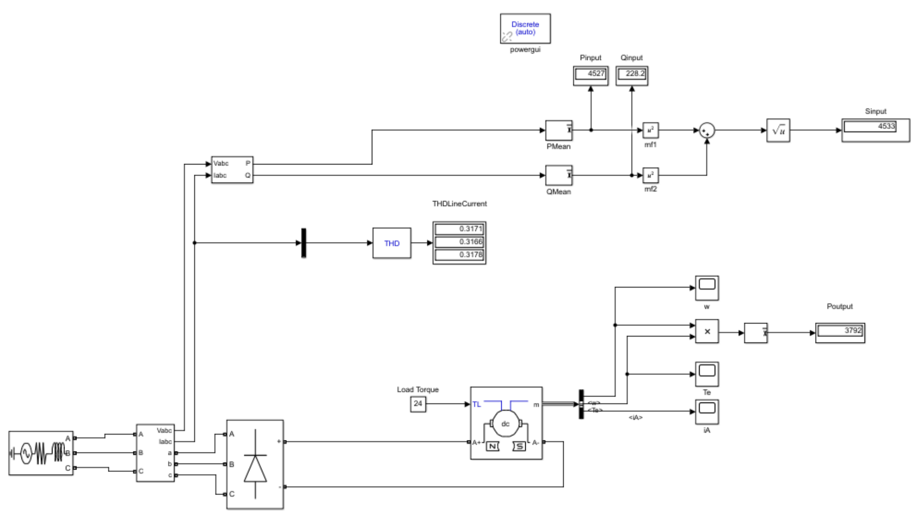

Figure 8: Schematic of Question 2

Figure 9 and 10 shows the armature current vs simulation time and ripple for some selected intervals.

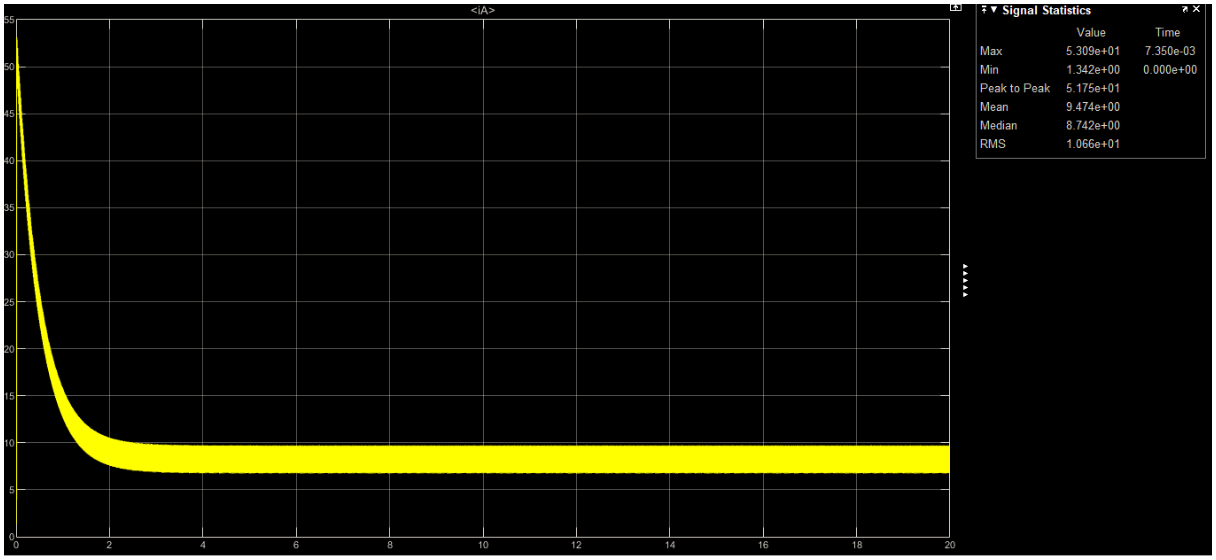

Figure 9: Waveform of Armature Current

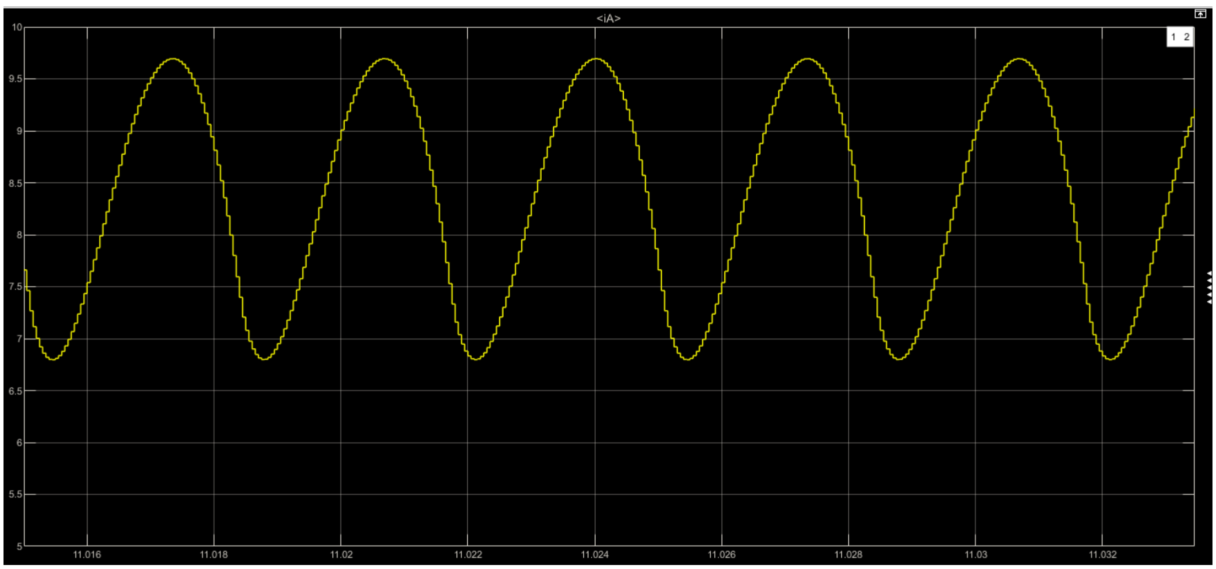

Figure 10: Waveform of Armature Current with Selected Time Intervals

Figure 11 shows the speed of the simulation.

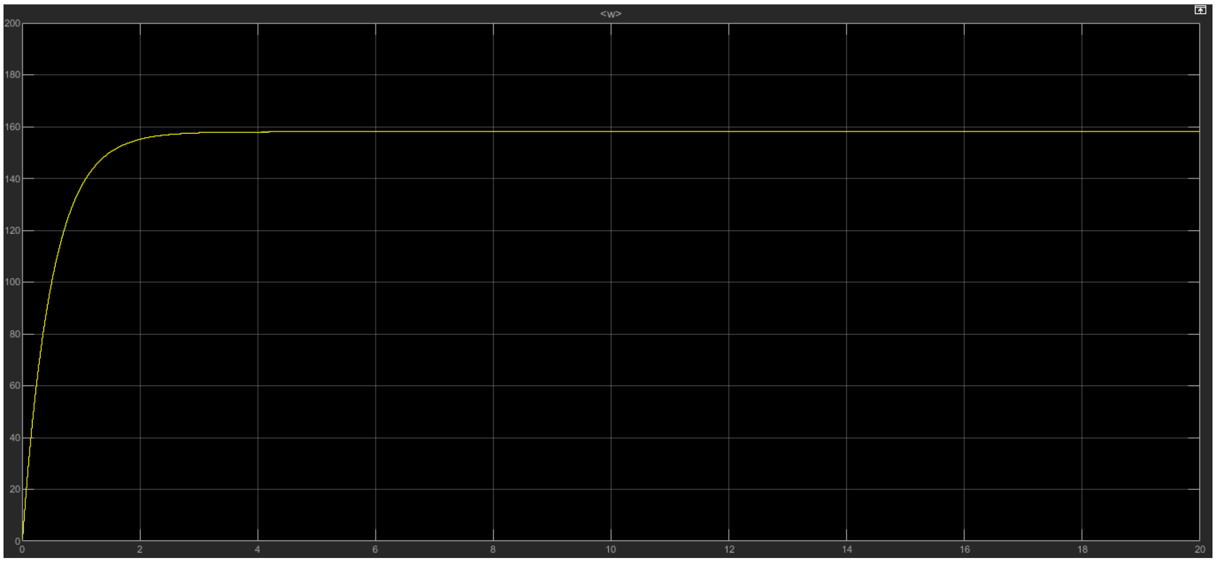

Figure 11: Waveform of Speed

Figure 12 and 13 shows the Torque vs simulation time and ripple for some selected intervals.

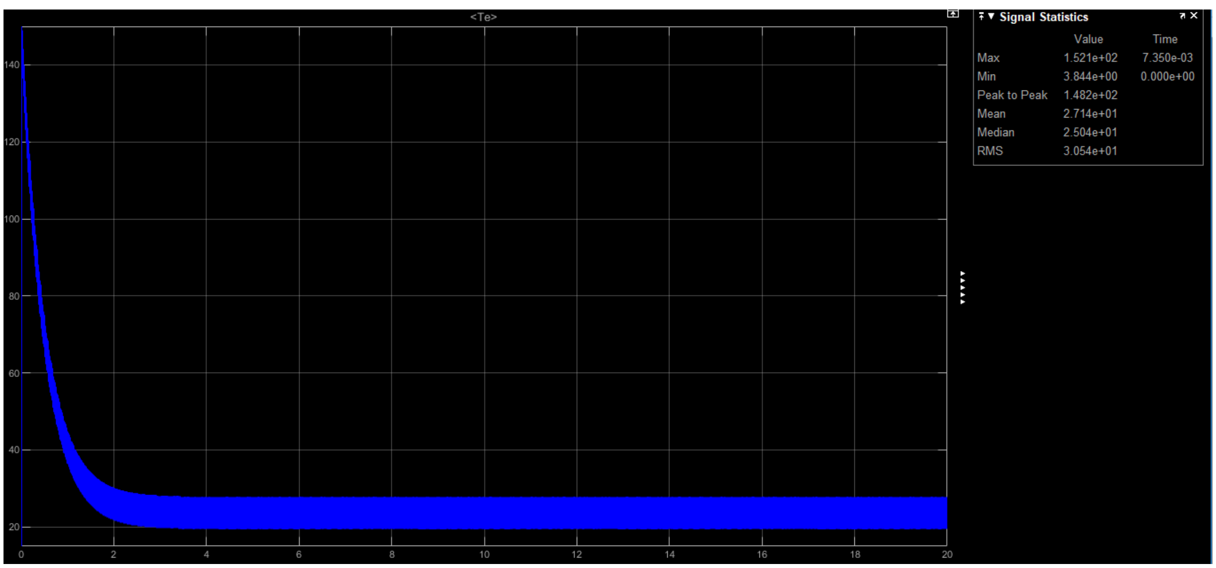

Figure 12: Waveform of Torque

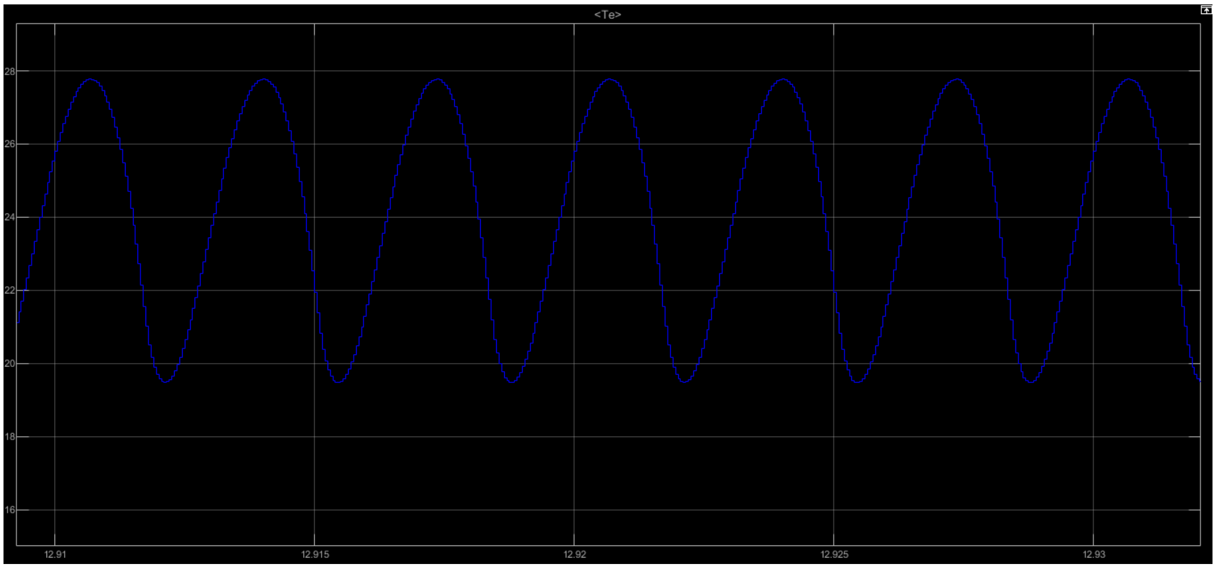

Figure 13: Waveform of Torque with Selected Time Intervals

b) The mean torque is measured 27, the ripple torque is measured 8.3 and the frequency is 300Hz. This 8.3 ripple value is too high for practical applications. The frequency is measured six times higher for source because of the bridge which is used is six pulse rectifier.

THD of the line current shows in Figure 14.

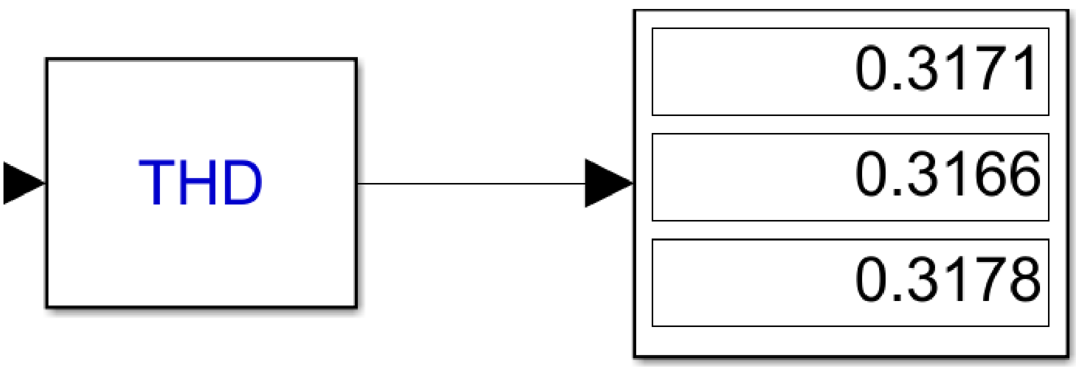

Figure 14: THD of Line Current

Theoretical result is 0.3108 so this simulation result is very near of the ideal result. The difference is leaded by small source inductance.

c) In part 2-a, the mean torque is measured 27 so we need to reduce it <2.7. To do that we use 2 methods which are adding series inductance to armature and adding parallel capacitor to armature. Figure 15 and 16 shows the new schematics of the system.

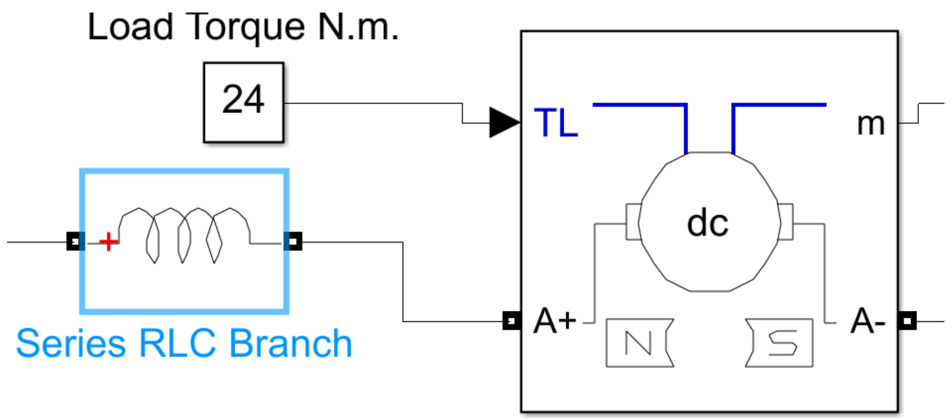

Figure 15: Schematic of Series L

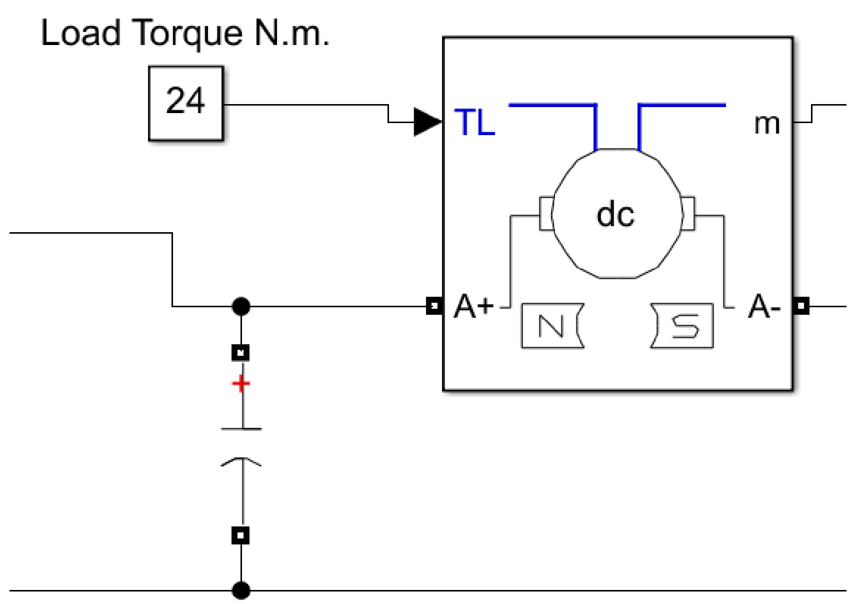

Figure 16: Schematic of Parallel C

We added series 50mH inductor and parallel 1mF Capacitor.

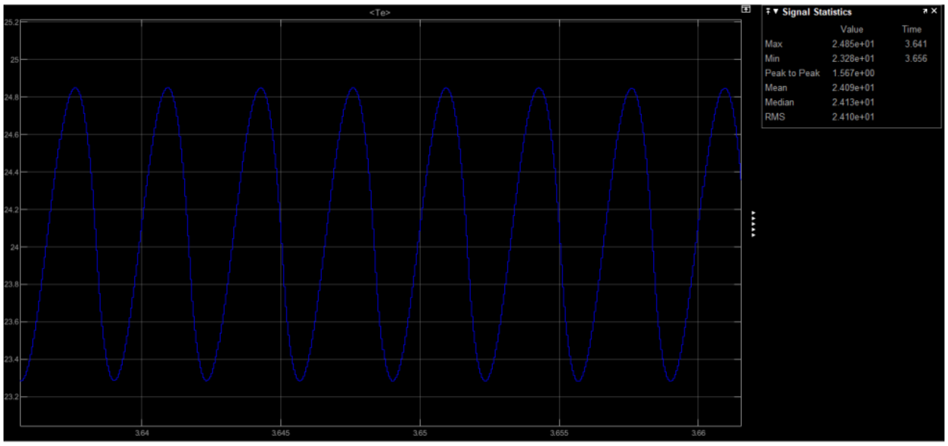

Figure 17: Ripple Graph for Added Series Inductance

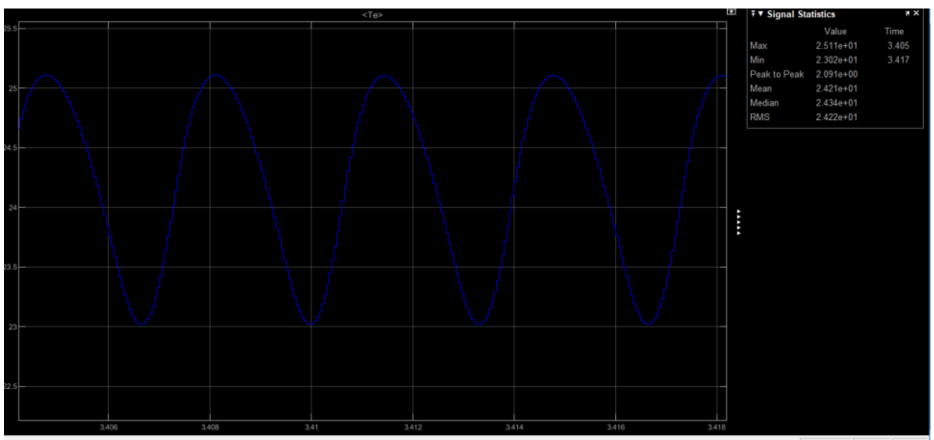

Figure 18: Ripple Graph for Added Parallel Capacitor

We measured 1.6 and 2.1 ripple for two methods.

These methods provide advantage to reduce ripple armature current and torque but the cost of the system will increase.

d) Measured powers of units are shown in Figure 19. Power loss and efficiencies are shown in Table 1.

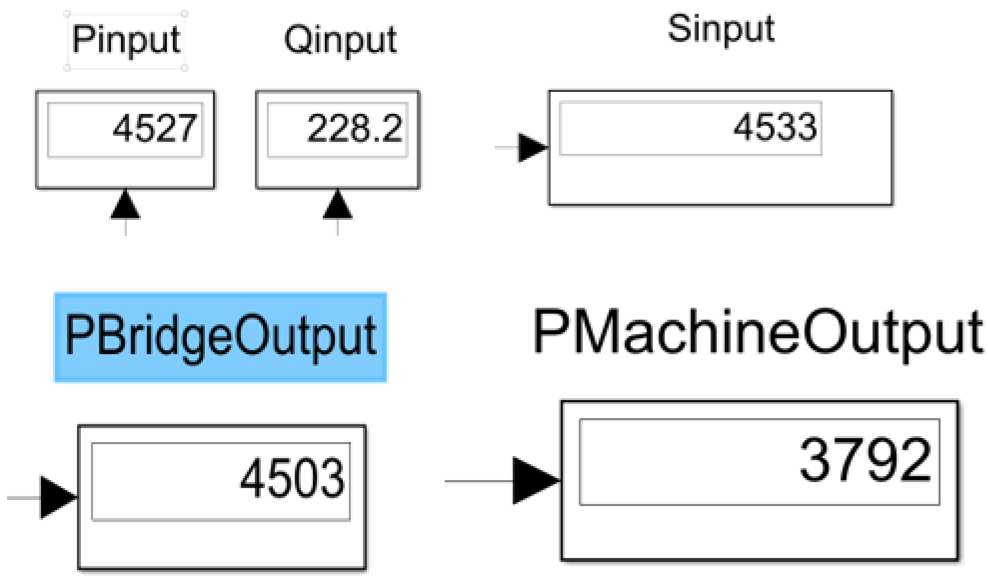

Figure 19: Powers

Table1: Efficiencies

Unit	Power(W)	Efficiency (%)
Input	4527	100
Output of Bridge	4503	99
Output of Machine	3792	84

Armature resistance and bridge on resistance lead the loss of power. Bridge on resistance is 20 mΩ and armature resistance is 10Ω so, armature resistance leads more power loss.

3.

a.

In this topology is named as 12-pulse rectifier. There is a delta transformer in the source side. However, in the load side, there are wye and delta transformer.

6 pulse come from delta transformer in load side lie full bridge, controlled rectifier.

Other 6 pulse come from y transformer. However, these pulses do not overlap the other 6 pulse because there is 30-degree phase shift in wye-delta transformers. That is, line to neutral voltages of the wye transformer lag behind the line to neutral voltage of the delta transformer, as known. Therefore, total 12 pulse at the load.

There is another version of the 12-pulse rectifier. In this case, there is wye transformer instead of delta transformer. Voltage of the load is same however line to neutral voltage of the delta transformer has 30-degree phase shift, lead behind the source voltage instead of lag.

There is also 18-pulse, 24-pulse and 36-pulse version of this topology. Difference is that phase shifting transformer must be used. Increasing pulse decreases the ripple voltage. This means that output like DC more

Filtering capacitor value of the load side increases when output voltage increases as known therefore in HVDC and UHVDC using capacitor becomes more expensive. Some case, this are not applicable. Therefore, this topology is used for HVDC and UHVDC because output has less ripple than full-wave rectifier.

b.

As mentioned before, for decreasing ripple, capacitors are used. However, for high voltage, big capacitors are needed. Although, transformers are expensive, in high voltage case, 12 pulse (or 24 pulse etc.) converters are used because capacitor cost is higher than cost of the transformer. Moreover, as mentioned before, in some cases, there is no possible capacitor to decreasing ripple. For this case, 12 pulse (or 24 pulse etc.) converters must be used.

For low voltage case, because the cost of the capacitor is smaller than transformers', 12 pulse (or 24 pulse etc.) converters are not preferred.

For same average output voltage, increasing the pulse number decreases the source voltage. However, increases the average current and current is closer to DC.

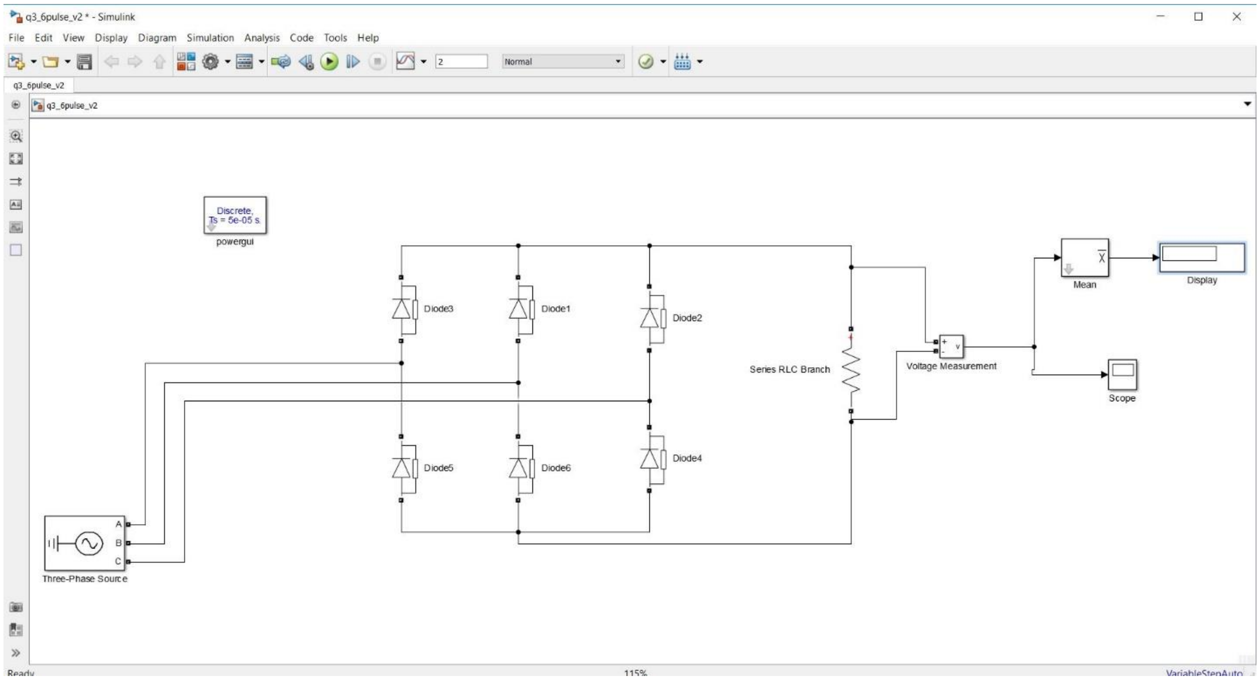

Figure 20 The Schematic of the 6 Pulse Converter

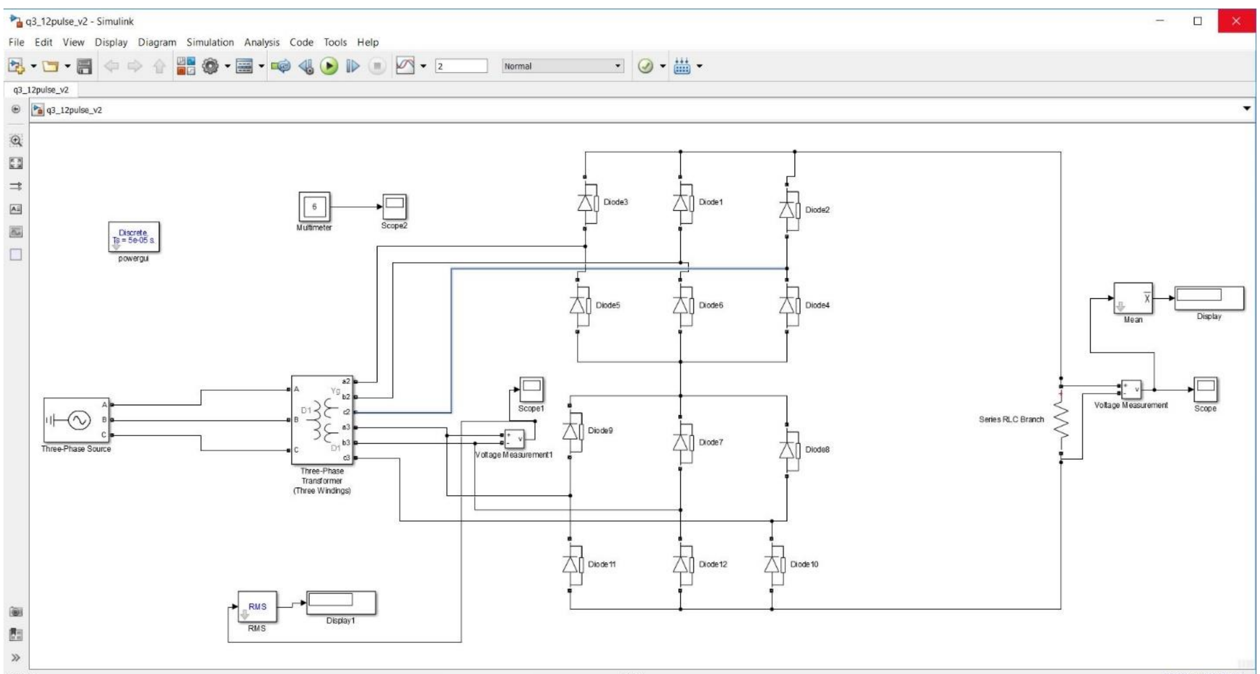

Figure 10 the Schematic of the 12 Pulse Converter

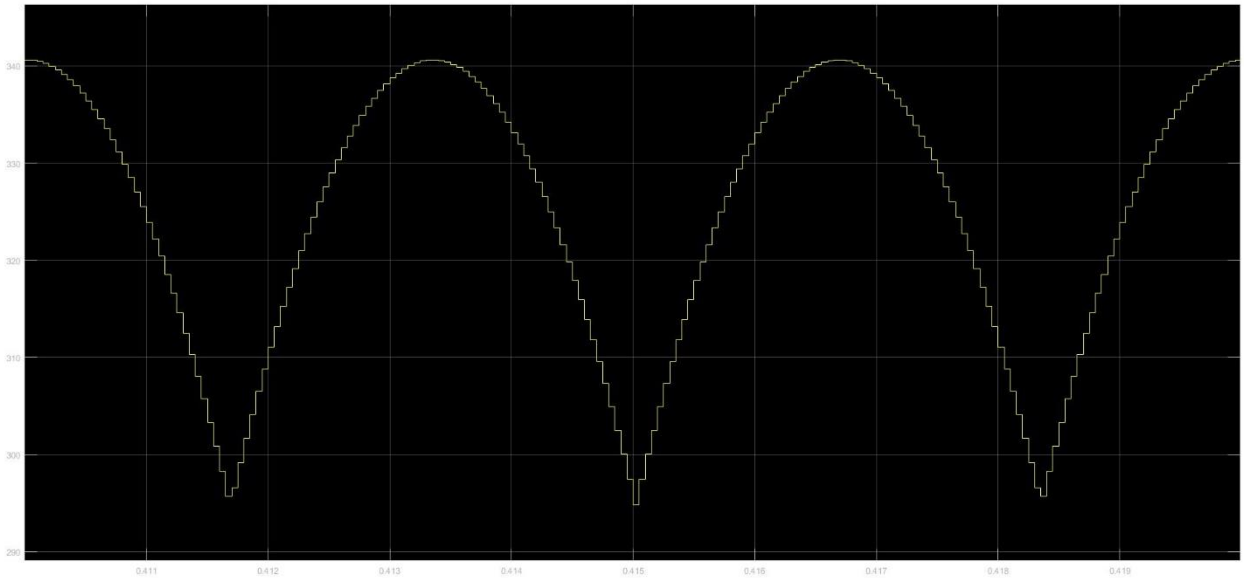

Figure 22 The Output Voltage Waveform of the 6 Pulse Rectifier

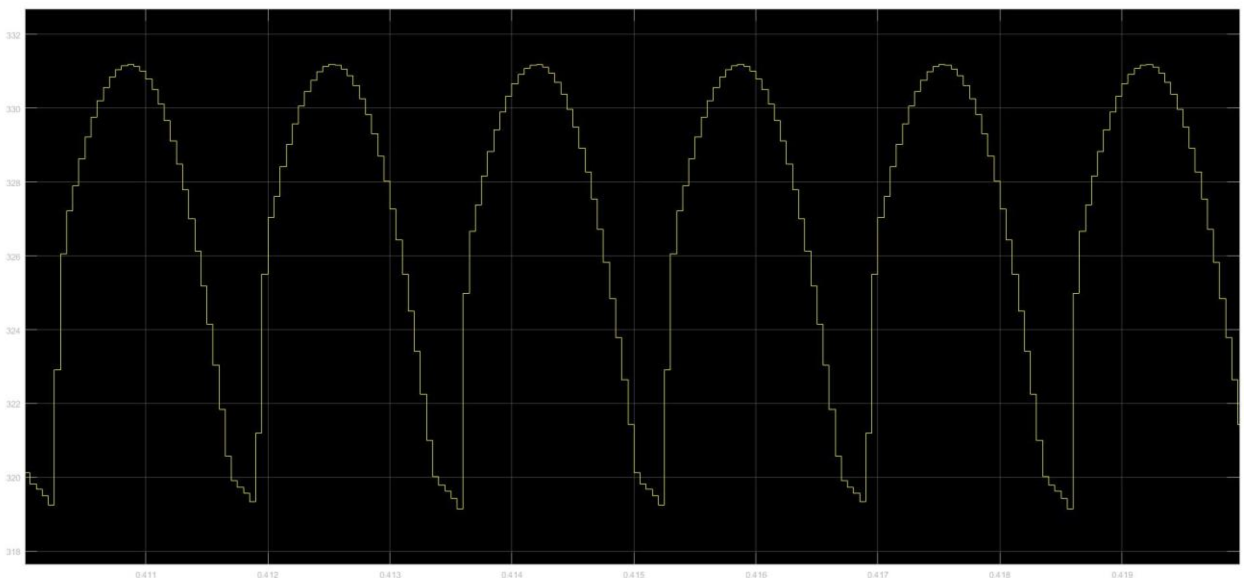

Figure 23 The Output Voltage Waveform of the 12 Pulse Rectifier

These graphs are obtained for same average of the output voltage and shown in the time interval.