EE 463 STATIC POWER CONSERVATION-PROJECT 1 REPORT

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Question 1)

A)

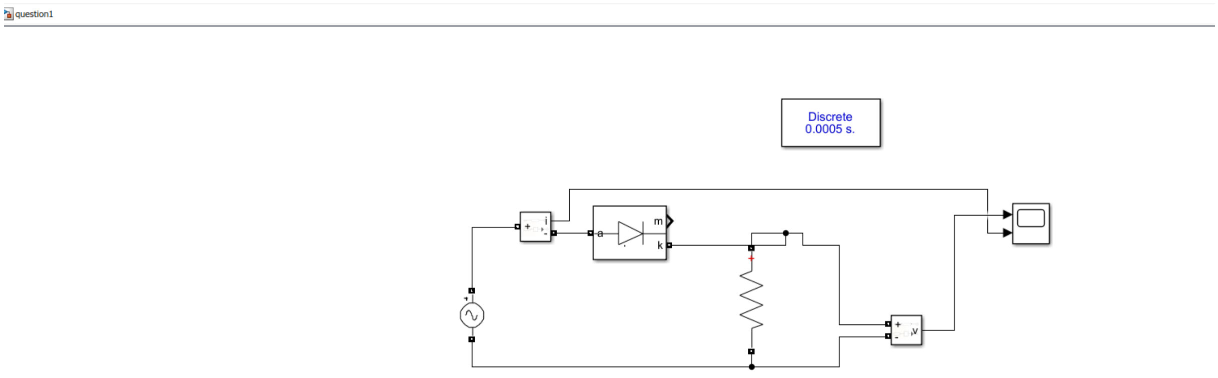

Figure 1: Simulink schematic of half-wave rectifier

The voltage output of a single-phase half-bridge rectifier can be observed in figure 2,3,4.

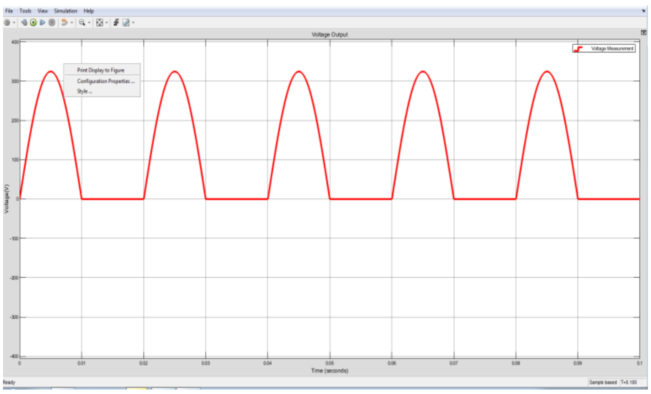

Figure 2: Output voltage of half-bridge rectifier in 1ns

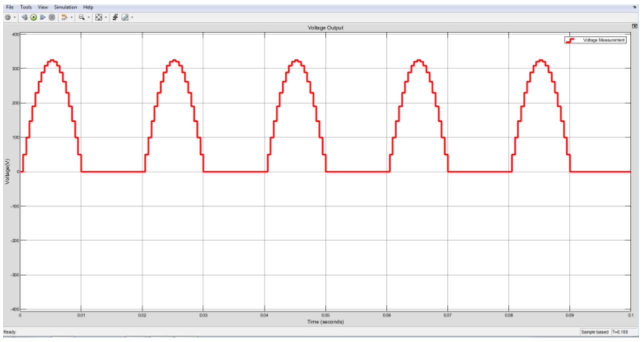

Figure 3: Output voltage of half-bridge rectifier in 0.5ms

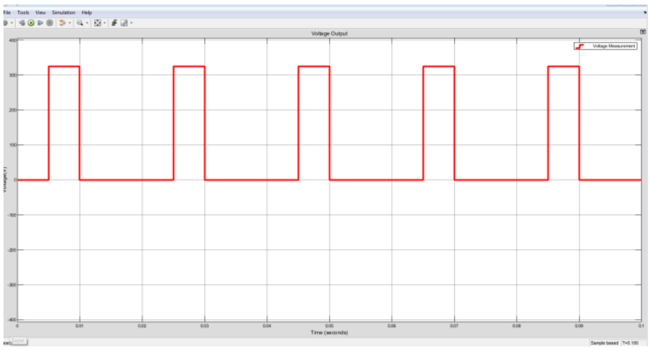

Figure 4: Output voltage of half-bridge rectifier in 5ms

B) Obviously, observation is that higher sampling frequency gives smoother curves. When sampling time is 1ns, it does not even look like a sampled signal. It looks like a pure sinusoid. When the sampling period rises, smoothness starts disappearing. Especially with T=5ms, it is observed that the signal s a duty cycle and far from the real signal. With such a high sampling time it won't be possible to even recover the original signal.
There is a tradeoff between performance and operation time. Higher frequencies obviously achieve many realistic results but take longer to do the simulation. On the other hand, lower frequencies lack performance but it takes less time to do the operation.

C) Average voltage formula is given below

$$V_{av}=\frac{1}{T}\int_0^T Vd * dt$$

$$=(2V_{srms}*\sqrt{2})/(2*pi)= 0,45V_{srms}$$

$$=103.5V$$

For the calculation of THD, harmonics of the wave must be calculated. In the first step, Fourier transformation must be made. Current wave equations are given below;

$$I(t)= 0 \text{ when } -pi/w<t<0$$

$$I(t)= I_{max}*sin(wt) \text{ when } 0<t<pi/w$$

$$a_0=\frac{1}{pi}\int_0^{pi} sin(wt) * dt=\frac{1}{Pi}$$

$$a_n=0 \text{ when } n=1,3,5,7\ldots$$

$$a_n=\frac{-2}{(n-1)*(n+1)*pi} \text{ for } n=2,4,6,8\ldots$$

$$b_1=1/2$$

$$b_n=0 \text{ for all } n \text{ values}$$

$$THD=\frac{\sqrt{0.21^2+0.042^2+0.018^2\ldots\ldots}}{1/2}\approx 0.43$$

D)

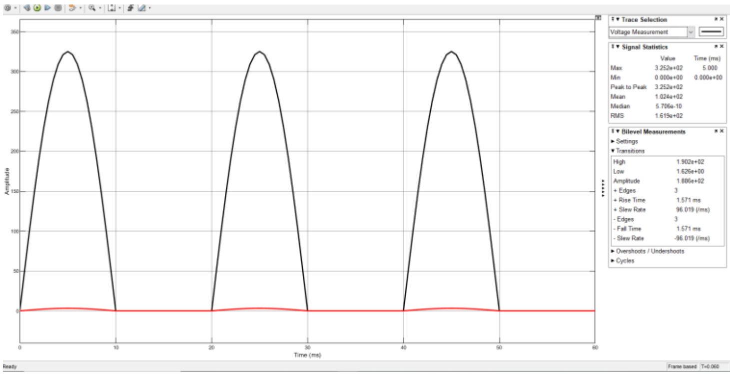

Figure 5: Mean of output voltage

The diode in MATLAB is not an ideal diode. It has some mom-idealities. Hence, there is a slight fluctuation which can be observed in "Fiugre5" but it is not a significant one. We can say that it is close enough to ideal.

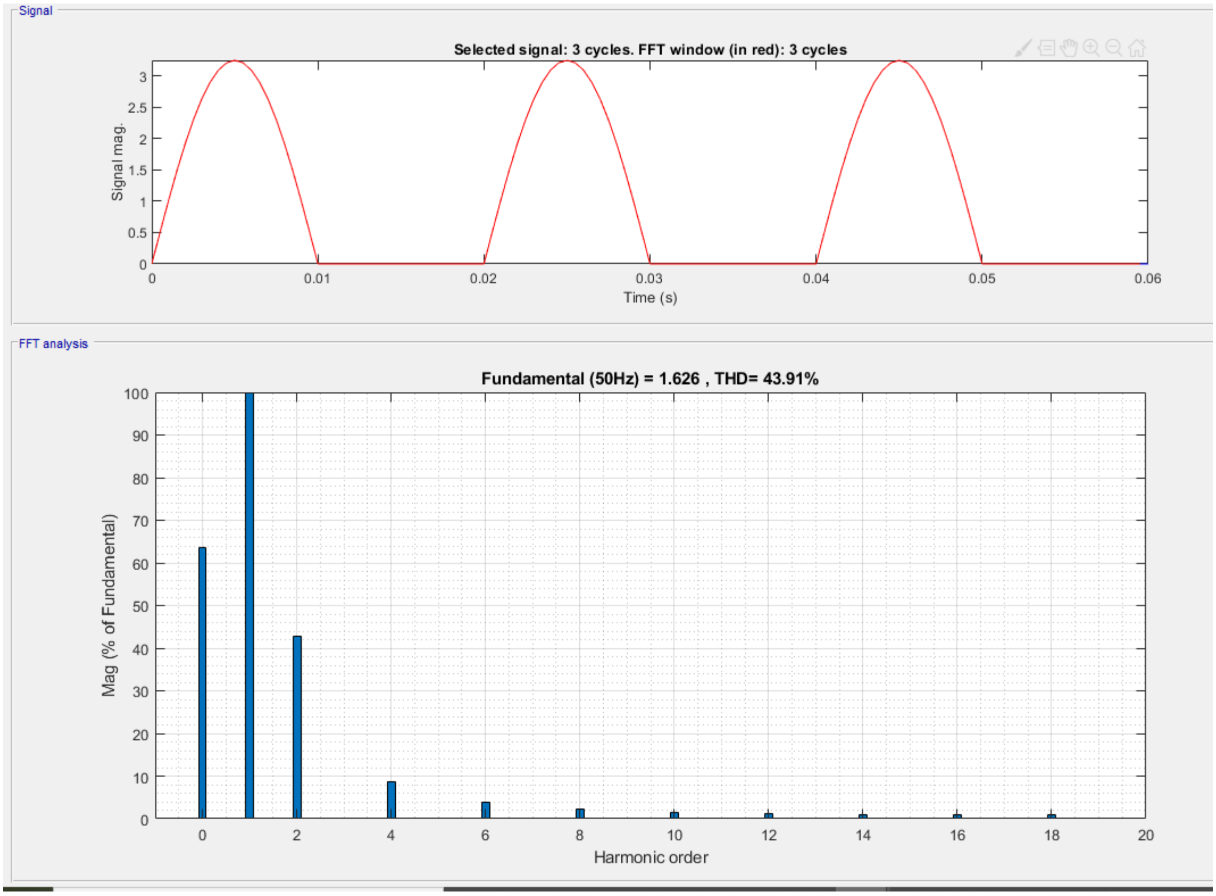

Figure 6: THD measurement of input current

As harmonics increase, their magnitude decreases and harmonics go to infinity with decaying. Since we cannot sum all harmonic waves as it goes to infinity, we can find THD values only smaller than measurement values. Unlike us, a computer can measure THD for a long-range of values. Hence, THD value computed by a computer is larger than the THD value found by calculation although there is not a big difference in-between. It can be seen in "Figure 6" that harmonics' magnitude decreases with increasing frequency.

Question 2)

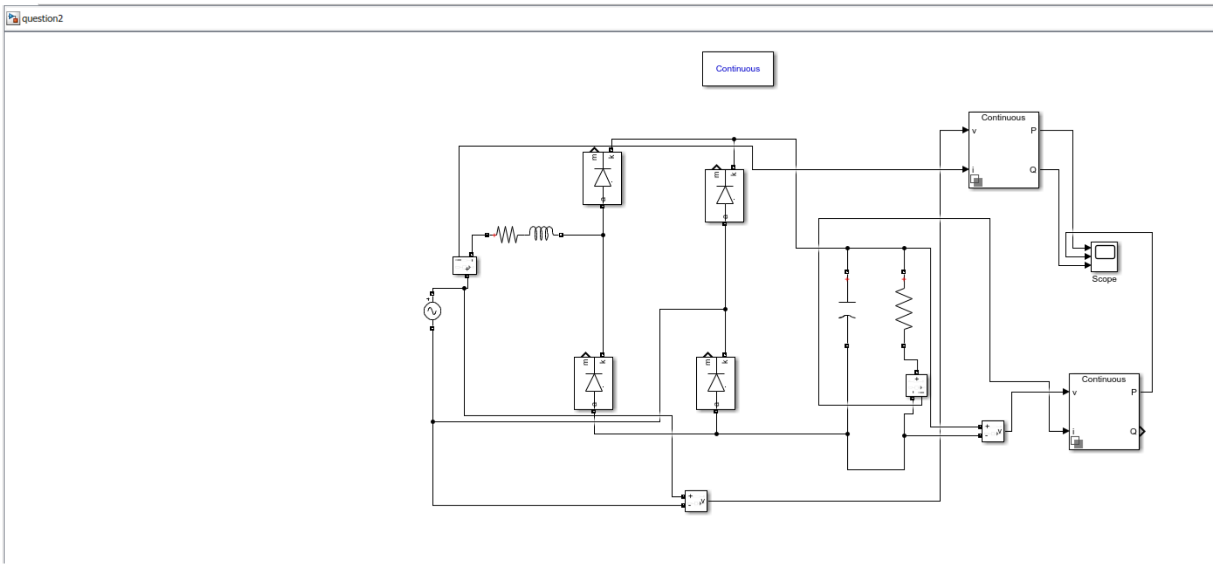

Figure 7: Simulink schematic of full-wave rectifier

A) It represents the grid line. Since cables are not superconductive, some of the energy is lost on its way to load. This loss is represented by a resistor. Also, the current carried to create the magnetic field. This is represented by an inductance.

B) In the simulation we tried a big capacitance for decreasing output voltage peak-to-peak ripple. Firstly, we tried 1mF I take output which is shown in "Figure 8".

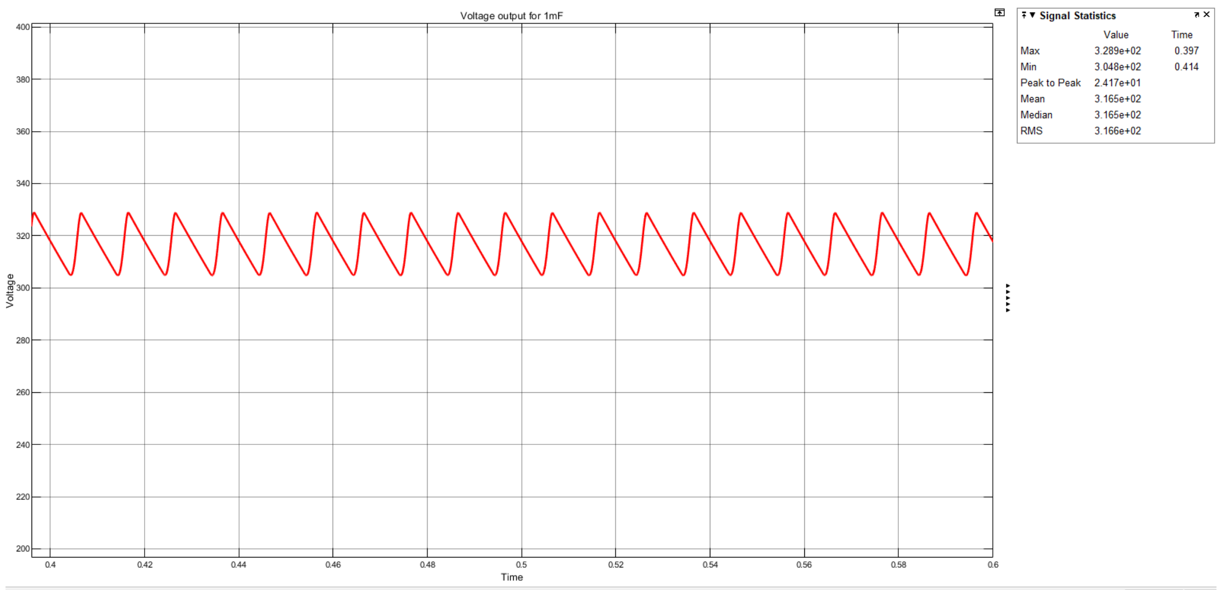

Figure 8: Voltage output for 1mF

Its peak to peak ripple is %7. Hence, the capacitance value must be increased. 1.5mF is suitable for %5 peak to peak ripple value.

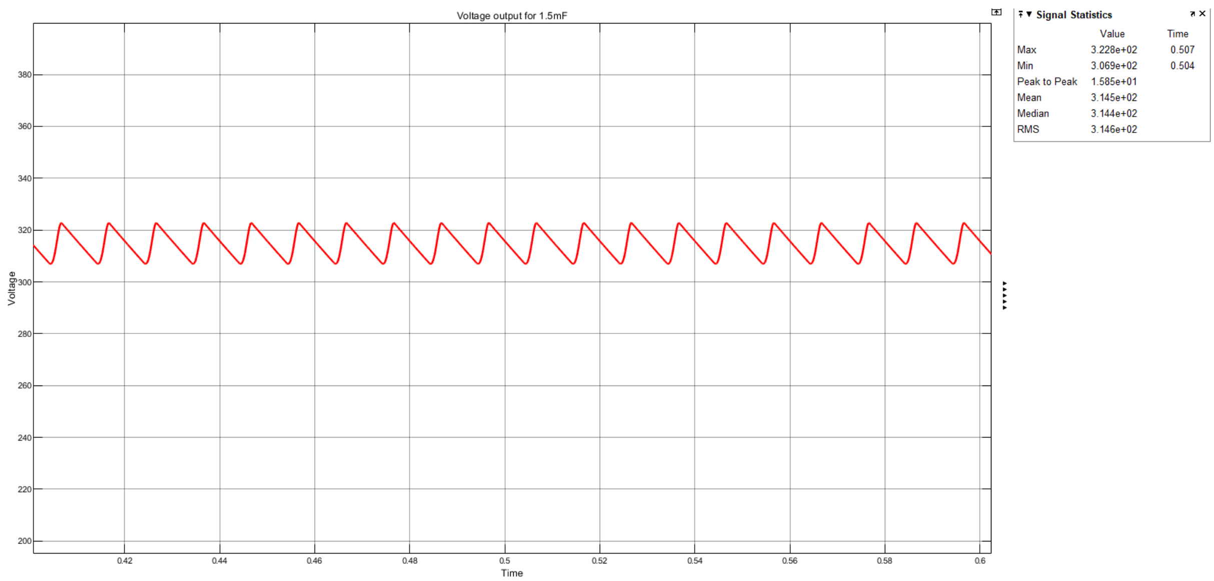

Figure 9: Voltage output for 1.5mF

As we see in figure 9 peak to peak voltage is 16V as we calculate peak to peak ripple value is $\frac{16}{322} * 100 = \%4.96$

İt is near the %5 value.

C)

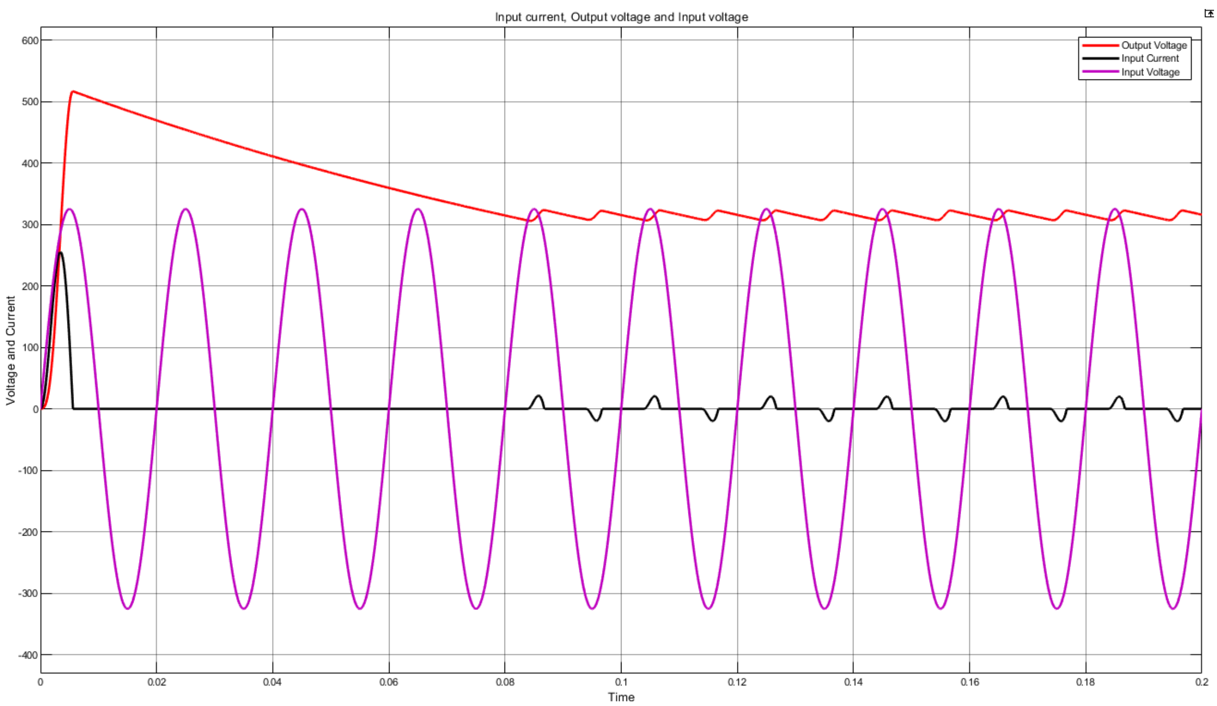

Figure 10: Input current input voltage and output current for a full-wave rectifier

D)

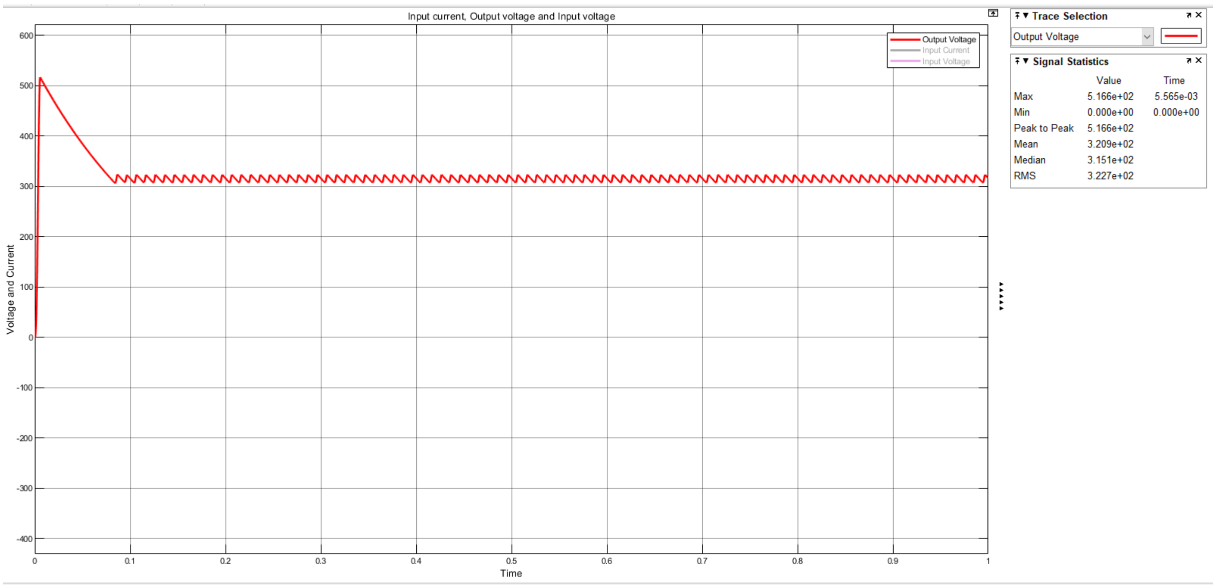

Figure 11: Average voltage of Output

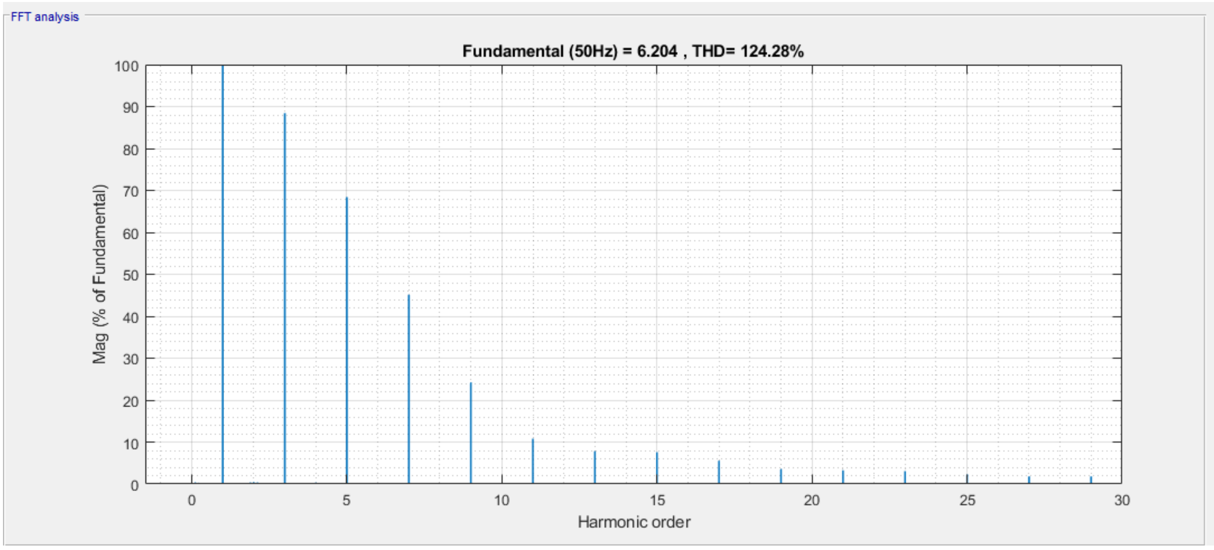

Figure 12: THD of input current

In Simulink, we measure the real power and reactive power of input P=987 W and Q=186 VAR so apparent power is equal to 1004.3 VA.

$$\frac{987}{1004.3} = 0.98$$

E)

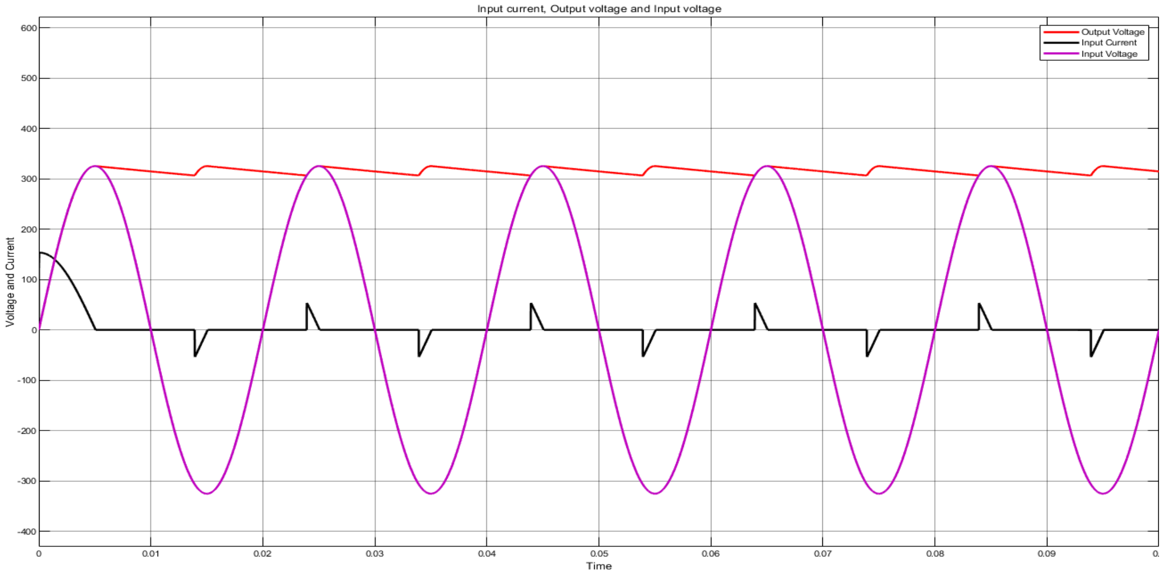

Figure 13: Input current input voltage and output current for full-wave rectifier without Rs and Ls

Significant difference is that the output stabilizes better with R-L and voltage waveform is smoother. Also, output overshoot and delay are resolved after the introduction of R-L.

F) The maximum input current is 53.5 A so we must choose 60A diode and the maximum reverse voltage is -325.5V. Hence, our diode must stand this value. That's why we choose a 400V 60A diode. It is part number is APT60D40BG. Its manufacturer is Microsemi Corporation. Non-Repetitive Forward Surge Current is 600A as we see in figures we cannot reach the 600A so we can use this diode.

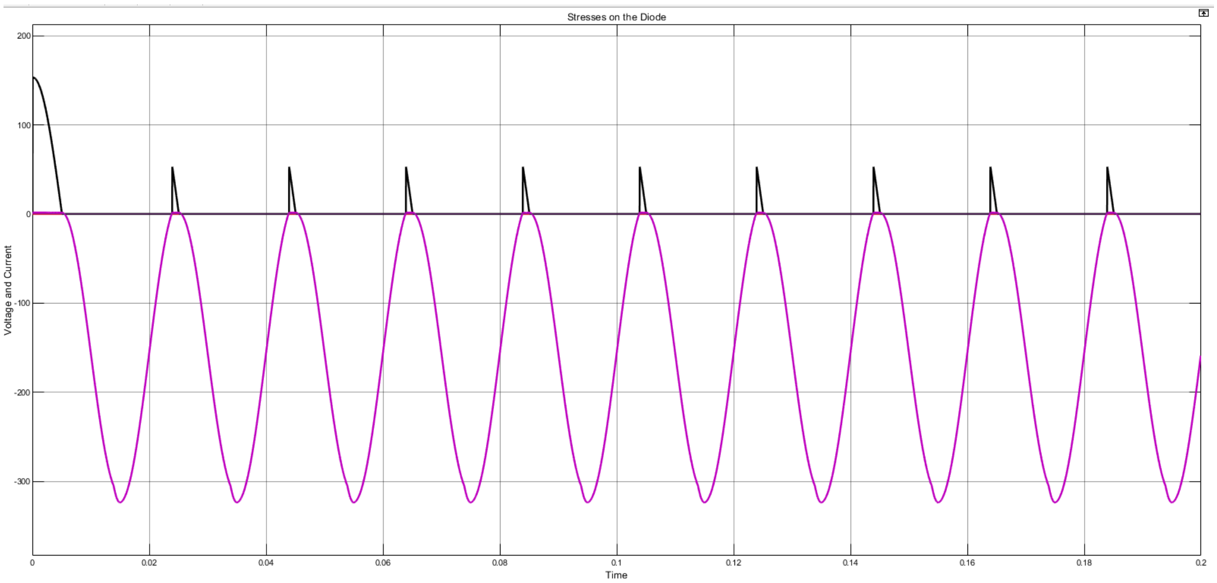

Figure 14: Stresses on the diode

G) Rectifier efficiency

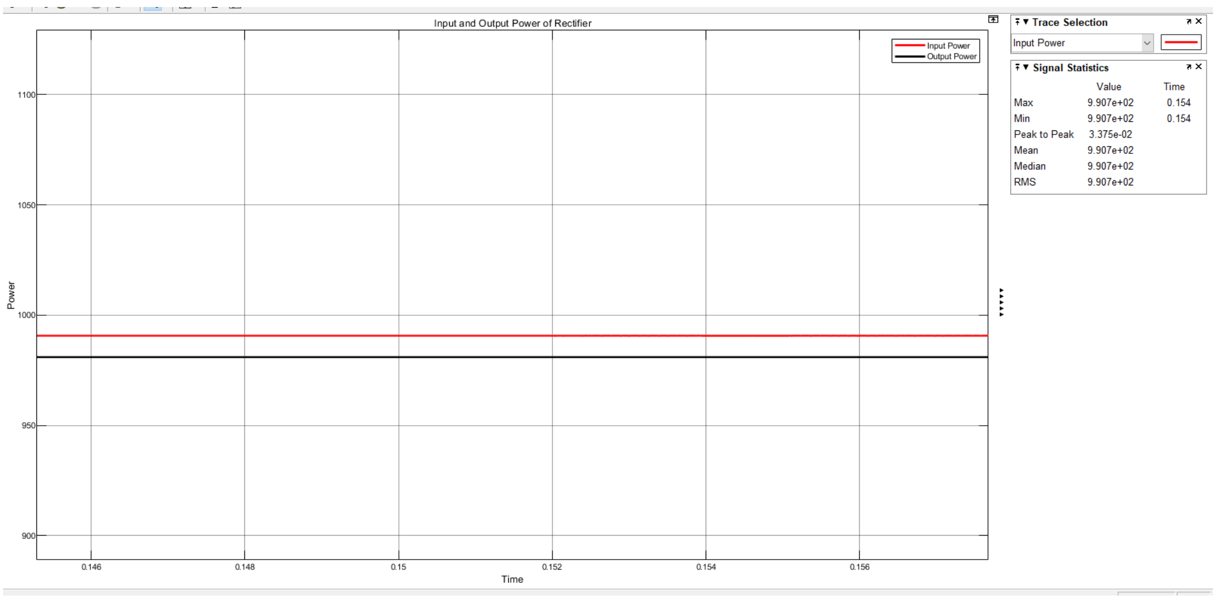

Figure 15: Input and Output Power of Rectifier

As we see in figure 15 input power is 990.4W and output power is 981 W.

*Efficiency = (Pout/Pin)*100*

$$\frac{981}{990.4} * 100 = \%99,05$$

Question 3)

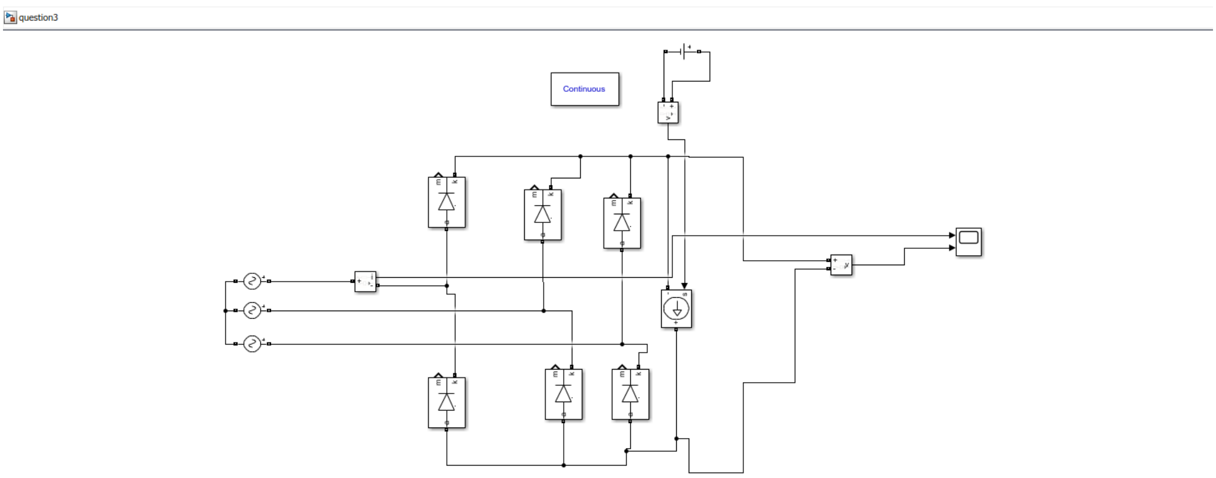

Figure 16: Simulink schematic of three-phase full-wave rectifier

A) Measured average voltage is 522V

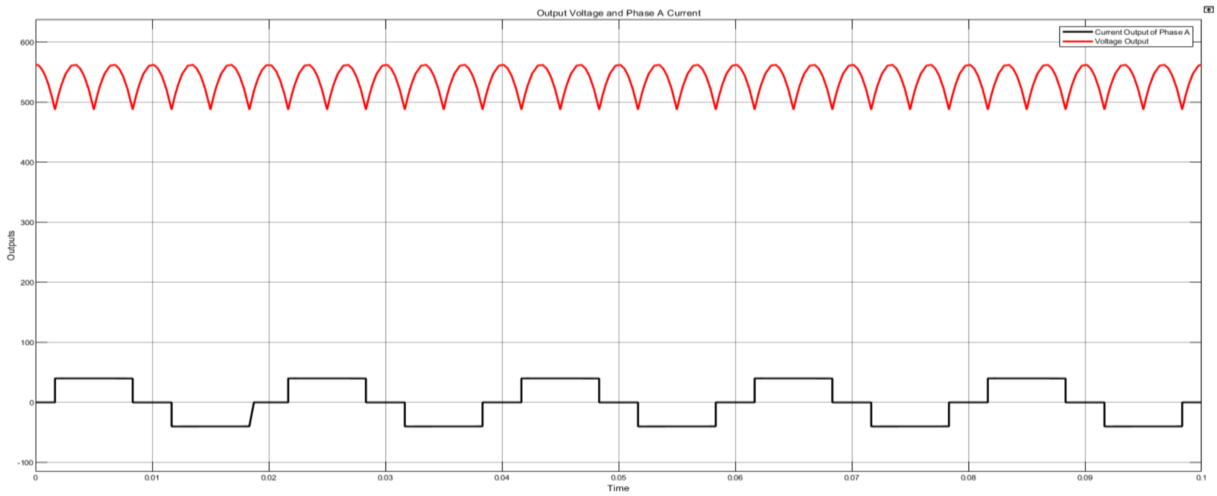

Figure 17: Phase A current and output voltages

B) We can calculate average voltage with the calculating area of voltage wave as we see in figure 17

$$V_{av}=\frac{1}{T}\int_0^T Vd * dt$$

$$A=\int_{-pi/6}^{pi/6} \sqrt{2} * V\cos(wt) * d(wt)=\sqrt{2} * V$$

$$V_{av}=\frac{A}{T}$$

$$V_{av}=\frac{A}{pi/3}=540V$$

Calculated average is slightly higher than simulation results.

C)

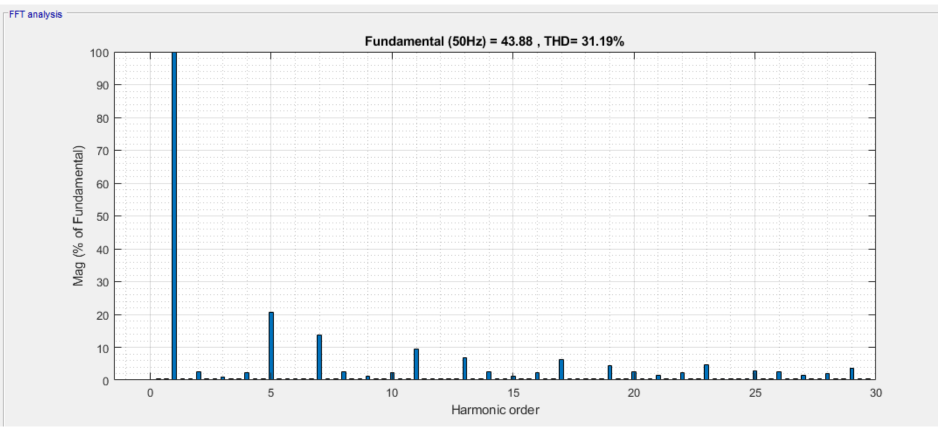

Figure 18: Harmonic analysis for input current

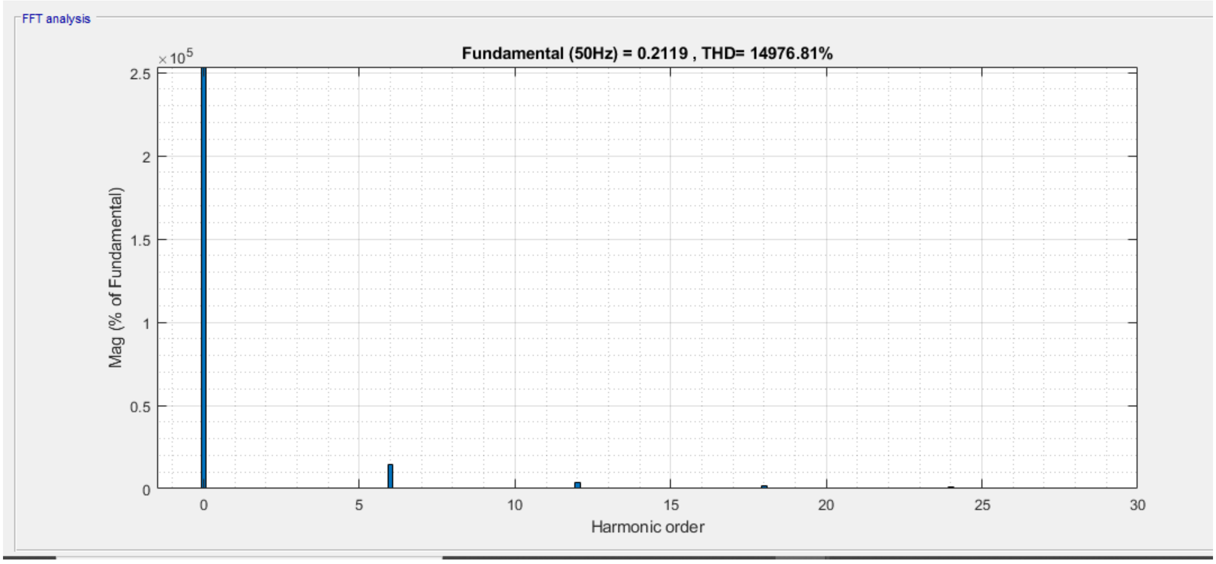

Figure 19: Harmonic analysis for output voltages

What we observe here is that current has odd harmonics whereas voltage has even harmonics. This indicates that average current in zero (not RMS) but voltage has even harmonics which makes average different from zero. We also observe a high pulse in "0"th harmonic of voltage. This implies that it has a dominant DC component.

D) Measured average voltage is 509V

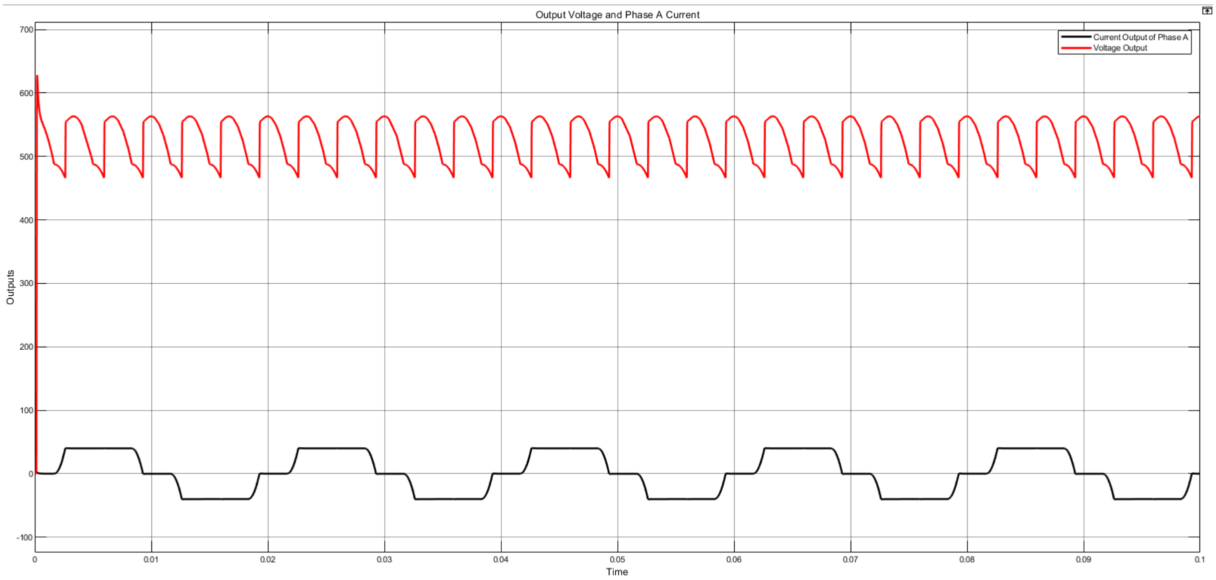

Figure 20: Phase A current and output voltages for 1mH

Obviously, we don't have a signal rising up and down instantly now. Since inductance is introduced, the current cannot change rapidly. Rather, it follows a differentiable path whenever it tends to change. Since the change in inductance current induces a voltage across the inductor, it affects phase voltage too.

E) For calculating average voltage, we must calculate area loss of voltage

$$A_{loss}= w*L_s*I_d \text{ (Area lost every 60 degrees)}$$

$$\Delta V = 6\, w*L_s*I_d/2pi$$

$$V_d = V_{d0} - \Delta V$$
$$V_d = 1.35*V-(3/pi)*w*L_s*I_d$$
$$V_d = 540-12=528V$$

Once again we observe theoretical value to be slightly higher than simulation result. However, both values have decreased with the introduction of inductor.

F)

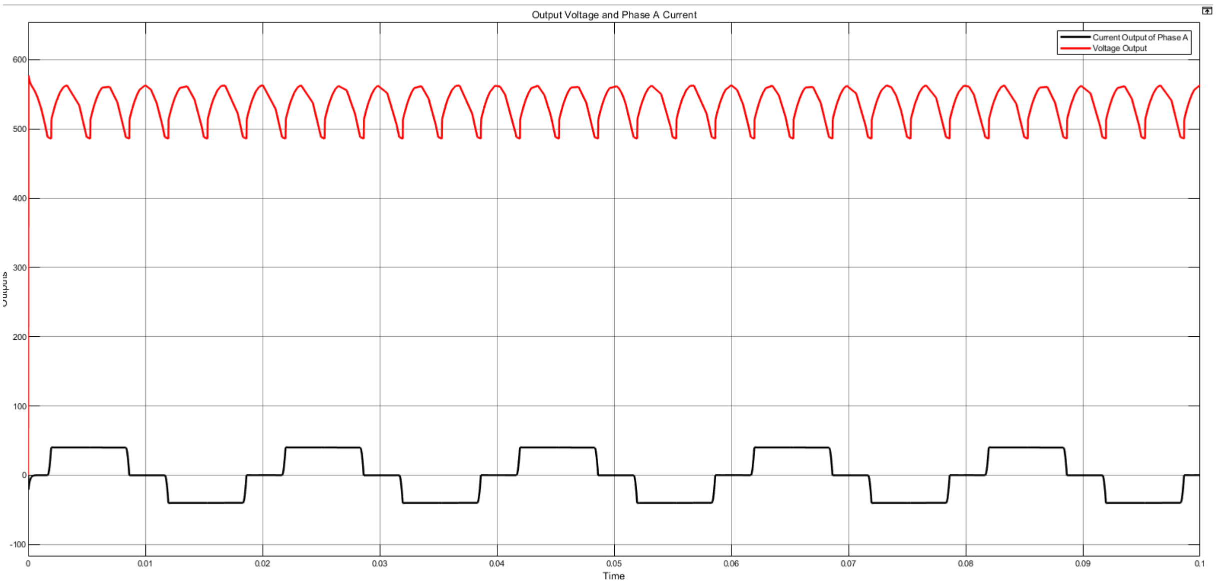

Figure 21: Phase A current and output voltages for 0.1mH

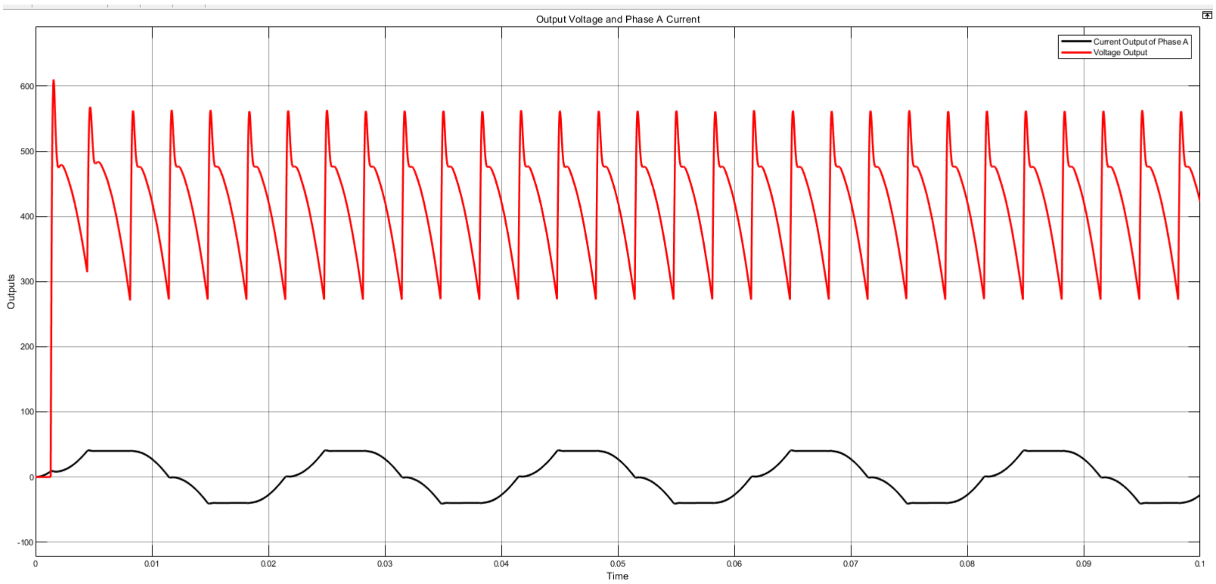

Figure 22: Phase A current and output voltages for 10mH

As we see in figure 21 and 22 when we increase the inductance current voltage loss increases because of commutation. When inductance increase current capability is increase so inductance current became zero very slowly so all diode became on state in that time it is called commutation.

Question 4)

Hamza SOLAK spent 1.5 days doing this homework.

Muhammed BARIŞ has spent 8 hours.