Anıl Yalçınkaya No:2376085

EE 464 Homework 3

1.

a) 400V DC rating means that our max output voltage is 400V. Considering load is sin load 400V max voltage is equals to 282.84 Vrms. So our amplitude modulation ratio is 230/282.84 = 0.813. This calculation is confirmed by simulation rms of output current is around 23 A which means Vrms = 10*23 = 230 V

b) Frequency modulation ratio can be found from fs/f. So mf = 1500/50 = 30 for fs = 1500 Hz and mf = 980/50 = 19.6 for fs = 980 Hz.

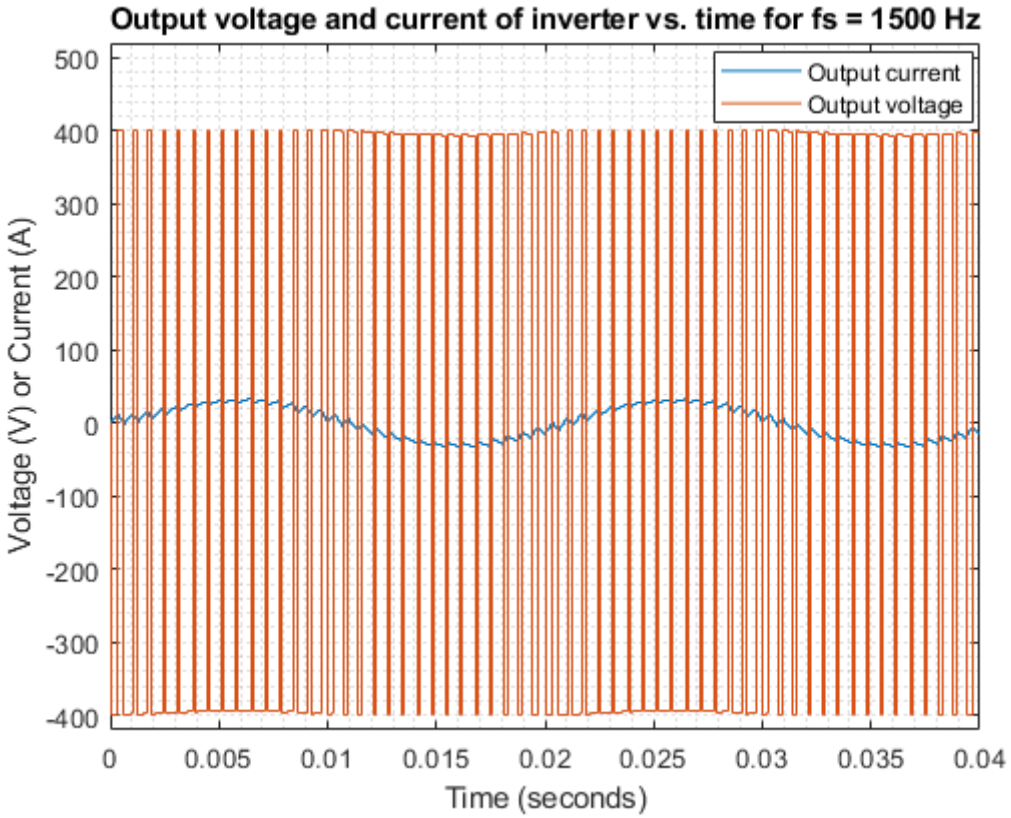

Figure 1. Voltage and Current graph of bipolar PWM system with fs = 1500 Hz and Vd = 400 V

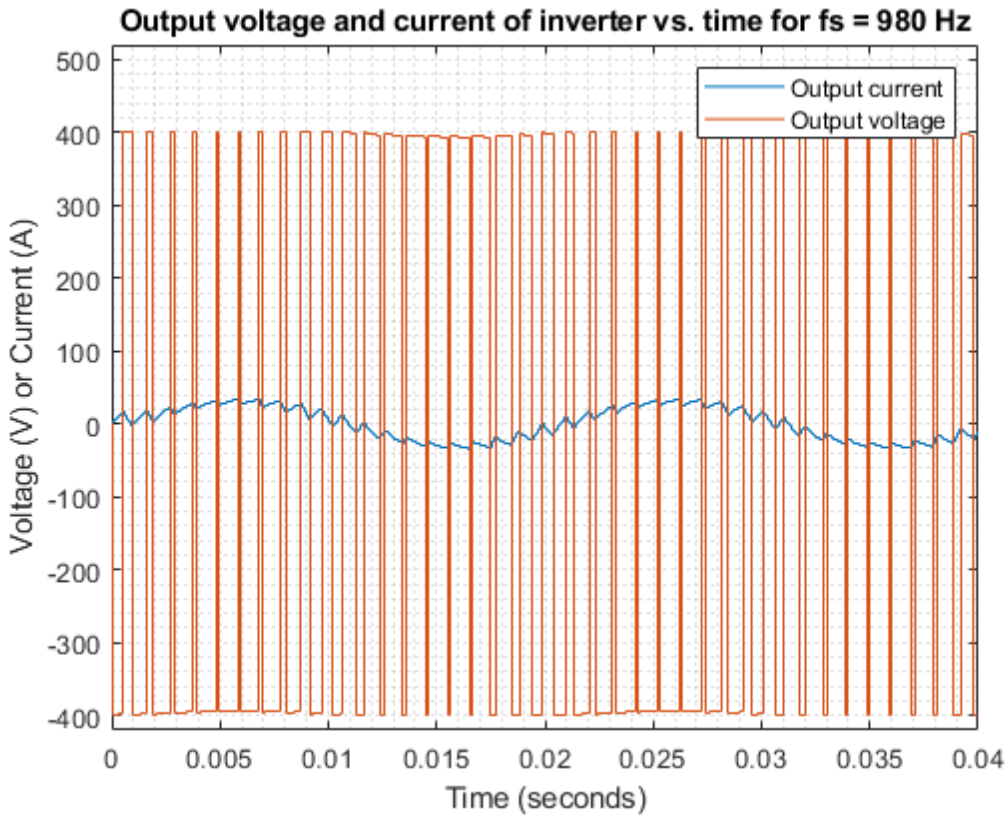

Figure 2. Voltage and Current graph of bipolar PWM system with fs = 980 Hz and Vd = 400 V

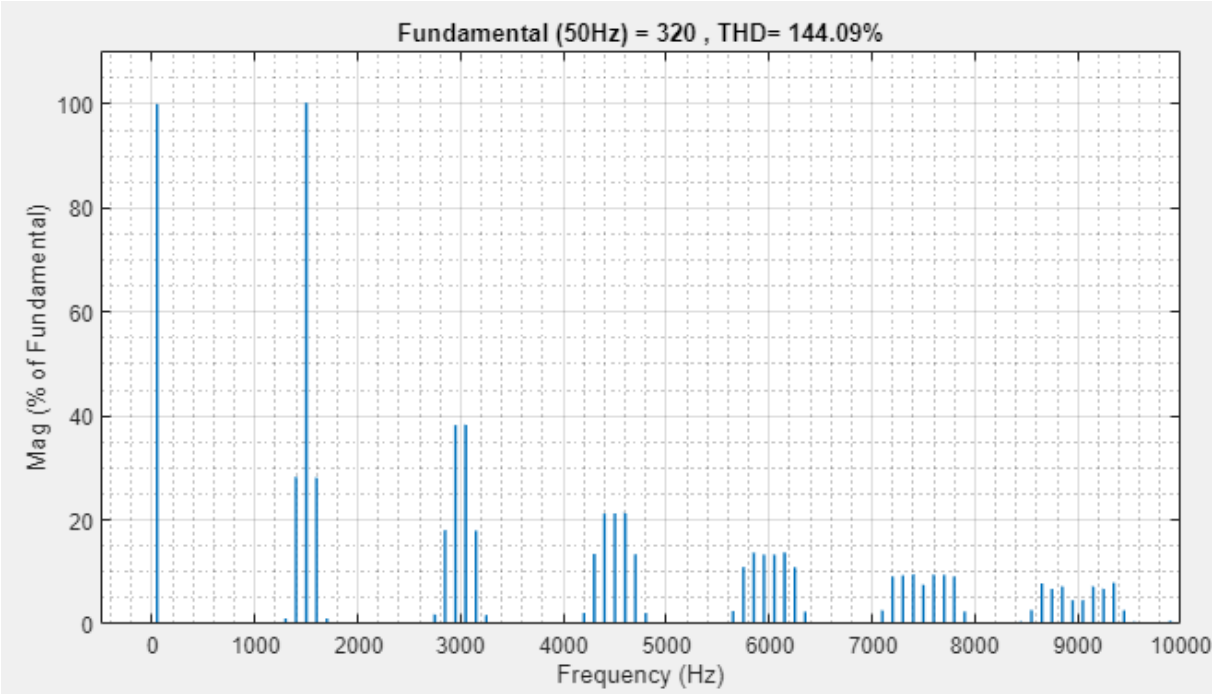

Figure 3. FFT of inverter output voltage of bipolar PWM system with fs = 1500 Hz and Vd = 400 V

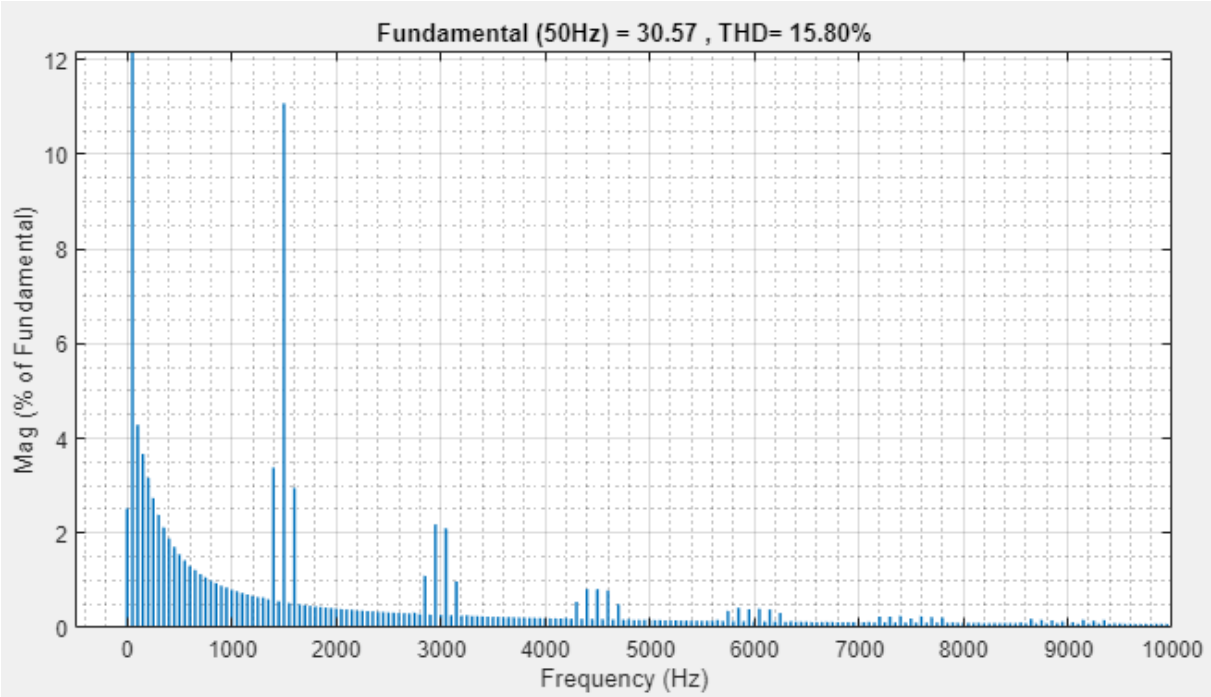

Figure 4. FFT of inverter output current of bipolar PWM system with fs = 1500 Hz and Vd = 400 V

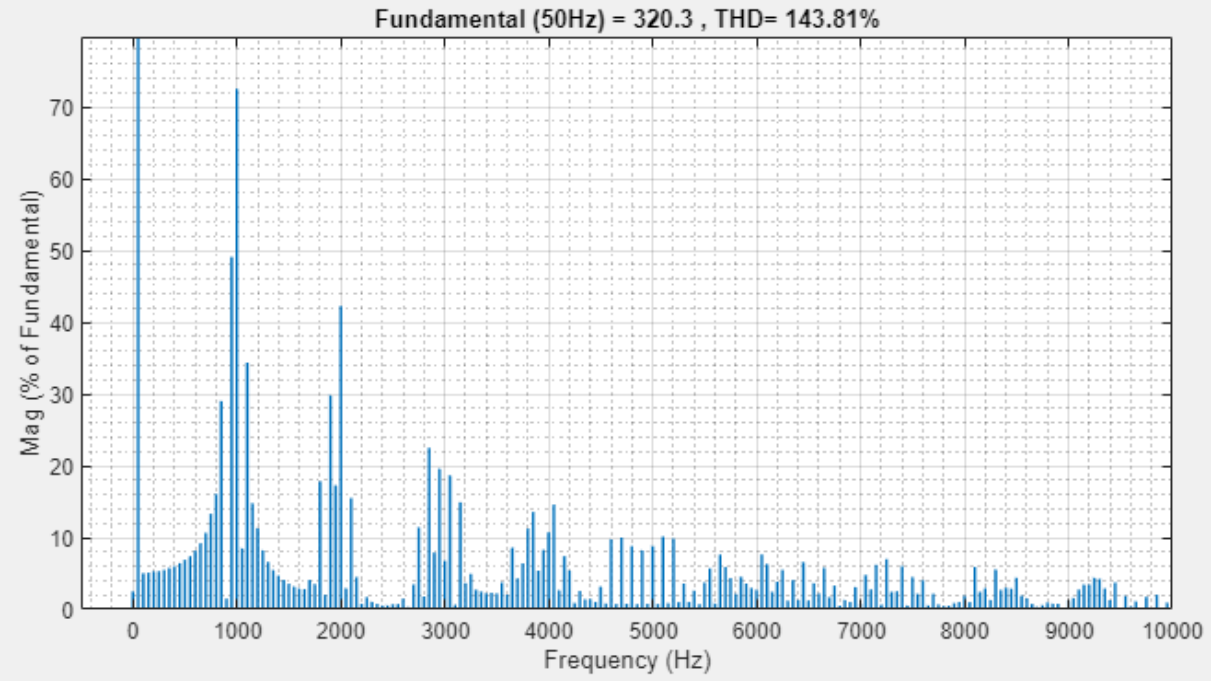

Figure 5. FFT of inverter output voltage of bipolar PWM system with fs = 980 Hz and Vd = 400 V

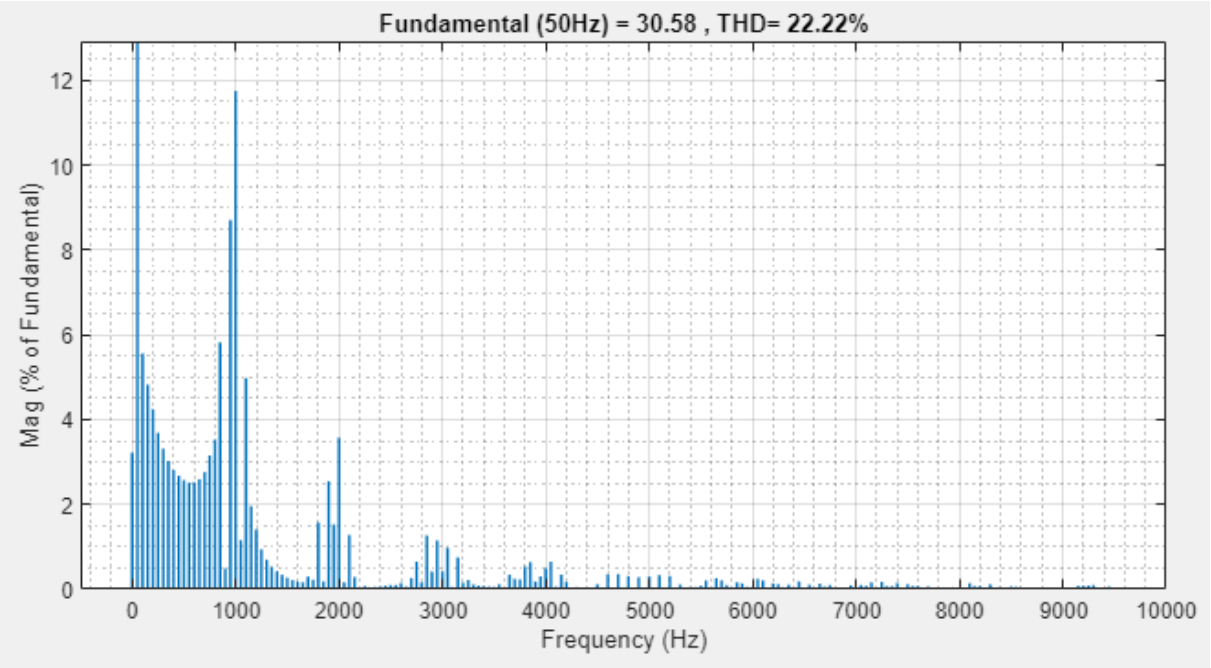

Figure 6. FFT of inverter output current of bipolar PWM system with fs = 980 Hz and Vd = 400 V

Voltage waveforms produce rough sinusoid like structure but current waveform is much closer to sinusoid because of inductor acting as filter.

Results was as expected most of the harmonics are focused around mf and its multiples. We could see pattern that is shown in lecture notes but figures 3 and 4 are more accurate than 5 and 6. Magnitude of harmonics are reduced as frequency increases.

But we see harmonics outside of mf values especially at current waveforms. One of the reasons for this is errors while taking FFT analysis at Simulink (for figure 5. and 6.). But even at ideal conditions we would see harmonics outside of mf for current waveforms because it is different from voltage waveform. Current waveform is closer to sin wave than voltage waveform. We can see that from its much lower THD value. This is caused by inductance off the load acting as filter. While this reduces harmonics around k*mf significantly it produces new harmonics all around the spectrum like in figure 4.

Switching frequency did not have a major effect at THD values. THD of voltage was mostly same but THD of current is increased with decreasing frequency. When frequency decreases inductive filter is less effective because inductor is low pass filter so it filters high frequencies better.

c)

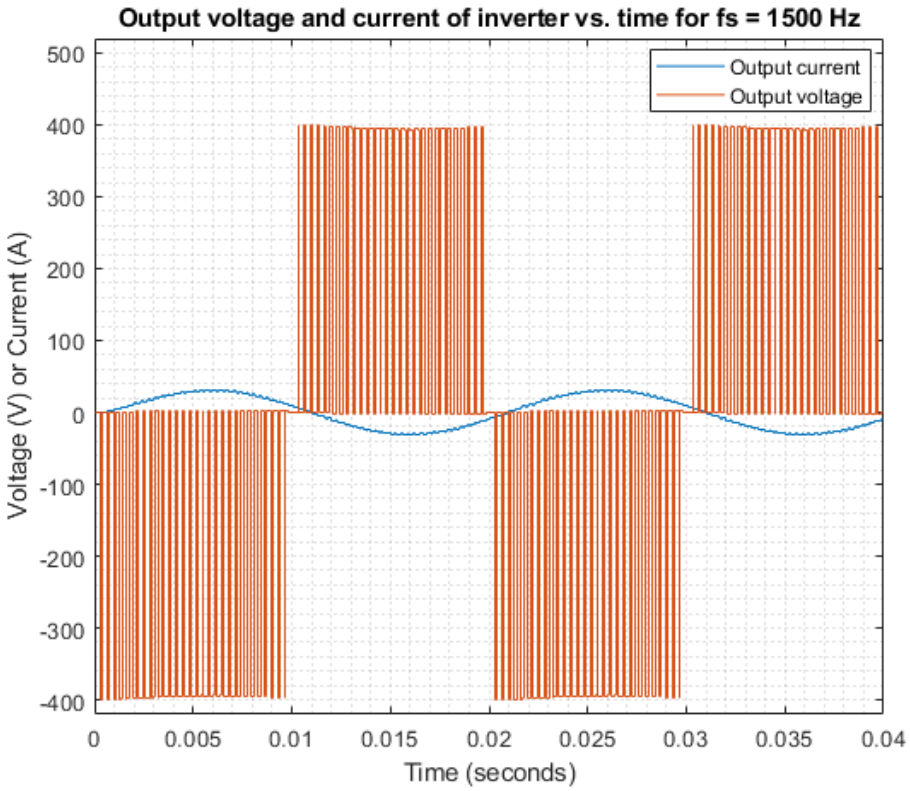

Figure 7. Voltage and Current graph of unipolar PWM system with fs = 1500 Hz and Vd = 400 V

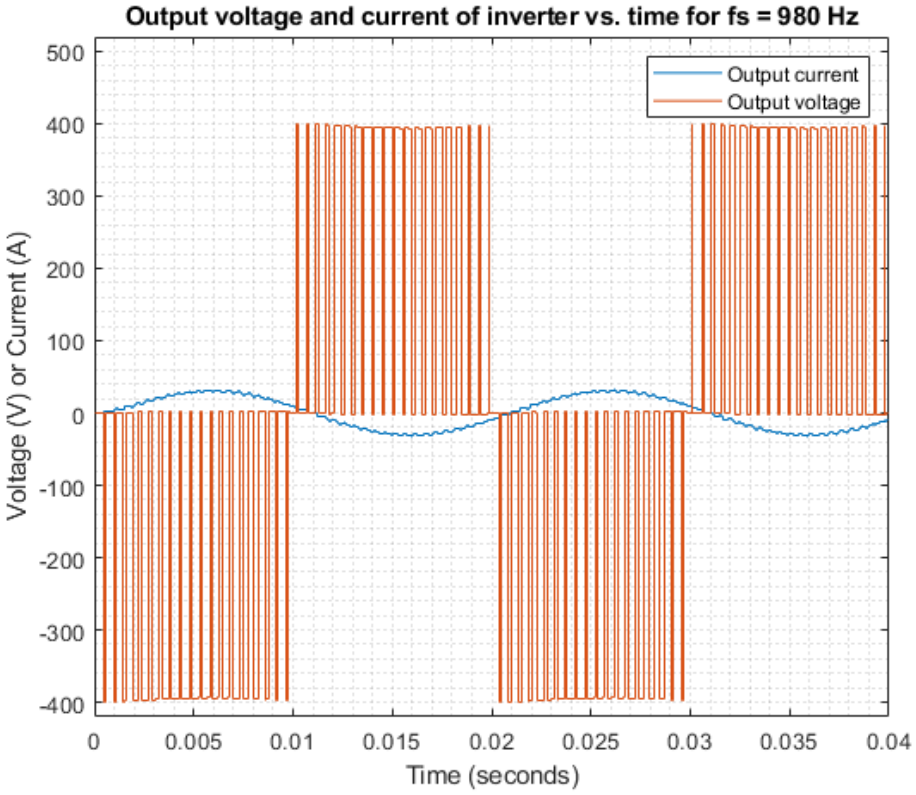

Figure 8. Voltage and Current graph of unipolar PWM system with fs = 980 Hz and Vd = 400 V

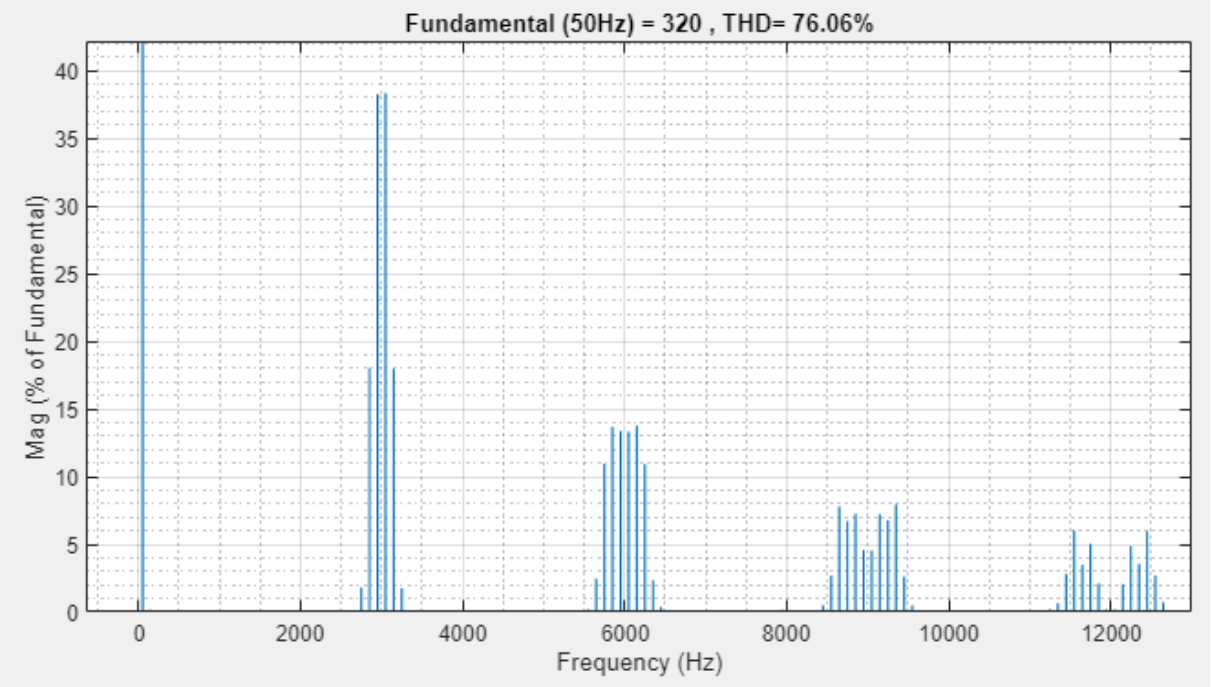

Figure 9. FFT of inverter output voltage of unipolar PWM system with fs = 1500 Hz and Vd = 400 V

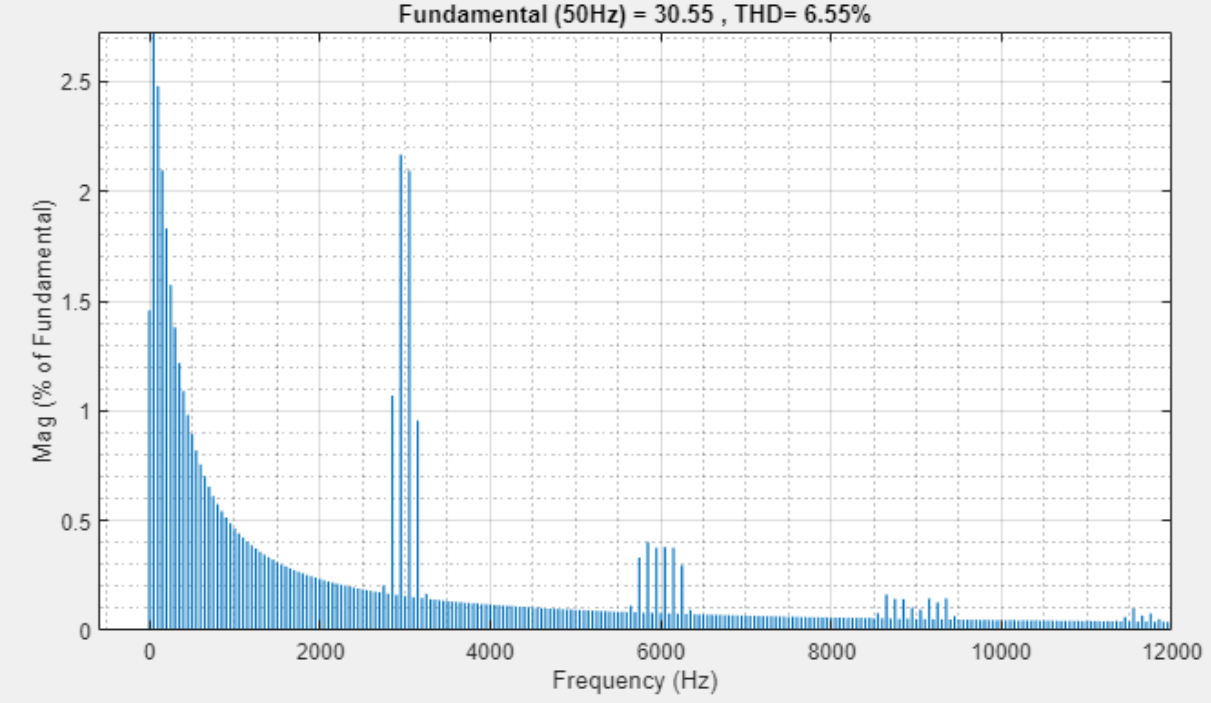

Figure 10. FFT of inverter output current of unipolar PWM system with fs = 1500 Hz and Vd = 400 V

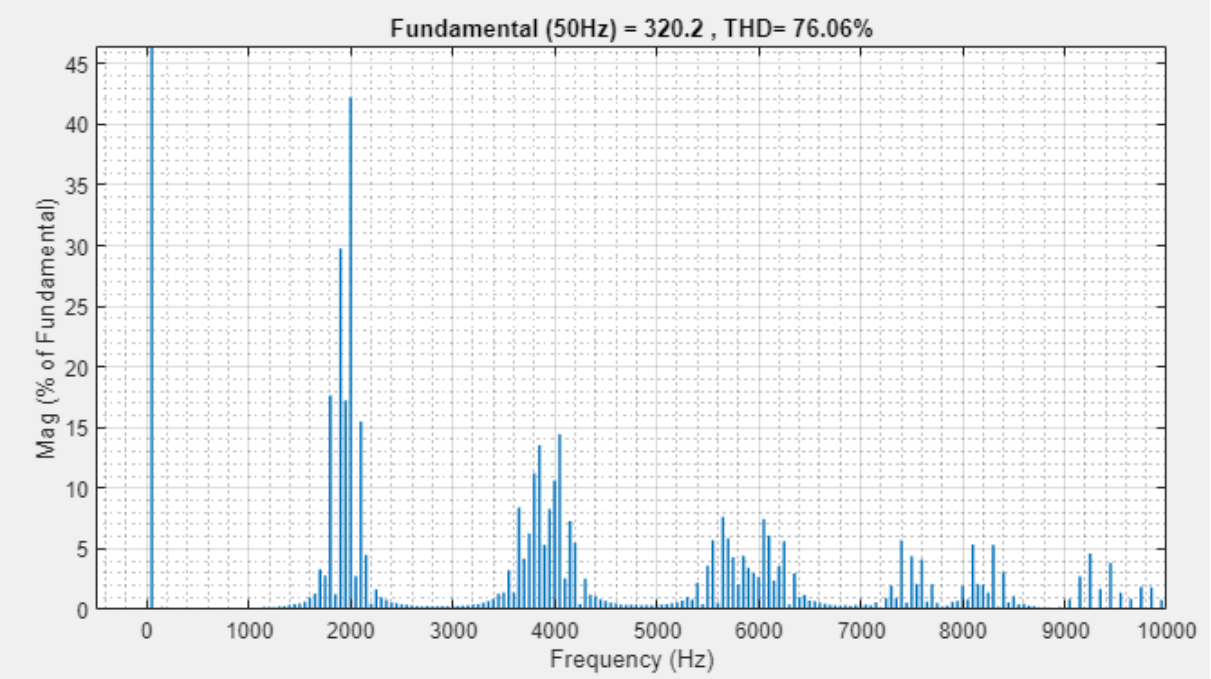

Figure 11. FFT of inverter output voltage of unipolar PWM system with fs = 980 Hz and Vd = 400 V

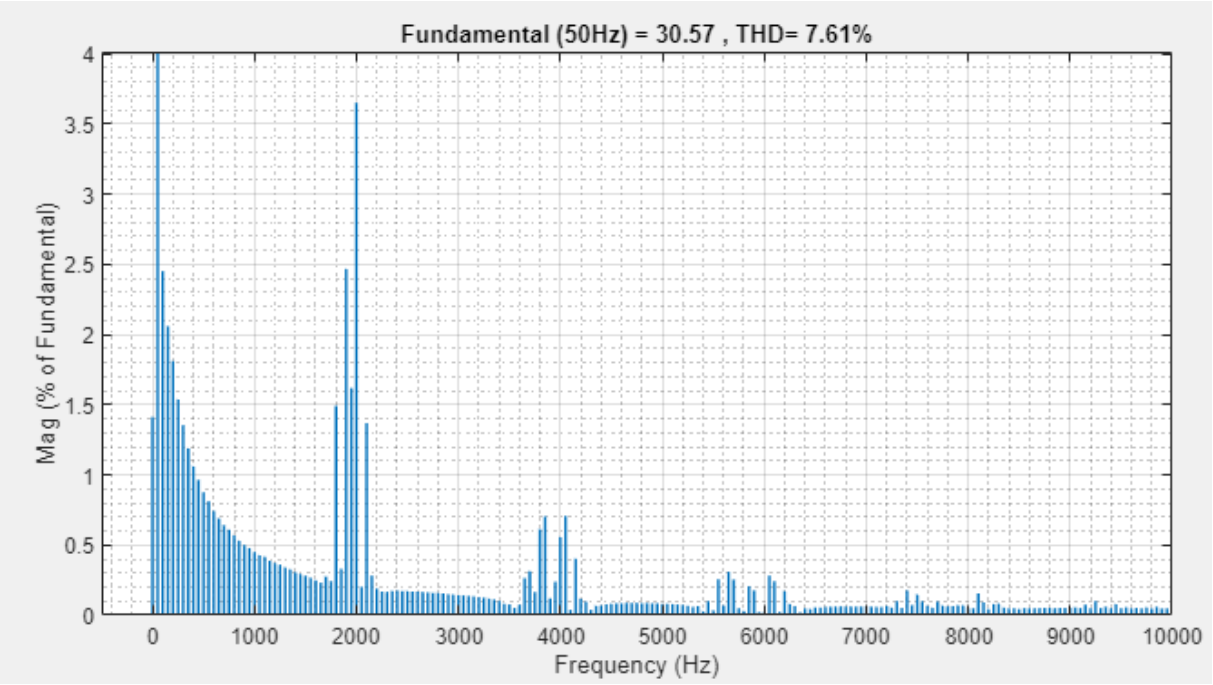

Figure 12. FFT of inverter output current of unipolar PWM system with fs = 980 Hz and Vd = 400 V

With unipolar control frequency modulation ratio is same but harmonics starts at 2mf. And they are mostly present at 2mf*k. This why their THD is lot smaller than bipolar converters. This is desirable outcome because we prefer to keep THD as low as possible for most applications.

With unipolar converter we can use VD, 0, -VD voltages but with bipolar converter we can only use VD, -VD. So, with unipolar converter we have more options to form final waveform closer to sinusoid. We can confirm this from figures. But its control is more complicated we need 2 different sin waves compered to 1 in bipolar controller.

All the thing that said in 1. b) also applicable for this part.

2.

a) 300V DC equals to 212.13Vrms but our required voltage is 230Vrms. So ma msut be bigger than 1 but ma is not equal to 230/212.13 = 1.084 because relationship between outout voltage and ma becomes non linear after 1. For example with ma of infinity output voltage becomes square wave and voltage ratio is 1.2732. I do not know exact formulation to find ma value after 1 but from simulation I found ma as 1.13. It is bigger than 1.084 as expected

b)

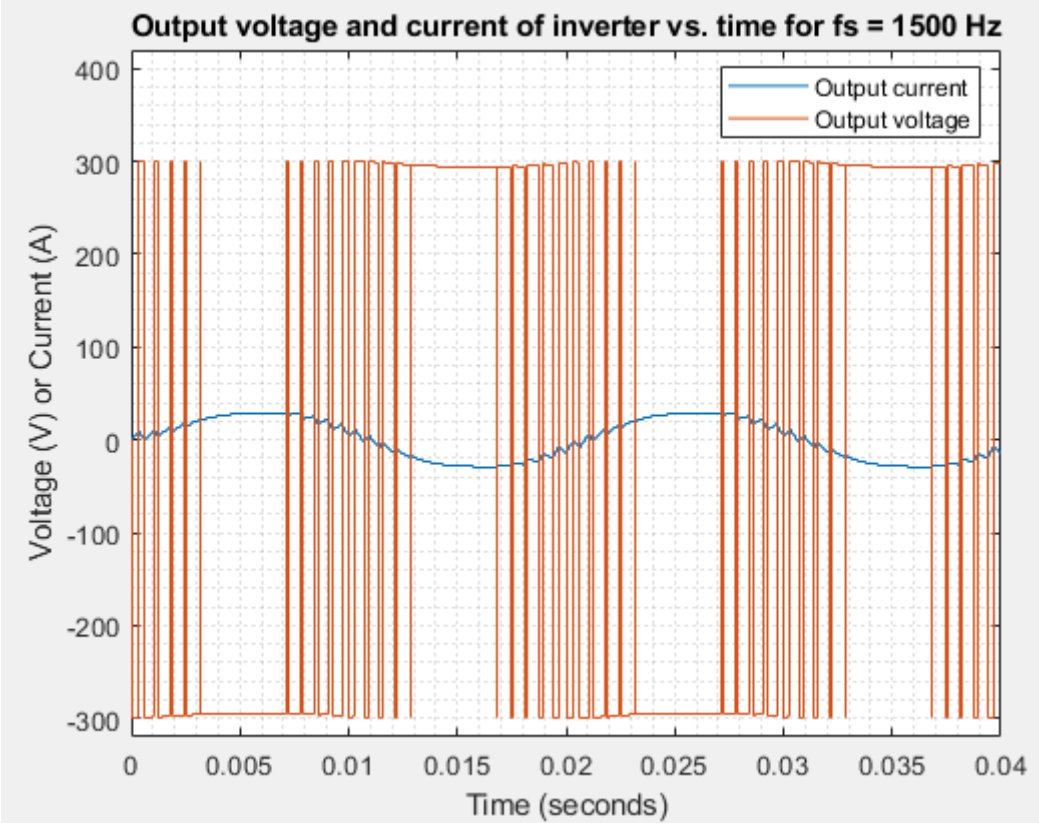

Figure 13. Voltage and Current graph of bipolar PWM system with fs = 1500 Hz and Vd = 300 V

Voltage waveform is closer to square wave as we expected because we will reach maximum output voltage with square wave.

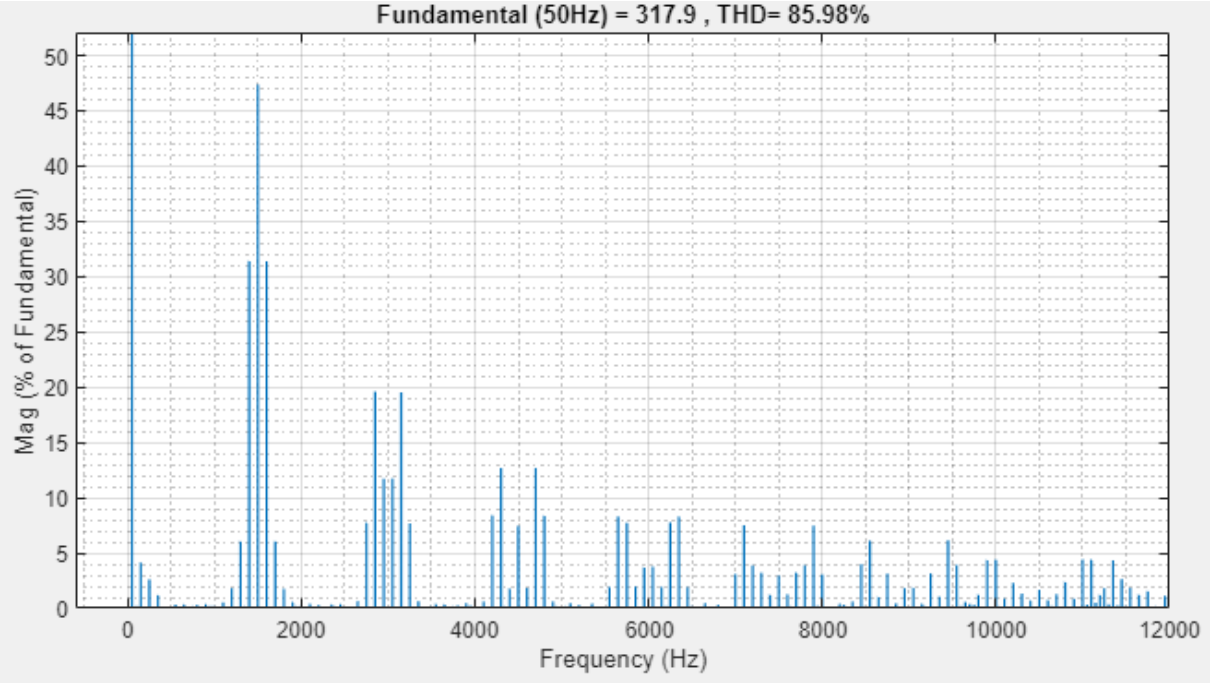

Figure 14. FFT of inverter output voltage of bipolar PWM system with fs = 1500 Hz and Vd = 300 V

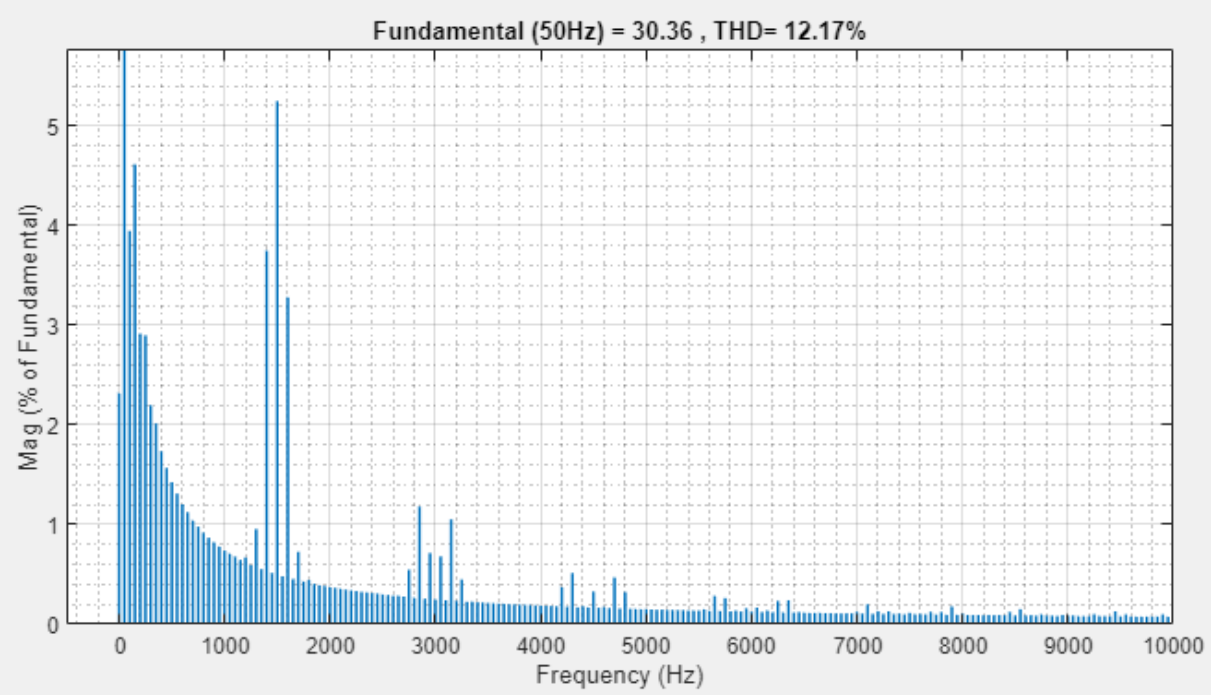

Figure 15. FFT of inverter output current of bipolar PWM system with fs = 1500 Hz and Vd = 300 V

THD values are lower compered to VD = 400V case because our voltage waveform is closer to square and square waveform has THD of %48.3. With increased ma THD value comes closer to that value. From what we see from part 1 and 2 more sharp changes our waveform has higher its THD is. Although our harmonics were improved it is still not as good as unipolar case.

Otherwise that our results was similar to part 1. b)