Group 7

LAB 2-1
9/20/2023

Leif Dixon, Leslie Deras, Ryan Guthrey, Emmanuel Mvutu, Swayam Mehta

OBJECTIVES

The purpose of this experiment is to simulate an H-bridge DC/AC Inverter in Simulink. The goal of exercise 1 is to calculate the capacitor and resistor values after selecting the duty cycle, switching frequency, and input voltages. The goal of exercise 2 is to get familiar with how a PV source operates when interfaced with an H-bridge PV inverter.

MATERIALS/EQUIPMENT NEEDED

Matlab: Simulink

Equipment used in simulation:

- Four Mosfets
- One Inductor
- One Capacitor
- One Resistor
- DC Voltage Supply
- PWM Generator

Exercise 1

Questions:

1- Define your nominal operating conditions and specifications, i.e. switching frequency, input voltage, duty cycle, load resistance value, inductor and capacitor values, etc. R1C1. Provide a justification on how to pick your inductor and capacitor values.

- Inductor: 25*10^-5
- Capacitor: 1.25*10^-6
- Frequency: 60 rad/sec
- Switching Frequency: 30000 Hz
- Duty Cycle: 80%
- Load Resistance: 2 Ohms
- 30 Volts

In our experiment, the selection of components was a function of the choice of voltage, duty cycle, and estimated power output parameters. In this, we selected a duty cycle of 80% and an input voltage of 30 volts. The simulation was tested using the previous capacitor, inductor, and resistor sizes. Adding capacitors to the simulation became a necessity to help smooth out the rippling effect, when this occurred, the value of each capacitor needed to be dropped. Also, it became necessary to change the inductor value, the previous value was too small and resulted in a simulation error. Using these values, several tests were performed to find a value for the switching frequency. The frequency had to be increased to be able to pick up the ripple effect in the circuit leading to a 30000 Hz switching frequency.

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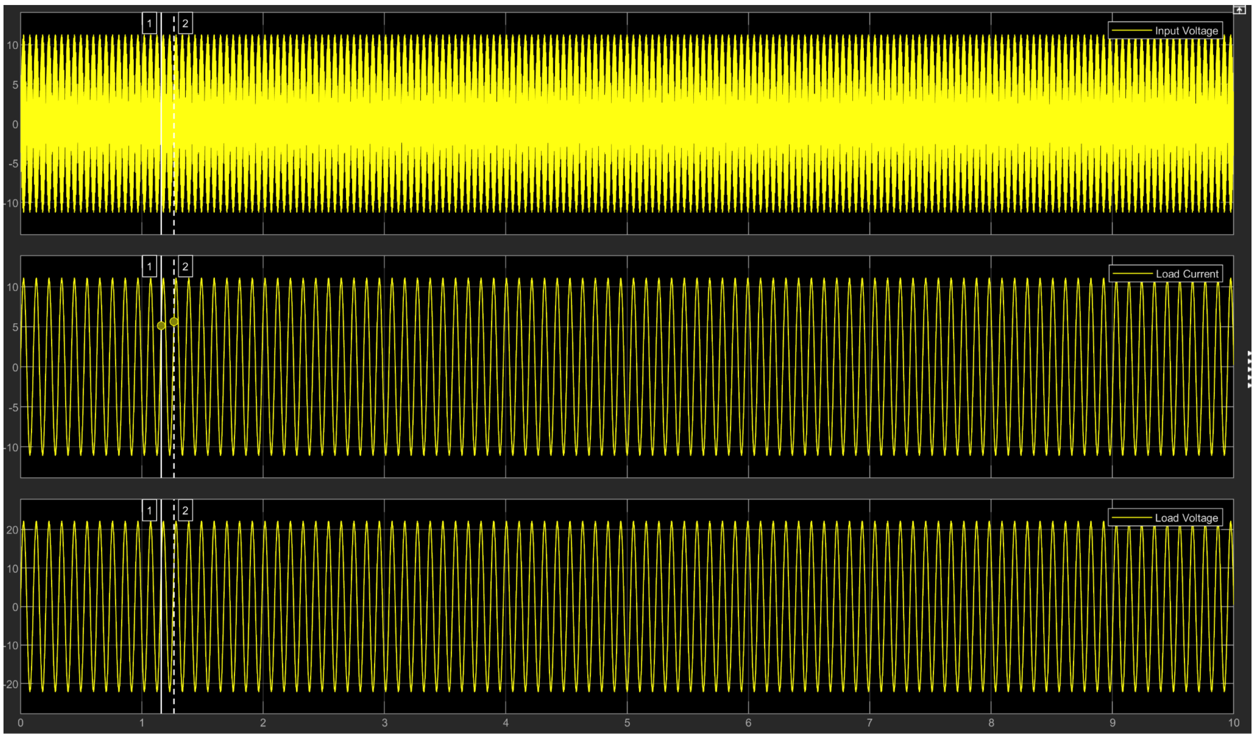
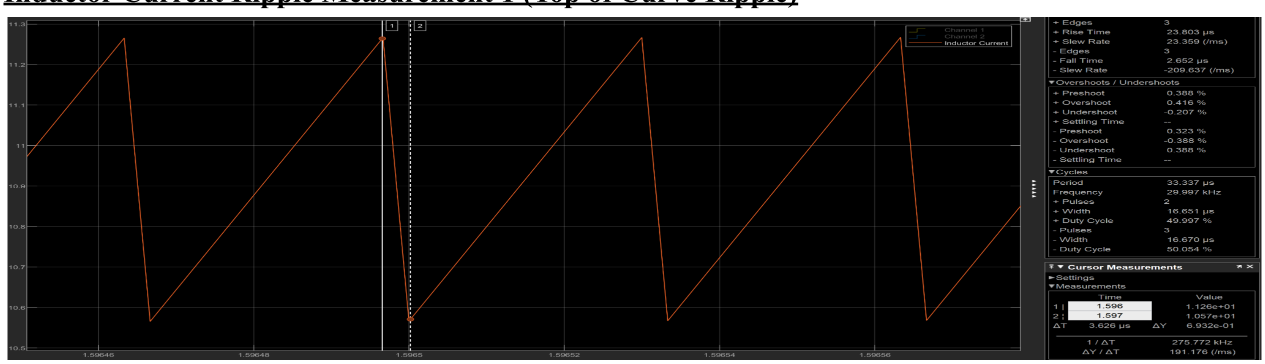
2- Provide the theoretical input-output voltage relationship. This is sometimes called the conversion ratio. With your simulation, include a plot showing the input and output voltage. Does it follow the theoretical (calculated) value?

The conversion ratio is 0.8. Ideal = 24/30 = 0.8, Simulation = 22/30 = 0.73.
Yes, it is close to the theoretical value, but there is loss due to voltage rippling. The figure below shows the input and output current (load), and voltages of the system.



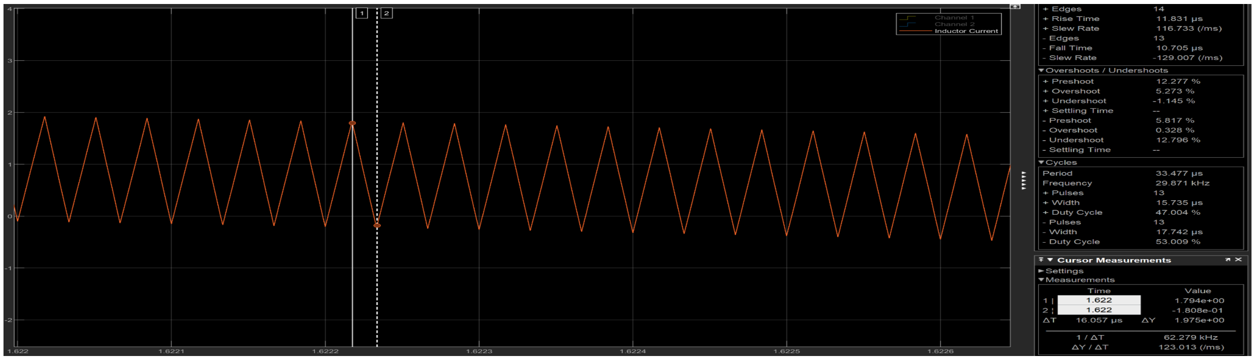
3- At different instances (three or more), measure the current ripple in the inductor and voltage ripple across the output (capacitor) at your nominal operating point. With your simulation include a plot with your measurements.

<u>Inductor Current Ripple Measurement 1 (Top of Curve Ripple)</u>



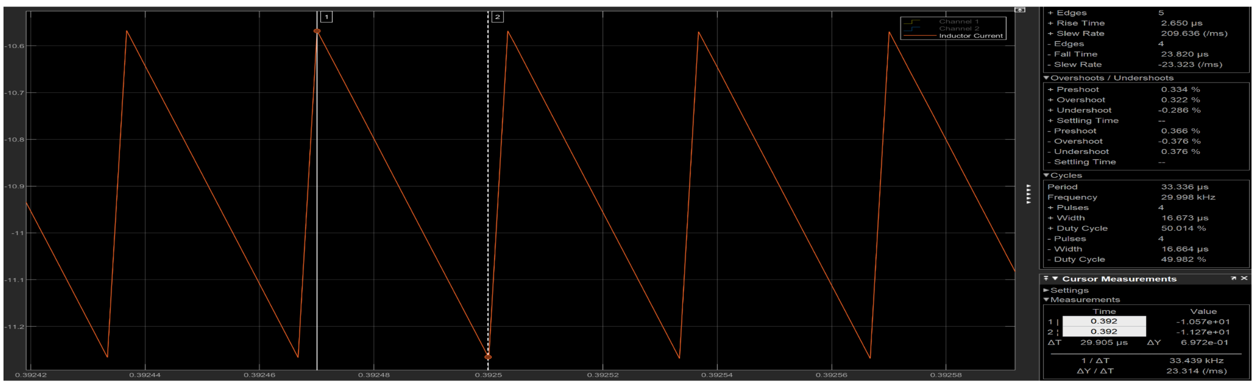
The ripple at the top of the Inductor Current is (1.126e+01 - 1.057e+01) = 0.69.

Inductor Current Ripple Measurement 2 (Middle of Curve Ripple)



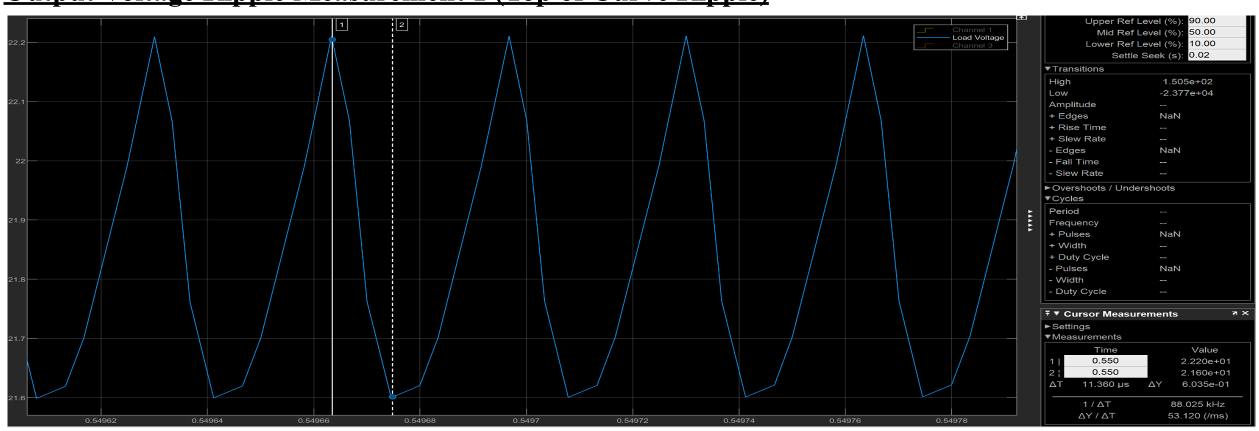
The ripple of the Inductor Current at the middle part of the curve is (1.794 - (-1.808e-01)) = 1.9748.

Inductor Current Ripple Measurement 3 (Bottom of Curve Ripple)



The ripple of the Inductor Current at the bottom part of the curve is (-1.057e+01 - (-1.127e+01)) = 0.7.

Output Voltage Ripple Measurement 1 (Top of Curve Ripple)



The ripple of the Load Voltage at the top part of the curve is (2.220e+01 - 2.160e+01) = 0.6.

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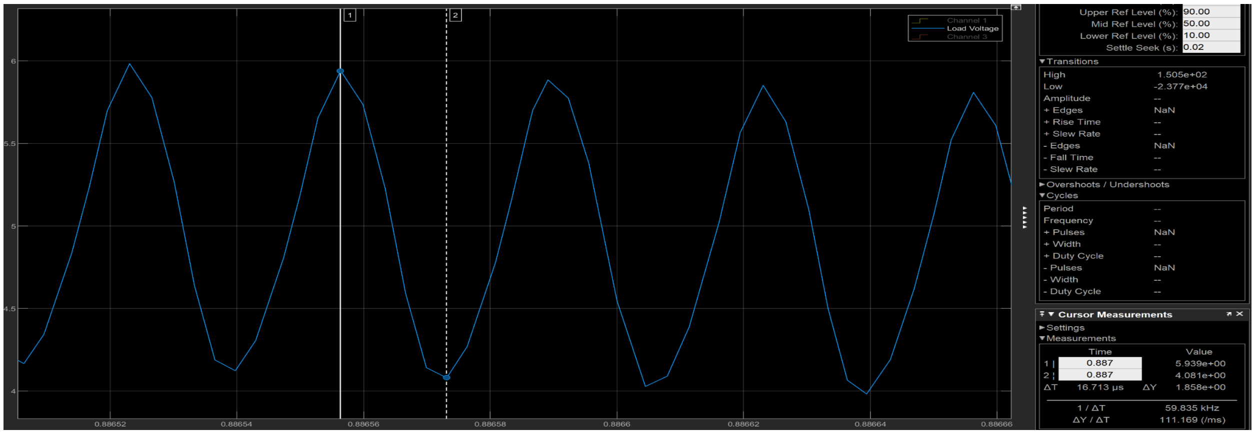
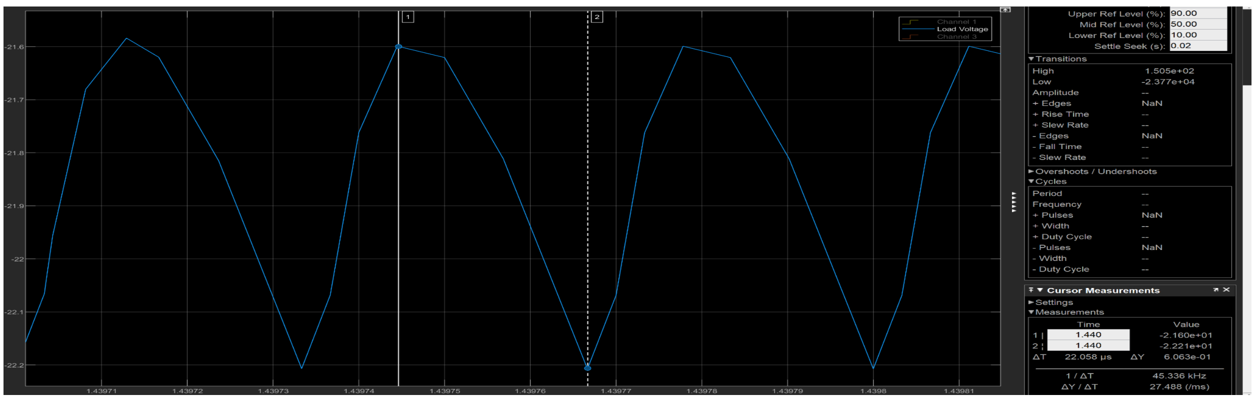
Output Voltage Ripple Measurement 2 (Middle of Curve Ripple)



The ripple of the Load Voltage at the middle part of the curve is (5.939e+00 - 4.081e+00) = 1.858.

Output Voltage Ripple Measurement 3 (Bottom of Curve Ripple)

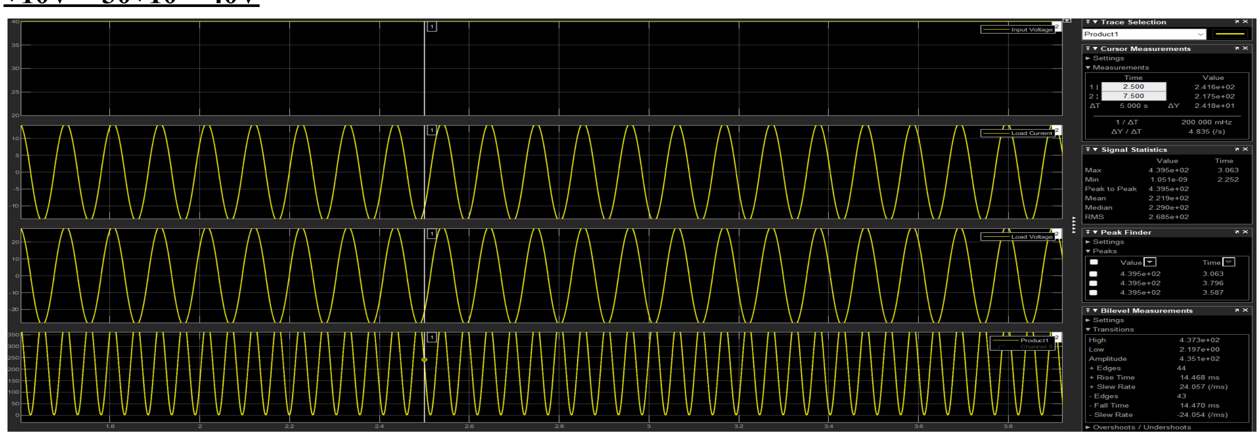


The ripple of the Load Voltage at the bottom part of the curve is (-2.160e+01 - (-2.221e+01)) = 0.61.

4- Change the input voltage ±10V and run your simulation.

a. In one plot, measure the output voltage, output current, and output power

+10V = 30+10 = 40V



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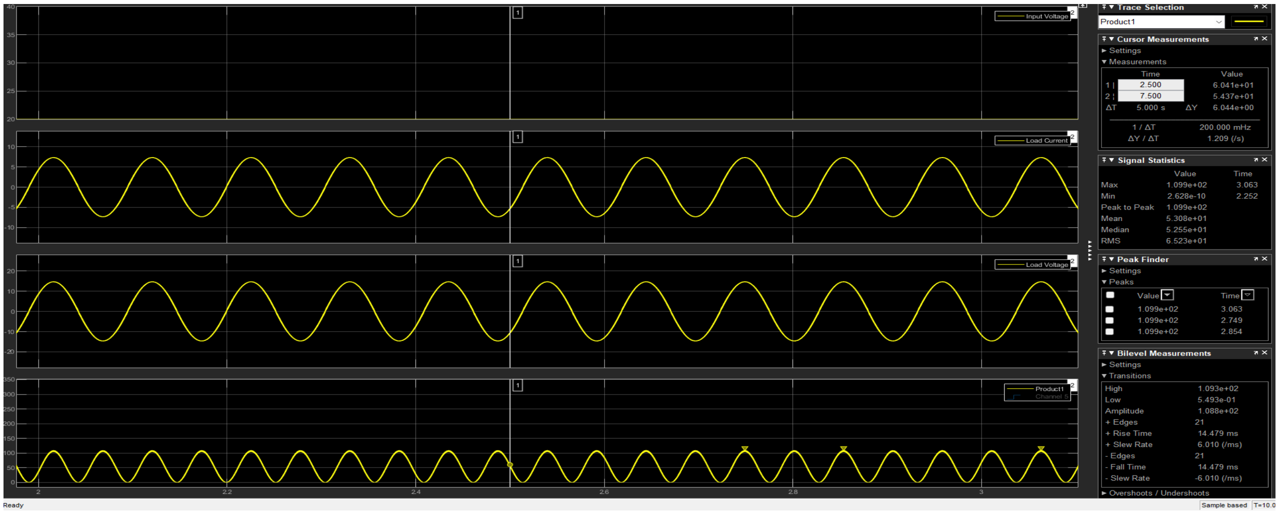
-10V=30-10=20V

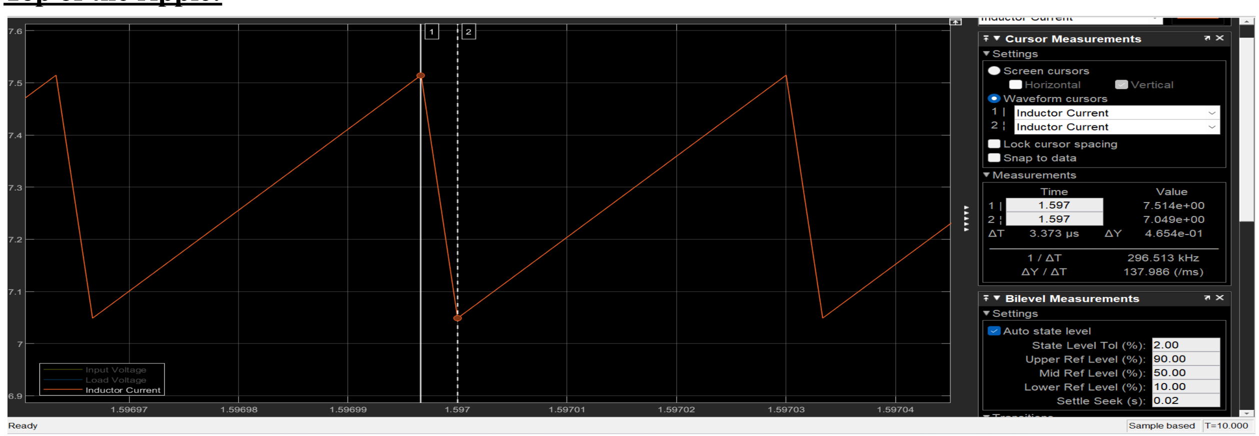


b. In another plot, show the inductor current and output voltage. Measure the inductor current ripple and output voltage ripple at different instances. Compare them with your nominal operating point.

- The ripple current for the top ripple varies by .69 - .4654 = .2246. The ripple current for the bottom ripple varies by .7 - .4648 = .2352. This shows that the nominal value has a higher ripple than the ripple current at 20 volts for both the top and bottom ripple.
- The ripple voltage for the top varies from .6 - .042 = .558. The ripple voltage for the bottom ripples varies by .61 - 0.04 = .57. Which again shows that the ripple for the nominal value is higher than the ripple voltage at 20 volts for both the top and bottom.

Inductor Current Ripple at 20V:

Top of the ripple:



(7.514e+00)-(7.049e+00)=.4654 Amps

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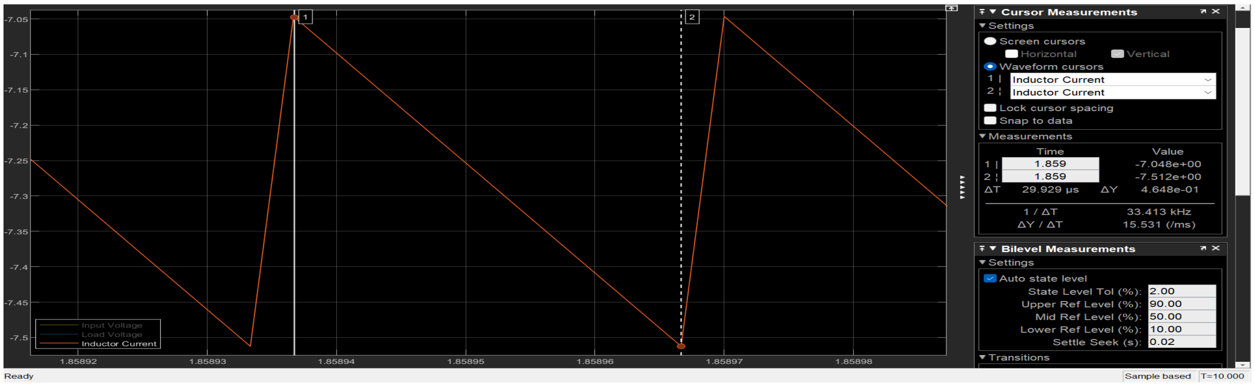
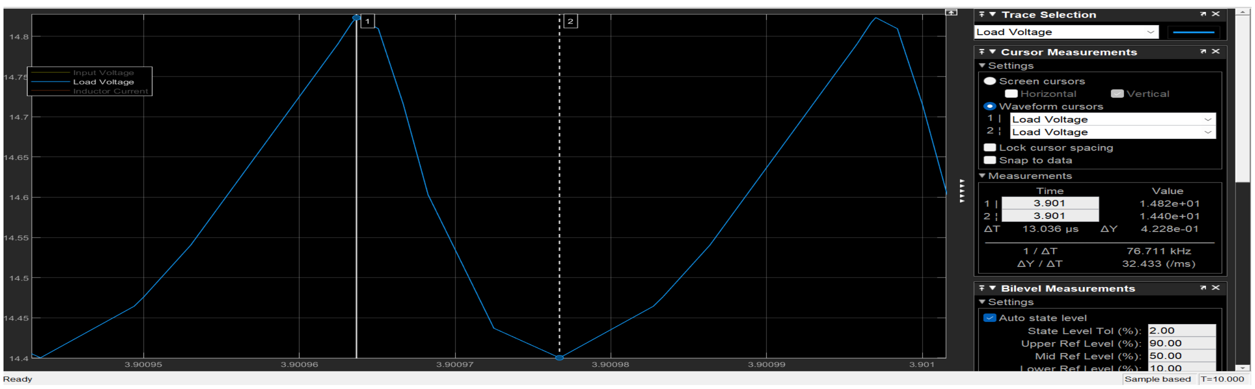
Bottom of the Ripple



(-7.048e+00)-(-7.512e+00)=.464 Amps

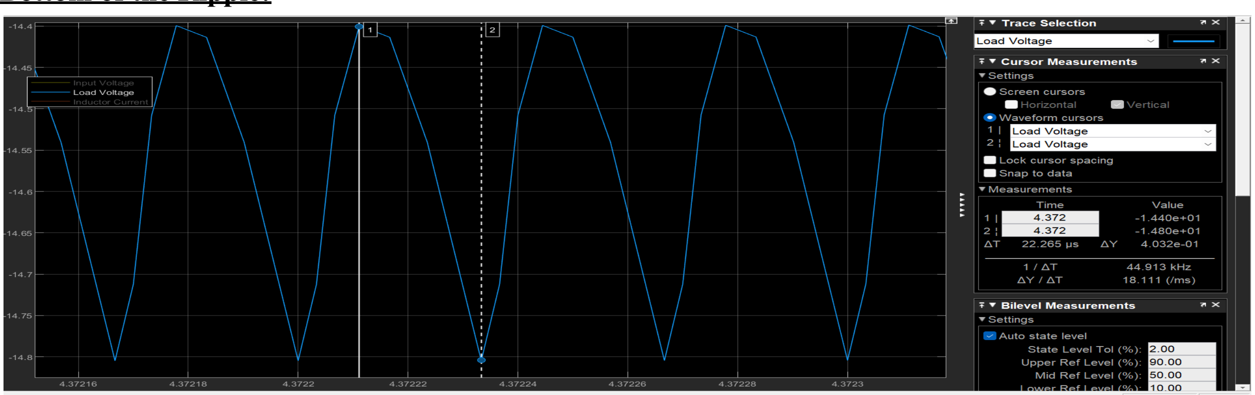
Output Voltage Ripple at 20V:

Top of the Ripple



(1.482e+01) - (1.440e+01) = 0.42 Volts

Bottom of the Ripple:



(-1.440e+01) - (-1.480e+01) = 0.4 Volts

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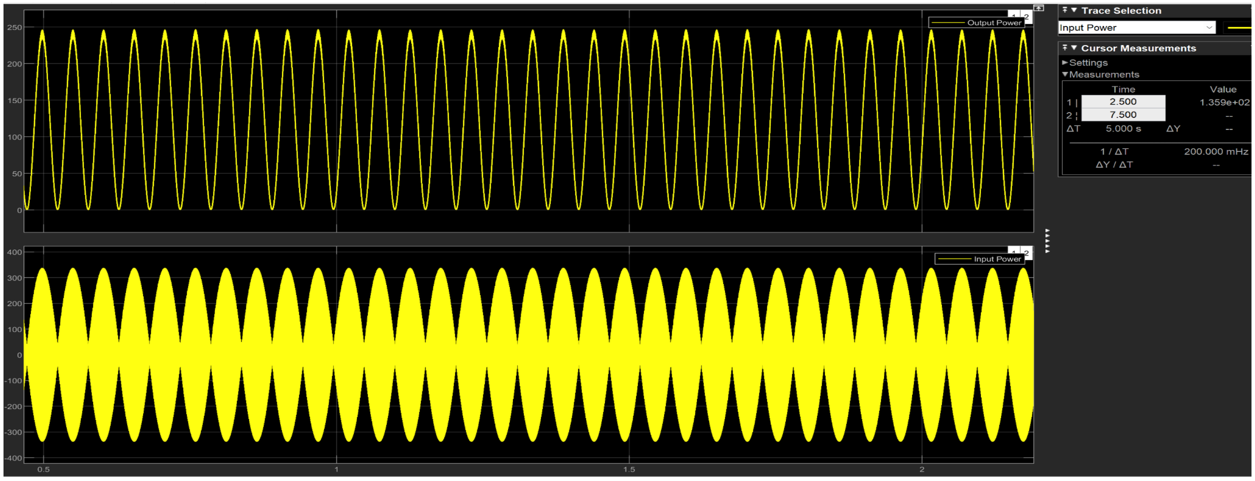
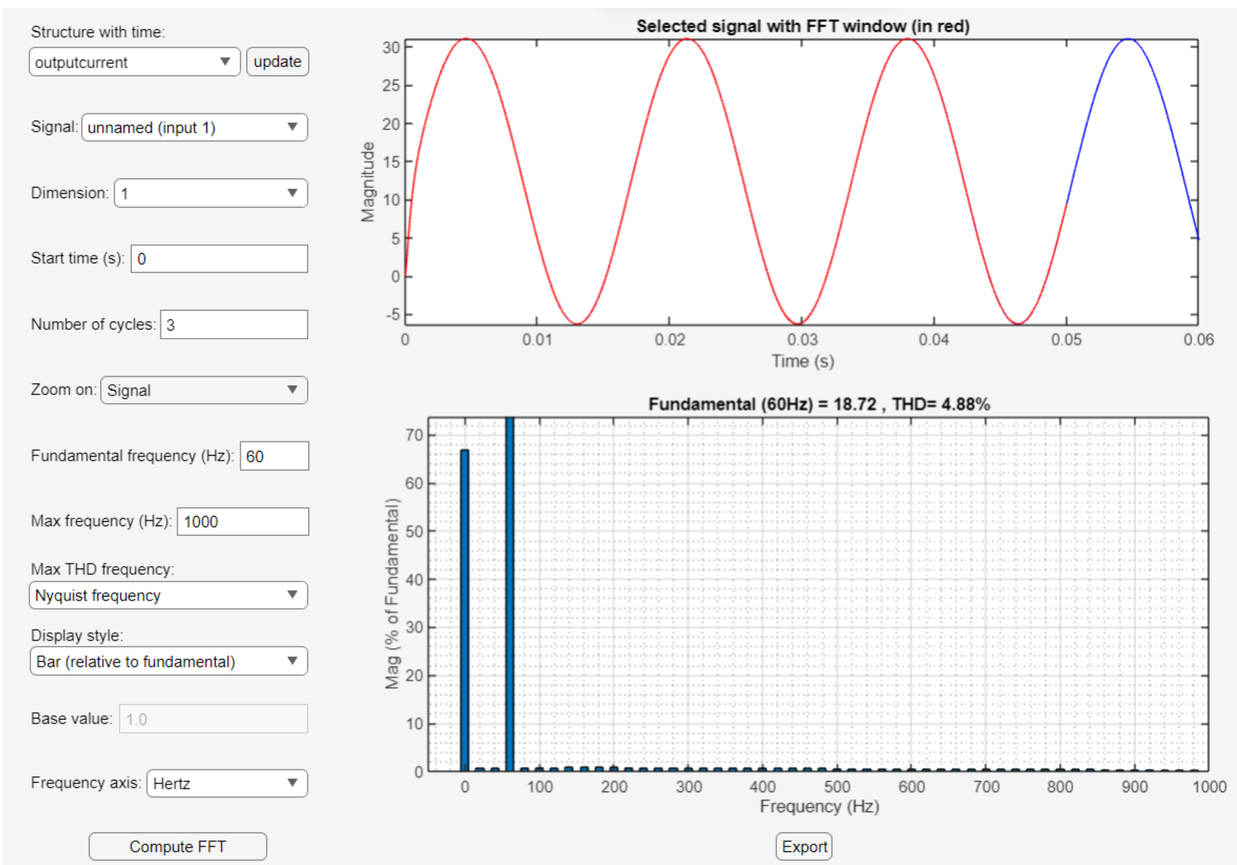
5- Capture the input and output power by multiplying the respective current by voltage.



6- Measure the total harmonic distortion (THD) of the output current. Make sure it is less than 5%. If not, you need to change your filter values.

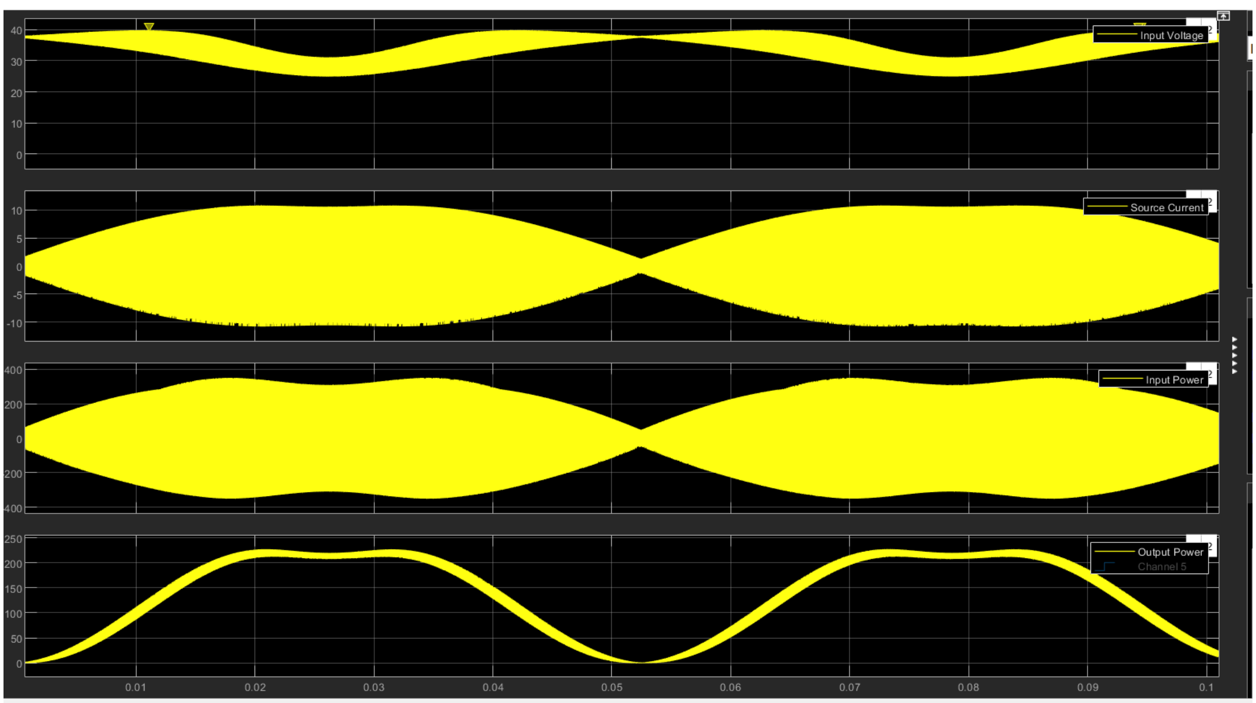


Sampling time = 8.5191e-06 sec.
Samples per cycle = 1956
DC component = 12.54
Fundamental = 18.72 peak (13.24 rms)
THD = 4.88%

0 Hz	DC	66.96%	90.0°
20 Hz	---	0.76%	269.5°
40 Hz	---	0.77%	268.6°
60 Hz	Fnd	100.00%	-10.9°
80 Hz	---	0.81%	267.1°
100 Hz	---	0.84%	264.3°
120 Hz	h2	0.63%	35.0°
140 Hz	---	0.85%	258.6°
160 Hz	---	0.87%	254.6°
180 Hz	h3	0.90%	257.1°
200 Hz	---	0.85%	248.1°
220 Hz	---	0.84%	245.3°

Exercise 2

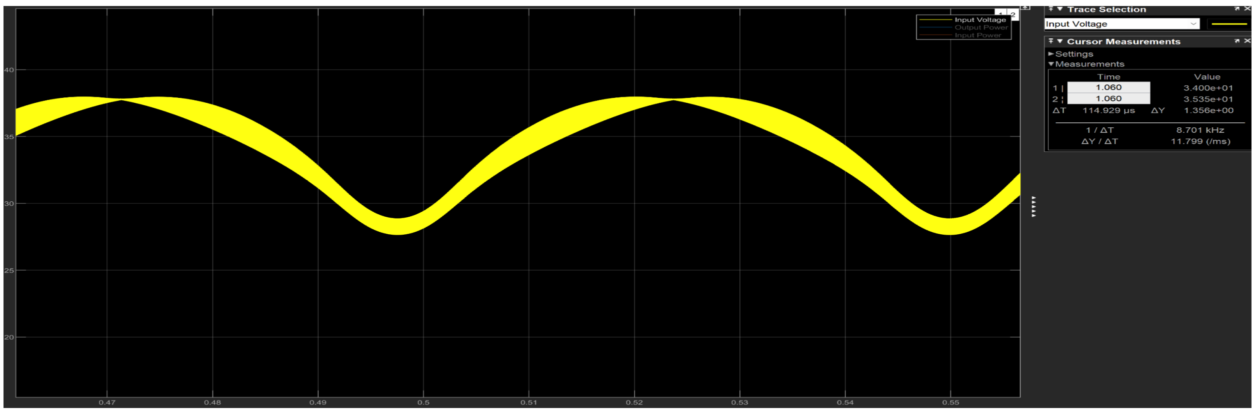
1- Capture the PV outputs: voltage, current, and power. In the same plot, capture the output (AC) power, and load resistor. Choose a small value for the capacitor, i.e. 10e-6 F. Can you measure the DC link voltage ripple?



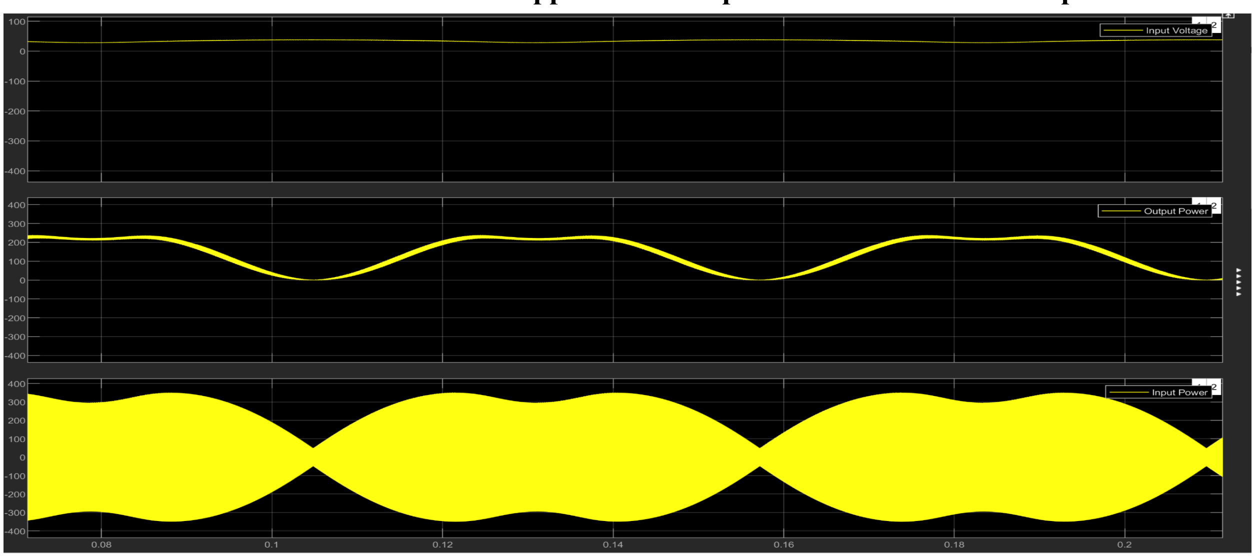
The DC link could not be measured due to how it varies depending on the section of the wave being observed. At the peaks, the ripple is significantly smaller when compared to the in-between parts of the wave making for an inconsistent rippling effect.

2- Increase the value of the capacitor such that the PV voltage (DC link voltage) ripple is more than two volts. Report on the final value for the capacitor with your voltage ripple measurement. You may need to increase your simulation time to reach a steady state condition

The New Capacitor value is 5e^-5 F @ 1.5 seconds



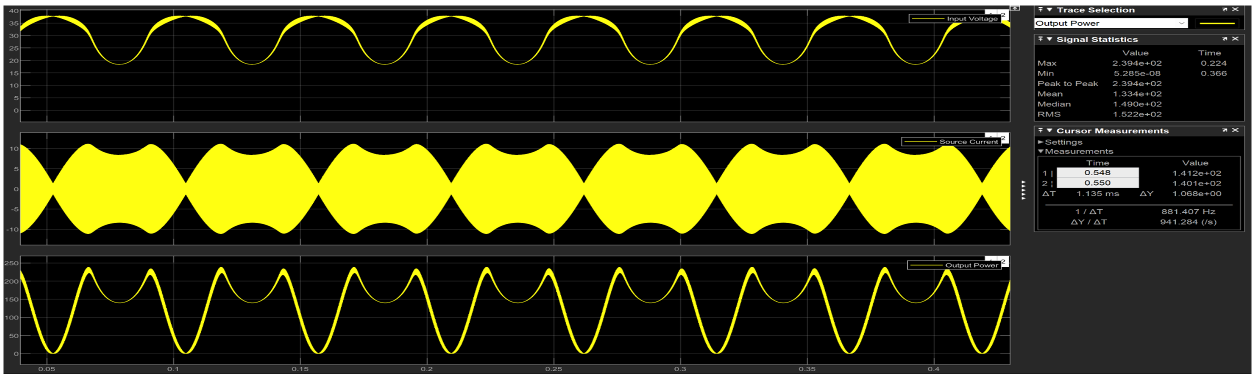
3- With the new DC link capacitor value, capture the DC and AC power. Is it the max? Is power available from the PV? How much is the ripple in the DC power measured at the PV panel?



The input power maxed out at approximately 350.4W which is the maximum output for the PV panel plus capacitor however, the AC power output is 238.5W which is just under what the solar panel could give to the load to use. The power ripples from 350.4W down to 297W, the smaller individual ripples change as a function of time making it difficult to give a pinpoint ripple of the particular line.

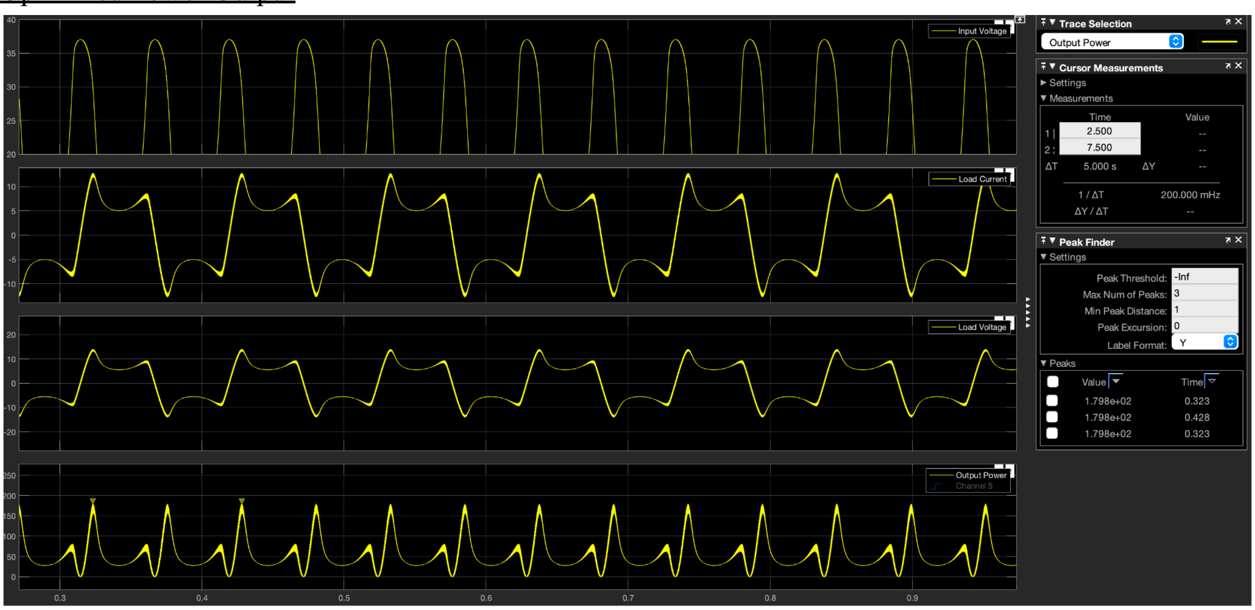
4- Alter the load resistance value and/or duty cycle to capture the maximum power available in the SolarWorld PV panel. You will have oscillations. Record and report the values. Record the DC voltage and current and compare them with the datasheet.

Max power = 239.4W which is slightly better than the previous 238.5W however it is slightly below the 250.338W the PV is supposed to be able to get. This was achieved by adjusting the duty cycle to 1.
Datasheet = max power = 250.338 W
Simulation = Max Power = 239.4W
Datasheet = MaxI= 8.05A
Simulation = MaxI = 11.13A
Datasheet =MaxV= 31.1V
Simulation = MaxV = 37.98V



5- Change the irradiance level to 600 W/m2. Measure the input and output power. Alter the load resistance to maximize the output power. What is the PV voltage? Compare it with the voltage recorded in the previous problem.

<u>Optimized Power Output</u>



1.2 Ω = 179.8 Watts
Given the new Irradiance levels, the unoptimized resistance of 2 Ω leads to an output of 175.9 Watts. However, by reducing the resistance to 1.2 Ω it leads to an optimized output of 179.8 Watts.

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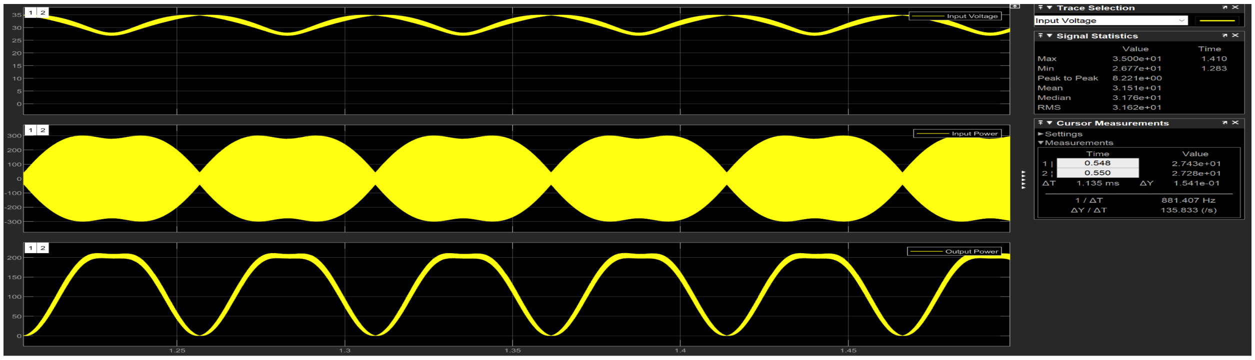
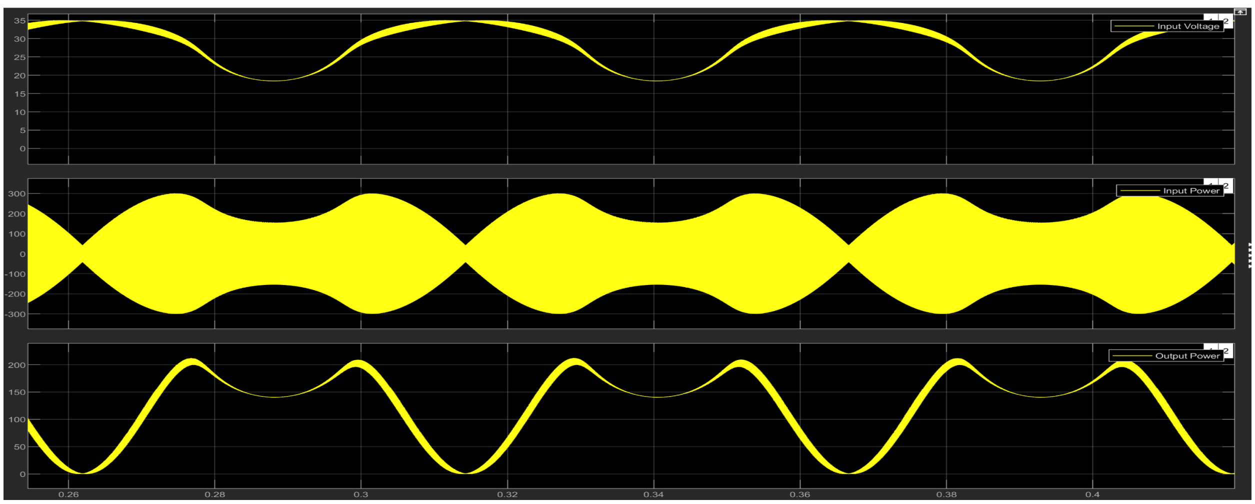
6- Use the nominal irradiance level of 1000 W/m2 but now at 50 degrees C. Repeat the simulation. Alter the load resistance to maximize the output power. What is the PV voltage? Compare it with the voltage recorded under nominal operating points

<u>Unoptimized Power Output</u>



The max output power before the optimization is 200.2W.

<u>Optimized Power Output</u>



The max output power after the optimization is 212.2W.

The PV voltage at 50 degrees C dropped the max input voltage to 35V as opposed to the previous nominal max voltage which was 37.98V. This means that increasing the heat caused a 2.98V drop in the incoming voltage to the circuit.

CONCLUSION:

Photovoltaic solar systems introduce several challenges when attempting to produce AC mains voltage. The primary concern is converting the DC voltage to an AC Sinusoidal waveform free from distortion and harmonics that can damage sensitive devices downstream of the solar panels generating power. In this lab, the students learned invaluable insights into the inner workings of an inverter, specifically a method of creating the sine wave through the use of an H-bridge, which is a circuit composed of a PWM generator and 4 MOSFETs. This waveform was then filtered with the use of a filter network composed of 3 capacitors and one inductor. These components had to be chosen carefully to minimize the harmonics in the circuit that would produce unacceptable noise output. Furthermore, given different light conditions, further optimization of the output resistance can lead to greater efficiency.