LAB 2-2

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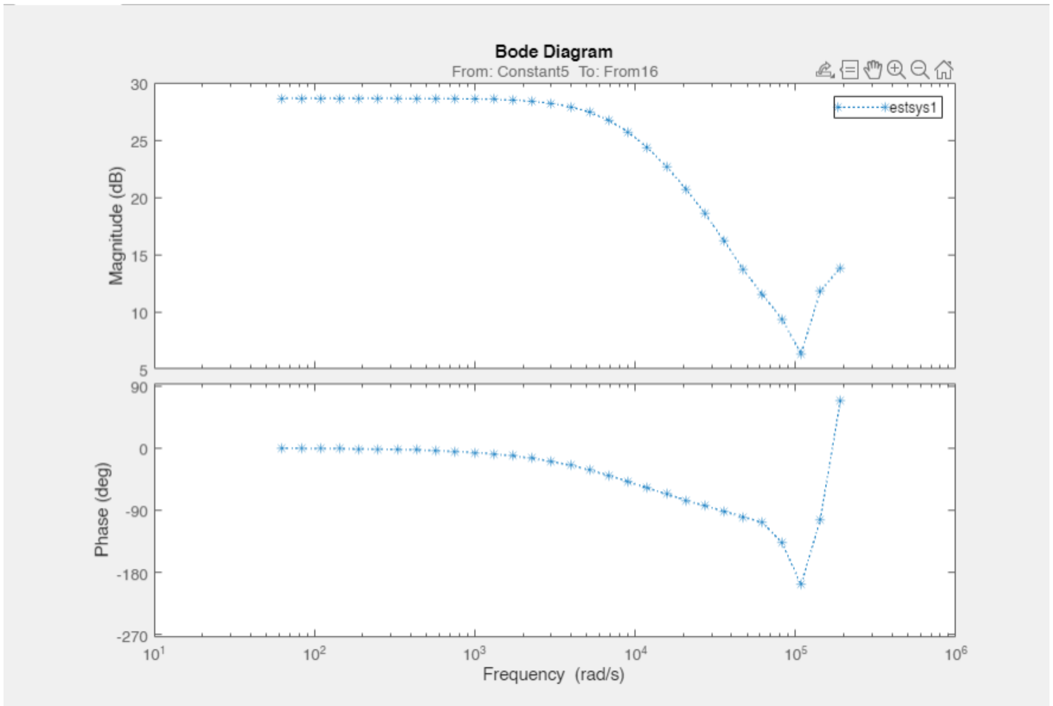
OBJECTIVES

The objective of this lab is to design and simulate a closed-loop control system for an H-bridge DC/AC inverter interfacing with a photovoltaic (PV) array using Matlab/Simulink. The simulation aims to validate the system's performance under nominal and various altered conditions, such as changes in input voltage and load resistance. The lab will also involve deriving or estimating transfer functions for different system components and designing PID controllers based on these transfer functions.

MATERIALS/EQUIPMENT NEEDED

- Four Mosfets
- One Inductor
- One Capacitor
- One Resistor
- DC Voltage Supply
- PWM Generator
- PID Controller
- Matlab Simulink

Results:



ran simulation for 0.5 sec
Snapshot: 1e-6 sec
Amplitude 0.05
Freq: 10-30000 Hz

Exercise 1 PostLab

Questions:

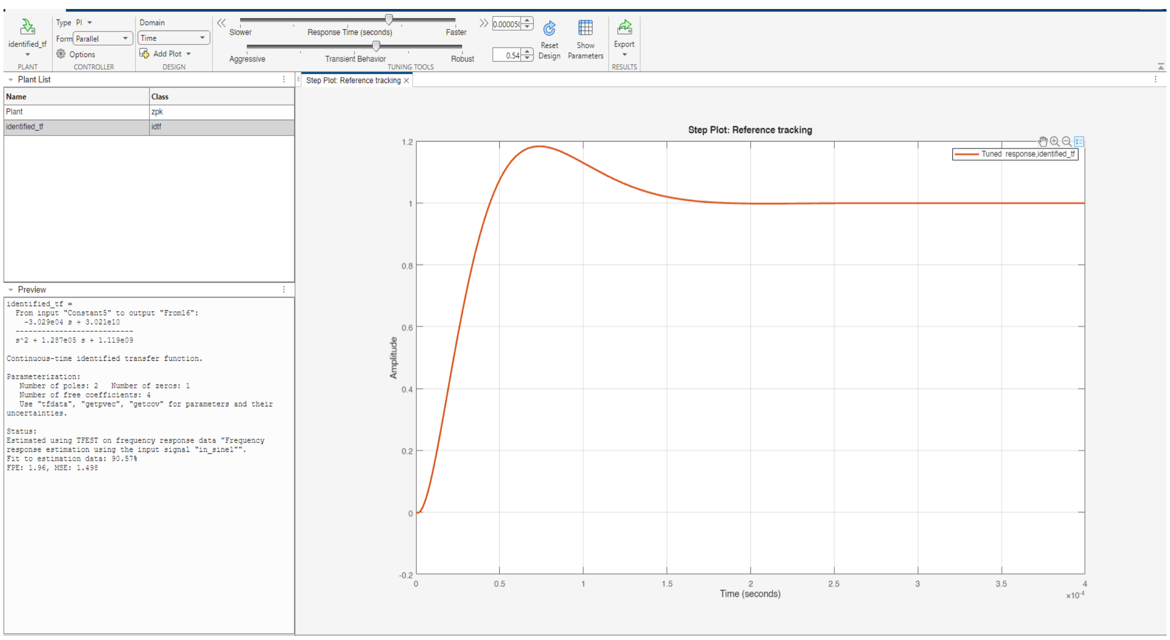
1. **Operating Points:** Tabulate the nominal operating conditions and specifications, i.e, switching frequency, input voltage, duty cycle, load resistance value, inductor and capacitor values, etc. You can use the previous lab's values.

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

2. Transfer Function:

```
identified_tf =
  From input "Constant5" to output "From16":
    -3.029e04 s + 3.021e10
  --------------------------
  s^2 + 1.287e05 s + 1.119e09

Continuous-time identified transfer function.

Parameterization:
   Number of poles: 2   Number of zeros: 1
   Number of free coefficients: 4
   Use "tfdata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using TFEST on frequency response data "Frequency response estimation using the input signal "in_sine1"".
Fit to estimation data: 90.57%
FPE: 1.96, MSE: 1.498

Model Properties
```

3. **Controller Design**: Report on the PI(D) gains for the compensator



Controller Parameters

	Tuned
Kp	0.14734
Ki	3199.2056
Kd	n/a
Tf	n/a

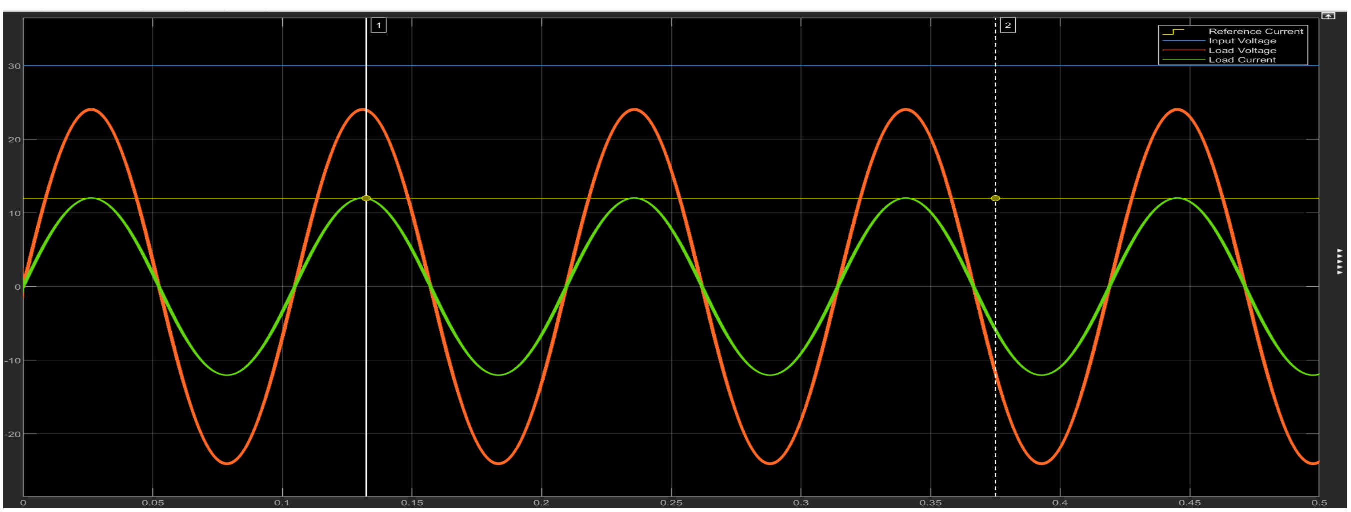
Performance and Robustness

	Tuned
Rise time	2.97e-05 seconds
Settling time	0.00015 seconds
Overshoot	18.3 %
Peak	1.18
Gain margin	27.6 dB @ 3.24e+05 rad/s
Phase margin	54 deg @ 3.94e+04 rad/s
Closed-loop stability	Stable

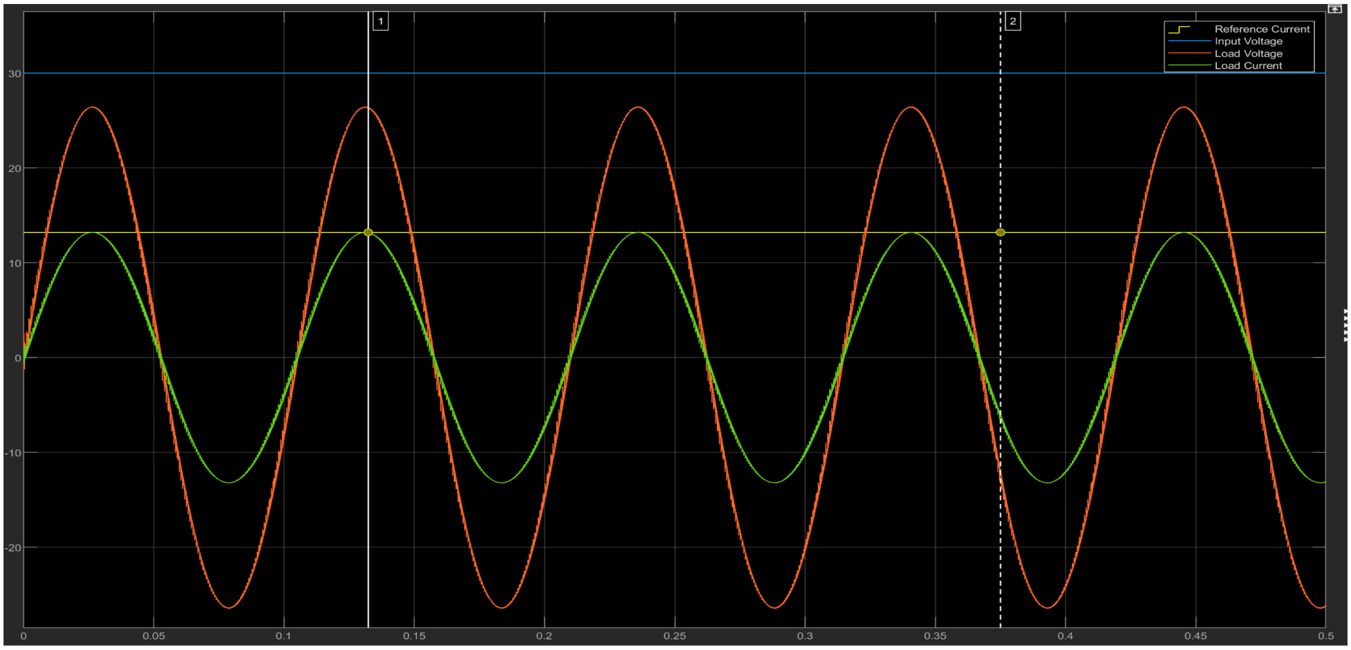
Overshoot >20%

4. Verification:

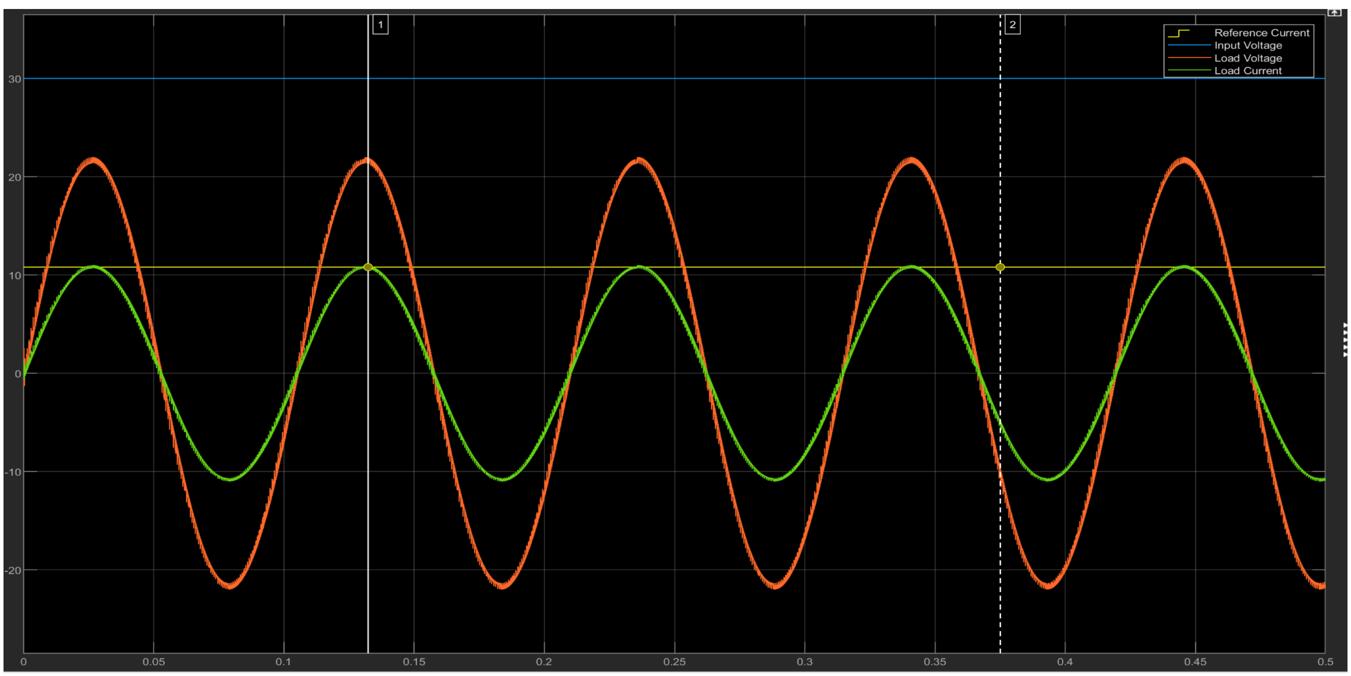
a.



b. +10% Reference Current

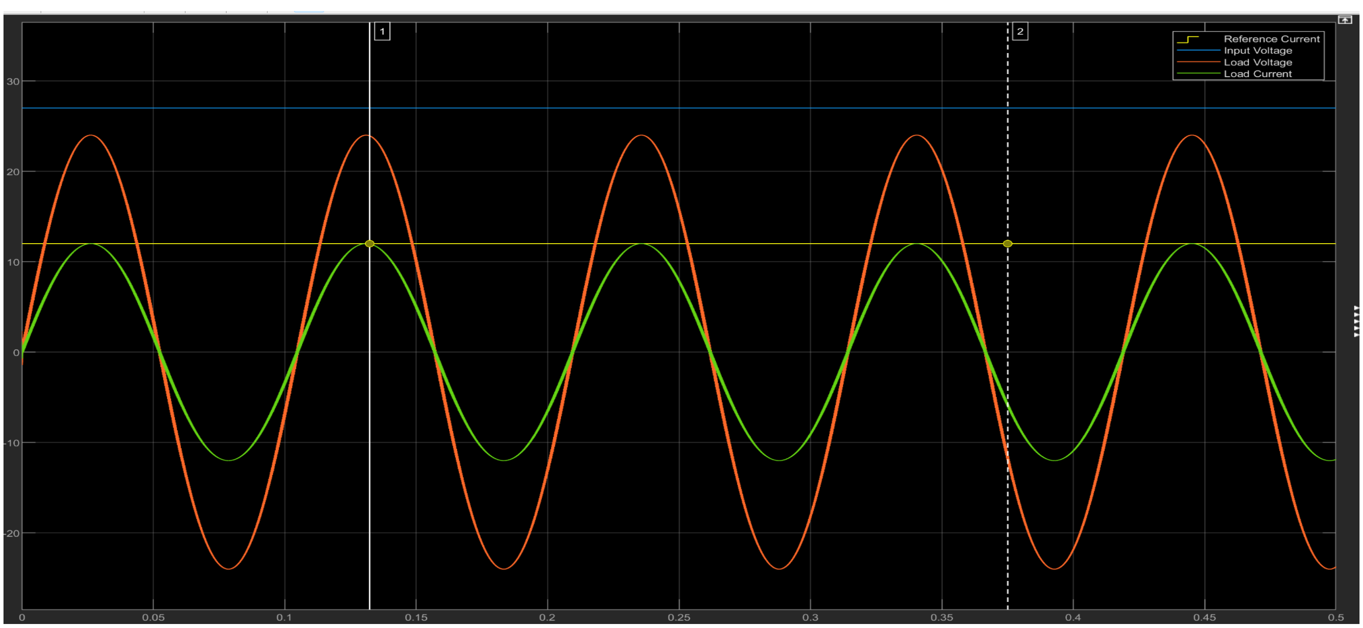


c. -10% Reference Current

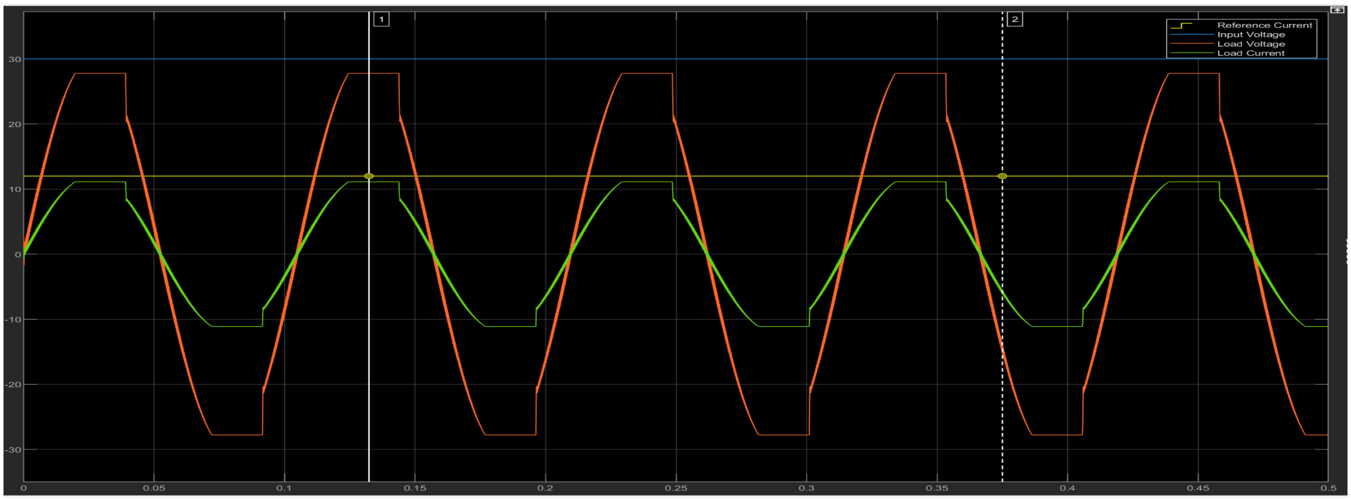


d. +10% Supply Voltage

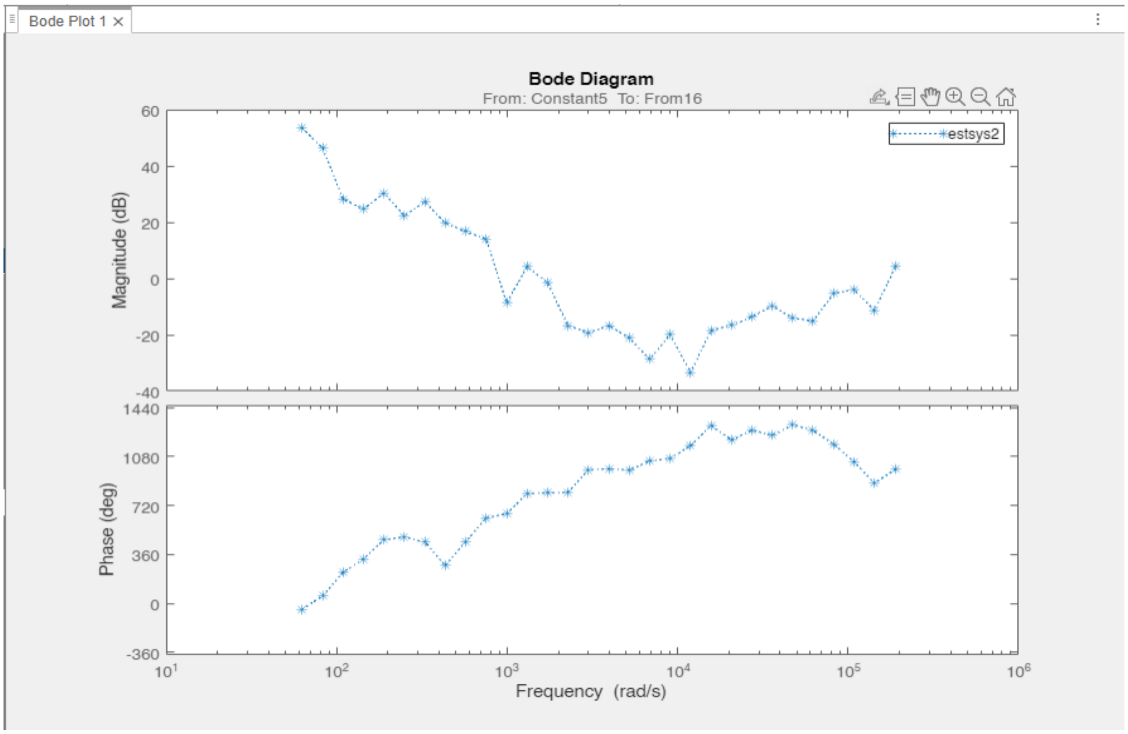
e. -10% Supply Voltage



f. +25% higher load resistance



Exercise 2 PostLab

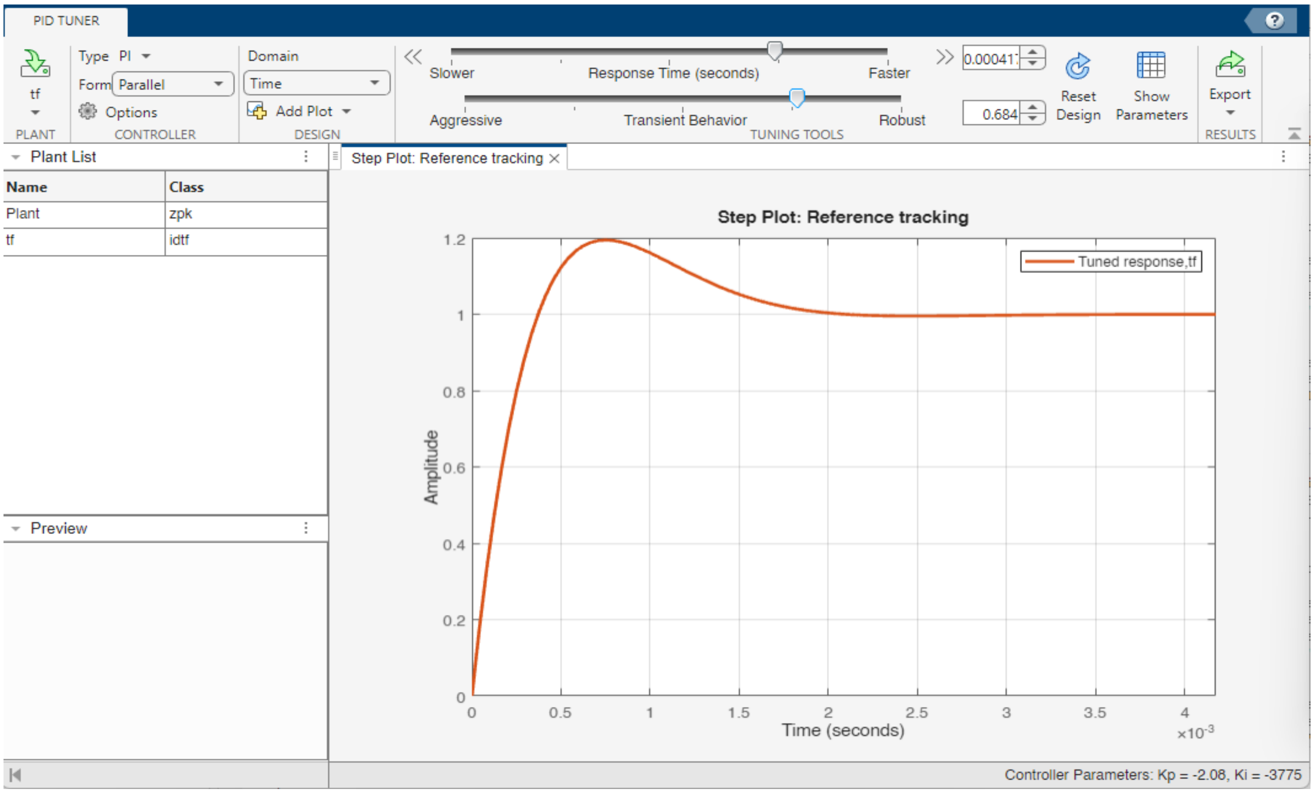


1. **Transfer Function:** Report the transfer function between the input (output/inductor current) to the output (DC voltage).

```
tf =
  From input "Constant5" to output "From16":
    -2154 s^3 - 1.147e05 s^2 - 3.081e07 s - 1.513e09
  -----------------------------------------------------
  s^4 - 17.65 s^3 + 1.342e04 s^2 - 1.29e05 s + 3.769e07

Continuous-time identified transfer function.

Parameterization:
   Number of poles: 4   Number of zeros: 3
   Number of free coefficients: 8
   Use "tfdata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using TFEST on frequency response data "Frequency response estimat
Fit to estimation data: 91.76%
FPE: 101.5, MSE: 58.78

Model Properties
```

Exercise 2 PostLab

2. **Optional: Controller Design:** Report on the PID gains needed to construct the closed-loop system



Show Parameters

Controller Parameters

	Tuned
Kp	-2.0796
Ki	-3775.3018
Kd	n/a
Tf	n/a

Performance and Robustness

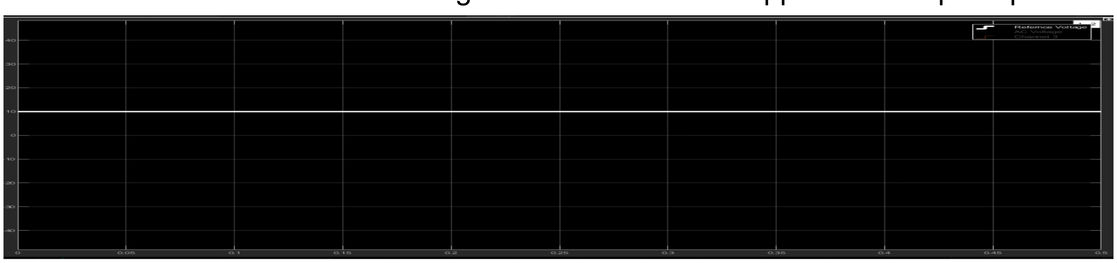
	Tuned
Rise time	0.000281 seconds
Settling time	0.00175 seconds
Overshoot	19.4 %
Peak	1.19
Gain margin	-35.9 dB @ 364 rad/s
Phase margin	68.4 deg @ 4.79e+03 rad/s
Closed-loop stability	Stable

Close

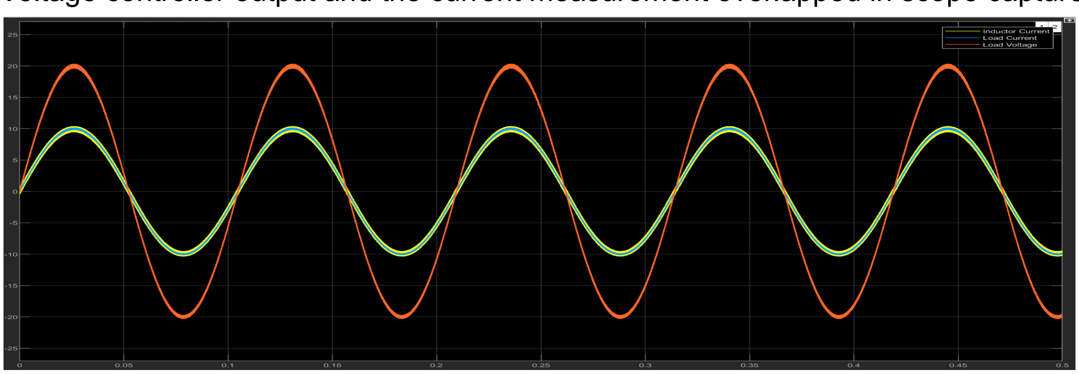
3. Simulation Verification:

3.1:

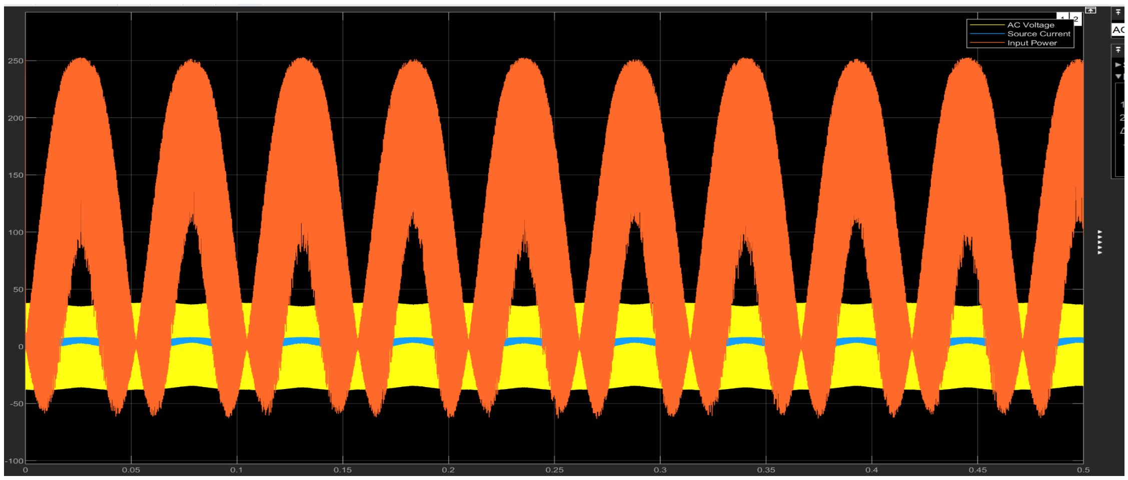
a. DC link reference and DC link voltage measurement overlapped in a scope capture



b. Voltage controller output and the current measurement overlapped in scope capture

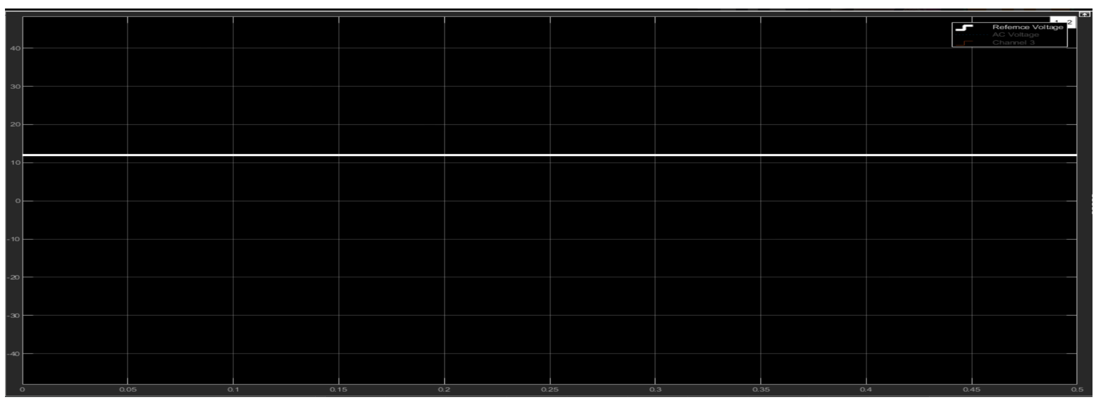


c. PV Current, PV power, AC power

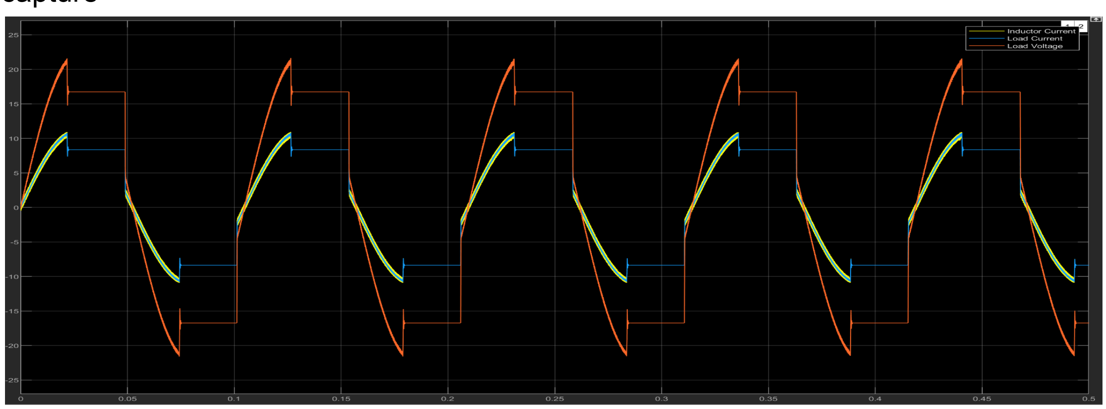


3.2:

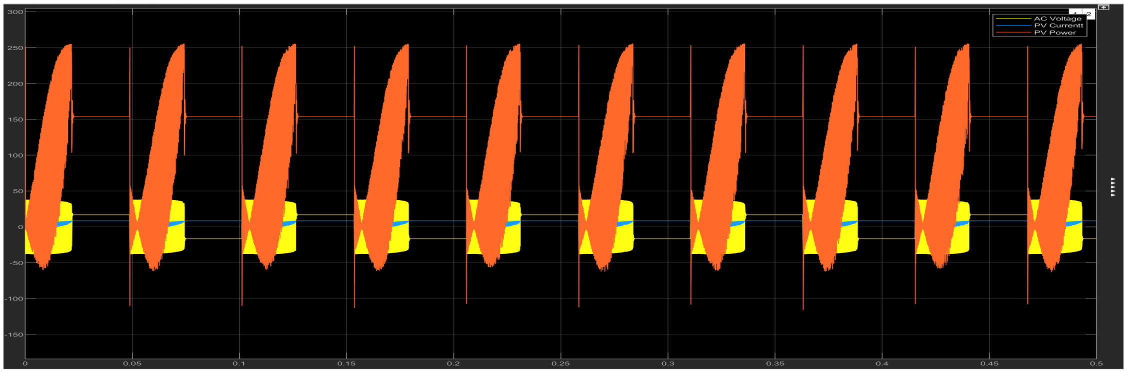
1. **+10% Input Reference DC Voltage**
   a. DC link reference and DC link voltage measurement overlapped in a scope capture



   b. Voltage controller output and the current measurement overlapped in scope capture

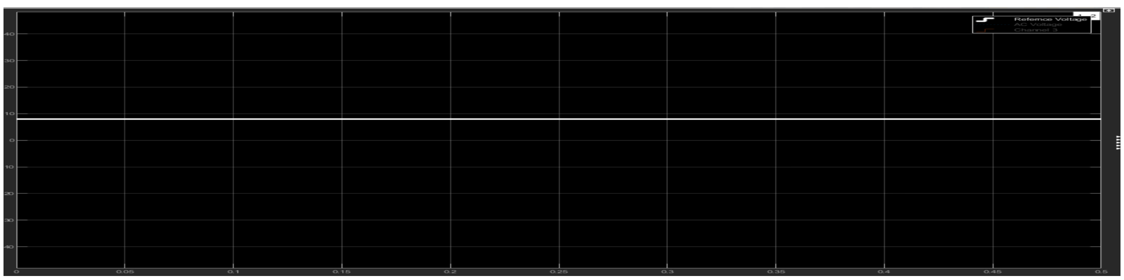


c. PV Current, PV power, AC power

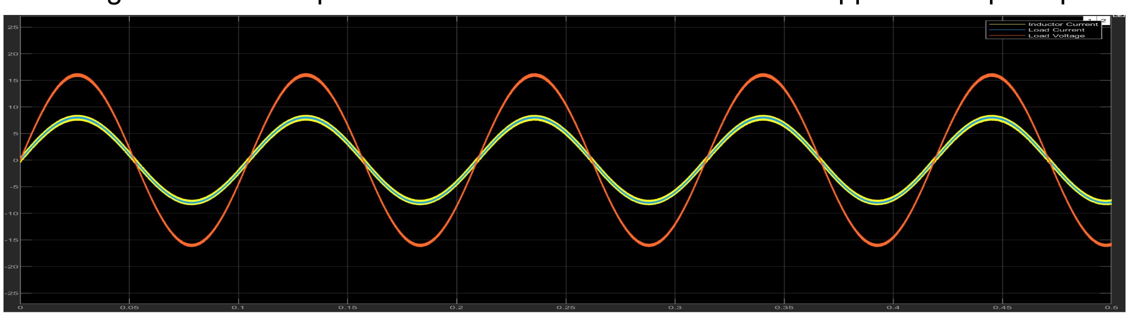


2. -20% Input Reference DC Voltage

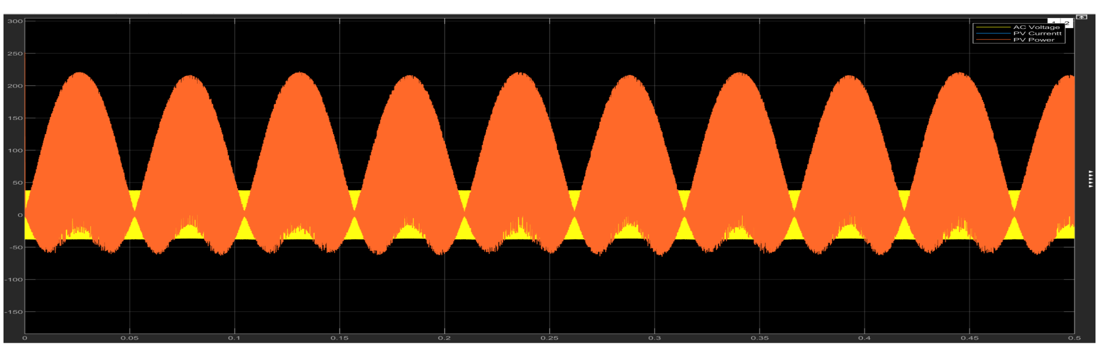
a. DC link reference and DC link voltage measurement overlapped in a scope capture



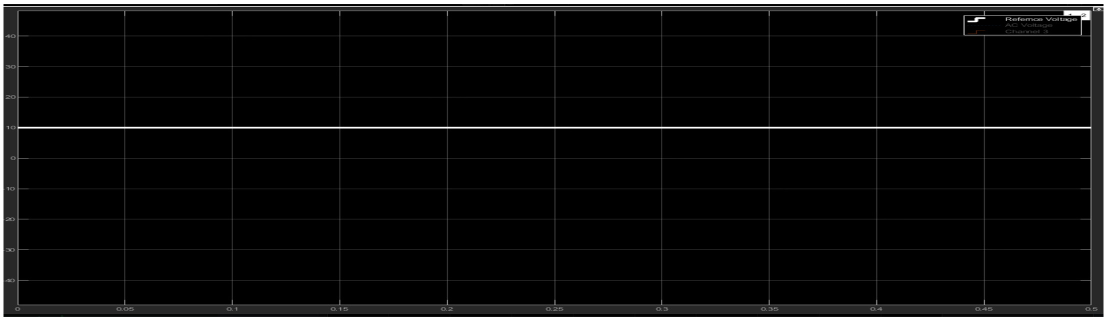
b. Voltage controller output and the current measurement overlapped in scope capture



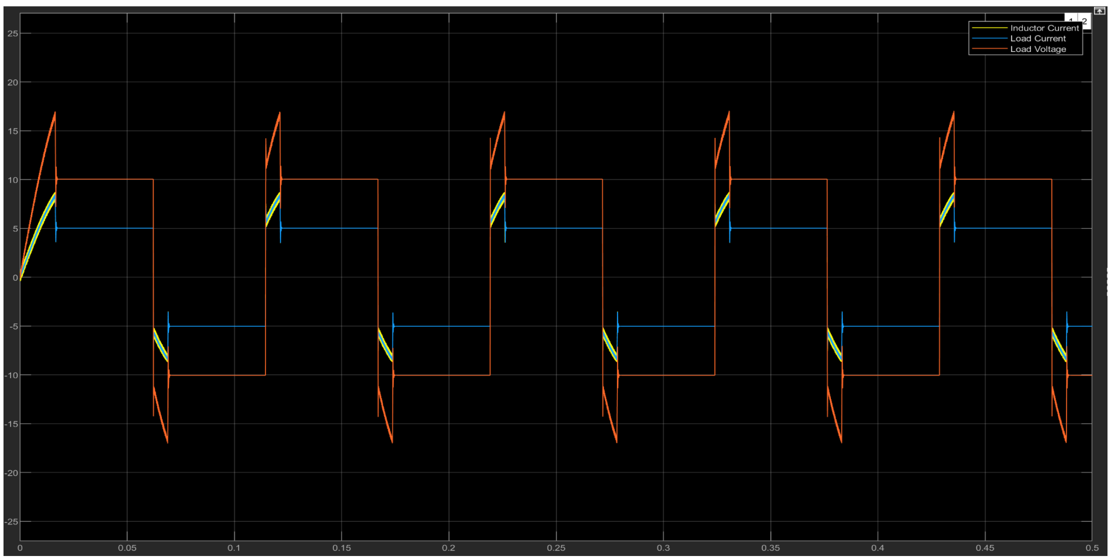
c. PV Current, PV power, AC power



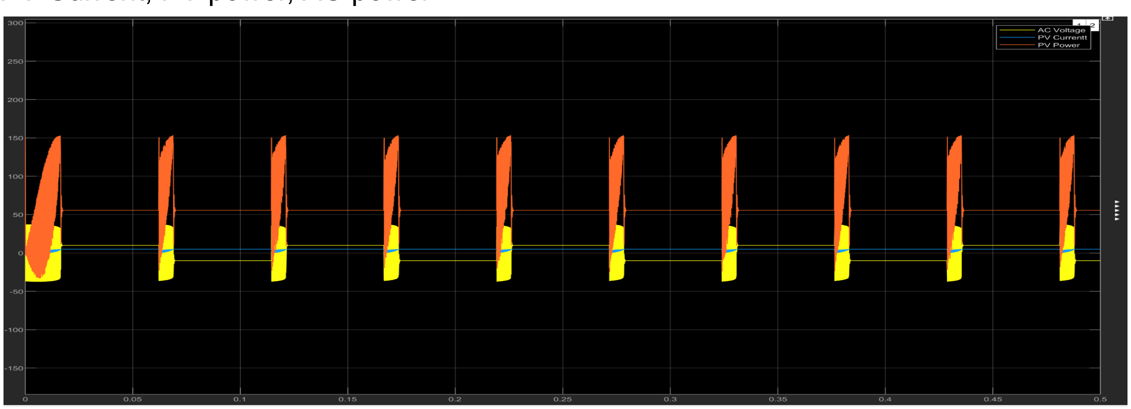
2. **Change the irradiance level to 600W/m² from nominal operating conditions**
   a. DC link reference and DC link voltage measurement overlapped in a scope capture



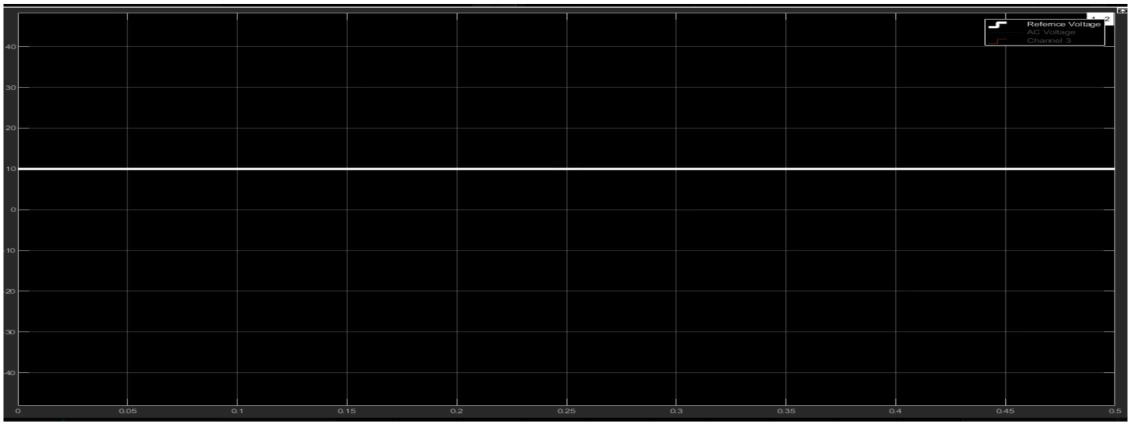
   b. Voltage controller output and the current measurement overlapped in scope capture



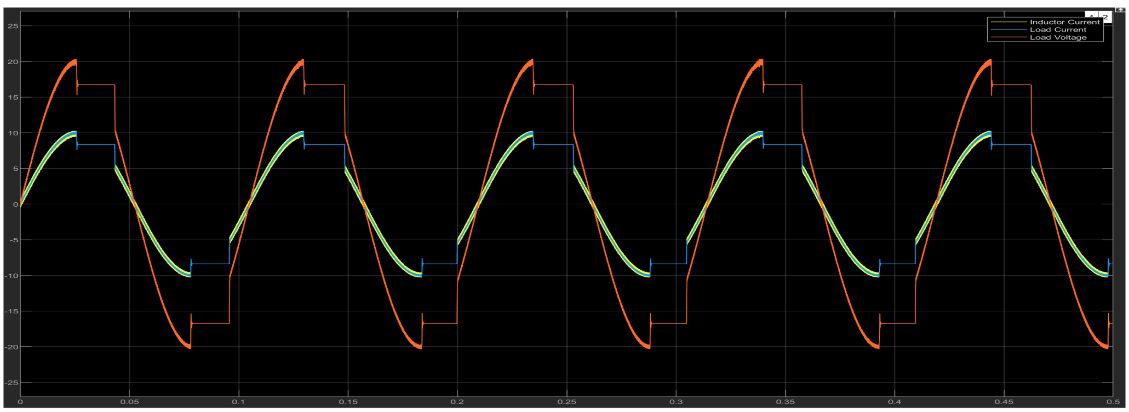
   c. PV Current, PV power, AC power



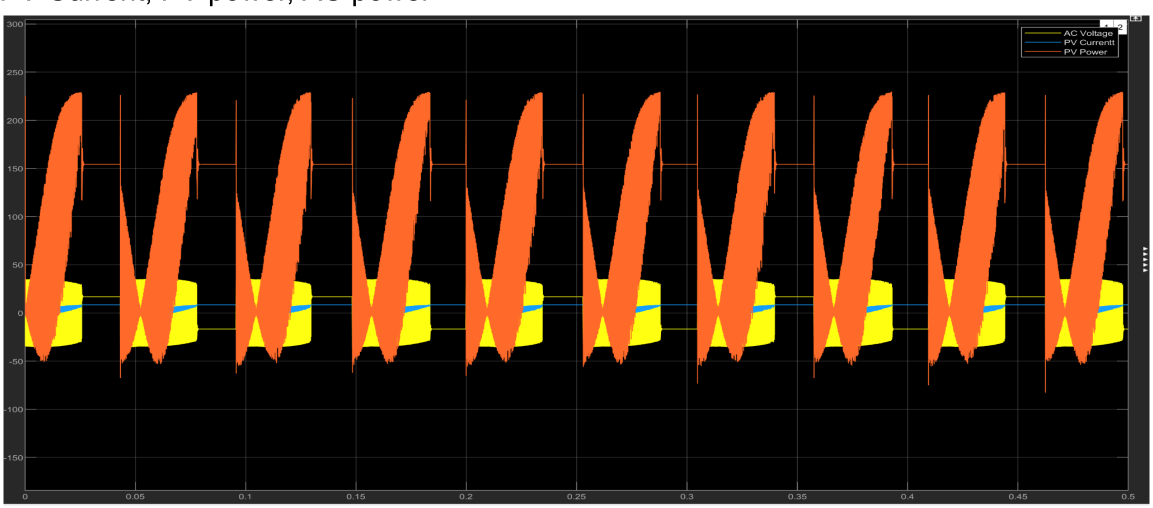
4. **Use the nominal irradiance 1000W/m^2 but now at 50 degree C**
   a. DC link reference and DC link voltage measurement overlapped in a scope capture



   b. Voltage controller output and the current measurement overlapped in scope capture



   c. PV Current, PV power, AC power



CONCLUSION:

In this lab, we successfully designed and simulated a closed-loop control system for an H-bridge DC/AC inverter interfacing with a PV array using Matlab/Simulink. The goal of this circuit is to convert the solar photovoltaic variable DC input to a sinusoidal alternating current with less than one percent total harmonic distortion (THD). To achieve this, we ran an open loop analysis of our circuit, followed by a bode plot simulation and subsequently tuning the circuit to achieve the given metrics. Upon finding a suitable transfer function, enabled the closed loop PID controller, and made further tweaks to various parts of the circuit design. We used the PID tuning to create system stability and transient behavior, which were verified through simulation under various operating conditions.