Design a PI controller for the **buck converter**, with an IGBT and supplied from a 230Vrms grid **:**

- *Vo (=setpoint) = 50 Vdc*
- *Fs = 25 Khz*
- *Vripple = 200mV*
- *Iripple = 0.2A*
- *R=5ohms*

a) Model the rectifier (with a capacitor of 100mF) + buck converter in Simulink.

b) Decrease the capacitor to 100uF, and analyze the result

c) Add a PI controller (Kp=100, Ki=8) and check the rising time and the overshooting.

d) At t=250ms, change the setpoint to 75Vdc

Question 1: Model the rectifier (with a capacitor of 100 mF) + buck converter in Simulink.

Answer 1:

Instead of MOSFET, in BUCK converter IGBT with diode is used.

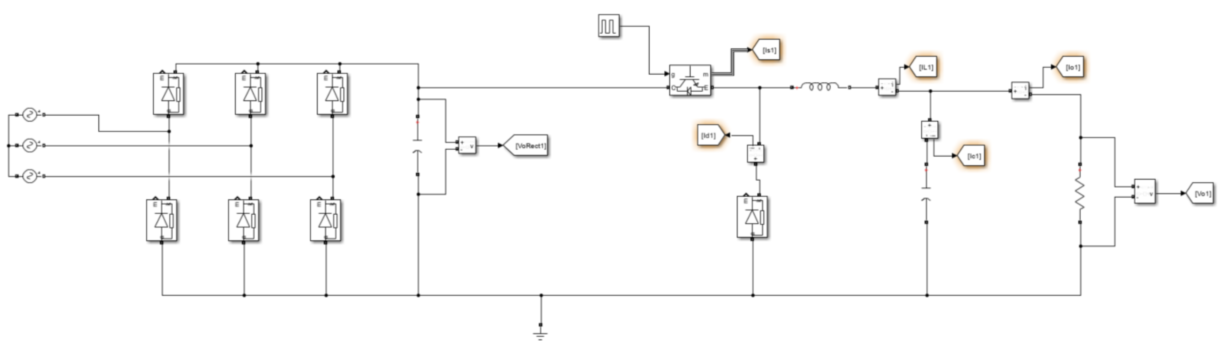

Figure 1. Circuit Model in Simulink

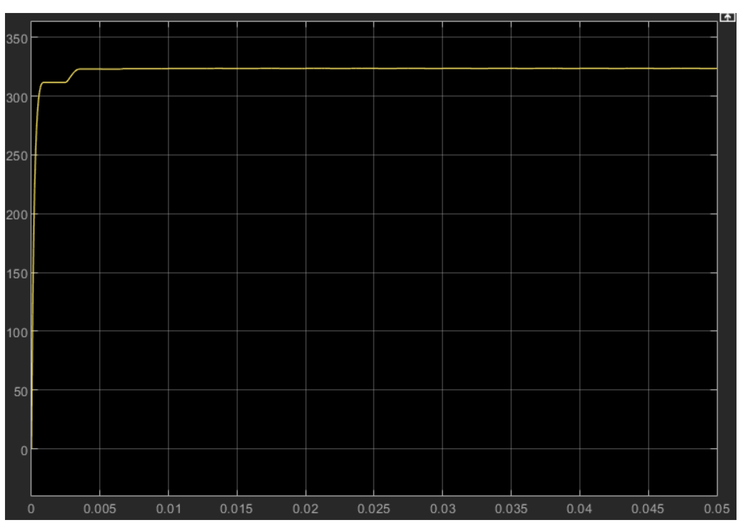

Figure 2. Voltage After Rectifier

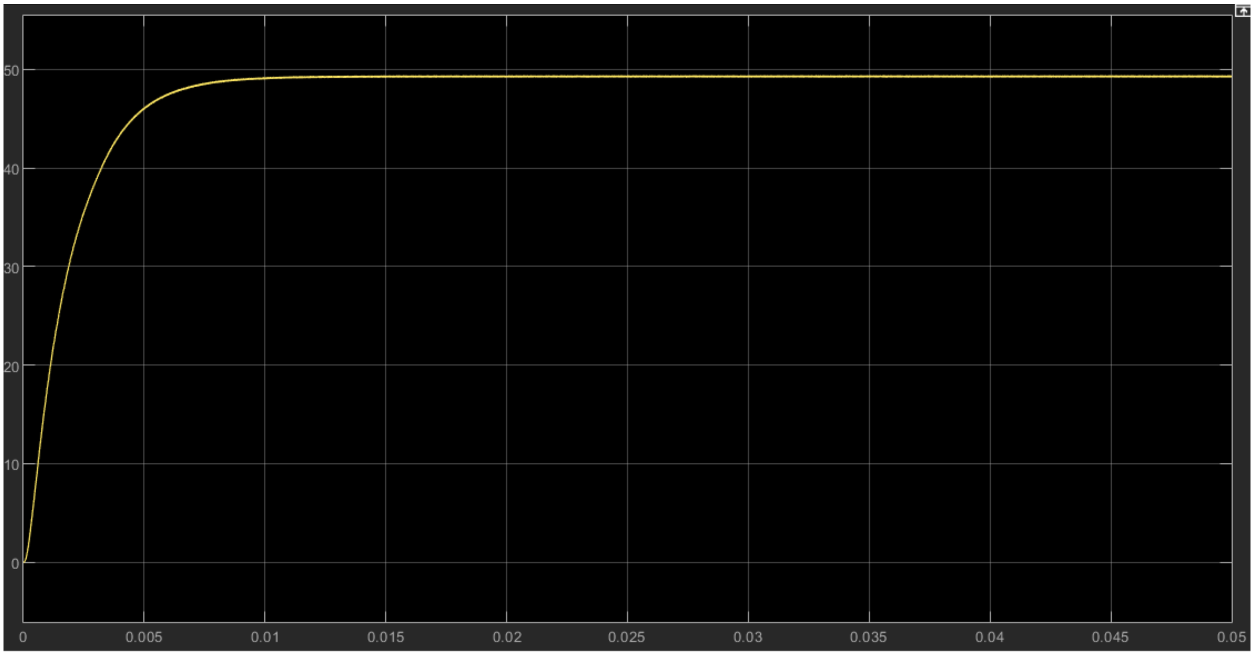

Figure 3. Voltage After Buck Converter

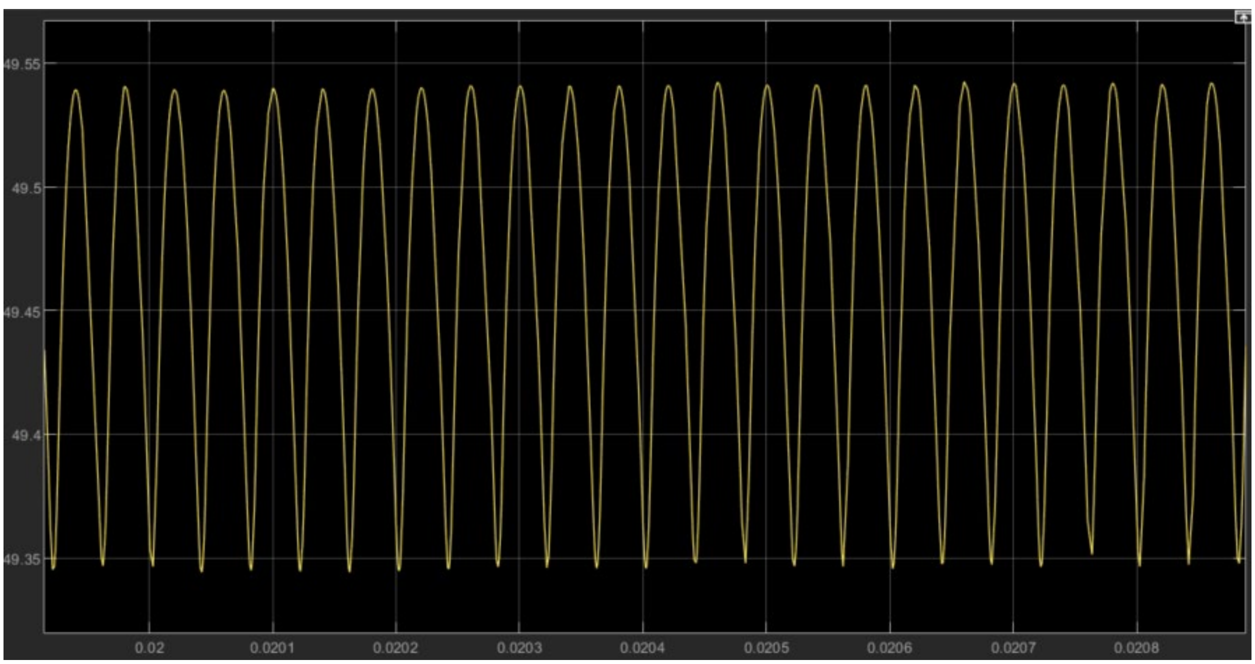

Figure 4. Output Voltage Ripple

Voltage ripple is 200 mV.

Question 2: Decrease the capacitor to 100 uF, and analyze the result.

Answer 2:

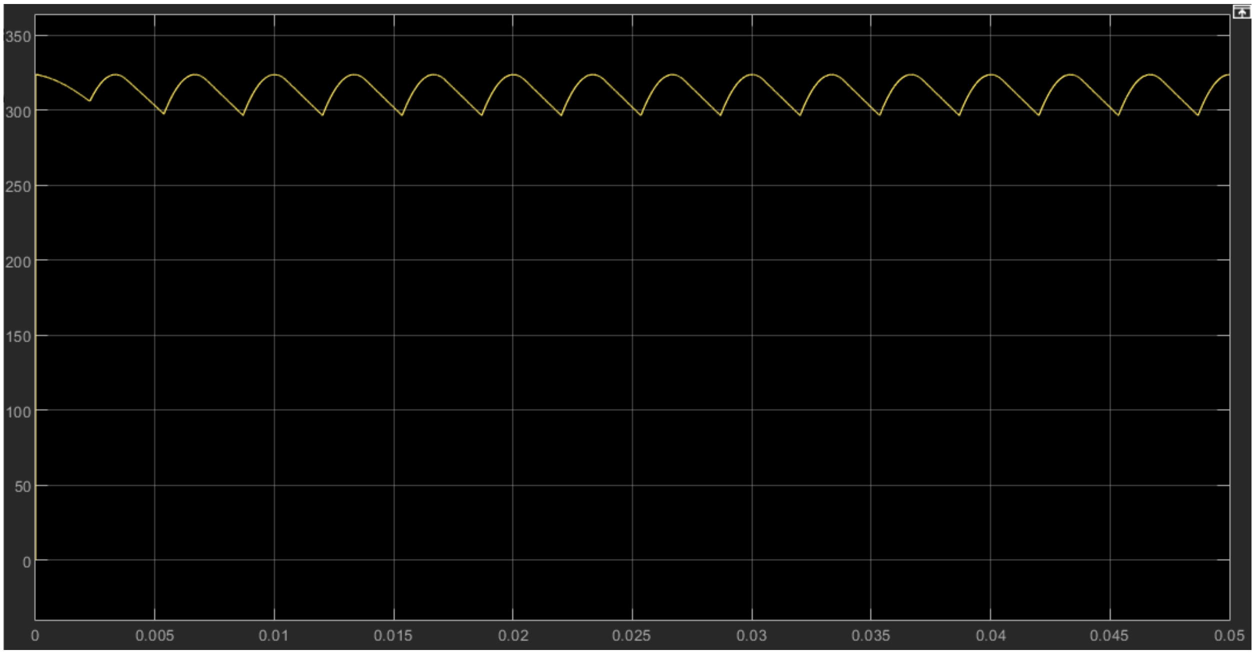

Figure 5. Voltage After Rectifier

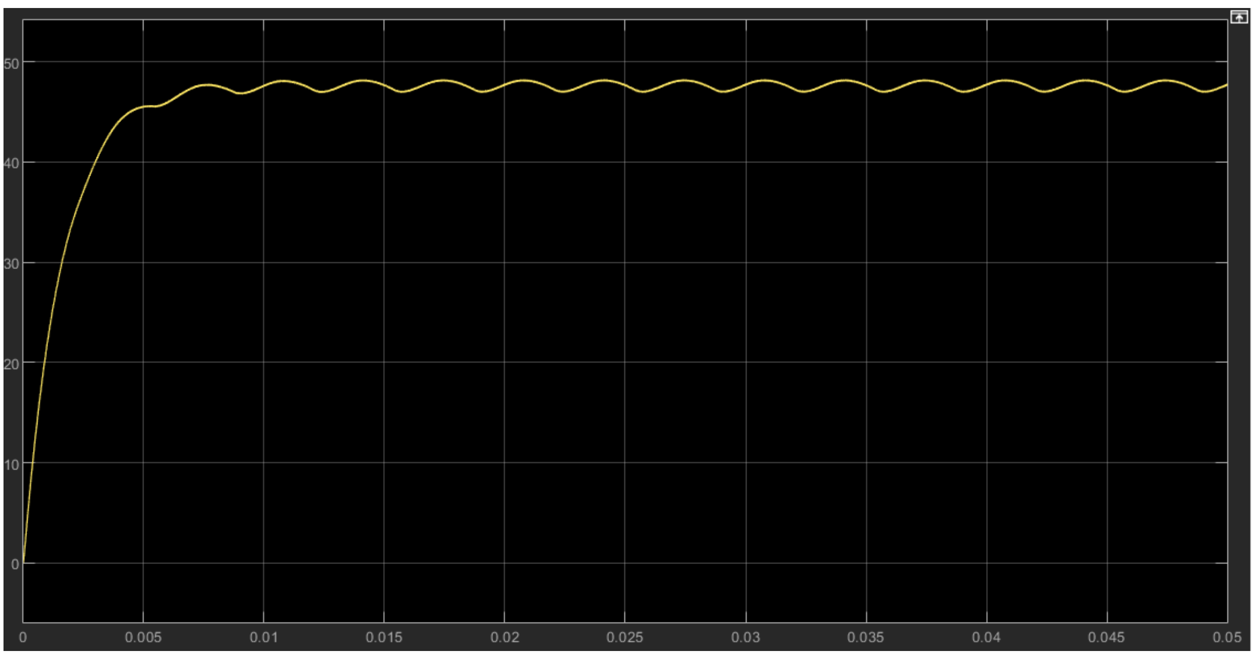

Figure 6. Voltage After Buck

The capacitor acts as a filter to reduce the voltage ripple by storing energy during the peaks of the rectified waveform and discharging it during the troughs. Using a small capacitor after a rectifier increases the ripple because the capacitor is not large enough to sufficiently smooth out the variations in the rectified voltage.

Question 3: Add a PI controller (Kp=100, Ki=8) and check the rising time and the overshooting.

Answer 3:

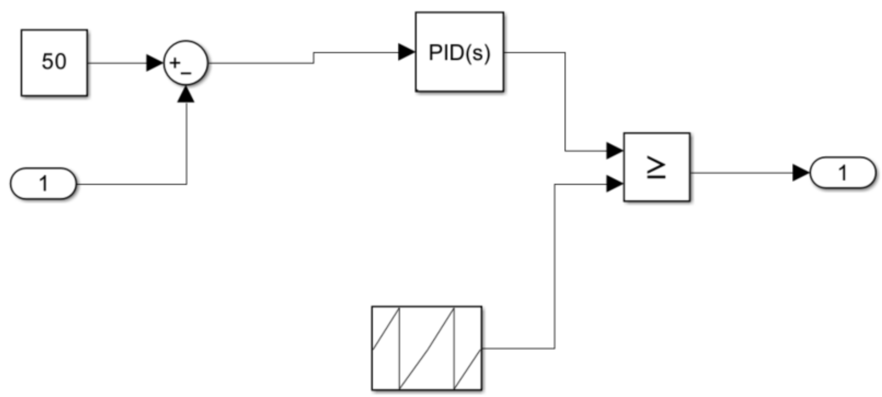

Figure 7. PI Controller

A PI (Proportional-Integral) controller is a common feedback control mechanism used to maintain a system's output at a desired setpoint. It can regulate the output voltage of a buck converter in response to disturbances or changes in the reference voltage.

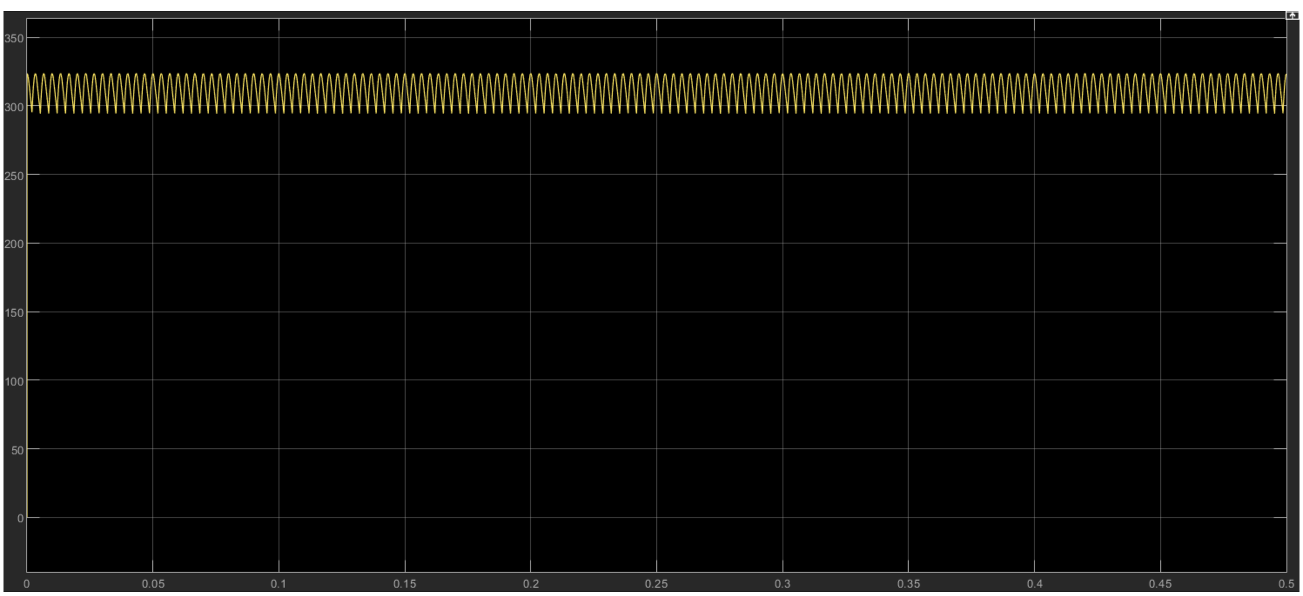

Figure 8. Voltage After Rectifier

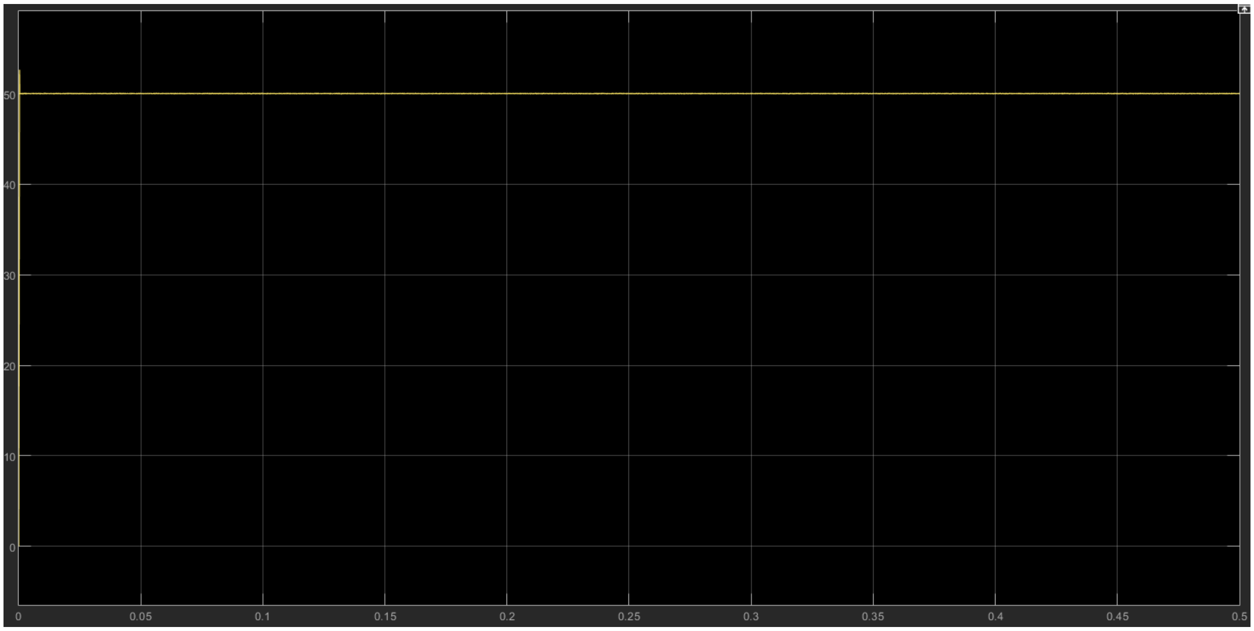

Figure 9. Voltage After Buck using PI Controller

Overshoot is the maximum percentage by which the response overshoots the desired value. The extent to which the output voltage temporarily exceeds the steady-state (desired) voltage after a step change.

Expressed as:

$$Overshoot\ (\%) = \frac{V_{max} - V_{steady-state}}{V_{steady-state}} * 100$$

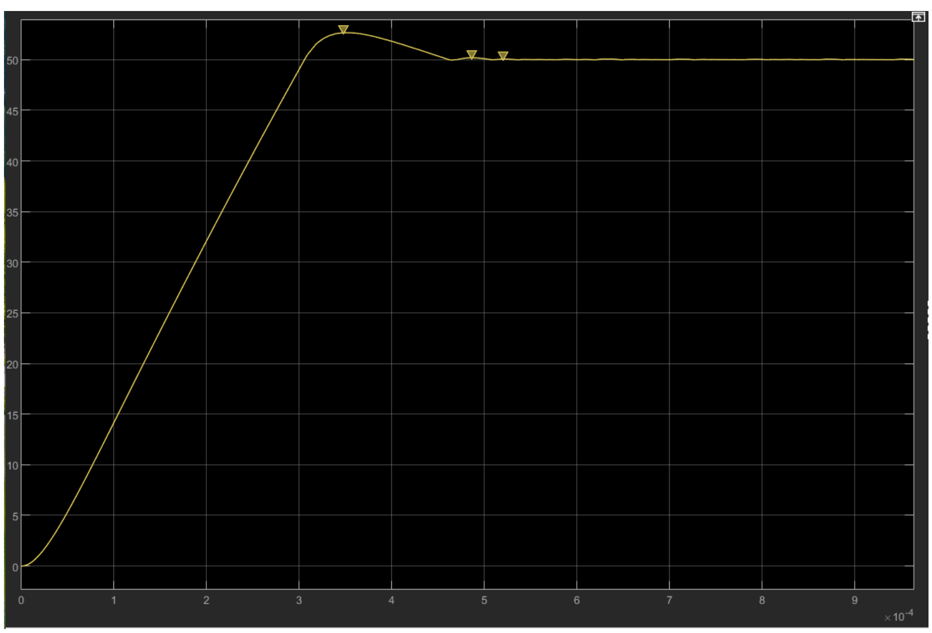

Figure 10. Transient Response

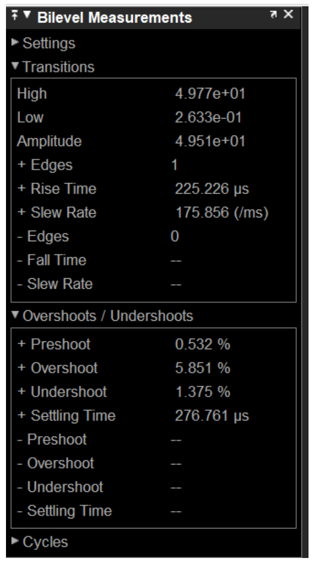

Figure 11. MATLAB Overshoot and Rising time Calculations

Overshoot is 5.851% during the transient response.

Overshoot when NOT including transient response:

$$Overshoot\ (\%) = \frac{V_{max} - V_{steady-state}}{V_{steady-state}} * 100 = \frac{50.09 - 50}{50} * 100 = 0.18\%$$

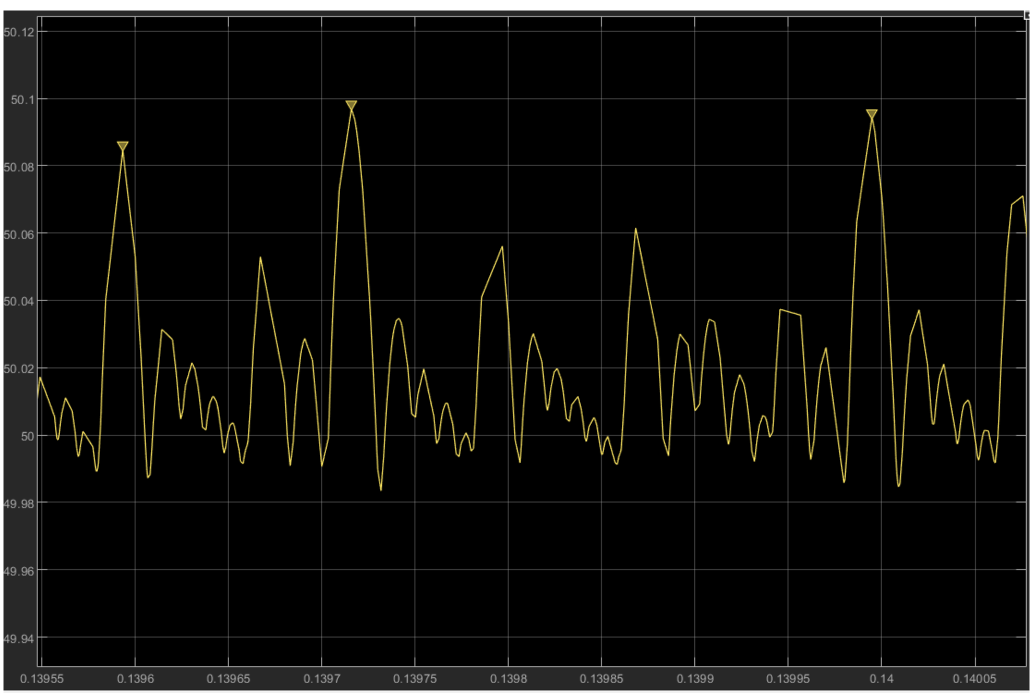

Figure 12. Overshooting occurs when the system reacts too aggressively to changes

Rising time is time it takes for the output voltage of your system (the buck converter output) to rise from a low percentage to a high percentage of its final (steady-state) value after a change in input or reference. Typically measured from 10% to 90% of the final steady-state output. Indicates how quickly the buck converter responds to a step input or disturbance. A shorter rise time suggests that your PI controller responds quickly, but it might increase the chance of overshoot. Rising time includes the transient response of the system.

Rise time is 225.226 micro seconds.

Question 4: At t = 250ms, change the setpoint to 75 Vdc.

Answer 4:

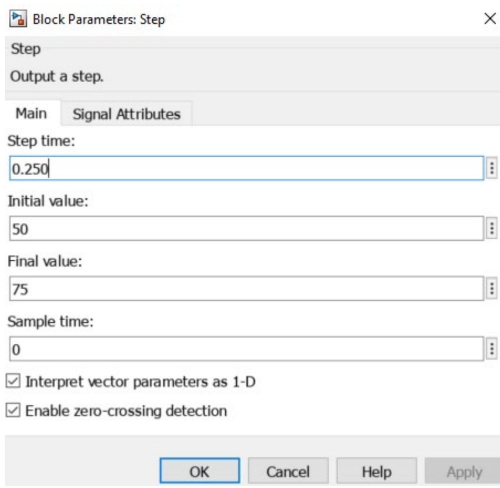

Figure 13. Step in order to achieve desired voltage after 250 ms

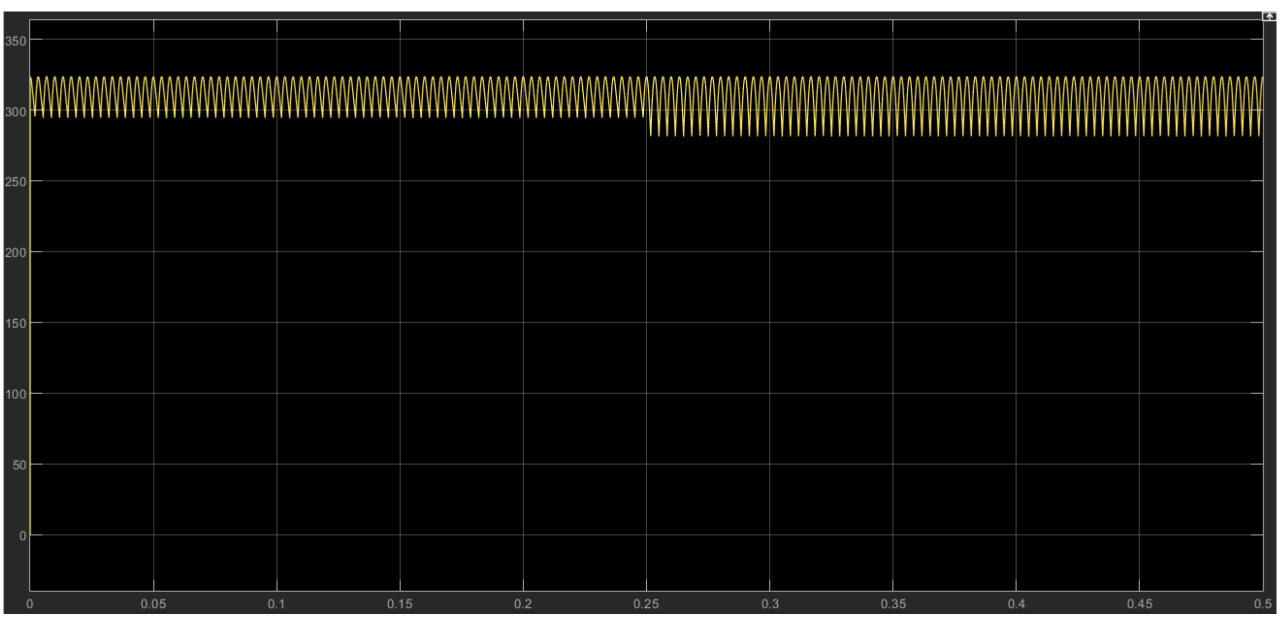

Figure 14. Voltage After Rectifier

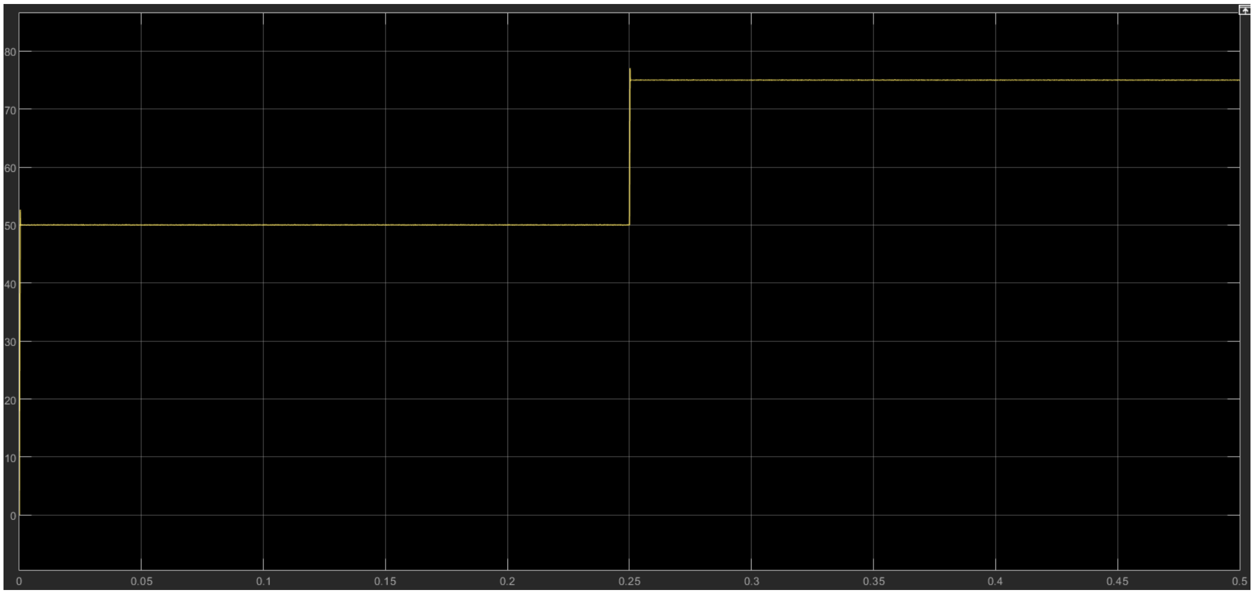

Figure 15. Voltage After Buck using PI Controller