# PROBLEM 1

Please run Problem 1 a, b and then c without clearing your workspace !

## 1a

State Feedback Gain Matrix (K): 0.6446 -7.4479 0.5907
Integral Gain (Ki): -3.2914

## 1b

The stationary error for f = 500 N and r = 0 is almost zero : -5.4436e-09

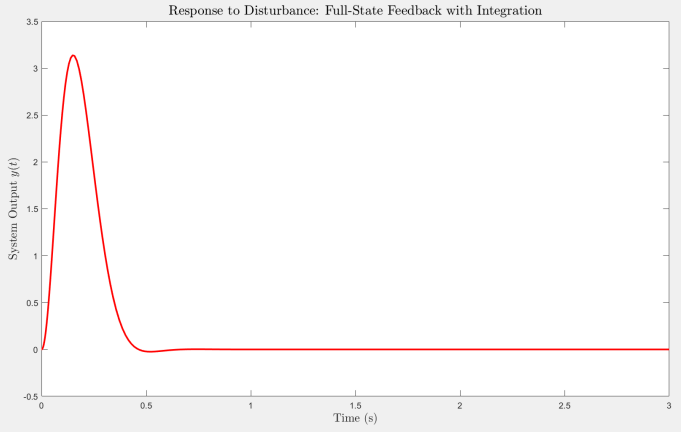


Figure 1: Output y

## 1c

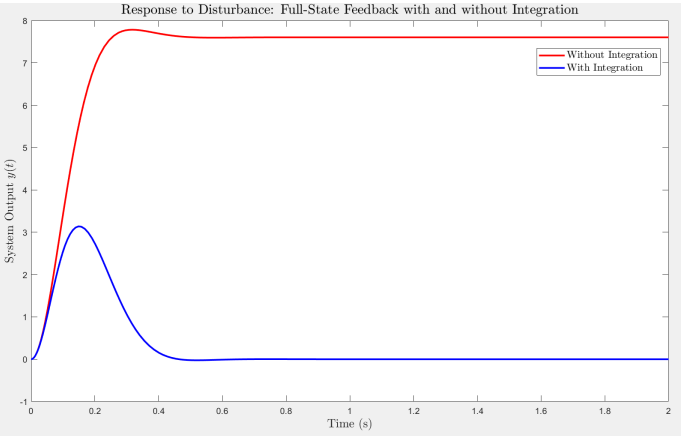


Figure 2: Step Response for Reference Input (r = 1)

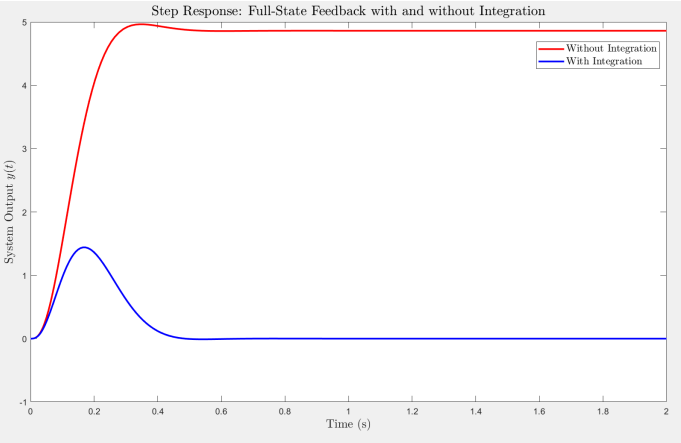


Figure 3: Response to a 500 N Disturbance

# Problem 2a

Using permutation P Matrix for Reordering States

### Transformed $A$ Matrix:

$$A = \begin{bmatrix} -0.0667 & 0 & 0.0499 & 0 \\ 0 & -0.0335 & 0 & 0 \\ 0.0499 & 0 & -0.0499 & 0 \\ 0 & 0 & 0 & -0.0251 \end{bmatrix}$$

### Transformed $B$ Matrix:

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0.0051 & 0.0051 \\ 0.0377 & -0.0377 \end{bmatrix}$$

### Transformed $C$ Matrix:

$$C = \begin{bmatrix} 2.0000 & 0 & 0 & 0 \\ 0 & 0.1000 & 0 & 0 \end{bmatrix}$$

# Problem 2b

### L Matrix

$$L = \begin{bmatrix} 0.6180 & 0 \\ -0.0000 & 0 \end{bmatrix}$$

### M Matrix

$$M = \begin{bmatrix} -0.1116 & 0 \\ 0.0000 & -0.0251 \end{bmatrix}$$

### N Matrix

$$N = \begin{bmatrix} 0.0051 & 0.0051 \\ 0.0377 & -0.0377 \end{bmatrix}$$

### P Matrix

$$P = \begin{bmatrix} -0.0028 & 0 \\ 0.0000 & 0 \end{bmatrix}$$

# Problem 2c

Simulink results

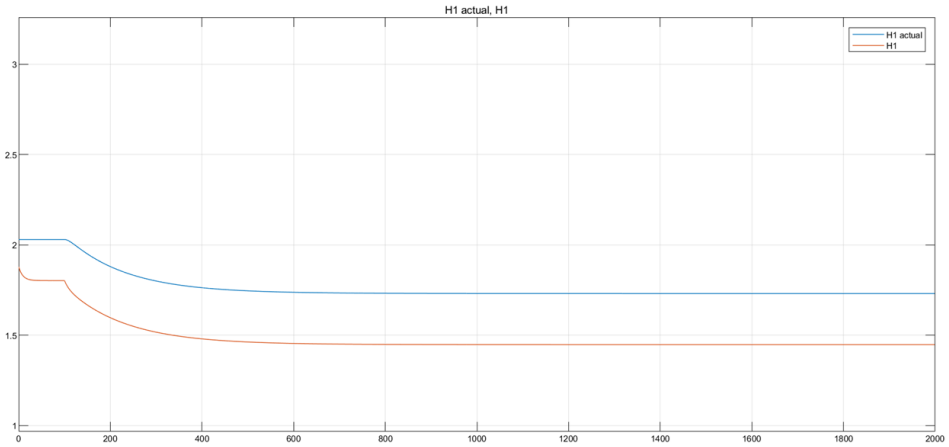


Figure 4: H1

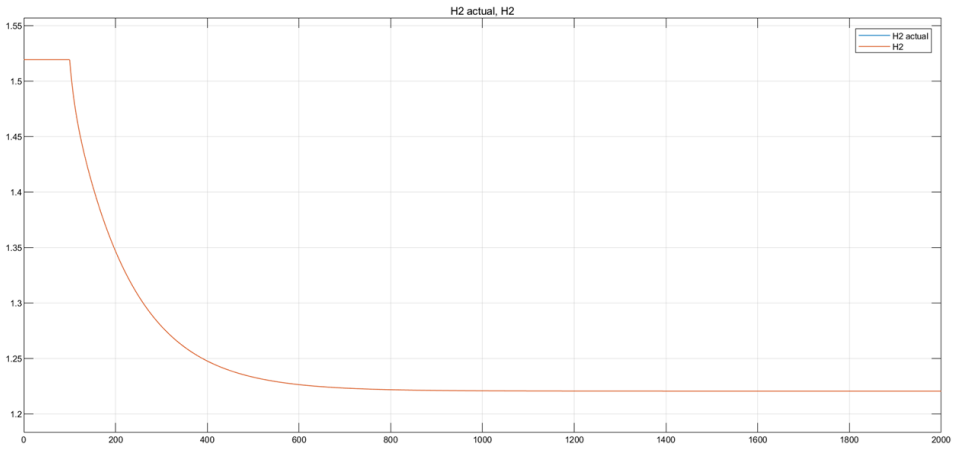


Figure 5: H2

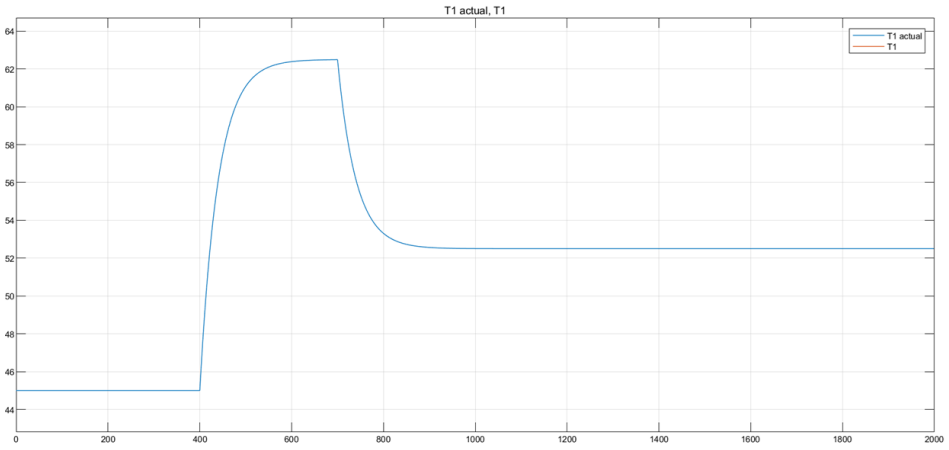


Figure 6: T1

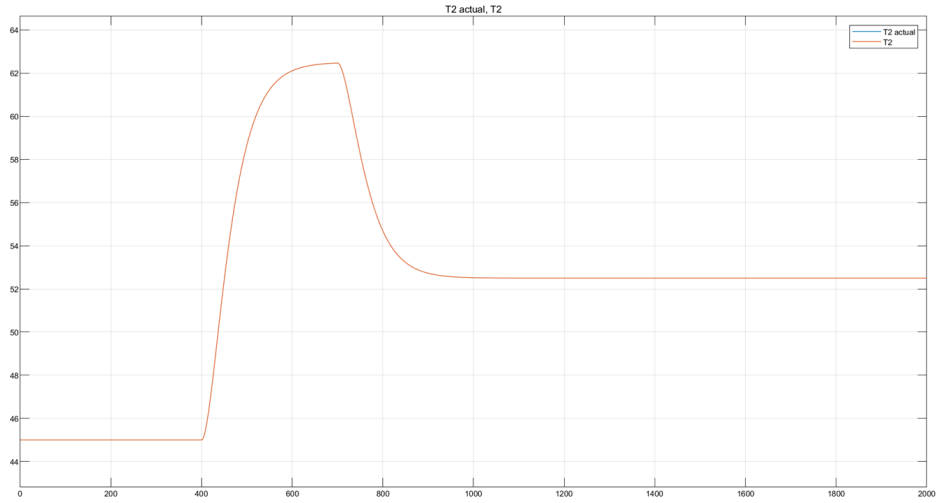


Figure 7: T2

# Problem 3a

## State Feedback Gain ($K$)

$$K = \begin{bmatrix} 1137.30 & -318.69 & -152.40 \end{bmatrix}$$

## First Integrator Gain ($K_i$)

$$K_i = \begin{bmatrix} -817.50 \end{bmatrix}$$

## Second Integrator Gain ($K_{i2}$)

$$K_{i2} = \begin{bmatrix} -817.50 \end{bmatrix}$$

# Problem 3b

The simulation shows that the system successfully tracks the reference signal but kind of exihibits an overshoot and lag, possbily due to high integral gains.

# Problem 3c

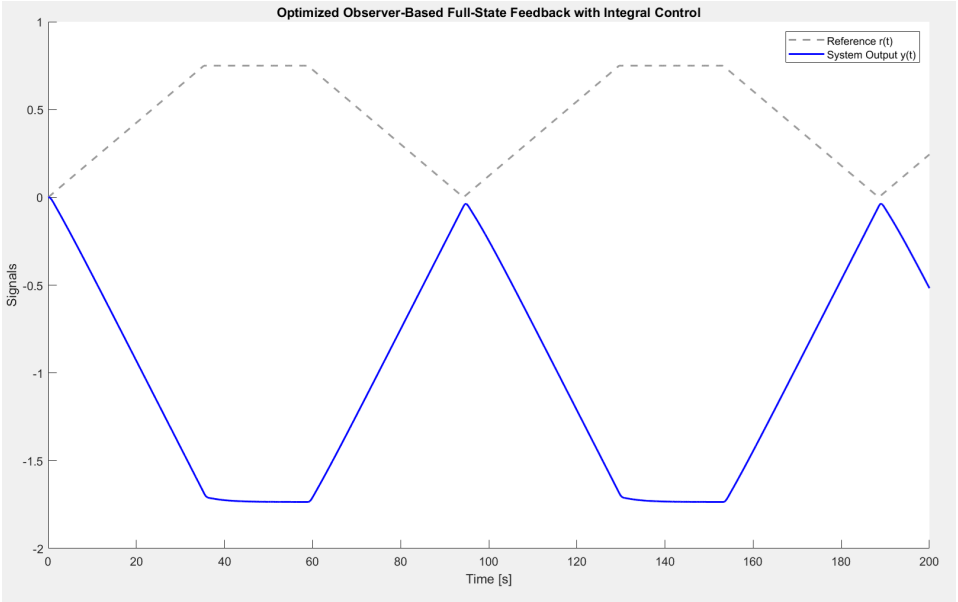


Figure 8: 3c

# Problem 3d

The results of Part (d) are almost identical to Part (c), which in turn confirms that the observer-based full-state feedback controller behaves as expected.

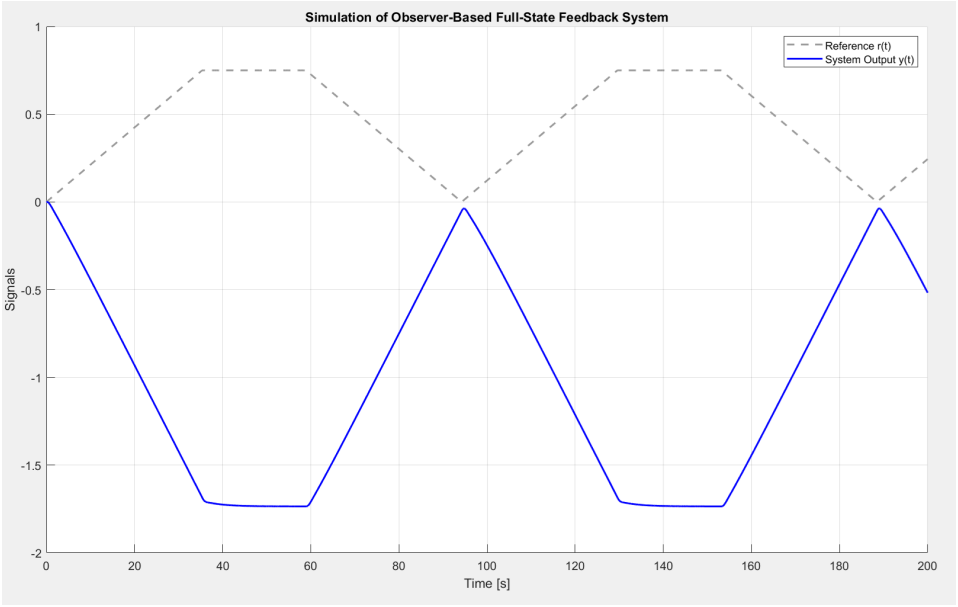


Figure 9: 3d

# Problem 3e

From the bode plot, it can be seen that : The observer-based system - blue dashed line -responds more to low-frequency disturbances than the full-state feedback system - red line. This shows that gradual perturbations may have a larger impact. At high frequencies, both systems perform similarly, successfully rejecting disturbances. The observer provides extra phase lag, which may somewhat delay the disturbance reaction but is expected due to state estimation. If necessary, to move the observer poles to the left I think might improve disturbance rejection.

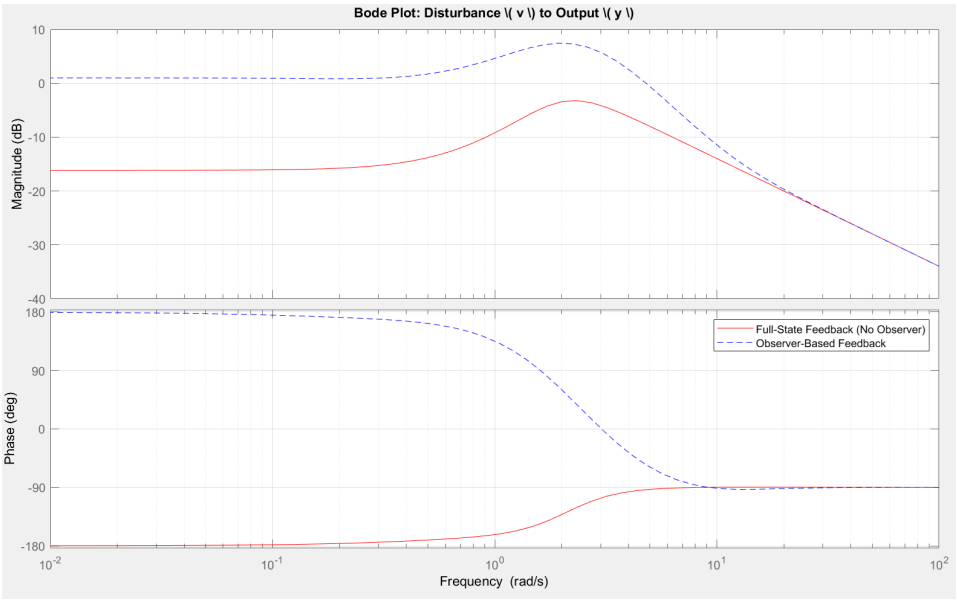


Figure 10: 3e