Contents

***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

1 Stability

2 Routh Hurwitz Criterion

2.0.1. The characteristic equation of linear time invariant system is given by

$$\nabla(s) = s^4 + 3s^3 + 3s^2 + s + k = 0 \tag{2.0.1.1}$$

Find the condition for the system to be BIBO stable using the Routh Array.

Solution:

$$\nabla(s) = s^4 + 3s^3 + 3s^2 + s + k = 0 \tag{2.0.1.2}$$

The Routh hurwitz criterion:-The number of roots of the polynomial that are in the right half-plane is equal to the number of sign changes in the first column.

$$\begin{vmatrix} s^4 \\ s^3 \\ s^2 \\ s^1 \\ s^0 \end{vmatrix} \begin{vmatrix} 1 & 3 & k \\ 3 & 1 & 0 \\ \frac{8}{3} & k & 0 \\ \frac{\frac{8}{3}-3k}{\frac{8}{3}} & 0 & 0 \\ k & 0 & 0 \end{vmatrix} \tag{2.0.1.3}$$

Given system is stable if

$$k > 0, \frac{\frac{8}{3} - 3k}{\frac{8}{3}} > 0 \tag{2.0.1.4}$$

$$\frac{8}{3} - 3k > 0 \tag{2.0.1.5}$$

$$3k < \frac{8}{3} \tag{2.0.1.6}$$

$$(0 < k < \frac{8}{9}) \tag{2.0.1.7}$$

for example the zeros of polynomial $s^4 + 3s^3 + 3s^2 + s + 0.5 = 0$ are

$$s1 = -0.08373 + 0.45773i \tag{2.0.1.8}$$

$$s2 = -0.08373 - 0.45773i \tag{2.0.1.9}$$

$$s3 = -1.41627 + 0.55075i \tag{2.0.1.10}$$

$$s4 = -1.41627 - 0.55075i \tag{2.0.1.11}$$

2.0.2. Modify the Python code in Problem to verify your solution by choosing two different values of k.

Solution: The following code

```
codes/ee18btech11008/ee18btech11008.py
```

provides the necessary soution.

- In first case,k=0.5 which is in the range of $(0, \frac{8}{9})$ has no sign changes in first column of its routh array.So the system is stable.
- In second case,k=3 which is not in the range of $(0, \frac{8}{9})$ has 2 sign changes in first column of its routh array.So the system is unstable.

3 Compensators

4 Nyquist Plot