

## CONTENTS

1	Stability	1
2	Routh Hurwitz Criterion	1
3	Compensators	1
4	Nyquist Plot	1

**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

$$\nabla(s) = s^4 + 3s^3 + 3s^2 + s + k = 0 \quad (2.0.1.1)$$

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

**Solution:**

$$\nabla(s) = s^4 + 3s^3 + 3s^2 + s + k = 0 \quad (2.0.1.2)$$

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.

$$\begin{array}{c|ccc} s^4 & 1 & 3 & k \\ s^3 & 3 & 1 & 0 \\ s^2 & \frac{8}{3} & k & 0 \\ s^1 & \frac{\frac{8}{3}-3k}{\frac{8}{3}} & 0 & 0 \\ s^0 & k & 0 & 0 \end{array} \quad (2.0.1.3)$$

Given system is stable if

$$k > 0, \frac{\frac{8}{3} - 3k}{\frac{8}{3}} > 0 \quad (2.0.1.4)$$

$$\frac{8}{3} - 3k > 0 \quad (2.0.1.5)$$

$$3k < \frac{8}{3} \quad (2.0.1.6)$$

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

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

$$s1 = -0.08373 + 0.45773i \quad (2.0.1.8)$$

$$s2 = -0.08373 - 0.45773i \quad (2.0.1.9)$$

$$s3 = -1.41627 + 0.55075i \quad (2.0.1.10)$$

$$s4 = -1.41627 - 0.55075i \quad (2.0.1.11)$$

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 solution.

- 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