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**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

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

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

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

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

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

1 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.

## 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:-

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

Given system is stable if

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

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

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

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

## 3 COMPENSATORS

## 4 NYQUIST PLOT