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

2.1. **Question** In the feedback system given below

$$G(s) = \frac{1}{(s+1)(s+2)(s+3)} \tag{2.1.1}$$

The positive value of k for which the gain margin of system is exactly 0 dB and phase margin of system is exactly 0 degree is?

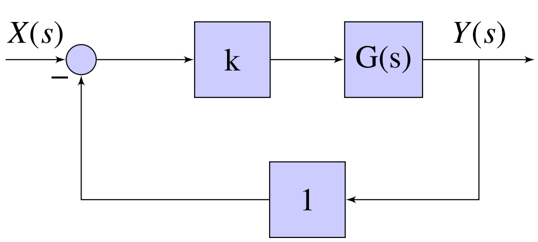


Fig. 2.1

2.1

2.2.

2.3. **Technique description** As given in question we see that gain margin is 0 dB and phase margin is 0 degrees. This implies that system is just enough stable and will become destabilized on just small increase in gain. Hence the system is marginbally stable.
The stability of the system can be checked by Routh-Hurwitz Stability Criterion

2.4. **Routh Hurwitz Criterion** Sufficient condition for Routh-Hurwitz Stability Criterion:The sufficient condition is that all the elements of the first column of the Routh array should have the same sign. This means that all the elements of the first column of the Routh array should be either positive or negative.

2.5. the Routh array for characteristic equation

$$q(s) = a_0 s^n + a_1 s^{n-1} + ... + a_{n-1} s + a_n = 0 \tag{2.5.1}$$

can be constructed as:

$$\begin{vmatrix} s^n \\ s^{n-1} \\ s^{n-2} \\ \vdots \end{vmatrix} \begin{vmatrix} a_0 & a_2 & a_4 & \cdots & \\ a_1 & a_3 & a_5 & \cdots & \\ b_1 & b_2 & b_3 & \cdots & \\ \vdots & \vdots & \vdots & \ddots & \vdots\cdots \end{vmatrix} \tag{2.5.2}$$

where

$$b_1 = \frac{a_1 a_2 - a_0 a_3}{a_1} \tag{2.5.3}$$

$$b_2 = \frac{a_1 a_4 - a_0 a_5}{a_1} \tag{2.5.4}$$

$$c_1 = \frac{b_1 a_3 - a_1 b_2}{b_1} \tag{2.5.5}$$

$$c_2 = \frac{b_1 a_5 - a_1 b_3}{b_1} \tag{2.5.6}$$

2.6. **Solution** The Routh array for equation

$$s^3 + 6s^2 + 11s^1 + (6+k) \tag{2.6.1}$$

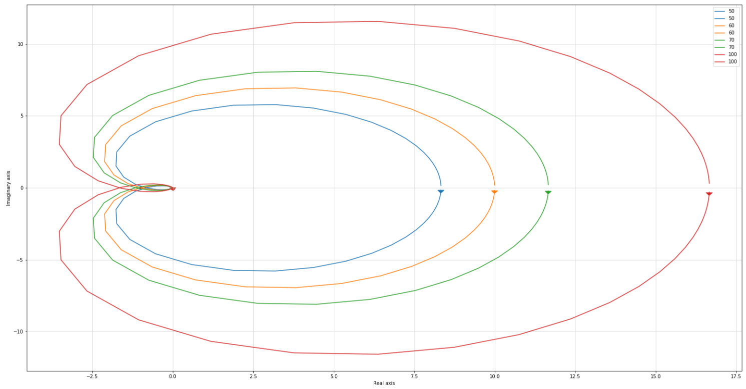
$$\begin{vmatrix} s^3 \\ s^2 \\ s^1 \\ s^0 \end{vmatrix} \begin{vmatrix} 1 & 11 \\ 6 & (6+k) \\ \frac{66-(6+k)}{6} & 0 \\ (6+k) & 0 \end{vmatrix} \tag{2.6.2}$$

2.7. Now since the system is marginally stable therefore s^1 row is ≥ 0
So

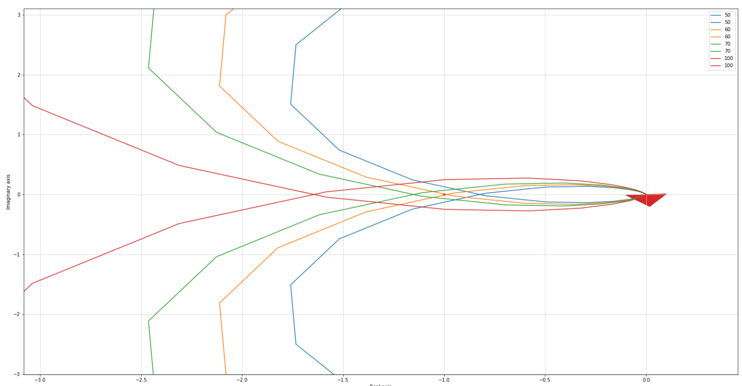
$$\frac{66-(6+K)}{6} > 0 \tag{2.7.1}$$

Hence

$$k = 60 \tag{2.7.2}$$



2.8.
Verification using Plots



3 Compensators

4 Nyquist Plot