

## EXERCISE 5

### STABILITY ANALYSIS USING BODE PLOT

**Date:**

**Reg. No. :**

**LAB PREREQUISITES:**

Exercise 1 to 4

**PREREQUISITE KNOWLEDGE:**

Fundamentals of MATLAB programming

**OBJECTIVES:**

The objective of this exercise is to analyze the stability of the system with help of Bode plot using MATLAB.

**PRELAB:**

Draw a Bode plot for the given open loop transfer function.

**BODE PLOT:**

Bode Plot deals with the frequency response of a system simultaneously in terms of magnitude and phase. More precisely, the log-magnitude and phase frequency response curves are known as Bode Plots. Such plots are useful due to the following reasons: – For designing lead compensators – For finding stability, gain and phase margin. For finding stability, gain and phase margin – For system identification from the frequency response.

Rules for Construction of Bode Plots:

Follow these rules while constructing a Bode plot.

- Represent the open loop transfer function in the standard time constant form.
- Substitute,  $s=j\omega$  in the open loop transfer function.
- Find the corner frequencies and arrange them in ascending order.
- Consider the starting frequency of the Bode plot as  $1/10^{\text{th}}$  of the minimum corner frequency or 0.1 rad/sec whichever is smaller value and draw the Bode plot upto 10 times maximum corner frequency.
- Draw the magnitude plots for each term and combine these plots properly.
- Draw the phase plots for each term and combine these plots properly.

**Note** – The corner frequency is the frequency at which there is a change in the slope of the magnitude plot. From the Bode plots, we can say whether the control system is stable, marginally stable or unstable based on the values of these parameters.

- Gain cross over frequency and phase cross over frequency
- Gain margin and phase margin

Phase Cross over Frequency:

The frequency at which the phase plot is having the phase of  $-180^\circ$  is known as **phase cross over frequency**. It is denoted by  $\omega_{pc}$ . The unit of phase cross over frequency is **rad/sec**.

Gain Cross over Frequency:

The frequency at which the magnitude plot is having the magnitude of zero dB is known as **gain cross over frequency**. It is denoted by  $\omega_{gc}$ . The unit of gain cross over frequency is **rad/sec**.

The stability of the control system based on the relation between the phase cross over frequency and the gain cross over frequency is listed below.

- If the phase cross over frequency  $\omega_{pc}$  is greater than the gain cross over frequency  $\omega_{gc}$ , then the control system is **stable**.
- If the phase cross over frequency  $\omega_{pc}$  is equal to the gain cross over frequency  $\omega_{gc}$ , then the control system is **marginally stable**.
- If the phase cross over frequency  $\omega_{pc}$  is less than the gain cross over frequency  $\omega_{gc}$ , then the control system is **unstable**.

Gain margin GM:

GM is equal to negative of the magnitude in dB at phase cross over frequency.

$$GM = 20 \log \left( \frac{1}{M_{pc}} \right) = 20 \log M_{pc}$$

Where,  $M_{pc}$  is the magnitude at phase cross over frequency. The unit of gain margin (GM) is **dB**.

Phase Margin:

The formula for phase margin PM is

$$PM = 180^\circ + \phi_{gc}$$

Where,  $\phi_{gc}$  is the phase angle at gain cross over frequency. The unit of phase margin is **degrees**.

The stability of the control system based on the relation between gain margin and phase margin is listed below.

- If both the gain margin GM and the phase margin PM are positive, then the control system is **stable**.
- If both the gain margin GM and the phase margin PM are equal to zero, then the control system is **marginally stable**.
- If the gain margin GM and / or the phase margin PM are/is negative, then the control system is **unstable**.

**PROGRAMS, OBSERVATIONS AND INFERENCES**

**1. Write the Matlab program for drawing the Bode plot for the given system and also list out different gain and phase margin by varying the gain value 'K' of the open loop system. By considering the phase margin as reference, draw the step responses for stable and unstable systems by choosing proper 'K' values.**

**PROGRAM**

```

clc;
clear all;
close all;
num=[1];
den=[1 6 5 0];
sys=tf(num,den)
w=logspace(-1,2,400);
for k=1:3:40
    [mag, phase, w]=bode(k*sys,w);
    [gm,pm,wgc,wpc]=margin(mag,phase,w);
    fprintf('gain');disp(k);
    fprintf('gain cross over frequency');disp(wgc);
    fprintf('phase cross over frequency');disp(wpc);
end
k1=input('Enter the stable k1');
figure(1);
bode(k1*sys,w);
sys1=feedback(k1*sys,1)
figure(2);
step(sys1);
k2=input('Enter the unstable system k2');
figure(3);
bode(k2*sys,w);
sys2=feedback(k2*sys,1)
figure(4);
step(sys2);

```



**RESULTS & INFERENCES:**

Evaluation Component	Maximum Marks	Marks Obtained
Pre-lab Tasks	10	
In-Lab Tasks	20	
Post-lab Tasks	10	
Bonus Tasks	10	
Signature of Faculty with Date		

*(This page must be the last page of the exercise)*