Laboratory Work 3

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1. Introduction

In this lab we were tasked with estimating gain, phase and delay margins by using mathematical model and verify this calculation from the real system. We need to design a controller by using the given specifications and determine the GM, PM, and DM from the bode plots. So that we can compare these results with real system.

2. Laboratory Work

PART 1

The controller Design is given as like this:

$$G_c(s) = (\frac{1}{s+\tau_{LPF}})(\frac{K_c(s+80)}{s})$$

Where $K_c = \frac{1}{K_g}$ and $\tau_{LPF} = \frac{3}{\tau_P}$. From lab1: $K_g = 14$ and $\tau_P = 0.1022$

So, we get, $\boldsymbol{K_c = 1/7}$ **and** $\boldsymbol{\tau_{LPF} = 29.35}$

By using this MATLAB code ($G_c(s) * G_p(s)$):

```
num = [2 160];

den= [0.1022 3.99957 29.35 0];

sys = tf(num,den);

bode(sys);

margin(sys)

allmargin(sys)
```

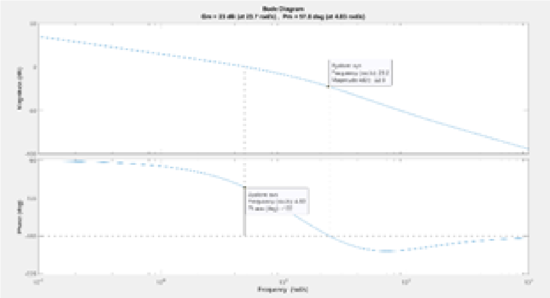

Figure 1 (Bode Plot-GM and PM are marked)

From Figure 1, we can see that the **GM = 23 dB and PM = 57.82°**

And $\boldsymbol{\omega_c} = \mathbf{4.8318}\ rad/s = \mathbf{276.841}$°/s

As a result, $\boldsymbol{DM}(\boldsymbol{delay\ margin}) = \frac{\boldsymbol{PM}}{\boldsymbol{\omega_c}} = \frac{\mathbf{57.82}}{\mathbf{276.842}} = \mathbf{0.208\ s}$

PART 2 - GM

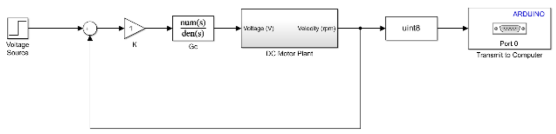

Figure 2 (lab3_step_GM.slx)

We used the Simulink diagram in figure 2 to calculate the GM. Controller is the one we found in the previous part and we need to give different values to **K** in order to find the range that the system becomes unstable. Input is set to 40u(t).

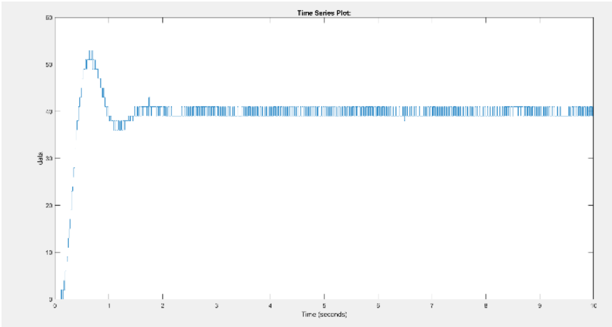

Figure 3 (K = 1, **STABLE**)

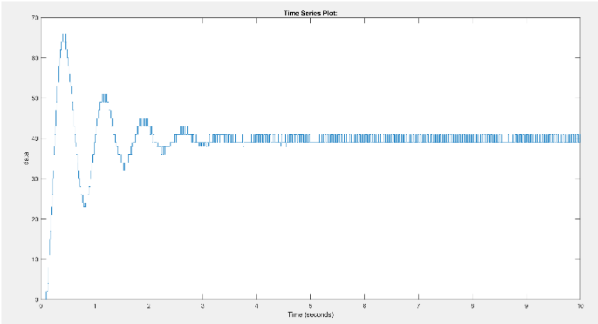

Figure 4 (K = 2, **STABLE**)

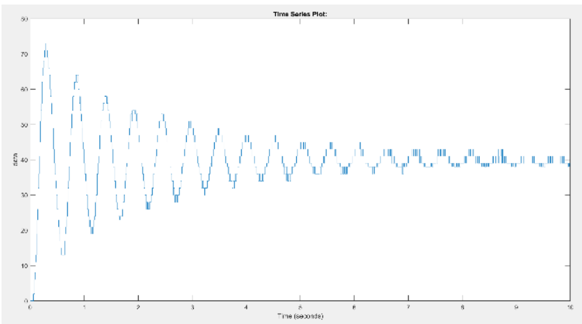

Figure 5 (K = 4, **STABLE**)

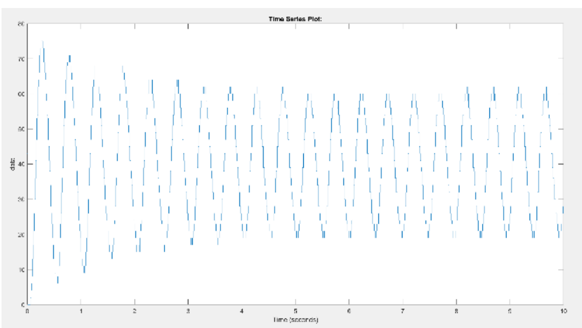

Figure 6 (K = 5, **BARELY STABLE**)

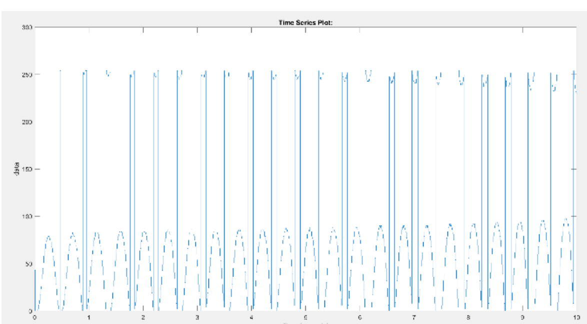

Figure 7 (K = 6, **UNSTABLE**)

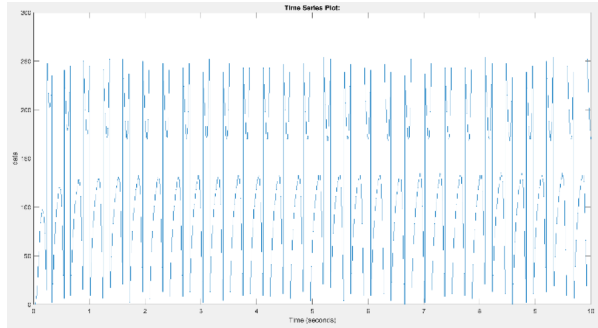

Figure 8 (K = 15, **UNSTABLE**)

As you can see from the figure the system becomes when the K value exceeds the 6. Which corresponds to **GM=20log(K) ~ 15.563 Db**

PART 2 – DM

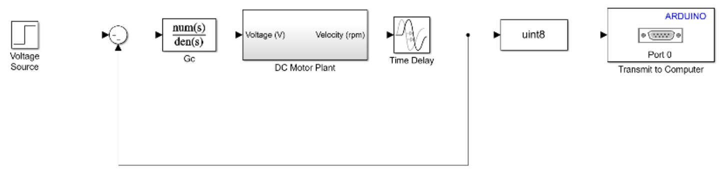

Figure 9 (lab3_step_DM.slx)

In here you see from the Simulink file that we can change the time delay of the system. This will enable us to find DM of the system. Input is one again set to 40u(t).

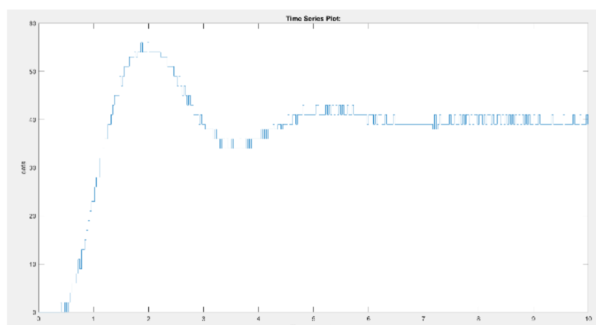

Figure 10 (Delay = 0.01, **STABLE**)

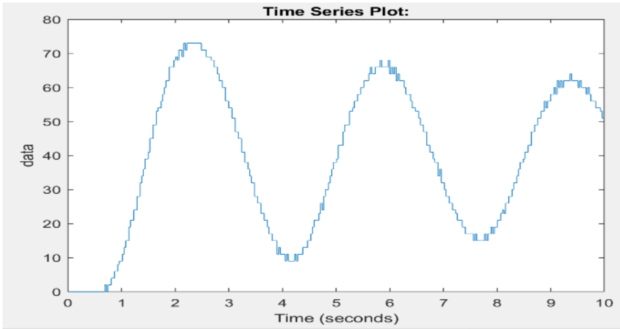

Figure 11 (Delay = 0.1, **STABLE**)

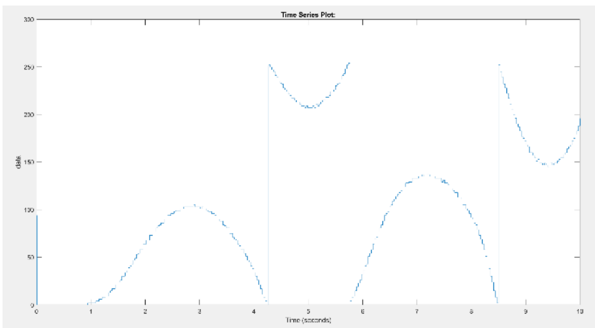

Figure 12 (Delay = 0.2, **UNSTABLE**)

As you can see from the figures that the **DM is close to 0.2 seconds.**

3. Conclusion

The estimated GM was 23 dB and DM was 0.201 seconds. Calculated GM is 15.563 dB and DM is close to 0.2 seconds. Delay margin is reasonably close to the estimated value and the gain margin is slightly less than the estimated value. Even though our mathematical model is just an approximation, the calculated and estimated results appear to be reasonably close to each other. It seems that the gain margin is little bit less in the real system compared to its mathematical model.