National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering and Computer Science

Faculty Member: Ma'am Neelma Naz **Dated:** 21/09/2022

Semester: 6th **Section:** BEE 12C

EE379: Control Systems

Lab 11: **PID controller Implementation for QNET DC Motor**

Lab Instructor: Sir. Yasir Rizwan

Group Members

Student Name	Reg. No.	Lab Report Marks / 10	Viva Marks / 5	Total /15
Muhammad Ahmed Mohsin	333060			
Imran Haider	332569			
Zafar Azhar	340908			

1 TABLE OF CONTENTS

PID controller Implementation for QNET DC Motor

2 OBJECTIVES

The objectives of this lab are:

1. Understand the principles of PID control based on specific applications.

2. Design a PID controller using MATLAB and analyze its performance in terms of stability, settling time, and steady-state error for a given application.

3. Tune the three different gains of PID controller to get the desired response in each case.

3 LAB TASK 1

Design Problem 1 : Design of proportional controller for motor speed Using the techniques learnt in lab 10 and the model of QNET DC motor found in lab 3, design a simple proportional controller for the speed control of the DC motor. The controller should meet the following specifications : 1. %OS < 25% 2. Settling time is less than 0.5 seconds.

3.1 MATLAB CODE

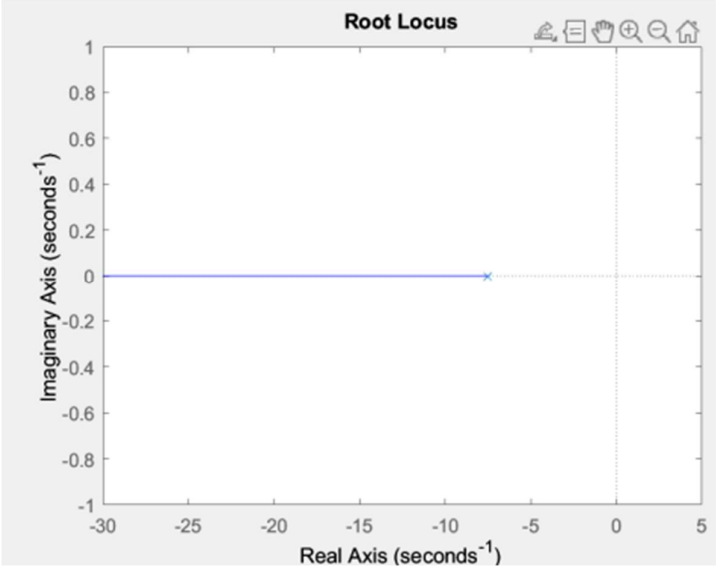
```
%# Clear the workspace and command window
clear
clc

%# Define the numerator and denominator of the open-loop system
num = [25];
den = [1 7.5];

%# Create the transfer function of the open-loop system
sys = tf(num, den);

%#%% Open-loop system properties
%# Get the step response information of the open-loop system
sys_param = stepinfo(sys);

%# Get the steady-state error of the open-loop system
```

```
SSError = abs(1-dcgain(sys));

%%% Proportional controller
%% Plot the root locus of the open-loop system
rlocus(sys);

%% Define the proportional gain
Kp = 0.3;

%% Create the proportional controller
ctrl = zpk([],[],Kp);

%% Create the closed-loop system
sys_cl = feedback(series(ctrl,sys),1);

%% Get the step response information of the closed-loop system
sys_param = stepinfo(sys_cl);

%% Get the steady-state error of the closed-loop system
SSError = abs(1-dcgain(sys_cl));
```

3.2 SCREENSHOT

```
sys_param =

  struct with fields:

        RiseTime: 0.292934199550913
   TransientTime: 0.521609926045303
    SettlingTime: 0.521609926045303
     SettlingMin: 3.015002471326164
     SettlingMax: 3.333245657733601
       Overshoot: 0
      Undershoot: 0
            Peak: 3.333245657733601
        PeakTime: 1.406111963454989


SSError =

   2.333333333333333
```

```
sys_param =

  struct with fields:

        RiseTime: 0.146467099775456
   TransientTime: 0.260804963022653
    SettlingTime: 0.260804963022653
     SettlingMin: 0.452250370698926
     SettlingMax: 0.499986848660040
       Overshoot: 0
      Undershoot: 0
            Peak: 0.499986848660040
        PeakTime: 0.703055981727505


SSError =

   0.500000000000000
```



We observe that the overshoot is less that 25 percent and settling time is between 0.25 to 0.5 seconds.

4 LAB TASK 2

Design Problem 6 : Design and implementation of a PD controller for motor position Design a PD controller for the position control of the DC motor, to meet the following specifications : 1. OS < 25% 2. Settling time is less than 0.5 seconds.

4.1 MATLAB CODE:

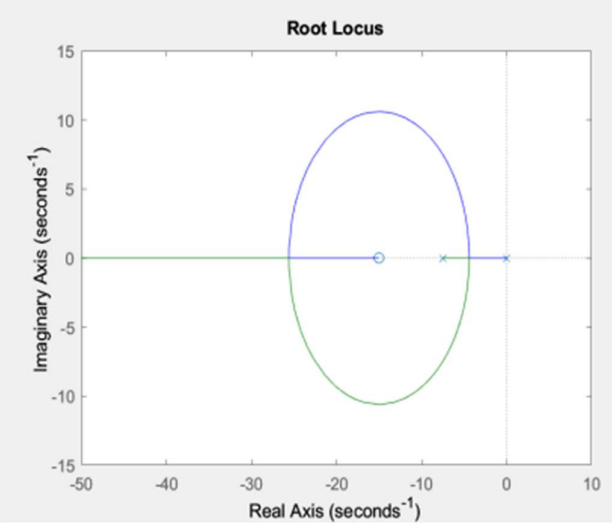
```
%# Clear the workspace and command window
clear
clc

%# Define the numerator and denominator of the open-loop system
num = [25];
den = [1 7.5 0];

%# Create the transfer function of the open-loop system
sys = tf(num, den);

%#%% Open-loop system properties
%# Get the step response information of the open-loop system
sys_param = stepinfo(sys);

%# Get the steady-state error of the open-loop system
SSError = abs(1-dcgain(sys));

%#%% PD controller design
%# Display a message
display('Closed Loop System after PD Controller Design');

%# Define the zero location of the compensator
zero_loc = -15;

%# Create the compensator transfer function
compensator = zpk(zero_loc,[],1);

%# Plot the root locus of the open-loop system with the compensator
rlocus(series(compensator,sys));

%# Define the proportional gain and derivative gain of the controller
Kd = 1;
Kp = -Kd*zero_loc;

%# Create the proportional and derivative parts of the controller
ctrl_p = zpk([],[],Kp); %proportional part of controller
ctrl_d = zpk(0,[],Kd); %derivative part of controller
```

```
%# Create the controller transfer function
ctrl = parallel(ctrl_p,ctrl_d);

%# Create the closed-loop system
sys_cl = feedback(series(ctrl,sys),1);

%# Get the step response information of the closed-loop system
sys_param = stepinfo(sys_cl);

%# Get the steady-state error of the closed-loop system
SSError = abs(1-dcgain(sys_cl));
```

4.2 SCREENSHOT:

```
sys_param =

  struct with fields:

        RiseTime: NaN
   TransientTime: NaN
    SettlingTime: NaN
     SettlingMin: NaN
     SettlingMax: NaN
       Overshoot: NaN
      Undershoot: NaN
            Peak: Inf
        PeakTime: Inf


SSError =

   Inf
```

```
Closed Loop System after PD Controller Design

sys_param =

  struct with fields:

         RiseTime: 0.058725397312805
    TransientTime: 0.255119046965670
     SettlingTime: 0.255119046965670
      SettlingMin: 0.914399167802591
      SettlingMax: 1.075174548726858
        Overshoot: 7.517454872685914
       Undershoot: 0
             Peak: 1.075174548726858
         PeakTime: 0.138863593300562


SSError =

     2.220446049250313e-16
```



In this we observe that the overshot in less than 25 percent and the settling time is less that 0.5 seconds as per requirement. Moreover, there were no restrictions on the steady state error.

5 LAB TASK 3

Note that in the transfer function of motor position vs voltage there is a pole at the origin. Therefore, the system type is 1. Consequently, the closed loop system will have zero steady state error for a step input. If the requirement is to have zero steady state error for step input, then we do not need a PI controller. If the input is a ramp, then there will be a non-zero steady state error. In that case we may have a PI compensator to increase the steady state error. Design a PID controller to meet the following specifications. 1. %OS < 25 2. Settling time is less than 0.5 seconds 3. Zero steady state error for ramp input

5.1 MATLAB CODE:

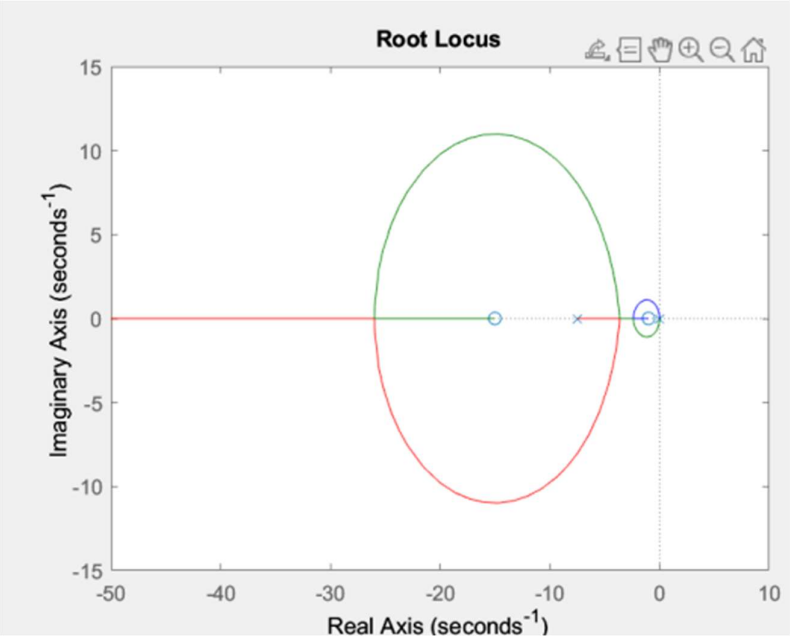
```
%# Clear the workspace and command window
clear
clc

%# Define the numerator and denominator of the open-loop system
num = [25];
den = [1 7.5 0];

%# Create the transfer function of the open-loop system
sys = tf(num, den);

%#%% Open-loop system properties
%# Get the step response information of the open-loop system
sys_param = stepinfo(sys);

%# Get the steady-state error of the open-loop system
SSError = abs(1-dcgain(sys));

%#%% PID controller design
%# Display a message
display('Closed Loop System after PID Controller Design');

%# Define the zero locations of the compensator
zero_loc_pi = -1;
zero_loc_pd = -15;

%# Create the compensator transfer function
compensator = zpk([zero_loc_pi, zero_loc_pd],0,1);

%# Plot the root locus of the open-loop system with the compensator
```

```
rlocus(series(compensator,sys));

%# Define the proportional, integral, and derivative gains of the controller
Kd = 1;
Kp = -(zero_loc_pd+zero_loc_pi)*Kd;
Ki = zero_loc_pd*zero_loc_pi*Kd;

%# Create the proportional, integral, and derivative parts of the controller
ctrl_p = zpk([],[],Kp); %proportional part of controller
ctrl_i = zpk([],0,Ki); %integral part of controller
ctrl_d = zpk(0,[],Kd); %derivative part of controller

%# Create the controller transfer function
ctrl = parallel(parallel(ctrl_p,ctrl_i),ctrl_d);

%# Create the closed-loop system
sys_cl = feedback(series(ctrl,sys),1); % closed loop sys

%# Get the step response information of the closed-loop system
sys_param = stepinfo(sys_cl);

%# Get the steady-state error of the closed-loop system
SSError_Ramp = abs(1-dcgain(sys_cl));

%# Define the ramp input
ramp = tf([1],[1 0]);

%# Create the ramp-modified closed-loop system
sys_cl1 = series(sys_cl,ramp);

%# Get the step response information of the ramp-modified closed-loop system
sys_param = stepinfo(sys_cl1);

%# Get the steady-state error of the ramp-modified closed-loop system
SSError_Ramp = abs(1-dcgain(sys_cl1));
```

5.2 SCREENSHOT:

```
sys_param =

  struct with fields:

         RiseTime: NaN
    TransientTime: NaN
     SettlingTime: NaN
      SettlingMin: NaN
      SettlingMax: NaN
        Overshoot: NaN
       Undershoot: NaN
             Peak: Inf
         PeakTime: Inf


SSError =

   Inf
```

```
sys_param =

  struct with fields:

         RiseTime: 0.055981076240986
    TransientTime: 0.311129475910152
     SettlingTime: 0.311129475910152
      SettlingMin: 0.909477171719281
      SettlingMax: 1.103391783348220
        Overshoot: 10.339178334822051
       Undershoot: 0
             Peak: 1.103391783348220
         PeakTime: 0.137508216319262


SSError_Ramp =

     1.110223024625157e-15
```



In this we observe that the overshoot was less than 25 percent and the settling time is 0.311 seconds which is also less than 0.5 seconds. The steady state error is so small that it can be approximated to zero almost.

6 CONCLUSION:

This lab was a valuable learning experience in the principles and practical applications of PID controllers. We learned how to implement different types of controllers using MATLAB, and obtained specific values for overshoot percentage, settling time, and steady-state error for each type of controller. Through these exercises, we also gained a deeper understanding of the importance of choosing the appropriate controller type for a given system, and the impact of controller parameters on system response. Overall, this lab provided a hands-on opportunity to apply the theoretical concepts of control systems and deepen our understanding of PID control.

Here are some of the key points from the lab:

PID controllers are a type of feedback controller that are widely used in a variety of applications.

PID controllers can be implemented using a variety of methods, including MATLAB.

The performance of a PID controller can be characterized by its overshoot percentage, settling time, and steady-state error.

The choice of PID controller type and parameters can have a significant impact on the performance of the system.

This lab provided a hands-on opportunity to learn about the principles and practical applications of PID controllers.