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PDC LAB

Experiment-1

Aim: To study PID controller tuning using "Ziegler-Nichols" technique in Simulink.

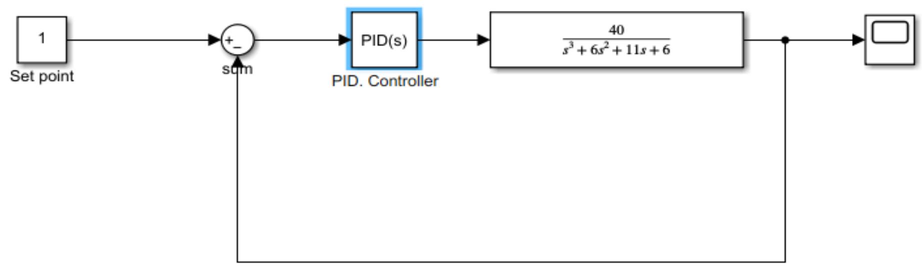
Theory:
A popular method for tuning P, PI, and PID controllers is the Ziegler–Nichols method. Ziegler and Nichols conducted numerous experiments and proposed rules for determining values of K_P, K_I, and K_D based on the transient step response of a plant. This method starts by zeroing the integral and differential gains and then raising the proportional gain until the system is unstable.Z-N tuning is based on frequency response analysis.It can be used graphically or analytically as well. It is a closed loop tuning method that can be used online while the process is in action.
Ultimate Gain – The gain of the controller at which sustained oscillatory behaviour occurs is called ultimate gain($\mathbf{K_U}$).
Ultimate Period – the period of sustained oscillation is termed as ultimate period ($\mathbf{P_U}$).

Controller	Proportional Gain	Integral Times	Derivative Time
P	$K_u/2$		
PI	$K_u/2.2$	$P_u/1.2$	
PID	$K_u/1.7$	$P_u/2$	$P_u/8$

Important-
- The co-relations are determined to provide .25 decay ratio response.
- (Kc)P>(Kc)PI, this is so because integral mode introduces additional phase lag with destabilizing effect, hence lower Kc in PI would compensate this.
- (Kc)PID is the highest, as the derivative action introduces additional phase lead with stabilizing effect.

The procedure is-
- Bring the system to steady-state condition.
- Use only P only controller and close the feedback loop.
- Introduce a setpoint change.
- Vary Kc to get sustained oscillations i.e. constant amplitude.
- The Kc so found is called ultimate gain (Ku), (amplitude ratio=1, phase angle—180).
- The period (Pu) of sustained cycling is also noted.

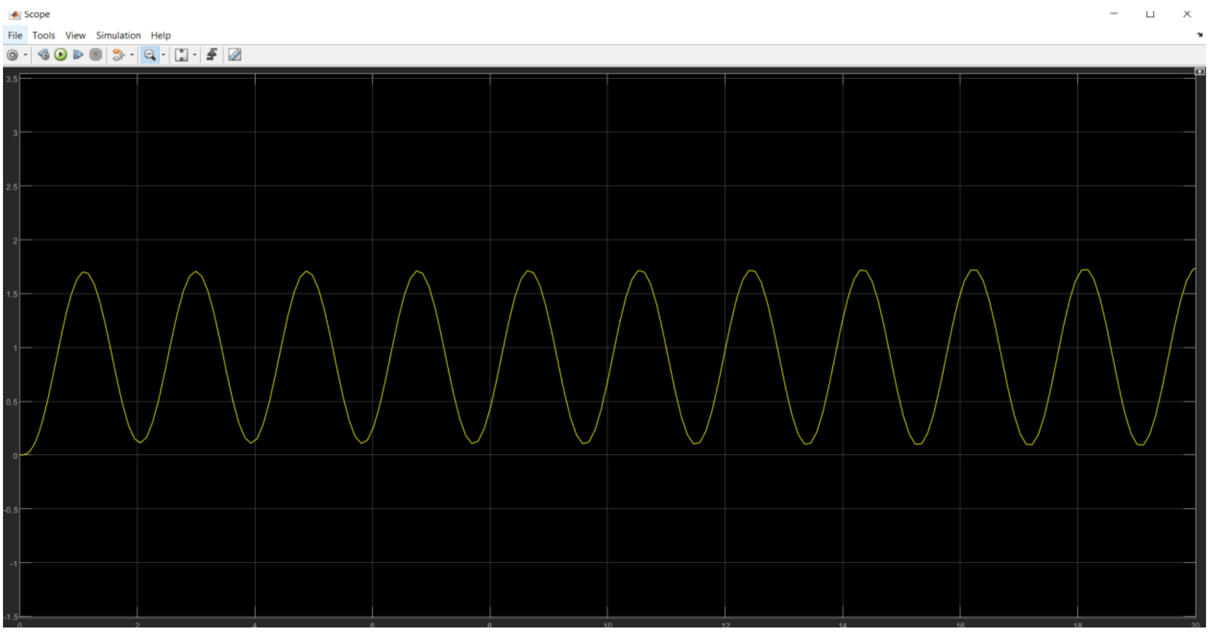
Block diagram



Observations:

For the transfer function $40/(s^3+6s^2+11s+6)$, the above sustained oscillations were found when $\mathbf{K_U=1.498}$ and $\mathbf{P_U=1.89}$

Graph of sustained oscillation by P controller



Calculations/Graphs:

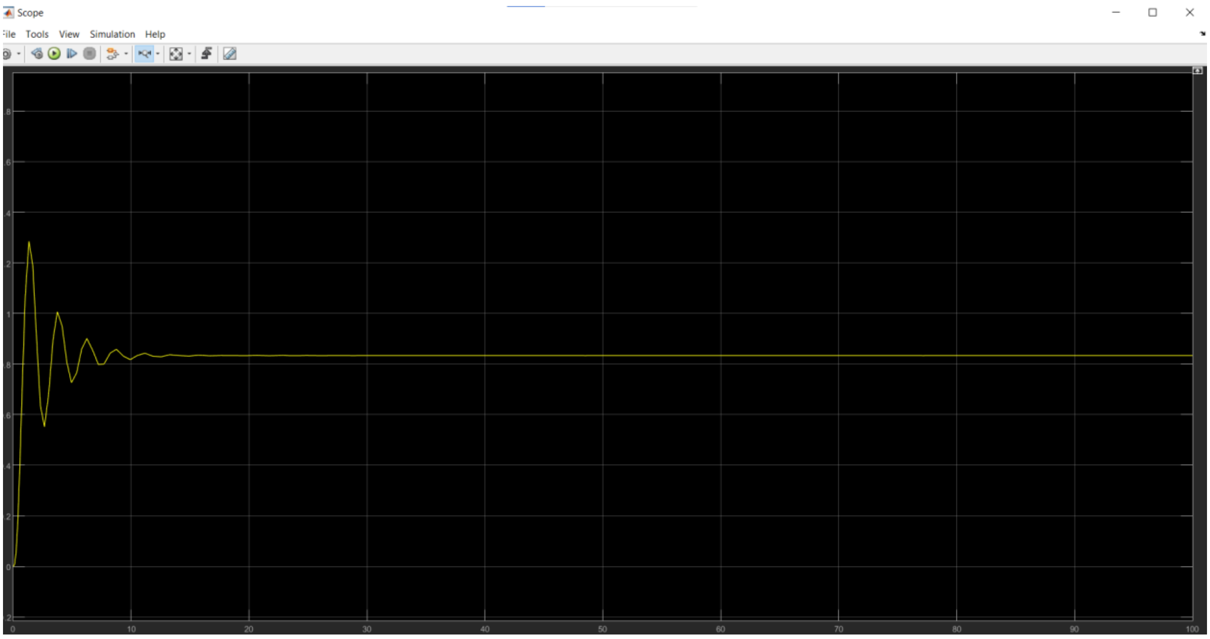
using Ziegler Nichols tuning table (shown above) , calculating the parameters :

Controller	Proportional Gain Kc	Integral Time (τ_I)	Derivative Time(τ_D)
P	0.749		
PI	0.68136	1.583	
PID	0.8817	0.95	.2375

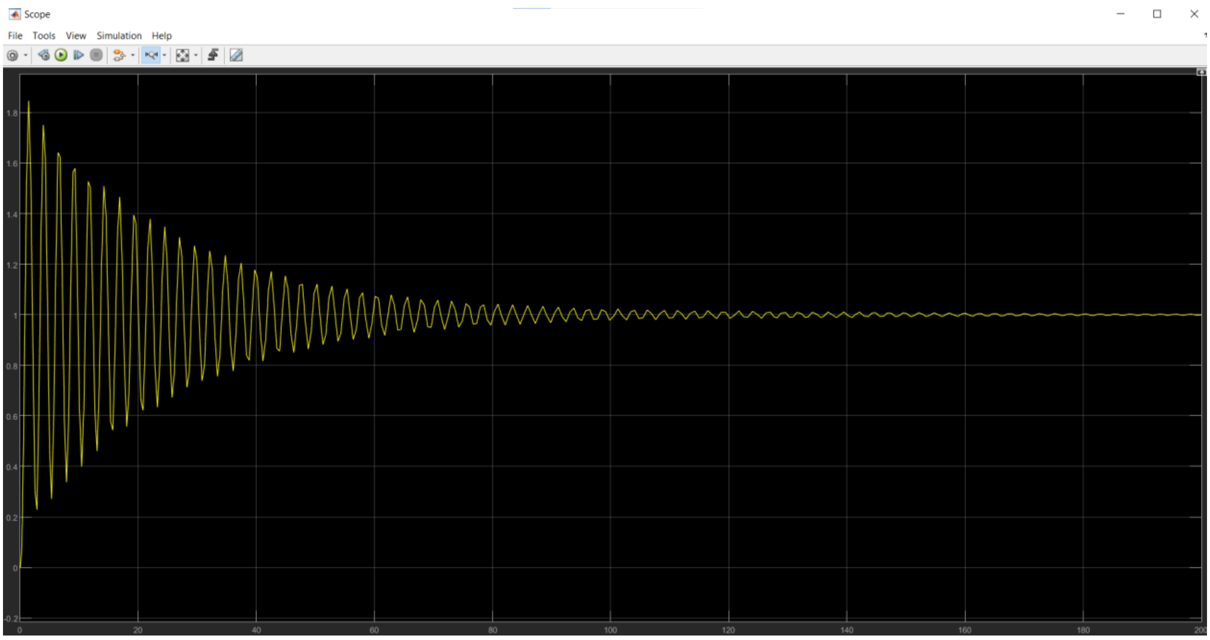
Since the Simulink takes the tuning parameters as, K_C,K_I K_D. Hence,

Controller	Kc	Ki	Kd
P	0.749		
PI	0.6813	0.43033	
PID	0.8817	0.928173	0.2094

● Graph After P Tuning by Ziegler-Nichols method:



● Graph After PI Tuning by Ziegler-Nichols method:



● Graph After PI Tuning by Ziegler-Nichols method:

Results:

- Ziegler- Nichols tuning parameters for <u>PID controller</u> is

  $\mathbf{K_c}$= 0.8817
  $\boldsymbol{\tau_i}$=0.95
  $\boldsymbol{\tau_d}$=0.2375
- Ziegler- Nichols tuning parameters for <u>PI controller</u> is

  $\mathbf{K_c}$= 0.68136 and $\boldsymbol{\tau_i}$=1.5833

Experiment-2

Aim: To study PID controller tuning using "Tyreus Luyben" technique in Simulink.

Theory:

The Tyreus-Luyben procedure is quite similar to the Ziegler–Nichols method but the final controller settings are different. Also this method only proposes settings for PI and PID controllers. These settings that are based on ultimate gain and period are given in the table

Controller	Proportional Gain Kc	Integral Time $(\boldsymbol{\tau_I})$	Derivative Time $(\boldsymbol{\tau_D})$
PI	$K_u/3.2$	$2.2P_u$	
PID	$K_u/2.2$	$2.2P_u$	$P_u/6.3$

The Tyreus Luyben closed-loop tuning method allows you to use the critical gain value K_u and the critical period of oscillation, P_u to calculate K_p . You can obtain the controller constants K_p , τ_I , and τ_D in a system with feedback. The Tyreus Luyben closed-loop tuning method is limited to tuning processes that cannot run in an open-loop environment. Determining the ultimate gain value, K_p. is accomplished by finding the value of the proportional only gain that causes the control loop to oscillate indefinitely at steady state. This means that the gains from the I and D controller are set to zero so that the influence of P can be determined. It tests the robustness of the Kp value so that it is optimized for the controller. Another important value associated with this proportional-only control tuning method is the critical period (P_u). The ultimate period is the time required to complete one full oscillation while the system is at steady state. These two parameters, Ku and Pu are used to find the loop-tuning constants of the controller (P, PI, or PID).

Procedure:

1. Prepare the appropriate block diagram consisting of the set point constant,comparator, controller, process function and scope. The diagram can be prepared with the help of elements present in Simulink library.

2. Now , according to Tyreus Luyben tuning method ,apply only P-controller with appropriate Kc value.

3. Run the simulation and observe the result of scope.

4.Keep on changing the Kc value until sustained oscillations are obtained.

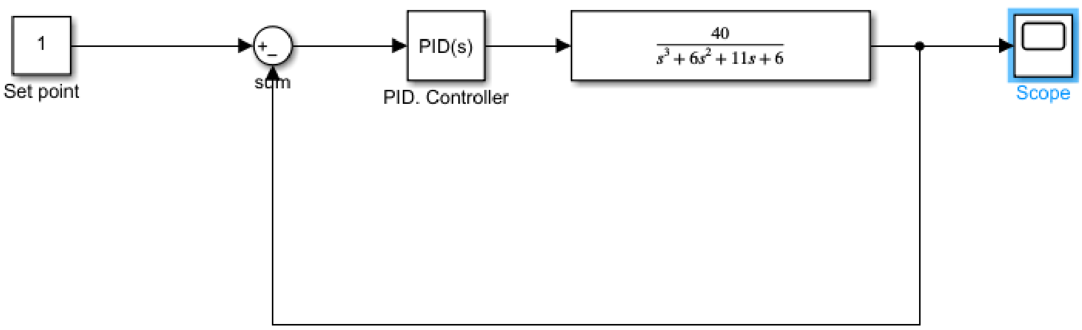
5.Record the Kc value this is the ultimate gain. Also, note down the ultimate period by observing the graph.

6. Using Tyreus Luyben method calculate the various tuning parameters.

7.Apply the calculated parameters according to the type of controller used.

8.Observe the plot in the scope for various controllers. Appropriate graph will be obtained ,if, tuning is done accurately

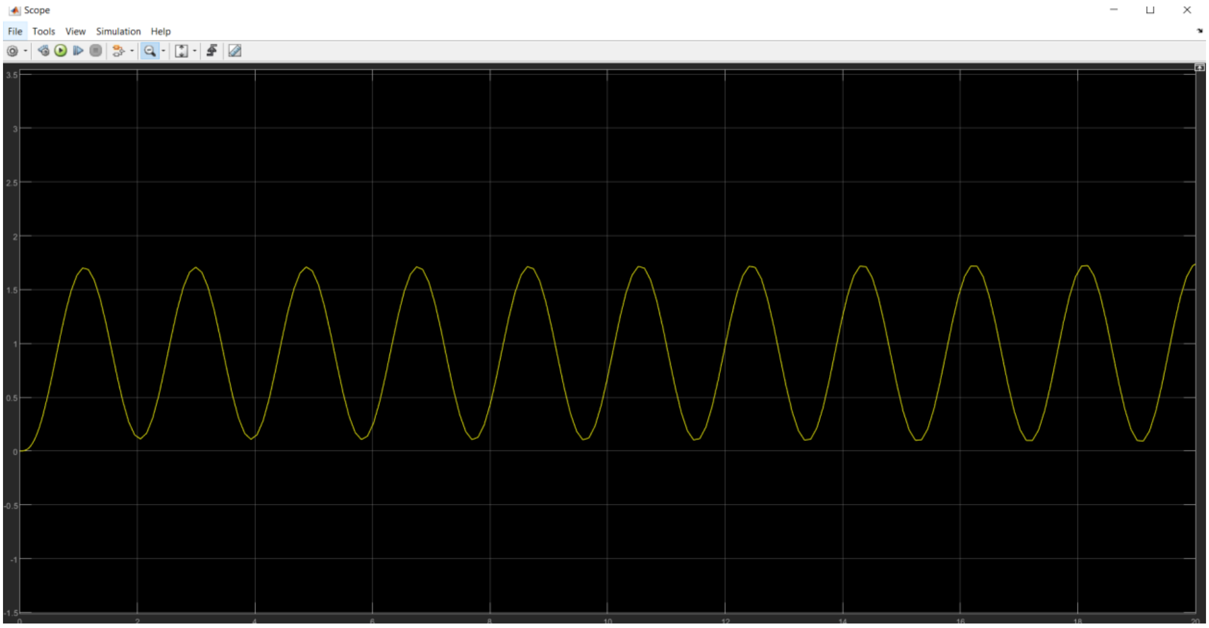
Block Diagram:



Observations:

For the transfer function 40/(s^3+6s^2+11s+6), the above sustained oscillations were found when **K_U=1.498** and **P_U=1.89**

Graph of sustained oscillation by P controller



Calculations/Graphs:

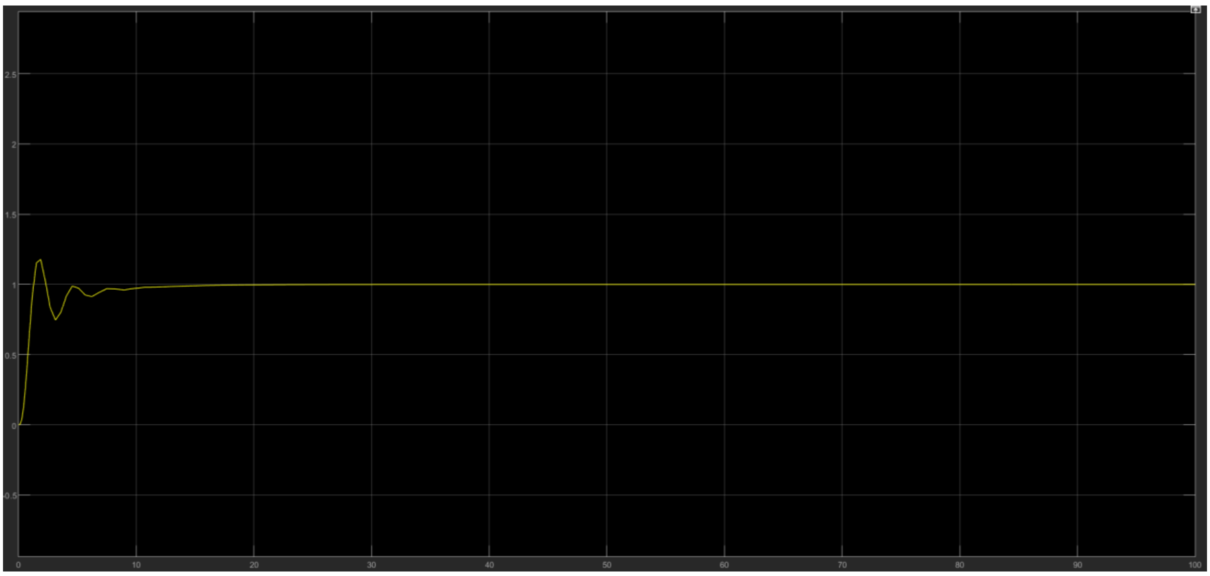
using ***"Tyreus Luyben"*** tuning table (shown above) , calculating the parameters :

Controller	Proportional Gain Kc	Integral Time **(τ_I)**	Derivative Time**(τ_D)**
PI	0.468	4.18	
PID	0.6809	4.18	0.30158

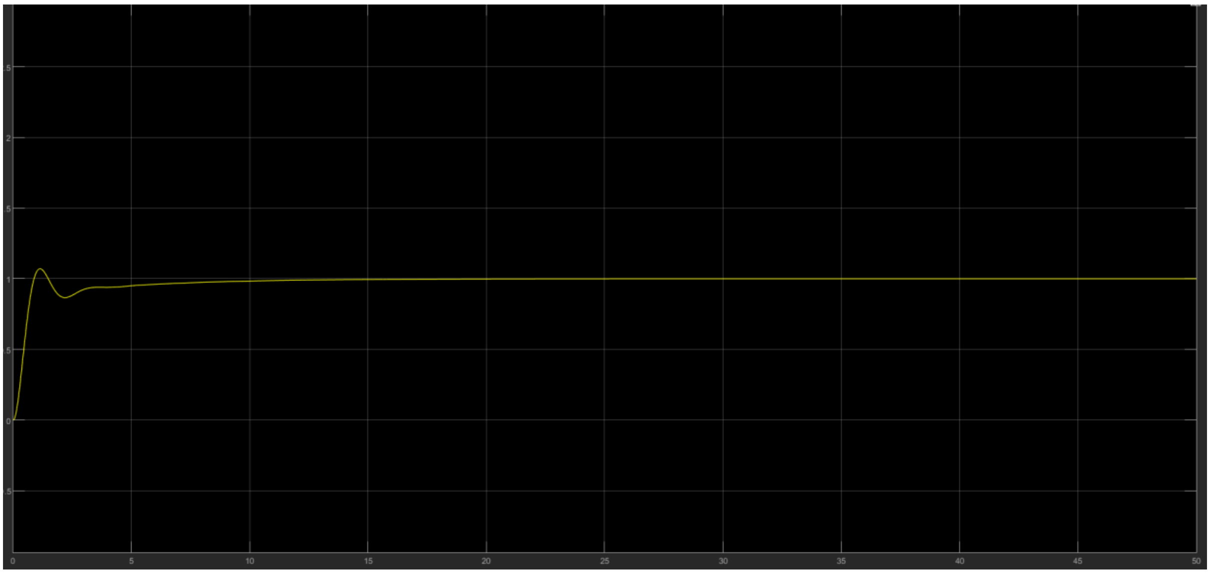
Since the Simulink takes the tuning parameters as, K_C,K_I K_D. Hence,

Controller	**Kc**	**K_I**	**K_D**
PI	0.468	0.11196	
PID	0.680	0.16267	0.20468

- Graph After PI Tuning :



● Graph After PID Tuning :



Results:

- Tyreus Luyben tuning parameters for <u>PID controller</u> is

  $\mathbf{K_c}$= 0.6809

  $\boldsymbol{\tau_i}$= 4.18

  $\boldsymbol{\tau_d}$= 0.30158

- Tyreus Luyben tuning parameters for <u>PI controller</u> is

  $\mathbf{K_c}$= 0.468

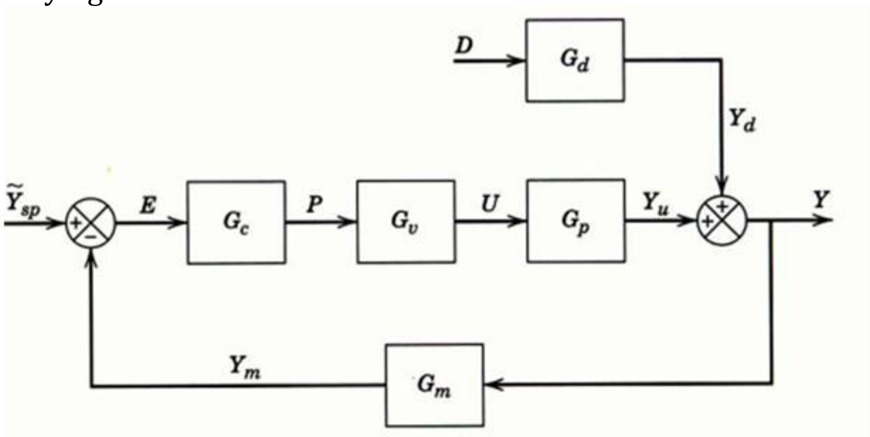
  $\boldsymbol{\tau_i}$= 4.18

Experiment-3

Aim: To study the stability analysis using Root-Locus Diagram in Matlab.

Theory:

1. Root-Locus method is a graphical technique
2. The graph is plotted on a complex plane and roots of the characteristic equation($1+G_{OL}=0$) are plotted.
3. This is done so that the location of all the roots can be seen at a glance with varying Kc.



4. The above is a closed loop block diagram. The transfer function of this is,

   $y' = [G_cG_pG_v/(1+G_cG_pG_mG_v)]y'_{sp} + [G_d/(1+G_cG_pG_mG_v)]d'$

   taking a servo case($d'=0$),

   $y' = [G_cG_pG_v/(1+G_cG_pG_mG_v)]y'_{sp}$

   Now $G_{OL} = G_cG_pG_mG_v$ (transfer function for open loop system).

Procedure:

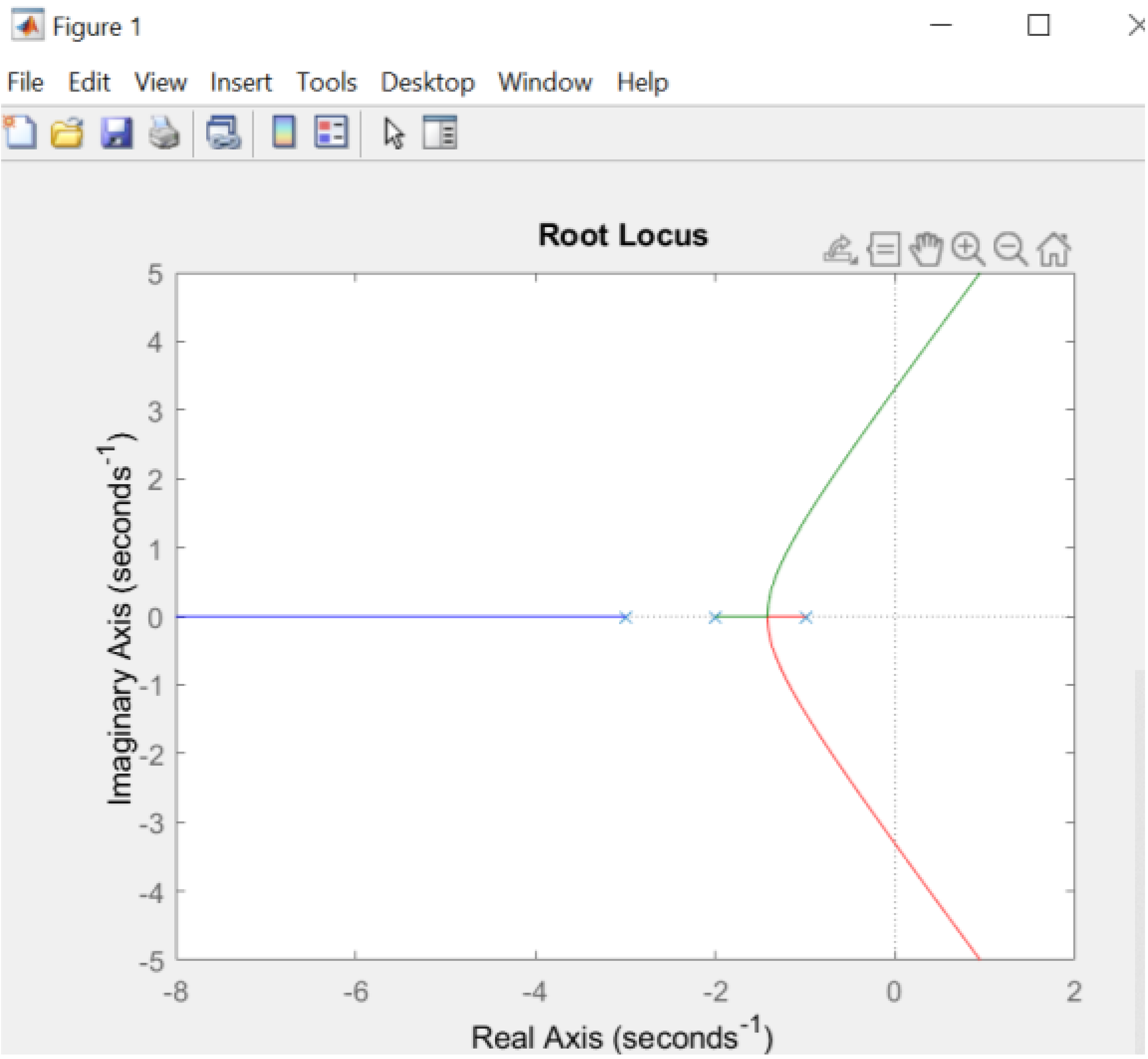
1. We will plot the graph in MATLAB UI.
2. Write the code for the program. We have the transfer function for open loop system.

   $$G_{OL}(s)=4/(s^3+6s^2+11s+6)$$

   and Kc=[0,20]
3. MATLAB CODE

```
process=tf([4],[1 6 11 6]); % coefficients of numerator and denominator
k=[0:1:20]; % range of Kc
rlocus(process,k,'-*') % gives the plot on complex plane
```

Observations:



The above graph is plotted in MATLAB.

Results:

1. When Kc=0,the 3 roots of the characteristic equation, i.e. -3,-2 and-1 are **on the real axis** (**Stable**).
2. As K_c increases,the roots move **away from the real axis(on the left plane)**,giving a more **oscillating response**.
3. When the roots are **on the imaginary axis**,the system is **marginally/critically stable**.
4. When K_c value further increases, the roots move to the **right side of the imaginary axis** and the system becomes **unstable**.

Inference(s):

✓ The number of root loci(branches)= number of poles of G_{OL}.
✓ When K_c>15 , then system becomes unstable.