Experiment No.: - 3

OPTIMIZATION OF COMPENSATOR GAIN

Aim of Experiment: Design a MATLAB Simulink to optimize the compensator gain to satisfy performance indexes (ISE, IAE, ITSE, ITAE) requirements for the problem shown below.

Problem: Referring to the block diagram of Fig. 1, consider that G(s)=100/s^2 and R(s)=1/s. Determine the optimal value of parameter K such that

a. $J_1 = \int_0^\infty e^2\,(t)dt$

b. $J_2 = \int_0^\infty |e(t)|\,dt$

c. $J_3 = \int_0^\infty te^2(t)dt$

d. $J_4 = \int_0^\infty te^2(t)dt$

are minimum.

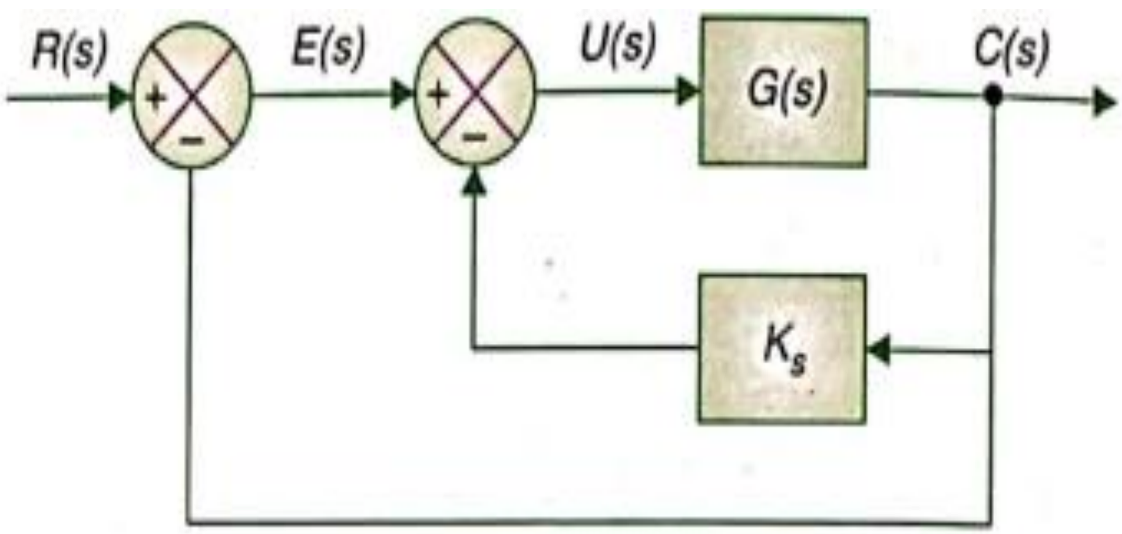

Fig. 1. Block Diagram for parameter optimization

Software Used: MATLAB 2020b / SIMULINK

Theory: In control system theory, a performance index is a quantitative measure of the performance of a system and is chosen so that emphasis is given to the important system parameters.

The four commonly used measures are Integral Squared Error (ISE), Integral Absolute Error (IAE), Integral Time Absolute Error (ITAE) and Integral Time Squared Error (ITSE) and are defined as:

$$\text{ISE}=\int_0^\infty e^2(t)\,dt$$

$$\text{IAE}=\int_0^\infty |e(t)|\,dt$$

$$\text{ITAE}=\int_0^\infty t|e(t)|\,dt$$

$$\text{ITSE}=\int_0^\infty te^2(t)dt$$

All the measures require a fixed experiment to be performed on the system (i.e., a fixed setpoint or disturbance change) and the integrals are evaluated over a fixed time period (in theory to infinity, but usually until a time long enough for the responses to settle).

ISE integrates the square of the error over time. ISE will penalize large errors more than smaller ones (since the square of a large error will be much bigger). Control systems specified to minimize ISE will tend to eliminate large errors quickly, but will tolerate small errors persisting for a long period of time. Often this leads to fast responses, but with considerable, low amplitude, oscillation.

IAE integrates the absolute error over time. It doesn't add weight to any of the errors in a systems response. It tends to produce slower response than ISE optimal systems, but usually with less sustained oscillation.

ITAE integrates the absolute error multiplied by the time over time. What this does is to weight errors which exist after a long time much more heavily than those at the start of the response. ITAE tuning produces systems which settle much more quickly than the other two tuning methods. The downside of this is that ITAE tuning also produces systems with sluggish initial response (necessary to avoid sustained oscillation).

ITSE is measure of system performance formed by integrating the square of the system error over a fixed interval of time; this performance measure and its generalizations are frequently used in linear optimal control and estimation theory.

Simulink Block for Problem:

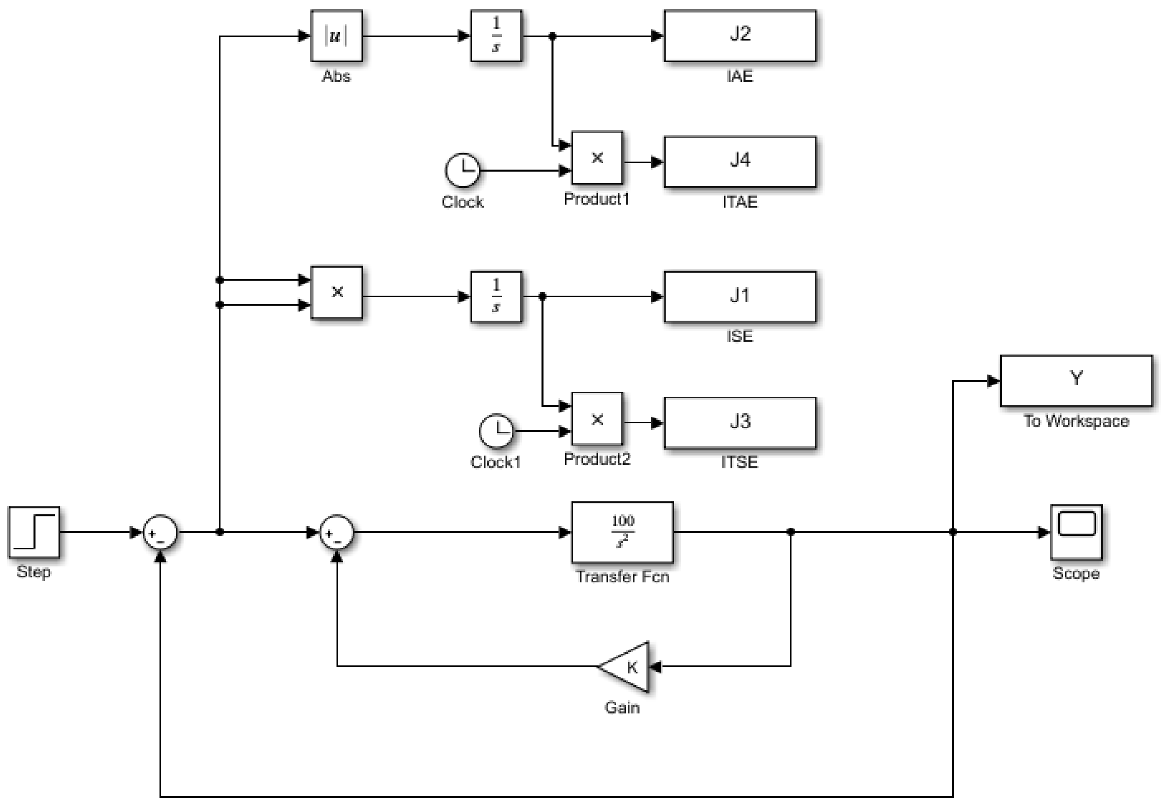

Fig. 2. Simulink Block Diagram for Problem

Code for Problem:

```
clear; clc;
a=0.01:0.01:1;
n=numel(a);
for i=1:n
    assignin('base','K',a(i));
    sim('Exp_no_1_3');
  PI1(i)=J1(end)
  PI2(i)=J2(end)
  PI3(i)=J3(end)
  PI4(i)=J4(end)
end
plot(a,PI1,a,PI2,a,PI3,a,PI4)
xlabel('Compensator Gain (K)');
```

```
ylabel('Performace Indexes');
title('Plot of Performace Indexes vs Gain (K)');
legend('ISE','IAE','ITSE','ITAE')
grid on
```

Plot for Problem:

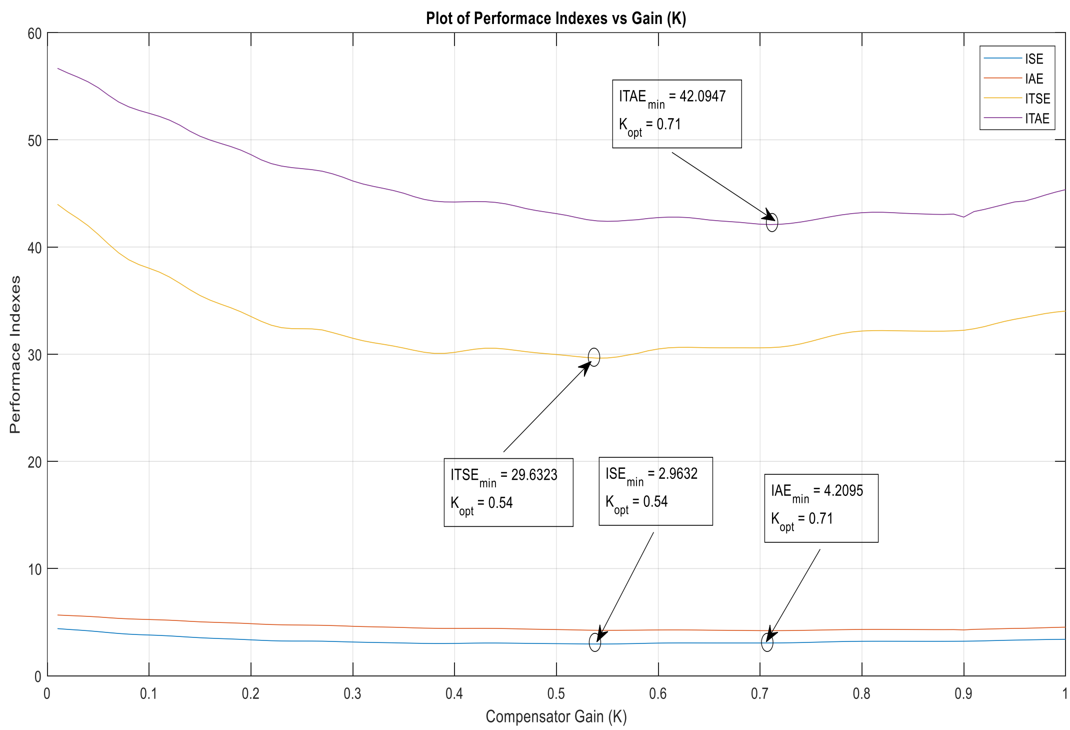

Fig. 3. Plot of PIs vs Gain K

Results: For given problem,

Optimal value of Compensator Gain k is 0.54 and the minimum ISE at this gain is 2.9632.

Optimal value of Compensator Gain k is 0.71 and the minimum IAE at this gain is 4.2095.

Optimal value of Compensator Gain k is 0.54 and the minimum ITSE at this gain is 29.6323.

Optimal value of Compensator Gain k is 0.71 and the minimum ITAE at this gain is 42.0947.

Conclusion: The given problem can easily be implemented in MATLAB/SIMULINK. The Optimum value of gain can be obtained for minimum ISE, IAE, ITSE and ITAE.