Control Systems

Lab Assessment #10

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Objective:

To design a compensator that ensures given performance characteristics of the ARM II electromechanical shoulder joint.

Experiment Design:

1. The Compensator:

To achieve the goal of reducing the steady-state error to half of the present error (0.0119) by redesigning the steady-state response with a lag compensator, the open-loop transfer function (tf) of the compensator is determined by poles and zeros. The poles are set at $-1/\beta T$, and the zero is at $-1/T$, with the condition $|1/\beta T| < |1/T|$. The magnitudes of the poles and zeros should be as close as possible, and the entire phase of the transfer function should be between -5 degrees to ensure compatibility with the transient response of the system.

Two possible combinations for the lag compensator are given: (Js+C)/(Ls+R) and (Ls+R)/(Js+C). The compensator parameters are specified as follows:

- Pole = -2.00, Zero = -4.0 Gc(s) = (5s + 20) / (5s + 10) = (s + 4) / (s + 2)
- Pole = -0.05, Zero = -0.1 Gc(s) = (10s + 1) / (10s + 0.5) = (s + 0.1) / (s + 0.05)
- Pole = -4.00, Zero = -20 Gc(s) = (0.05s + 1) / (0.05s + 0.2) = (s + 20) / (s + 4)
- Pole = -0.10, Zero = -0.05 Gc(s) = (2s + 0.1) / (2s + 0.2) = (s + 0.05) / (s + 0.1)

The chosen option is Option 2, which corresponds to $\beta = 2$. The relationship $\beta * Kc = 2$ is established, and the compensator transfer function is determined as:

Gc(s) = (s + 0.1) / (s + 0.05) = (10s + 1) / (10s + 0.5)

Therefore, the compensator transfer function is Gc(s) = (10s + 1) / (10s + 0.5), and it is designed to meet the specified requirements for reducing the steady-state error.

Code:

```
% Initialising the parameters
C = 1;
R = 0.5;
Kc = 1;
L = 10;
J = 10;

syms s

% Timescale
t =0:0.1:100;

% Transfer function
G = tf([15822.3,15822.3*4],[1,233.5,752.8,0]);

Gc_1 = tf([10,1],[10,0.5]);
Gs = G*Gc_1;
trans = feedback(Gs,1);
ramp =t;

[y,t] = lsim(trans,ramp,t);

% Error calculation
error = abs(t(end)-y(end))
```

Results:

```
>> Q1

error =

    0.0059
```

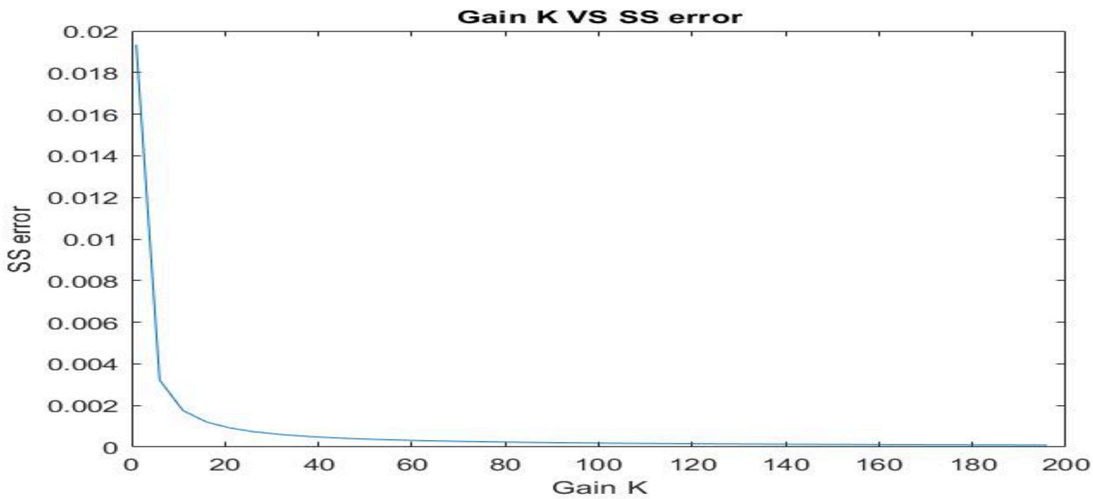
Inferences:

- The obtained results indicate that the given condition is met, with a new error of 0.0059, which is 50% of the initial error (0.0119).
- By referring to the provided information and visual representations, we can validate our calculated values and compare them with the results obtained from MATLAB.

2. The change:

```

% Timescale initialisation
t =0:0.1:100;
err=[];
syms s

% Looping the set
for K=1:5:200
    G = tf([4866*K,4866*K*4],[1,233.5,752.8,0]);
    Gc_1 = tf([10,1],[10,0.5]);
    Gs = G*Gc_1;
    trans = feedback(Gs,1);
    ramp =t;
    [y,t] = lsim(trans,ramp,t);

    error = abs(t(end)-y(end));
    err=[err,error];
end

err;
err1 = 0.011;
K=1:5:200;
figure
plot(K,err);
hold on;
plot(K,err1);
xlabel("Gain K");
ylabel("SS error");
title("Gain K VS SS error");
```

Results:



Inferences:

- Increasing the gain Kc provides an opportunity to achieve a further reduction in error while maintaining the same compensator components as in the previous section.
- The minimum error achieved is 0.0001 by varying the gain K.

- Setting Kv_new = 1e4 corresponds to β = 2, and the associated value of Kc is determined to be 55.
- Consequently, the new compensator is characterised by a Kc of 55.
- The trend observed from the plot illustrates that as K increases, there is a consistent decrease in the steady-state error.

3. Second order approximation:

Calculations:

```
% Transfer function initialisation
G = tf([15822.3,15822.3*4],[1,233.5,752.8,0]);

% Parameter
Kc =55;
Gc_1 = tf([Kc*10,Kc*1],[10,0.5]);
Gs = G*Gc_1;
trans = feedback(Gs,1);
ramp =t;
[y,t] = lsim(trans,ramp,t);

% Error
error = abs(t(end)-y(end))
```

Inferences:

- Through adjustments in the value of Kc, a redesigned compensator has been formulated to achieve a minimised error.
- The optimal error reduction is achieved by elevating Kc to 55.
- This refined compensator design effectively serves the intended purpose of minimising the error in the system.

Improvements and Learnings:

1. Incorporating the compensator into our design allows us to alter the system's response.
2. A program can be developed to fine-tune the value of K and optimise the utilisation of the compensator in the most favourable scenarios.