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Design of compensator for Servomechanism

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Abstract— *The objective of our project is to design the compensator for d.c. positional servo systems and stability analysis for frequency and time response using bode plot analysis. The proposed system is to gain the relative stability and improvement in transient response with the help of different compensators such as lag and lead compensators.*

Keywords—transfer function; lead compensator; system;control;feedback

1. Introduction

D.C. Servomechanism is a feedback system in which control variable is mechanical position. In a servo unit, there is potentiometer pair to sense input and output position, error amplifier ,DC servo motor, gear arrangement and a control circuit. There is a differential amplifier which amplifies the difference between reference input and actual output . The output of the differential amplifier is given to the D.C. Motor. The motor rotates in the direction to reduce the error. a At the same time , potentiometer wiper arm also rotates as it is coupled to the shaft of the motor. After desired angular position of motor shaft , the potentiometer reaches at such position where the electrical signal generated from the potentiometer becomes same as of reference signal given to amplifier. And motor stops where the differential output becomes zero.figure 1is the block diagram of system.

2.Need of compensators

Compensating networks are required to get the desired performance of the system. They compensate an unstable system to make it stable. With lead compensator, overshoot is minimized and transient response is improved. Lag compensators improve the steady state accuracy of the system. If both compensators are used they can improve total performance of system. Due to compensating networks poles and zeroes are introduced in the system which causes changes in the transfer function of the system. With this, performance specifications of the system may change.

2.1Need of compensator

A lead network is one in which has one pole and one dominating zero (the zero which is closer to the origin than all over zeros is known as dominating zero). To add dominating zero for compensation in control system then lead compensation network is selected. For phase lead network the basic requirement is that all poles and zeros of the transfer function of the network must lie on negative real axis.

3. System response without compensator

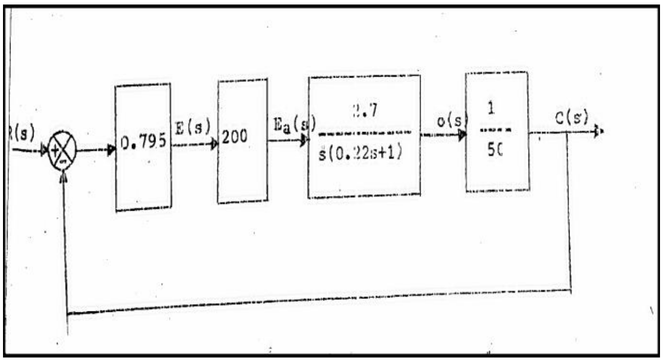

Fig-1:Block diagram of system

Closed loop transfer function of system

$$\frac{C(s)}{R(s)} = \frac{8.586}{s(0.22s+1)}$$

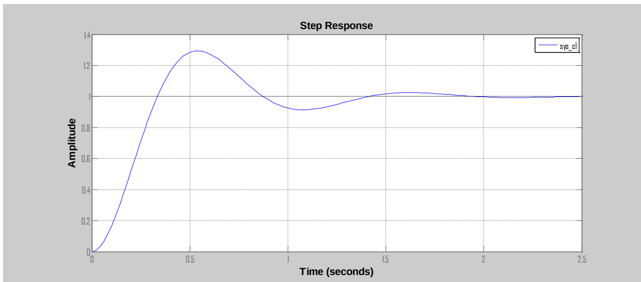

Chart-1:Step response of uncompensated system

TABLE -1: Step response

Step response	
Rise time	0.226 sec
Peak amplitude	1.26
% Overshoot	29.3
Settling time	1.73 Sec

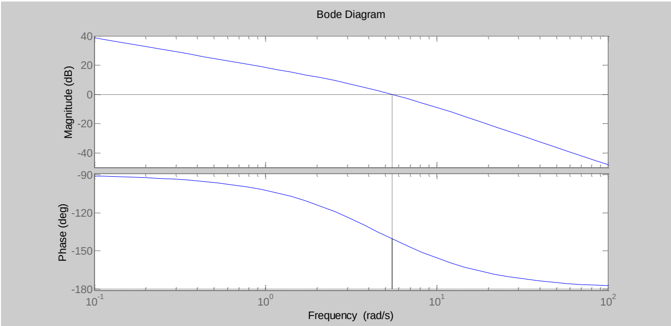

Chart-2: Bode plot of uncompensated system

From bode plot ,Phase Margin=39.6 degrees

4.DESIGN OF LEAD COMPENSATOR

The experimentation was carried out to get the desired characteristics of the system. With the help of compensator we tend to increase the margin to 50 degrees so we need to provide a additional lead of 10.4 degrees to the system. Firstly we derived and analyze the closed loop and open loop transfer function for the d.c. positional servo system. With this analysis we find out the step response by matlab software. The step response provides the value of rise time, peak amplitude, overshoot, settling time. With open loop transfer function we have also done bode plot analysis. The bode plot analysis gives gain margin, phase margin, gain crossover frequency, phase crossover frequency.

With all these parameters we came to know that steps should be taken to have better performance of the system. For satisfactory output of the system, gain is adjusted first. In practice, adjustment of gain alone cannot provide satisfactory results. This is because when gain is increased, steady state behavior of the system improves but results into poor transient response. In such cases it is necessary to redesign the entire system.

Now if the system is to be redesigned so as to meet the required specifications, it is necessary to change the system by adding an external device to it which is the compensator.

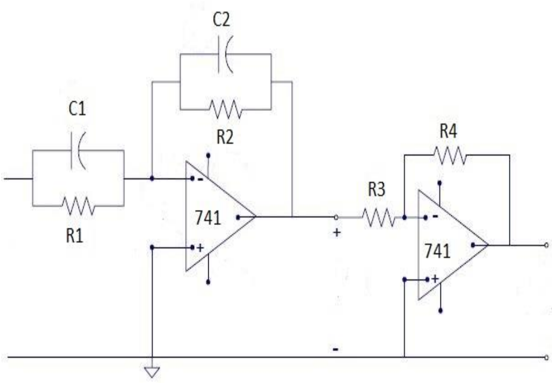

Fig-2: Circuit diagram of lead compensator

4.1 Calculations

From the bode plot of the uncompensated system the phase margin W_{PM} = 39.69 degrees

Required phase margin is 50 degrees

We need to add a margin of 50-39.69=10.31degrees

Keeping the safe limit we will add a margin of 10.31+5=15.31 degrees

Required phase margin $\O_m$=15.31 degrees

$$a = \frac{1 - sin15.31}{1 - sin15.31} = 0.5821$$

Frequency that contribute to the compensating network at $\O_m$is

$$W_{c2} 10log\frac{1}{0.5821} = 2.35dB$$

From the bode plot of uncompensated system Frequency at which uncompensated system have magnitude of -2.35dB become new crossover frequency

W_{c2}=W_m=6.46 rad/sec

Lower corner frequency W_1=1/t=4.9286 rad/sec

Upper corner frequency W_2= 1/at=8.4669 rad/sec

Transfer function of uncompensated system

$$G_c(s)=\frac{\left(\frac{s}{4.926}\right)+1}{\left(\frac{s}{8.4669}\right)+1}$$

K_c=0.5821

For 50 degree of phase margin the open loop transfer function of compensator is

$$G_c(s)=\frac{S+4.928}{S+8.4669}$$

From the circuit of lead network

Parallel branch impedances are

$$Z1(S)\frac{R1/C1S}{R1+(1/C1S)} = \frac{R1}{R1*C1S+1}$$

$$Z2(S)\frac{R2/C2S}{R2+(1/C2S)} = \frac{R2}{R2*C2S+1}$$

$$\frac{V2(S)}{V1(S)} = -\frac{Z2(S)}{Z1(S)} = -\frac{R2(R1*C1S+1)}{R1(R2*C2S+1)}$$

If another inverting op-amp with equal and forward feedback resistors are used the signal would be inverted and the compensator transfer function becomes

$$\frac{V2(S)}{V1(S)} = \frac{C1(S + 1/R1C1)}{C2(S + 1/R2C2)} = Kc\frac{s + a}{s + b}$$

K_C=C1/C2, a=1/(R1C1) and b=1/(r2c2)

TABLE-2: Components ratings

Component ratings	
R1	Pot 0-100k
R2	Pot 0-100k
R3	10k
R4	20k
C1	10uF
C2	22uF

5. RESULT

Transfer function of compensated network

$$\frac{8.586}{0.22s^2 + s} * \frac{s + 4.928}{s + 8.4669}$$

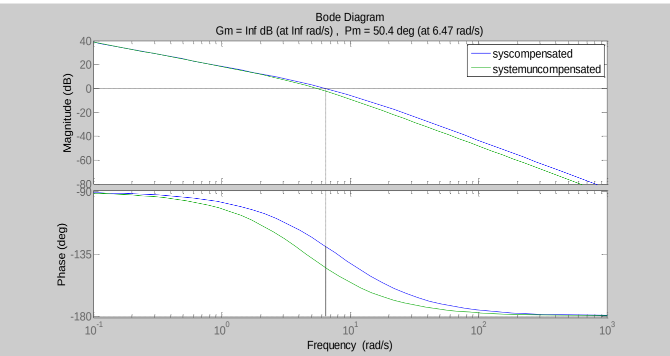

Chart-3:Bode plot of compensated and uncompensated system

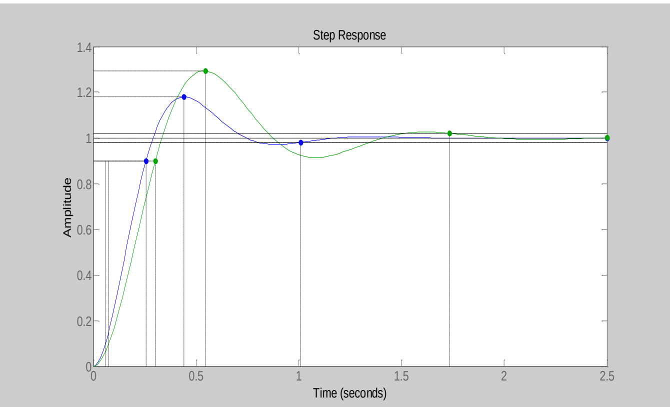

Chart-4:step response of compensated and uncompensated system

TABLE-3: Results

Result		
	Uncompensated	compensated
Rise time(sec)	0.226	0.197
Peak amplitude	1.29	1.18
% Overshoot	29.3	17.9
Settling time(sec)	1.73	1.01

From the result obtained we have seen that there is drop in peak amplitude, %overshoot and settling time decreases with the use of compensator hence the system act faster and the rate of response increases.

CONCLUSION

From this we have concluded that insertion of lead compensator in a system will improve the transient part of the system response.

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