Special Issue - 2016

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
CMRAES - 2016 Conference Proceedings

Design of Lead Compensator for Process Control using MULTISIM®

Sumant Kumar, Vinod K. Saw, Nilesh Srivastava, Amit Kumar and Bhargav. A
Dept. of Electrical and Electronics Engg.,
RVS College of Engineering and Technology,
Jamshedpur-831012, INDIA

Abstract— **This paper presents the procedure for designing a lead compensator using MULTISIM®. The stability of a process model is determined by its Phase Margin and Gain Margin. For the robust design of a closed loop system, it is required to keep these margins to be greater than zero. Lead, lag and lead-lag compensators are used to ensure that the stability margins are at the desired levels. In this paper, we present the stepwise procedure for designing a lead compensator to obtain the required stability margins with the help of suitable example.**

Keywords*— *Control System Design; Lead Compensator; Stability Margins .

I. INTRODUCTION

In the modern engineering systems design of stable control systems plays a significant role. Stable controllers for the plant process results in improved quality of the product, minimization of product, price, time for production, etc. It also prevents the occurrence of plant failures and other accidents. Several approaches are presented for designing of control systems such as Bode plot [1], Root Locus Technique [2], Nyquist plot [3] etc. These techniques are classified using the generic term classical control techniques. In the frequency domain approach, the stability of the system is measured using its stability margins namely the Phase Margin (P.M) and its Gain Margin (G.M). For a system to be stable these margins should be greater than zero. Compensators are used to ensure that the desired stability margins are achieved. Lead, Lag and Lead-Lag compensators are widely used for this purpose. In this paper, we present the systematic procedure for designing of a lead compensator using MULTISIM®.

The organization of the paper is as follows: next section discusses the Lead Compensator followed by the discussion of its design procedure in the third section. In the fourth section simulation results are presented and in the last section presents the conclusion of the work

II. LEAD COMPENSATOR

A lead compensator is characterized by the transfer function 'G_c' which is given in equation (1).

$$G_c = K_c \frac{\left(s+\frac{1}{T}\right)}{\left(s+\frac{1}{\alpha T}\right)} \qquad (1)$$

Here the parameter 'α' is a constant and should satisfy the following condition:

$$0 < \alpha < 1$$

The Bode plot of the lead compensator with $\alpha = 0.1$ [4] is shown in Fig. 1.

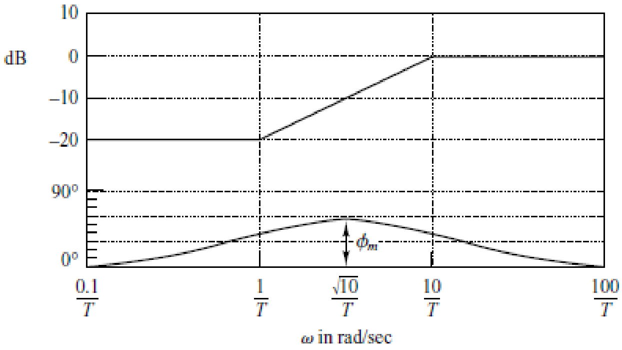

Fig.1. Bode Plot of the lead compensator with $\alpha = 0.1$

From the magnitude plot it can be seen that the lead compensator is basically a high pass filter and it can be realized using active filters. In the phase plot, the maximum phase 'ϕ_m' occurs at 'ω_m', which is given by equation (2). The value of 'ϕ_m' is given by equation (3).

$$\omega_m = \sqrt{\frac{1}{\alpha T^2}} \qquad (2)$$

$$\sin(\phi_m) = \frac{1-\alpha}{1+\alpha} \qquad (3)$$

III. LEAD COMPENSATOR DESIGN PROCEDURE

The following are the steps involved in designing of a lead compensator for the plant process characterized by the transfer function 'G_s'. The closed loop system along with the compensator is shown in Fig. 2.

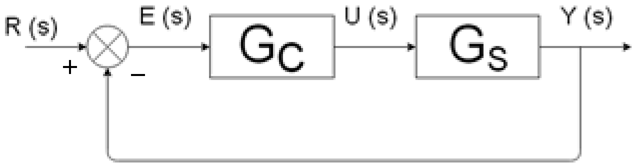

Fig.2. Closed loop system along with the compensator

1. The compensated system has an open loop gain determined by the equation (4).

$$G_cG_s = K_c\frac{\left(s+\frac{1}{T}\right)}{\left(s+\frac{1}{\alpha T}\right)}G_s = K_c\alpha\frac{(Ts+1)}{(\alpha Ts+1)}G_s$$

$$G_cG_s = \frac{(Ts+1)}{(\alpha Ts+1)}KG_s \qquad (4)$$

The value of K is taken so as to satisfy the error constant value.

2. Bode plot of the KG_s i.e. of the gain adjusted uncompensated system is plotted and the stability margins are calculated.
3. The necessary phase margin 'ϕ_m' to be added is calculated. Additional 5°-12° is added is order to accommodate the reduction in phase margin due to shifting of the magnitude plot to the right.
4. Using equation (3) the value of 'α' is calculated. The new gain crossover frequency is selected as that frequency at which the gain of the system KG_s is equal to -10 $log(1/\alpha)$. This frequency should also be the frequency at which the maximum phase 'ϕ_m' occurs. From equation (2), we can calculate the value of 'T'.
5. Since the values 'α', 'T' are known the transfer function of the compensator can be determined. The compensator can be designed using a high pass filter having the required transfer function characteristics.

IV. SIMULATION RESULTS

Consider the system shown in Fig. 3. We want to design a lead compensator such that the compensated system has a position error constant of 10 sec^{-1} phase margin of 150° and gain margin of at least 10 dB.

1. To satisfy the position error constant, the value of K should be 1.
2. The bode plot of the gain adjusted uncompensated system is shown in Fig. 4. The gain margin is found to be infinite and the phase margin was found to be 100 °.
3. The gain margin criterion has been satisfied and the phase margin has to be compensated for 50 °. An additional phase margin of 5° is added to compensate the shifting of the magnitude plot to the right. So, the total compensation needed is 55° i.e. ϕ_m=55°.
4. From equation (3), the value of α calculated and is found to be 0.1.
5. From the graph of the gain adjusted uncompensated system, the new crossover frequency is that frequency at which the gain is -10 $log(1/\alpha)$ i.e. -10 dB. This occurs at the frequency 5.1 KHz. From this the value of ω_m is found as follows:

$$\omega_m = (5100 \times 2 \times \pi) = 31883.7 \text{ rad/sec.}$$

6. From Equation (2) the value of '1/T' is equal to 10082.5.
7. For K being 1, the value of KC should be taken as 10.
8. The transfer function of the lead compensator becomes:

$$G_c = 10\frac{(s+10082.5)}{(s+101843)}$$

Finally the compensator is shown in Fig. 5. It can be seen that the compensator is a high pass filter and the parameters of the filter can be obtained easily obtained from the transfer function above. Bode plot of the compensated system is shown in Fig. 6 and it can be observed that the phase margin is close to 150°.

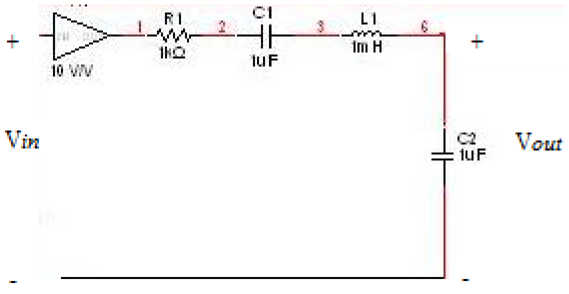

Fig. 3. The uncompensated system

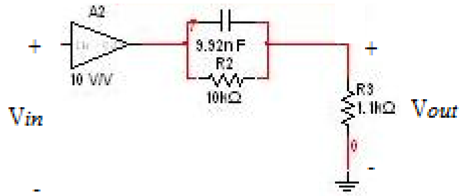

Fig. 5. The lead compensator

V. CONCLUSION

We have presented the detailed procedure for the design of lead compensator using MULTISIM®. Design procedure was explained with the help of an example and the results are reported. It is observed that using the lead compensator it is possible to achieve the desired stability margins.

REFERENCES

[1] Bode,H.W., *Network Analysis and Feedback Design*. New York:Van Nostrand Reinhold, 1945.

[2] Evans,W. R., "Control System Synthesis by Root Locus Method," AIEE Trans Part II, 69(1950), pp. 66–9

[3] Nyquist, H., "Regeneration Theory," *Bell System Tech. J.*, **11** (1932), pp. 126–47.

[4] Ogata, K., "Modern Control Engineering," Prentice-Hall, Upper Saddle River, NJ, pp. 493-502, 2010

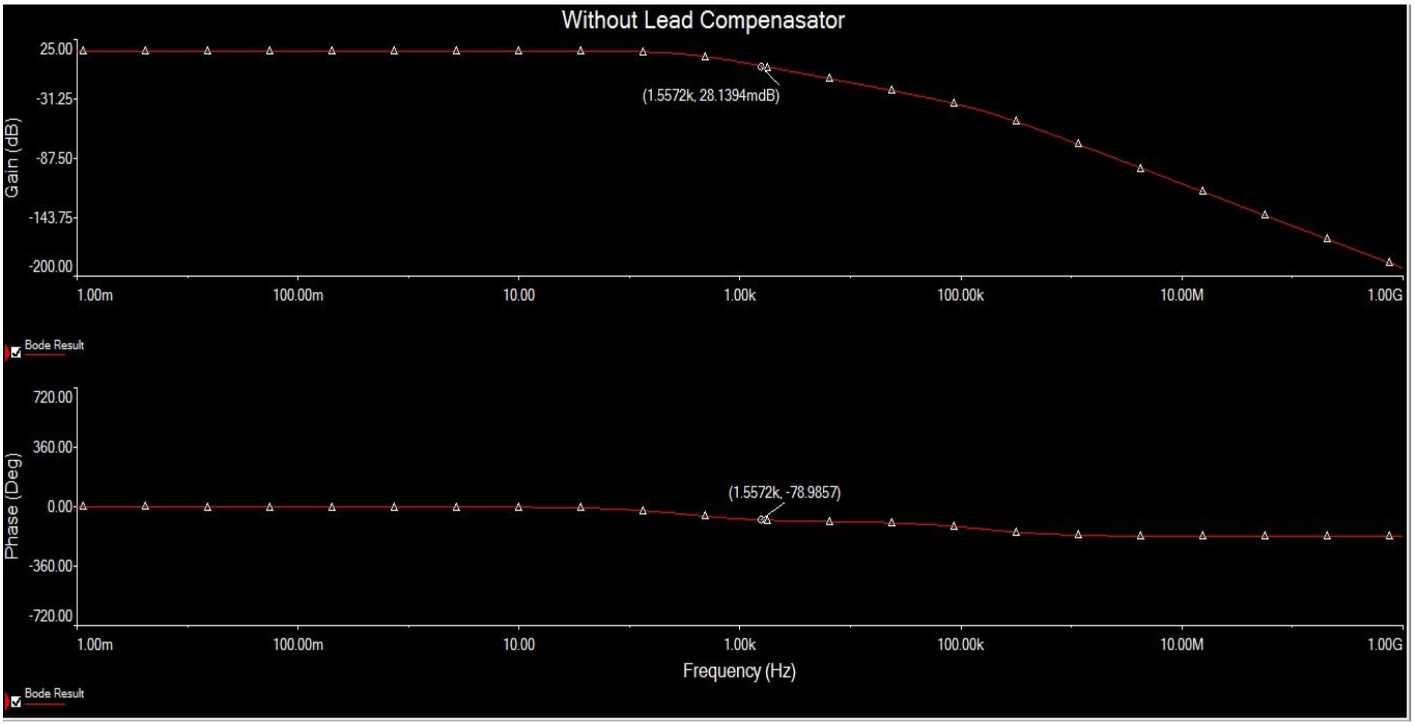

Fig. 4. Bode plot of the uncompensated system

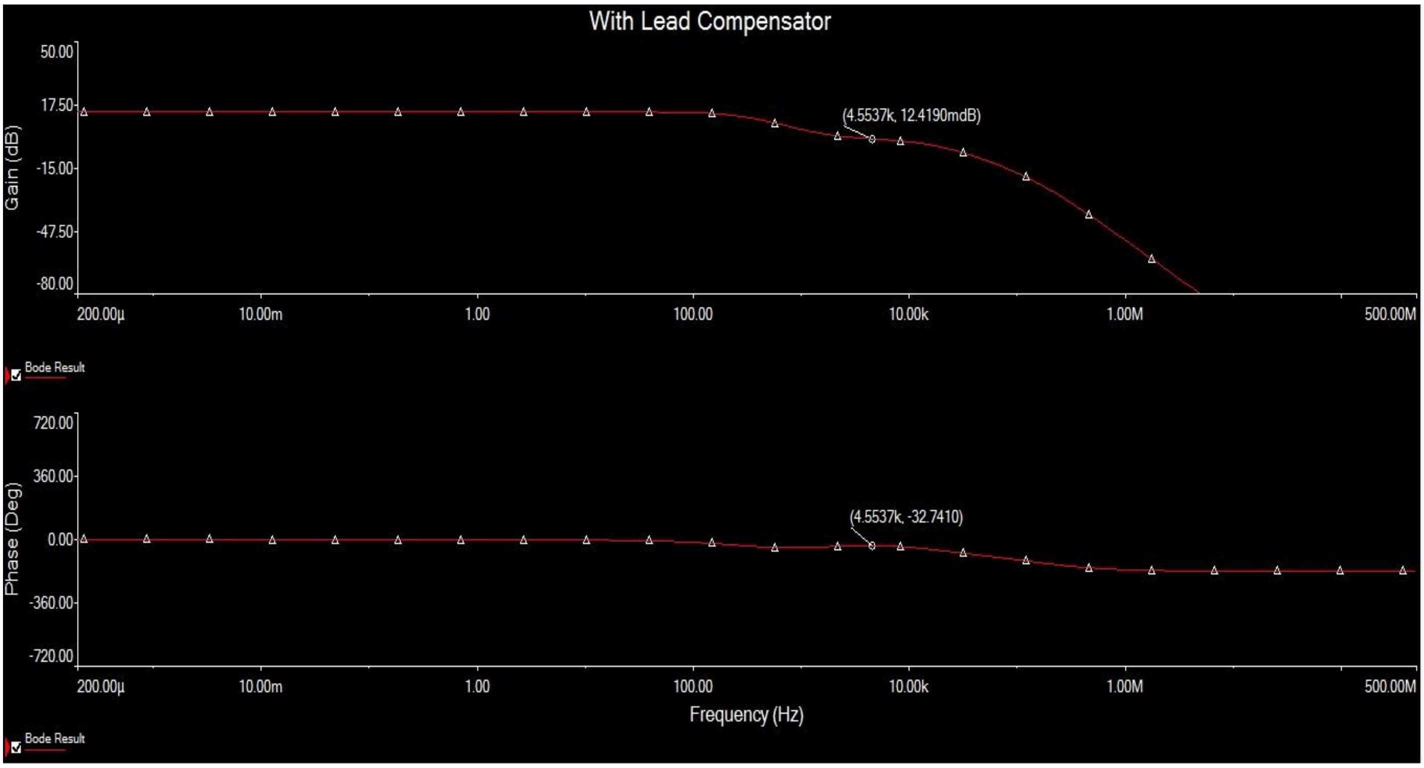

Fig. 5. Bode plot of the compensated system