

# Design of Compensators for Speed Control of DC Motor by using Bode Plot Techniques

Abhilash D. Karmankar<sup>1</sup>, Poonam R. Hatti<sup>2</sup>, Yogita R. Ashtekar<sup>3</sup>, Dinesh L. Mute<sup>4</sup>

<sup>1,2</sup> B.E. 4<sup>th</sup> Year Student of Electrical Engineering Department, DMIETR, Sawangi (Meghe), Wardha (MH), India

<sup>3,4</sup> Asst. Prof, Electrical Engineering Department, DMIETR, Sawangi (Meghe), Wardha (MH), India

**Abstract** - This paper introduces design of different compensators and their output response for speed control of DC motor. With this paper, engineers would be able to rapidly design compensators for speed control of DC motor. As shown by the example, the method can improve the efficiency as required. Also, with this paper we can compare the effect of different compensators on system and compare their parameters side by side. In this paper compensator is designed by using Bode Plot Techniques and MATLAB Programming, therefore it is easier to simulate any programming with the help of basic bode plot formulae and simple programming.

**Key Words:** Bode Plot, Compensator, Computer Aided Design, Desired Response Specification, and MATLAB.

## 1. INTRODUCTION:

In the particular project we are concentrating on system which is considered to be a DC motor. In a DC Motor we provide input as electrical power which is then converted to mechanical output. No system can be ideal and hence there are some power consuming elements. These causes the fall in efficiency and performance of the system. The system do not gives its actual performance. In a DC motor as considered has various power consuming elements such as inductance, resistance, friction, inertia, etc. It becomes possible to use a controller with the system which helps in providing desired response at the output. This can help to maintain speed, accuracy and performance of device.

A system is never perfect, there are some distorting parameters which do not gives the proper output. E.g. if a motor have to start, it will start after sometime, with particular input power. The time lapsed and the unused power are the effects of distortion.

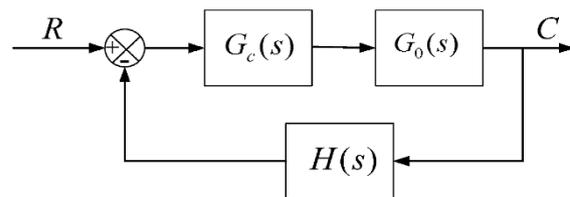


Fig -1: System block diagram of compensated system.

## 1.1 BODE PLOT TECHNIQUE:

In the frequency-response approach, we specify the transient-response performance in an indirect manner. The frequency domain specifications can be conveniently met in the Bode diagram approach.

Therefore the open loop has been designed by the frequency-response method, the closed loop poles and zeros can be determined. The transient-response characteristics must be checked to see whether the designed system satisfies the requirements in the time domain. If it does not, then the compensator must be modified and the analysis repeated until a satisfactory result is obtained.

Design in the frequency domain is simple and straightforward. The frequency-response plot indicates clearly the manner in which the system should be modified.

## 1.2 COMPENSATORS:

In order to obtain the desired performance of the system, we use compensating networks. It is a fundamental building block in classical control theory. There are two general types of compensators: Lead Compensators, and Lag Compensators. If we combine the two types, we can get a special Lead-Lag Compensator system.

Compensators influence disciplines as varied as robotics, satellite control, automobile diagnostics, and laser frequency stabilization. They are an important building block in analog control systems, and can also be used in digital control.

**2. DESIGNING PROCEDURE:**

1. Consider the second order transfer function "G(s)".
2. Put that transfer function in MATLAB.
3. Evaluate the value of  $\omega_{gc}$  (gain crossover frequency),  $\omega_{pc}$  (phase crossover frequency), Gm (gain margin), Pm (phase margin).
4. To get the desired output we have to assume the value of Pm, Kv, as per the manufacturer's requirement.
5. Calculate phase angle " $\phi_m$ " and constant "Kc".
6. Calculate lead constant " $\alpha$ " ( $\alpha = \frac{1 - \sin \phi_m}{1 + \sin \phi_m}$ ), lag constant " $\beta$ " ( $\beta = \frac{1 + \sin \phi_m}{1 - \sin \phi_m}$ ), or lag-lead constant as per the manufacturer's requirement.
7. Through " $\alpha$ " and " $\beta$ " we find out compensated zeros, poles and gain of the system.
8. By using the values of compensated zeros, poles and gain, we derive a compensated transfer function "Gc(s)".
9. We write a program in MATLAB.
10. In that program, insert the value of compensated and uncompensated system.
11. Evaluate step response for compensated and uncompensated system.
12. Evaluate the frequency domain parameters and compare those with uncompensated system.

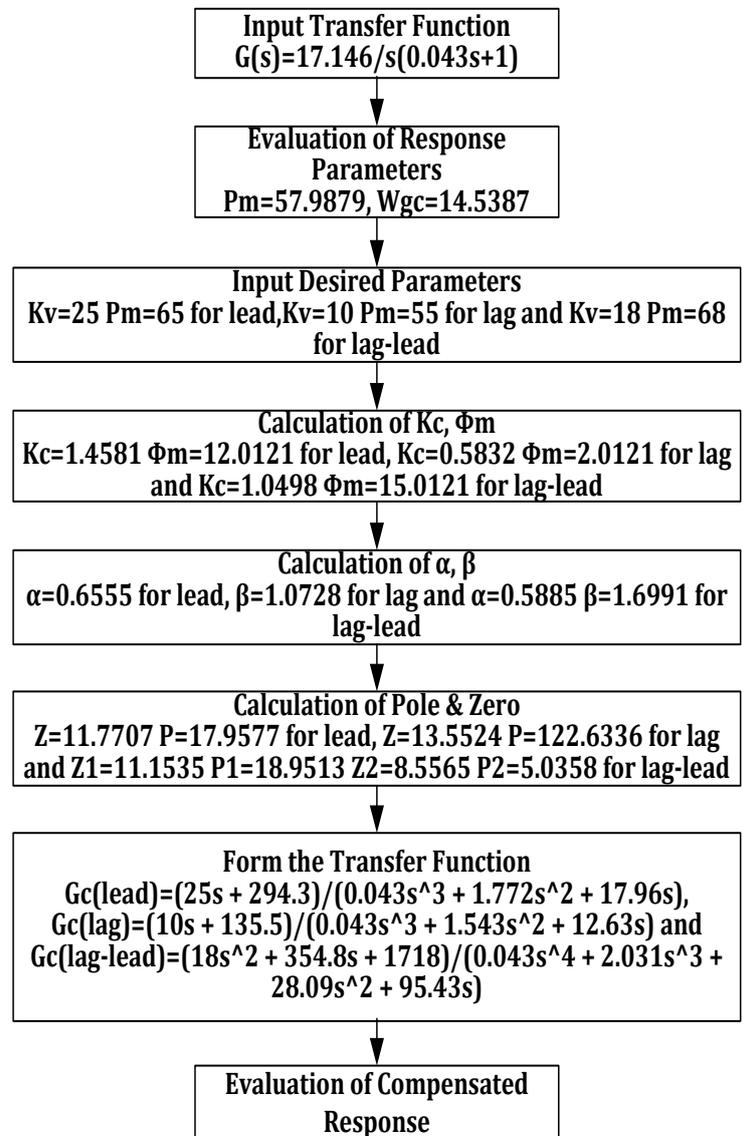
**2.1 NUMERICAL EXAMPLE:**

Consider the control system of open-loop transfer function:

$$G(s) = \frac{17.146}{0.043s^2 + s} \dots Eq. (1)$$

- 1) Design a lead compensator Gc1(s) such that the closed-loop system will have a phase margin of 65° and the static velocity error constant Kv=25.
- 2) Design a lag compensator Gc2(s) such that the closed-loop system will have a phase margin of 55° and the static velocity error constant Kv=10.
- 3) Design a lag-lead compensator Gc3(s) such that the closed-loop system will have a phase margin of 68° and the static velocity error constant Kv=18.

**2.2 STEP TO SOLVE THE NUMERICAL:**



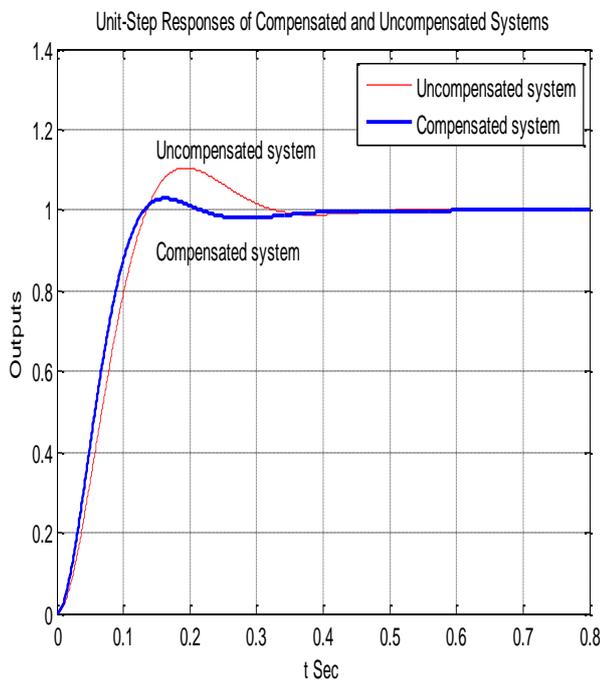
**Chart -1:** Flow chart to evaluate response of system.

Through this flow chart we refer the steps to solve the any numerical example with implementing basic formulae of bode plot techniques. And through MATLAB simulation software we get the unit step response of any type of system by implementing simple programming.

**2.3 RESPONSES:**

For lead compensation,

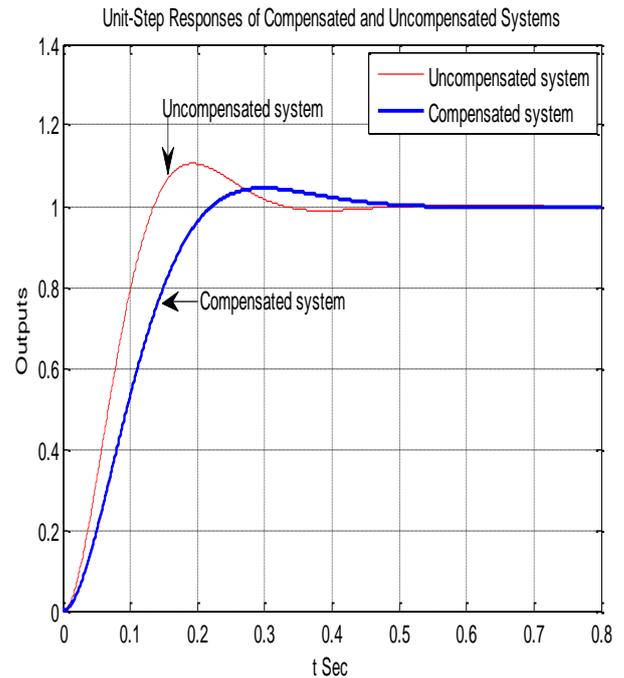
$$G(s) = \frac{25s + 294.3}{0.043 s^3 + 1.772s^2 + 17.96s} \dots Eq. (2)$$



**Fig.5:** Output response of lead compensation.

For lag compensation,

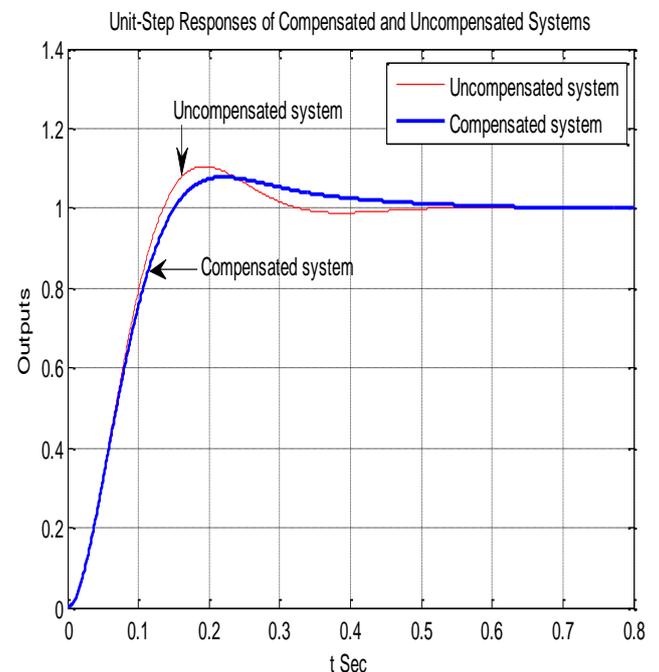
$$G(s) = \frac{10s + 135.5}{0.043 s^3 + 1.543s^2 + 12.63s} \dots Eq. (3)$$



**Fig -6:** Output response of lag compensation.

For lag-lead compensation,

$$G(s) = \frac{18s^2 + 354.8s + 1718}{0.043 s^4 + 2.031s^3 + 28.09s^2 + 95.43s} \dots Eq. (4)$$



**Fig -7:** Output response of lag-lead compensation.

From the above response we can observe the different effect of compensations of different comparators on a system and hence we can calculate the different parameters of system with and without effect of compensator as follows for given example.

**Table -1:** Output table to compare the values of main parameters of responses.

Parameters	Uncompensated System	Lead Compensated System	Lag Compensated System	Lag-Lead Compensated System
Phase margin (degree)	<b>57.9879</b>	<b>65.8943</b>	<b>65.5165</b>	<b>63.4630</b>
Gain crossover frequency	<b>14.5387</b>	<b>16.8889</b>	<b>9.6616</b>	<b>13.0632</b>
Peak overshoot	<b>10.5%</b>	<b>2.9%</b>	<b>4.5%</b>	<b>7.8%</b>
Rise time (sec)	<b>0.1355</b>	<b>0.1315</b>	<b>0.2220</b>	<b>0.1510</b>
Peak time (sec)	<b>0.1875</b>	<b>0.1579</b>	<b>0.2950</b>	<b>0.2115</b>
Settling time (sec)	<b>0.5370</b>	<b>0.5025</b>	<b>0.5010</b>	<b>0.5030</b>

### 3. CONCLUSIONS:

From the simulation result of lead and lag compensators, it is seen that, lead compensator improves the transient response and lag compensator improves the steady state response. And, if the lag-lead compensator response provide it improve both transient and steady state responses as compare to lag and lead compensators acting individually.

From the example we can see the method is effective and it can greatly reduce design time, in addition, it can also easily adjust the parameters online to optimize the compensator. In order to improve the efficiency and reduce the cost of the compensation for control system, the design of lead, lag, and lag-lead compensators for speed control of DC motor by using bode plot techniques via MATLAB Software is proposed. From the example we

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