PID Conventional Controller and LQR Optimal controller for Speed analysis of DC Motor: A Comparative Study

Rajkumar dwivedi[1], Devendra Dohare[2]

[1] M.Tech Student, Department of Electrical Engineering MPCT Gwalior (India)
[2] Assistant professor, Department of Electrical Engineering MPCT Gwalior (India)

--***---

Abstract - *This paper presents a comparative study of PID and LQR controller for the speed analysis & control of DC motor. The Proportional Integral Derivative controller is one of the most common types of feedback controllers used in dynamic systems. Simulation results are presented PID controller and Optimal Linear-Quadratic Regulator. Finally observed that Optimal Linear-Quadratic Regulator (LQR) gives better and dynamic response than PID controller for the speed control of dc motor.*

Key Words: *PID Controller, Optimal Linear-Quadratic Regulator (LQR), Speed Control analysis , modeling of DC Motor*

1. INTRODUCTION

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range [1]. The speed of DC motors can be adjusted within wide boundaries so that this provides easy controllability and high performance. DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses. DC motors are widely used in industrial applications, robot manipulators and home appliances, because of their high reliability, flexibility and low cost, where speed and position control of motor are required [2]. All control systems suffer from problems related to undesirable overshoot, longer settling times and vibrations and stability while going from one state to another state. Real world systems are nonlinear, accurate modelling is difficult, costly and even impossible in most cases conventional PID controllers generally do not work well for non-linear systems. Therefore, more advanced control techniques need to be used which will minimize the noise effects. To overcome these diffculties, there are three basic approaches to intelligent control: knowledge based expert systems, fuzzy logic, and neural networks. All three approaches are interesting and very promising areas of research and development [3-4].

In this paper, speed of a DC motor is controlled using different tuning LQR algorithms. The DC motors are popular in the industry control for a long time because they possess good characteristics, high response performance, high start torques characteristics, easier to be linearly controlled etc.

2. SPEED CONTROL AND MODELING OF DC MOTOR

The term speed control stand for intentional speed variation carried out manually or automatically DC motors are most suitable for wide range speed control and are there for many adjustable speed drives [5].The DC motor modeling fig 1 show in the below and   DC motor parameter given in the below [6].

- Input Voltage 6 V
- DC Motor Electric Resistance (Rm) =1Ω,
- DC Motor Electric Inductance   (Lm) = 0.5 H,
- Moment of Inertia of the Rotor   (J) 0.01 kg.m2
- Damping ratio of the Mechanical System (B) 0.001 (Nms)
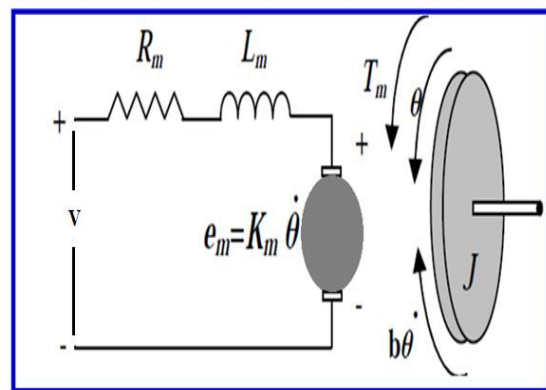- Motor Constant (Km) 0.01 Nm/A

Fig 1 DC motor modelling.

From Fig.1, the following equations can be written based on Newton's law combined with Kirchhoff's laws

$$V - Km\theta \quad = Rm\ i\ + Lm\ \frac{di}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

$$J\ddot{\theta} + b\dot{\theta} = Km\dot{i} - T_L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Because the back EMF eb is proportional to speed ω directly, then

The dc motor torque T_m is related to the armature current (I), by a constant factor K_t . The back emf (e_m) is related to the rotational speed by the following equations:

$$e_m = K_e\, \theta \dots\dots\dots\dots\dots\dots\dots\dots. (3)$$

$$T_m = K_t I \dots\dots\dots\dots\dots\dots\dots.. (4)$$

Assuming that, (motor torque constant) = (electromotive force constant of dc motor), Using Laplace Transforms,

$$S\,(Js+b)\,\theta\; K_m I(S) - T_L\,(s) \;\dots\dots\dots\dots (5)$$

$$(Lm\,(s)+Rm\,)I(S) = V\,(S) - KmS\theta\;\;(S) \dots\dots\dots\dots\dots (6)$$

By eliminating $I(S)$ between the two above equations, where the rotational speed is considered the output and the
Armature voltage is considered the input. Assuming (load torque) =0, even though it will not affects the transfer function.

$$\frac{\theta\,(s)}{V(s)} = \frac{K_m}{(L_m S + R_m)(JS + b) + K_m^2} \dots\dots\dots\dots\dots. (7)$$

$$\frac{\theta\,(s)}{V(s)} = \frac{0.01}{(0.5\,s + 1)(0.01s + 0.001) + (0.01)^2} \dots\dots (8)$$

3.PROPORTIONAL INTEGRAL AND DERIVATIVE CONTROLLER

The combination of proportional, integral and derivative control action is called PID control action. PID controllers are commonly used to regulate the time-domain behavior of many different types of dynamic plants. These controllers are extremely popular because they can usually provide good closed-loop response characteristics. Consider the feedback system architecture that is shown in Fig. 1 where it can be assumed that the plant is a DC motor whose speed must be accurately regulated [7]. PID control scheme is extensively used in control systems for various control applications. The combination of proportional, integral and derivative control action is called PID control action and the controller is called three action controllers. Although PD control deals neatly with the overshoot and rising problems associated with proportional control it does not reduce the problem with the steady-state error. Hence, PID controllers are used to

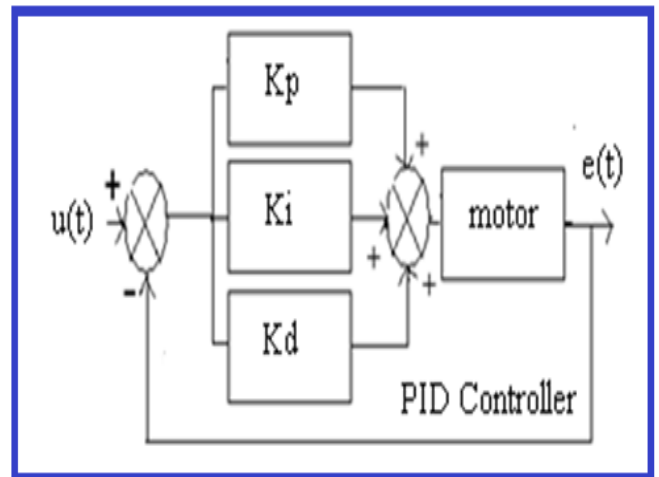reduce the steady-state error apart having the advantages of PD controllers.

FIG 2 PID CONTROLLER

4.   OPTIMALLINEAR-QUADRATIC   REGULATOR (LQR)

The liner quadratic regulator technique seeks to find the optimal controller that minimizes a given cost function (performance index). This cost function is parameterized by two matrices, Q and R, that weight the state vector and the system input respectively. These weighting matrices regulate the penalties on the excursion of state variables and control signal. One practical method is to Q and R to be diagonal matrix. The value of the elements in Q and R is related to its contribution to the cost function. To find the control law, Algebraic Riccati Equation (ARE) is first solved, and an optimal feedback gain matrix, which will lead to optimal results evaluating from the defined cost function is obtained [26].

Linear quadratic regulator design technique is well known in modern optimal control theory and has been widely used in many applications. The standard theory of the optimal control is presented in Dissertation. Under the assumption that all state variables are available for feedback, the LQR controller design method starts with a defined set of states which are to be controlled. The theory of optimal control is concerned with operating a dynamic system at minimum cost. The case where the system dynamics are described by a set of linear differential equations and the cost is described by a quadratic function is called the LQ problem. One of the main results in the theory is that the solution is provided by the linear-quadratic regulator (LQR). Fig 3 MATLAB Simulink model of DC motor using PID Controller
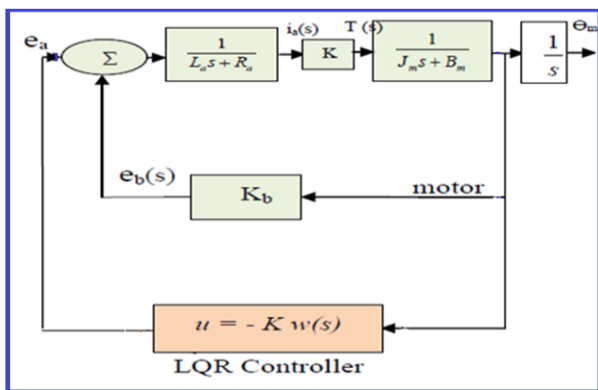
Fig 3 optimal LQR controller

The function of Linear Quadratic Regulator (LQR) is to minimize the deviation of the speed of the motor. The speed of the motor is specifying that will be the input voltage of the motor and the output will be compare with the input. The output must be the same as or approximately the same as the input voltage. The advantages of used LQR are it is easy to design and increases the accuracy of the state variables by estimating the state. The nice feature of the LQR control as compared to pole placement is that instead of having to specify where n Eigen values should be placed a set of performance weighting are specified that could have more intuitive appeal. The performance measure is a quadratic function Composed of state vector and control input [29].

5. SIMULATION RESULTS

The results of the system with using PID and Optimal LQR Controller of controllers are shown here. The responses of the system with PID and Optimal LQR Controller are being applied. In this section transfer function of the dc motor is used as a system and find out the response of the system.

(A)Response of PID controller- Fig 1 shows the step response of PID control. The PID controlled response of the system has considerably larger settling time and higher overshoot values. Hence, an attempt is made to further improve the dc motor response of the system using OPTIMAL LQR controller.
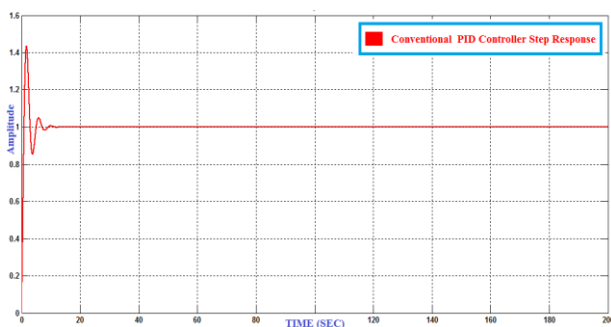

Fig 4 step response of PID controller

(B) Response of OPTIMAL LQR controller- Fig 2 shows the step response of optimal LQR controller. The optimal LQR controller controlled response of the system has considerably minimum settling time and reduced overshoot values. Fig 3 comparative step response for PID controller and optimal LQR controller system. Fig 10 and table 1 are shows that the response of the system has greatly improved using optimal LQR controller
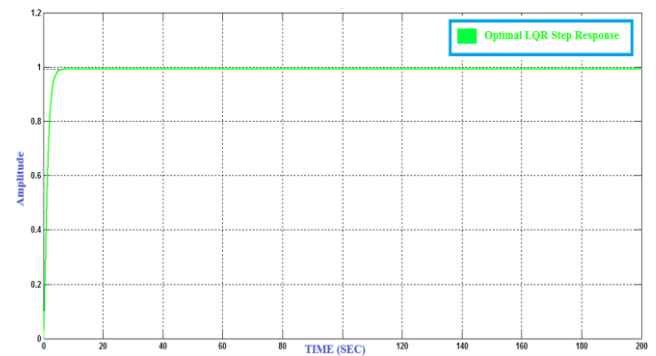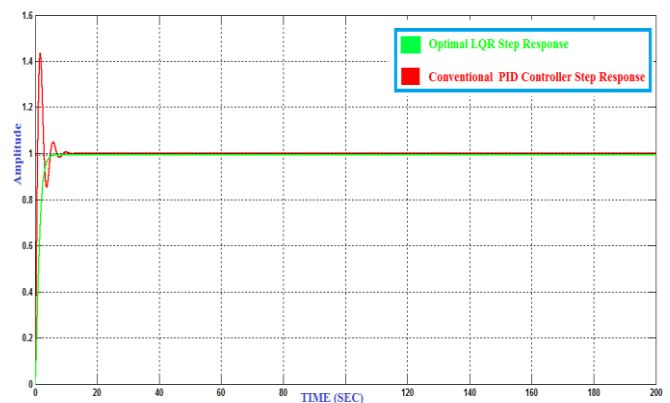

Fig 5 step response of optimal LQR controller

Fig 6 step response of PID controller and optimal LQR controller

Table 1 Comparison of results of PID and optimal LQR controller

CONTROLLER	SETTLING TIME	OVER SHOOT	RISE TIME
PID CONTROLLER	6.68	43.5	0.682
OPTIMAL LQR CONTROLLER	**4.19**	**0.00**	**2.4**

6. CONCLUSIONS

This mathematical modeling had to be done so the result that was get can be compare with the result, The LQR control methodology was investigated and its control performance was compared with that of the traditional dynamic system. The simulation results validate the proposed LQR methodology and display a better dynamic

performance in terms of transition time and speed overshoot and also stronger robustness of LQR control methodology than of traditional PID controller

REFERENCES

[1] Shashi Bhushan Kumar *, Mohammed Hasmat Ali**, Anshu Sinha, "Design and Simulation of Speed Control of DC Motor by Fuzzy Logic Technique with Matlab/Simulink", International Journal of Scientific and Research Publications, Volume 4, Issue 7, July 2014

[2] Md Akram Ahmad, Pankaj Rai, "Speed control of a DC motor using Controllers" Automation, Control and Intelligent Systems, November 19, 2014.

[3] Rekha kushwah#1, Sulochana Wadhwani *2, "Speed Control of Separately Excited Dc Motor Using Fuzzy Logic Controller", International Journal of Engineering Trends and Technology (IJETT) - Volume4 Issue6- June 2013.

[4] Liu Fan, Er Meng Joo" Design for Auto-tuning PID Controller Based on Genetic Algorithms" Nanyang Technological University Singapore IEEE Trans on ICIEA 2009.

[5] K.H. Ang, G. Chong and Y. Li, "PID control system analysis, design and technology," IEEE transaction on Control System Technology, Vol.13, No.4, 2005, pp. 559-576.

[6]Dr.Ch.Chengaiah1, K.Venkateswarlu2, "Comparative Study On Dc Motor Speed Control Using Various Controllers" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 3, Issue 1, January 2014.

[7] Aditya Pratap Singh, "Speed Control of DC Motor using Pid Controller Based on Matlab" Innovative Systems Design and Engineering, Vol.4, No.6, 2013.

[8] Pratap Vikhe1, Neelam Punjabi1, Chandrakant Kadu2, "Real Time DC Motor Speed Control using PID Controller in LabVIEW" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 3, Issue 9, September 2014.

[9] Saurabh Dubey 1, Dr. S.K. Srivastava2, "A PID Controlled Real Time Analysis of DC Motor" International Journal of Innovative Research in Computer and Communication Engineering Vol. 1, Issue 8, October 2013.