Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

A Tuning optimal Technique and PID controller Based Speed analysis For DC Motor

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Abstract — DC motors are important components of most of the process control industries. PID controllers are extensively used in DC motors for speed control. Tuning of PID controller parameters is an iterative process and needs an optimization to achieve the desired performance. Simulation results are presented PID controller and LQR controller. The MATLAB models have been developed using MATLAB SIMULINK and the comparative analysis is based on the speed responses finally observed that LQR gives better and better response than PID controller for the speed control of dc motor.

Keywords— Direct current motor, speed analysis control, PID controller and LQR

I. INTRODUCTION

The development of high performance DC motor drives is very important in industrial as well as other purpose applications, because of their simplicity, ease of application, reliability and favorable cost have long been a backbone of industrial applications. DC drives are less complex with a single power conversion from AC to DC. The DC drives are normally less expensive for most horsepower ratings. DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance [1].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 .Further the speed controller can always be designed to have sufficiently low effect on the non linearity of DC motor; so as to worst effect of parameter uncertainty can be accounted. In real time operation, the situation is different; design controller may encounter situation never imagined by designer before it took its present shape. Hence, in real time operation condition, risk of affecting nonlinearity of motor is always present. Here it is designed a controller which not affects the nonlinearity in DC motor [2].

DC motors are used in various applications such as defence, industries, Robotics etc. DC drives.

This paper proposes a new method to design a speed controller of a DC motor by selection of PID, LQR, the results of LQR is best among all methods are compared together. Using LQR to perform the tuning of the controller gives best results in the optimum controller being evaluated for the system every time.

II. CONVENTIONAL PID CONTROLLERS

A Proportional Integral Derivative controller widely used in industrial control system. The Proportional term responds instantaneously to the current error. Consider the characteristics parameters – proportional (P), integral (I), and derivative (D) controls, as applied to the diagram below in Fig. 1 A PID controller is simple three-term controller. The PID controller has three principal control effects. The proportional (P) action gives a change in the input (manipulated variable) directly proportional to the control error. The integral (I) action gives a change in the input proportional to the integrated error, and its main purpose is to eliminate offset. The less commonly used derivative (D) action is used in some cases to speed up the response or to stabilize the system, and it gives a change in the input proportional to the derivative of the controlled variable. The letter P, I and D stand for P- Proportional, I Integral, D- Derivative [3][9]. Fig 1 shows the PID controller.

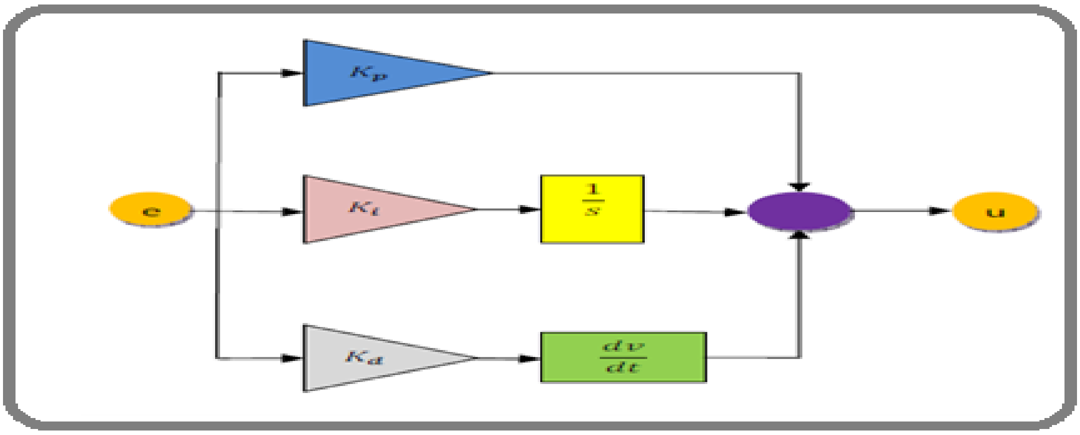

Fig 1 PID controller

PID controller is a generic control loop feedback mechanism (controller) widely used in industrial control system–a PID is the most commonly used feedback controller. Calculate an error value as the difference between measured process variable and a desired response. The controller attempts to minimize the error by adjusting the process control input [4] [5].
The performance measure to be minimized contains the following objectives of the PID controller that will be studied separately [7].
1. Minimize the maximum overshoot; Maximum overshoot is the maximum peak value of the response curve measured from the desired response of the system.

2. Minimize the rise time, time required for system response to rise from 10% to 90% (over damped); 5% to 95%; 0% to 100% (Under damped) of the final steady state value of the desired response,
3. Minimize the settling time, Time required for response to reach and stay within 2% of final value.

III. LINEAR QUADRATIC REGULATOR DESIGN

Linear quadratic regulator design technique is well known in modern optimal control theory and has been widely used in many applications. LQR is a method in modern control theory that used state-space approach to analyze such a system. Using state space methods it is relatively simple to work with Multi- Input Multi-Output (MIMO) system. Using state space methods it is relatively simple to work with Multi- Input Multi-Output system. Linear- Quadratic Regulator (LQR) optimal control problems have been widely investigated in the literature. The performance measure is a quadratic function composed of state vector and control input. If the linear time-invariant system is controllable, the optimal control law will be obtained via solving the algebraic Ricci equation optimal control. 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 [6]. The flow chart in Figure 2 shows. The mathematical modeling is doing to find the mathematical model for the separately excited DC motor where we will get the state-space model. This followed by getting the LQR controller from the state-space model. the Flow chart of Quadratic Regulator Linear-Quadratic Regulator (LQR) with speed analysis of separately excited DC motor. The MATLAB software is used to get the result. 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.

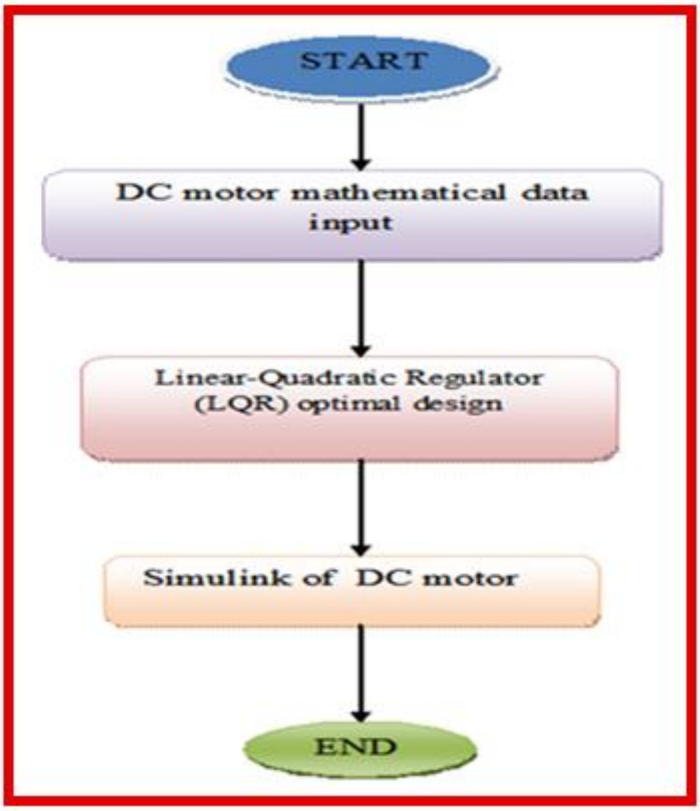

Fig 2 Flow Chart of LQR

IV. MODELLING OF DIRECT CURRENT MOTOR

Electric DC motor coverts electrical energy into Mechanical energy based on performance of electromagnetic induction. To achieve velocity control for the DC motor, the primary requirement is to model the DC motor system itself, in control system terminology it is called as plant modeling [8][10].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 3 show in the below and DC motor parameter given in the below [6].

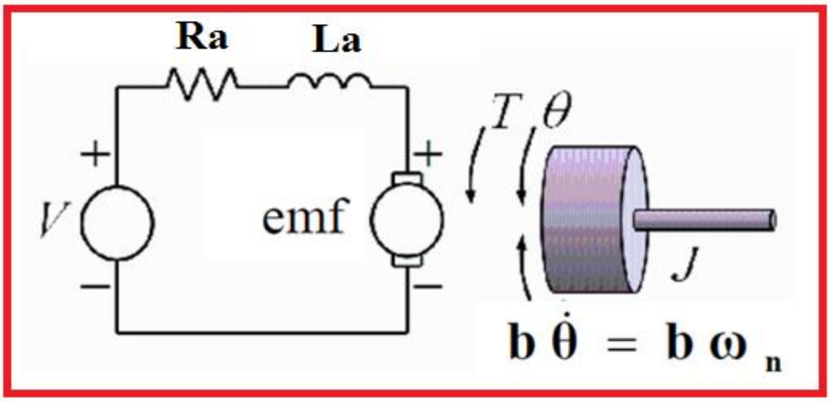

Fig 3 DC motor modelling.

A linear model of a DC motor consists of an electrical equation and mechanical equation. Using Kirchhoff's Voltage Law (KVL) and Newton's second law, the following equation is obtained:

$$\frac{d\, i_a}{dt} = -\frac{R_a}{L_a} i_a - \frac{K_b}{L_a}\dot{\theta} + \frac{Va}{L_a} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$\frac{d\theta}{dt} = \frac{K_T}{J} i_a - \frac{Bm}{J}\dot{\theta} \qquad (2)$$

Assuming the above equations, the steady state representation can be obtained as, fig 2 show the separately excited DC motor armature control system.

$$\begin{bmatrix} \frac{di_a}{dt} \\ \frac{d\theta}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-R_a}{L_a} & \frac{-K_b}{L_a} \\ \frac{K_T}{J} & \frac{-Bm}{J} \end{bmatrix} \begin{bmatrix} i_a \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{1}{L_a} \\ 0 \end{bmatrix} [V_a] \qquad (3)$$

$$y = [0 \quad 1] \begin{bmatrix} i_a \\ \dot{\theta} \end{bmatrix} \qquad (4)$$

The transfer function of the motor using the state space model by formula G(s) = C (s I - A)$^{-1}$ B in the equation (3) and (4) and obtain the equation 5 or 6.

$$\frac{\dot{\theta}\,(s)}{V\,(s)} = \frac{K_m}{(\,L_m S + R_m)(\,JS + b) + (K_m * K_m)} \dots\dots\dots\dots\dots\dots . (5)$$

$$\frac{\dot{\boldsymbol{\theta}}\,(\boldsymbol{s})}{\boldsymbol{V}\,(\boldsymbol{s})} = \frac{\mathbf{0.01}}{(\mathbf{0.5}\,\boldsymbol{s} + \mathbf{1})(\mathbf{0.01}\boldsymbol{s} + \mathbf{0.001}) + (\mathbf{0.01})^2} \dots\dots (\mathbf{6})$$

SIMULATION RESULT

TEST CASE 1:-

The performance and tuning using the optimal LQR controller has been compared with PID controllers. Data of dc motor described below in the APPENDIX table 1.

Figurer 4 shows the step response of PID control and in this case used PID parameter kp 2.10, ki 4.25 and kd 0.14**.** The PID controlled response of the system has considerably larger maximum settling time and higher overshoot values. The optimal LQR controller. Controlled response of the system has considerably reduced settling time and reduced overshoot values than PID controller. Its show in figure 5. Comparative step response results of PID controller and optimal LQR controller are shown in Figure 6 and table 1.

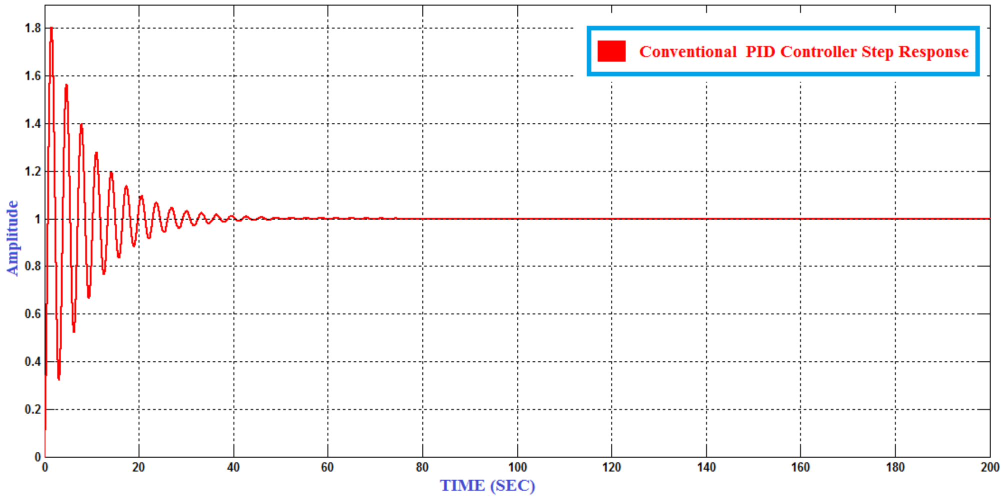

Figure 4 step response of PID controller.

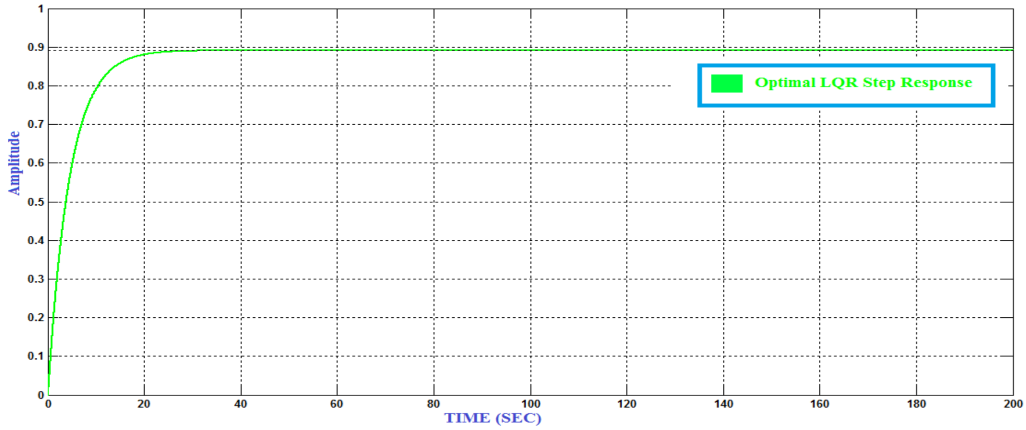

Figure 5. step response of LQR controller

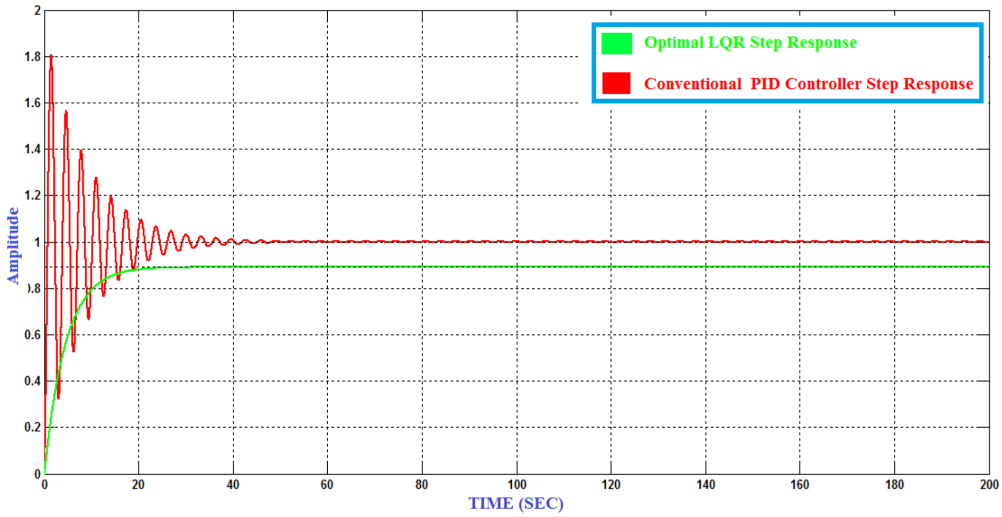

Figure 6 comparisons of PID controller and LQR controller

Table 1 Comparison of results of PID and optimal LQR controller

ALL Controllers response	**Settling Time (sec)**	**Peak amplitude**	**Overshoot (%)**
Conventional PID Controller Response	33.5	1.81	80.5
Optimal LQR Controller Response	**17.8**	**0.891**	**00**

Volume 02, Issue 11, [November – 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

Test Case 2:

Figurer 4 shows the step response of PID control and in this case used PID parameter Kp 3.10,Ki 4.25 and Kd 0.14 The PID controlled response of the system has considerably larger maximum settling time and higher overshoot values. The optimal LQR controller controlled response of the system has considerably reduced settling time and reduced overshoot values than PID controller. Response of the system has greatly improved using optimal LQR controller, its show figure 5.Comparative step response results of PID controller and optimal LQR controller are shown in Figure 6 and table 1

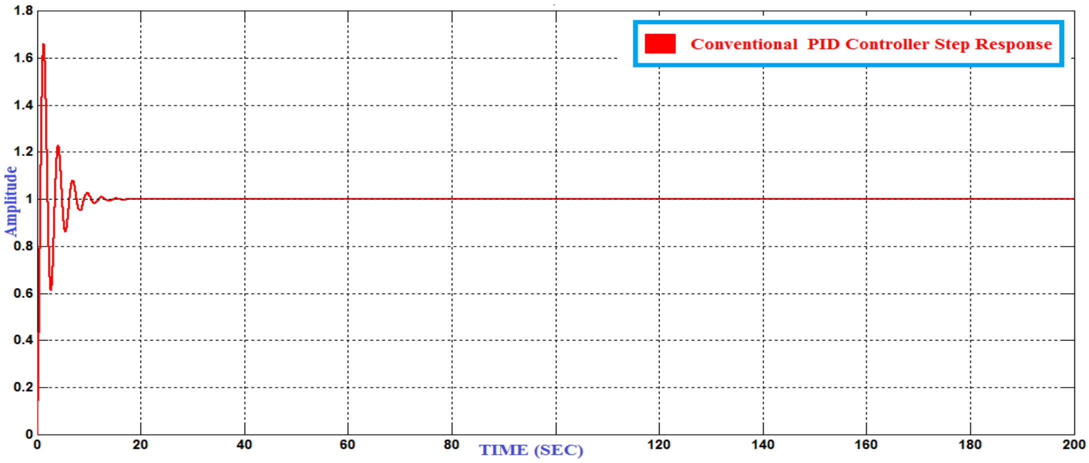

Figure 7 step response of PID controller

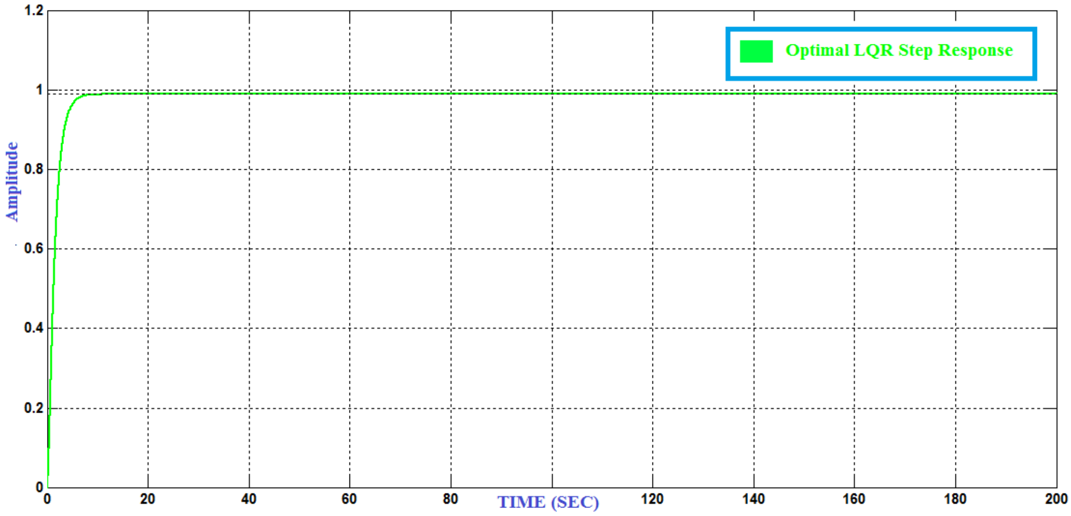

Figure 8 step response of o LQR controller

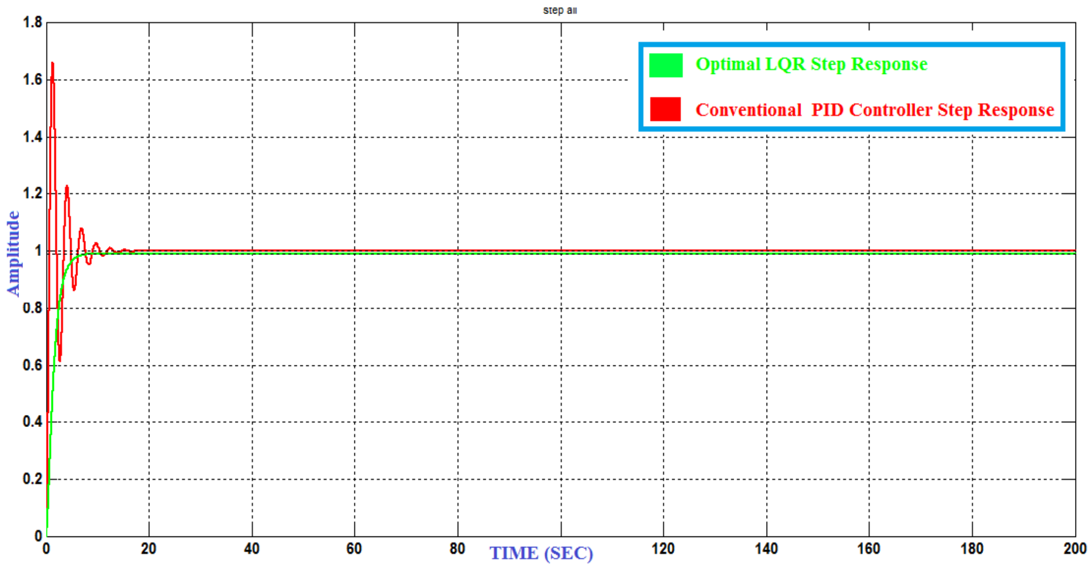

Figure 9 comparison step response of PID controller and LQR controller

Table 2 Comparison of results of PID and optimal LQR controller

ALL Controllers response	Settling Time (sec)	Peak amplitude	Maximum overshoot (%)
Conventional PID Controller Response	10.1	1.66	66.1
LQR Controller Response	**5.31**	**0.99**	**0**

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Volume 02, Issue 11, [November – 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

APPENDIX

***Table* 1 DC Motor data**

DC Motor Electric Resistance	**1 ohm**
DC Motor Electric Inductance	**0.5H**
Moment of Inertia of the Rotor	**0.01 kg.m2**
Damping ratio of the Mechanical System	**0.001 (Nms)**
Motor Constant	**0.01 Nm/A**