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“Performance Analysis of PID Controller for DC Motor Speed Regulation”

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Abstract- The evaluation of a proportional-integral-derivative (PID) controller's performance for efficient DC motor speed control. Based on the DC motor's electrical and mechanical properties, a mathematical model is created, and a closed-loop control system is created. In order to attain better dynamic performance, such as shorter rising times, less overshoot, and low steady-state error, the PID controller's parameters are adjusted. MATLAB/Simulink is used for simulation in order to assess the reaction of the system under various operating situations. The findings show that, in comparison to open-loop operation, the PID controller greatly improves the precision and stability of motor speed control. The study shows that a well-tuned PID controller is a dependable and effective way to regulate DC motor speed in industrial settings.

Keywords— PID controller, DC motor speed control, closed-loop control system, mathematical modeling, electrical and mechanical dynamics, parameter tuning, rise time, overshoot reduction, steady-state error minimization, MATLAB/Simulink simulation, system response analysis, stability improvement, control accuracy, industrial automation, performance optimization.

I. INTRODUCTION

Because of its straightforward design, great efficiency, and ease of speed control, DC motors are widely utilized in robotics, industrial automation, and electric drive applications. Particularly in applications with fluctuating loads and dynamic operating circumstances, maintaining precise and stable motor speed is crucial for guaranteeing system performance and dependability.

Closed-loop control methods, which continuously monitor and compare the actual motor speed with the intended reference value, are used to address these difficulties. Accurate speed regulation is ensured by adjusting the input voltage using the resultant error signal. The proportional-integral-derivative (PID) controller is still one of the most popular control techniques because of its ease of use, resilience, and efficacy under a variety of operating circumstances.

To enhance both transient and steady-state performance, the PID controller integrates three control actions: proportional, integral, and derivative. The derivative term improves system stability by forecasting future behavior, the integral term removes steady-state inaccuracy, and the proportional term offers instantaneous reaction. To get the best performance, these parameters must be properly adjusted.

The development of simulation tools like MATLAB/Simulink has made it feasible to precisely model dynamic systems and examine how they behave under various circumstances. Without requiring physical implementation, these tools offer a graphical environment for developing control systems, testing different controller configurations, and assessing performance. This method is ideal for contemporary engineering applications since it lowers development time, cost, and risk.

All things considered, efficient speed management of DC motors with PID controllers is essential to enhancing system stability, efficiency, and dependability, making it a key subject in control system engineering.

II. OBJECTIVES

- To comprehend the principles of speed control methods and DC motor operation.
- To research the function and importance of feedback control systems in enhancing motor function.
- To create and put into action a successful control plan for precise speed control.
- To improve overall performance, stability, and dependability of the system under different circumstances.
- To evaluate and enhance the system's dynamic reaction.
- To investigate real-world uses of control systems in real-time and industrial settings

III. METHODOLOGY:

System modeling, controller design, parameter tuning, and performance assessment utilizing a closed-loop control approach are all part of the DC motor speed regulation process.

1. Mathematical Modeling of DC Motor

The DC motor is modeled using electrical and mechanical equations.
Electrical equation:

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$$V(t) = L\frac{di(t)}{dt} + Ri(t) + e_b(t)$$

where V(t)is the applied voltage, Lis armature inductance, Ris armature resistance, i(t)is armature current, and e_b (t)is back EMF.

Back EMF is proportional to angular speed:

$$e_b(t) = K_b\,\omega(t)$$

Mechanical equation:

$$T(t) = J\frac{d\omega(t)}{dt} + B\omega(t)$$

where T(t)is torque, Jis moment of inertia, Bis friction coefficient, and ω(t)is angular speed.

Motor torque is:

$$T(t) = K_t\,i(t)$$

By combining these equations and applying Laplace transform, the transfer function of the DC motor is obtained as:

$$fracOmega(s)V(s) = fracK_t(Js+B)(Ls+R) + K_bK_t$$

2. PID Controller Design

A PID controller is used to minimize the error between reference speed and actual speed. The controller output is given by:

$$u(t) = K_pe(t) + K_i\int e(t)dt + K_d\frac{de(t)}{dt}$$

3. Implementing Closed-Loop Systems

The system is set up in a closed-loop manner in which:

- Actual speed and reference speed are contrasted.
- The PID controller processes the error signal.
- The motor is driven by the controller output.
- This feedback system guarantees ongoing correction and increased precision.

4. PID Adjustment

Standard methods for adjusting controller parameters include:

- The Ziegler-Nichols approach
- The method of trial and error
- MATLAB/Simulink tools for software-based tweaking

Tuning seeks to:

- Cut down on the rising time
- Reduce overshoot
- Get a quicker settling time
- Get rid of steady-state error

5. Analysis of Performance and Simulation

MATLAB/Simulink is used to simulate the entire system. Key time-domain parameters are used to assess performance:

- Rise time
- Time spent settling
- Overshoot at the peak
- Error in a steady state

To confirm robustness and stability, the system response is examined under various load disturbances

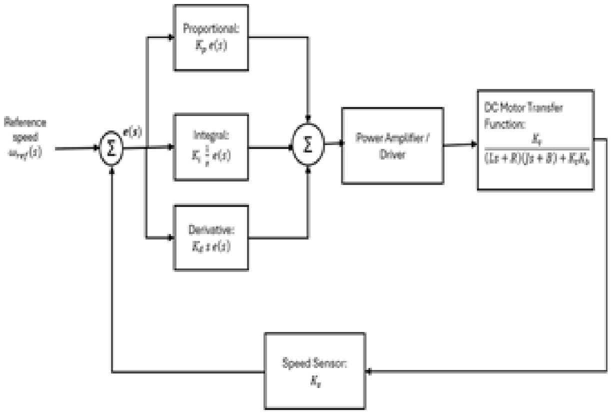
6.Validation

The PID controller's efficacy is confirmed by contrasting:

- Closed-loop versus open-loop response
- System performance: regulated versus uncontrolled

The outcomes attest to enhanced dynamic performance, precision, and stability.

IV. BLOCK DIAGRAM



- e(s): Error signal
- u(s): Control signal (armature voltage)
- ω(s): Actual speed (rad/s)
- K_s: Speed sensor gain

Parameters

- K_p: Proportional gain
- K_i: Integral gain
- K_d: Derivative gain
- K_t: Torque constant
- K_b: Back EMF constant
- R: Armature resistance
- L: Armature inductance
- J: Moment of inertia

- The system begins with a reference speed, which is the desired motor speed.
- A summation block (Σ) compares the reference speed with the actual motor speed and generates the error signal e(s).
- This error signal is fed into the PID controller, which consists of three components:
- Proportional (P): produces output proportional to the error for quick response;
- Integral (I): eliminates steady-state error by integrating the error over time; and
- Derivative (D): predicts future error and improves system stability.
- The combined output of these three actions forms the control signal u(s), which is fed into the power amplifier/driver, strengthening the signal to drive the motor.
- The DC motor generates angular speed ω(s)\omega(s)ω(s) by converting the electrical input into mechanical rotation.
- The real motor speed is measured by a speed sensor, which then transforms it into a feedback signal.
- A closed-loop system is created by returning this feedback signal to the summing block.
- To minimize mistake and sustain the intended speed, the loop continuously modifies the motor input

V. MATLAB SIMULATIONS:

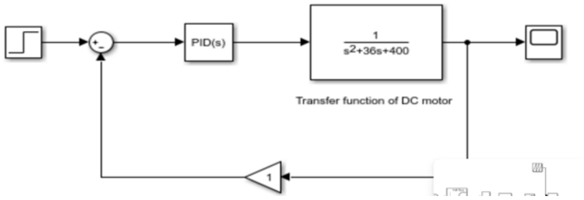


Fig. DC motor with PID controller step input

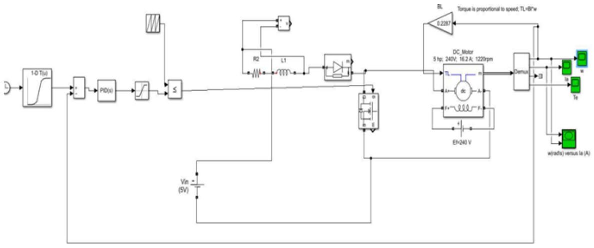


Fig.DC motor with PID controller

A closed-loop feedback system is the foundation for DC motor speed control utilizing a PID controller in MATLAB/Simulink. A transfer function that connects input voltage to output speed is used to simulate the motor. An error signal is produced by comparing the actual speed with a reference speed. The PID controller processes this error and modifies the control input to reduce the error.

By decreasing rise time, removing steady-state error, and boosting stability, the PID controller improves system performance by combining proportional, integral, and derivative actions. Using elements like step input, PID controller, transfer function, and scope, Simulink offers a graphical platform for modeling and simulating this system. The simulation aids in the effective analysis and optimization of system performance.

VI. RESULTS:

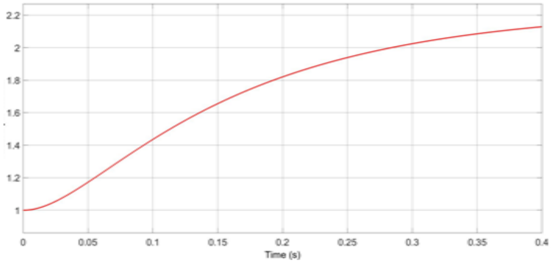
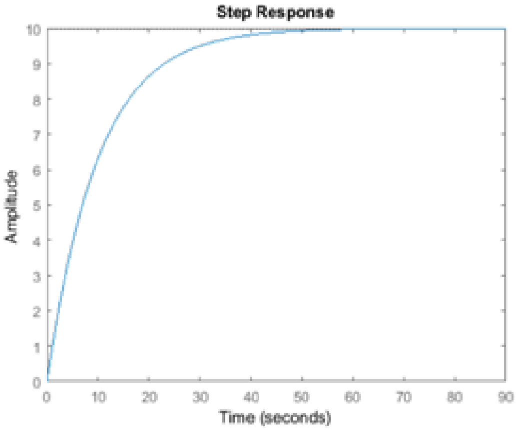


Fig. Speed of DC motor rad/ sec for P=10,I=50,d=100



MATLAB/Simulink was used to simulate the DC motor speed control system with a PID controller. According to the findings, the closed-loop system outperforms the open-loop system by a considerable margin.

Faster rise times and shorter settling times are achieved by the motor speed response with PID control, guaranteeing prompt achievement of the target speed. Accurate speed tracking is demonstrated by the reduction of overshoot and the near elimination of steady-state inaccuracy. Additionally, the system exhibits steady behavior in the face of load disruptions and changing operational conditions.

The PID controller's efficacy is confirmed by the output waveform seen in the scope, which displays a smooth and controlled response. Overall, the findings show that the DC motor's stability, accuracy, and dynamic performance are improved by the PID-based control system.

VII. CONCLUSION:

The DC motor speed control using a PID controller provides an effective and reliable solution for achieving accurate and stable performance. The closed-loop system significantly improves dynamic response by reducing rise time, minimizing overshoot, and eliminating steady-state error. The use of MATLAB/Simulink enables efficient modeling, simulation, and analysis of the system under different operating conditions.

The results confirm that a properly tuned PID controller enhances system stability and ensures precise speed regulation even in the presence of disturbances. Due to its simplicity and robustness, the PID control technique is well-suited for practical and industrial applications involving DC motor drives.

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