CHAPTER ONE

INTRODUCTION

1.1 General Concepts

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. Why do we need a speed motor controller? For example, if we have a DC motor in a robot, if we just apply a constant power to each motor on a robot, then the poor robot will never be able to maintain a steady speed. It will go slower over carpet, faster over smooth flooring, slower up hill, faster downhill, etc. So, it is important to make a controller to control the speed of DC motor in desired speed. 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 [1]. DC motors have been used in variable speed drives for a long time. The versatile characteristics of dc motors can provide high starting torques which is required for traction drives. Control over a wide speed range, both below and above the rated speed can be very easily achieved. The methods of speed control are simpler and less expensive than those of alternating current motors [2]. There are different techniques available for the speed control of DC motors. The phase control method is widely adopted in which ac to dc converters are used to supply the dc motors, but has certain limitations mainly it generates harmonics on the power line and it also has poor p.f. when operated at lower speeds [1]. Proportional-Integral-Derivative (PID) controllers are widely used in industrial processes, and can be implemented in different ways: as a stand-alone regulator or as a distributed component of a control system. Systems with slow dynamics and few performance requirements, as most industrial processes, can be easily controlled using a PID strategy. The incorporation of microprocessors in control systems has modified the meaning of controller's operational characteristics as well as its algorithms. This fact has made possible self-diagnosis and auto tuning. PID controllers are often implemented with poor tuning, that deteriorates the system performance, in order to let the controlled system work under different conditions [2]. As known from the literature, the auto tuning procedure is performed on the demand of the user, or colloquially after a 'button push'. Thus, it is not performed continuously in the adaptation loop, but rather when the need for tuning or re-tuning arises. This technique reiterates the design steps which the control engineer performs during the design of the controller. Firstly, a simple experiment is performed which determines some characteristics of the process. After that, using the data obtained, the controller parameters are calculated, and the designed controller is started. Such a feature of modern controllers is particularly useful during commissioning of control systems. Besides, auto tuning can also be used for the build-up of the table of controller parameters for gain scheduling [3]. The Ziegler and Nichols [1] methods are the most common PID tuning procedures. These methods are very simple and require few information of the system.

1.2 Problem Statement

Due to the use of DC motors in many applications and the need to control its speed and the problem of nonlinearity in its performance, it is necessary to find ways to control its speed. One of the most widely used methods of controlling this motor is PID controller.

1.3 Objectives

The main aim objectives of the project are:

- Drive mathematic model of DC motor.

- Control speed of DC motor using PID controller.
- Comparison the results

1.4 Methodology

- ✓ Cover all study about project
- ✓ Analysis the problem
- ✓ Modelling of DC motor
- ✓ Drive PID controller
- ✓ Testing and result

1.5 Project Layout

In the following chapter we are going to discuss more about the previous studies in chapter two. The literature review in chapter three, this chapter includes review DC motor and PID controller. In chapter four, the system design is included with detailed design steps. The result and analysis of the system in chapter five, and final chapter is the conclusion plus the recommendations.

CHAPTER TWO

THEORITICAL BACKGROUND

2.1 Introduction

From the very beginning, it has been realized by systems theorists that most real world dynamical systems are nonlinear. However, linearization of such systems around the equilibrium states yields linear models, which are mathematically obedient. In particular, based on the superposition principle, the output of the system can be computed for any arbitrary input, and alternately, in control problems, the input, which optimizes the output in some sense, can also be determined with relative ease. In most of the adaptive control problems, where the plant parameters are assumed to be unknown, the fact that the latter occur linearly makes the estimation procedure straightforward. The fact that most nonlinear systems thus far could be approximated satisfactorily by linear models in their normal ranges of operation has made them attractive in practical contexts as well. It is this combined effect of ease of analysis and practical applicability that accounts for the great success of linear models and has made them the subject of intensive study for over four decades. In recent years, a rapidly advancing technology and a competitive market have required systems to operate in many cases in regions in the state space where linear approximations are no longer satisfactory. To cope with such nonlinear problems, research has been underway on their identification and control using artificial neural networks based entirely on measured inputs and outputs. From the beginning of systematic automatic controller design there has been the problem of finding a proper controller structure and the controller parameters for a given process. The main difficulty that comes into sight is the need of the controller to be very well tuned for the whole range of its operating points rather than for one particular operating point. To overcome these circumstances, adaptive controllers were developed in the nineteen forties. Between nineteen sixties and nineteen seventies many fundamental areas in control theory were developed which later proved to be significant for the design of adaptive control systems, e.g. state space and stability theory.

2.2 Literature Survey

A number of authors have proposed different models for tuning PID based. The following table describes previous work in the same field with different objectives and findings. All papers listed below conclude that the can enhance the performance of the system developed regarding the performance criterion such as settling time, steady state error, peak time and overshoot.

Gaining Han et al: This work designs a lateral control dynamic model of the intelligent vehicle, which is used for lateral tracking control. This control model comprises PID control for heading angle and BP Neural network control for the PID parameters adjustment. Rodrigo Hernández-Alvarado et al: The actual work presents the development of a control algorithm to automatically tune the gains of a PID control, based on a neural network. The control algorithm was implemented on ROVs for trajectory tracking with unknown disturbances. The algorithm performance was evaluated in two instances: a numerical simulation and implemented on a ROV in real-time.

Kenan Muderrisoglu et al: In this study, linear quarter vehicle model has been controlled with using PID Method. Due to adaptive PID parameter estimation, Artificial Neural Networks has been built. Therefore, NN efficiency has been observed. Ideal PID parameters has been obtained with using Ziegler-Nichols Method. Because of insurance of the PID efficiency, proportion parameter amount has been limited to ideal proportion of controller. Elias Reichensdörfer et al: In this thesis, recurrent neural networks were applied for both system identification and PID tuning tasks. The goal was to investigate whether recurrent neural networks are suitable for those tasks and if they can compete with state-of-the-art control methods. For this purpose, several bench mark systems were implemented while each system had its unique difficulties in control. Simna Surendran, Vimal Kumar: The paper presents a method to use capability of neural networks to solve process control problem of finding optimum P and I parameters of a PI controller, within finite time without dangerous oscillations. The capability of designed NNs to predict ultimate gain and P & I parameters matching requirement specific to a given training set was verified using simulations discussed in this paper. Sherif A. Elbelady: In this paper a new adaptive tuning method for PID gains controller based on corresponding online auto-tuning neurons has been proposed So that the gains are updated continuously. Experimental position control of a pneumatic cylinder is achieved used STNPID controller. Huanxin Cheng et al: In this paper a comparison with the traditional PID neural network PID control process has advantages of smaller overshoot, more rapid adjustment and shorter adjustment time, meaning that the control performance is better; then its steady-state error is smaller than that of traditional PID control; in addition, PID parameter can adjust automatically and the results simulation show that the method can improve the control performance of heavy oil concentration. Rosmin Jacob, Senthil Murugan : MATLAB simulation is used to evaluate the performance of BASED based PID controller to control the speed of DC motor, and make a comparison between convential PID controller and BASED base PID.

2.3 Control Theory

Control theory is an interdisciplinary branch of engineering and mathematics that deals with the behavior of dynamical systems. The desired output of a system is called the reference. When one or more output variables of a system need to follow a certain reference over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system [3].

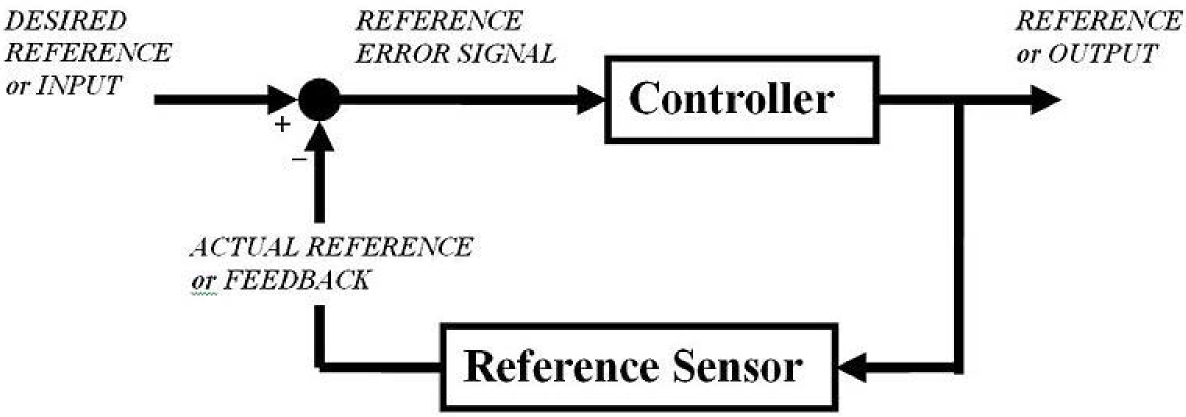

Figure 2.1 Concept of the feedback loop to control the dynamic behavior of the reference

If we consider an automobile cruise control, it is design to maintain the speed of the vehicle at a constant speed set by the driver. In this case the system is the vehicle. The vehicle speed is the output and the control is the vehicle throttle which influences the engine torque output. One way to implement cruise control is by locking the throttle at the desired speed but when encounter a hill the vehicle will slow down going up and accelerate going down. In fact, any parameter different than what was assumed at design time will translate into a proportional error in the output velocity, including exact mass of the vehicle, wind resistance, and tire pressure [4]. This type of controller is called an open-loop controller because there is no direct connection between the output of the system (the engine torque) and the actual conditions encountered; that is to say, the system does not and cannot compensate for unexpected forces [5]. For a closed-loop control system, a sensor will monitor the vehicle speed and feedback the data to its computer and continuously adjusting its control input or the throttle as needed to ensure the control error to a minimum therefore maintaining the desired speed of the vehicle. Feedback on how the system is actually performing allows the controller to dynamically compensate for disturbances to the system, such as changes in slope of the ground or wind speed [5]. An ideal feedback control system cancels out all errors, effectively mitigating the effects of any forces that may or may not arise during operation and producing a response in the system that perfectly matches the user's wishes [5]. The output of the system $Y(t)$ is fed back through a sensor measurement F to the reference value r(t). The controller C then takes the error e (difference) between the reference and the output to change the inputs u to the system under control P. This is shown in the figure. This kind of controller is a closed-loop controller or feedback controller. This is called a Single-Input-Single-Output (SISO) control system; (Multi-Input-Multi-Output) (MIMO) systems, with more than one input/output, are common. In such cases variables are represented through vectors instead of simple scalar values. For some distributed parameter systems, the vectors may be infinite-dimensional (typically functions).

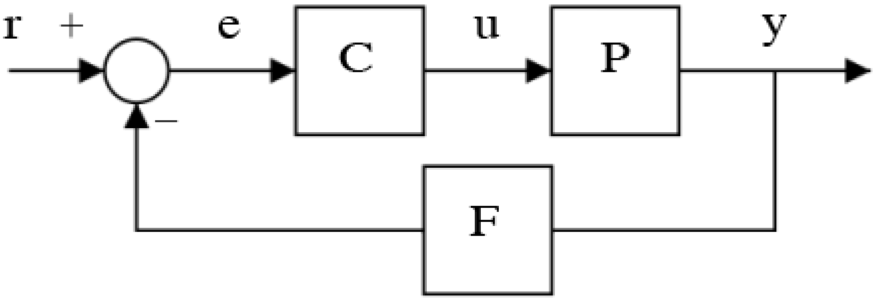

Figure 2.2 Closed-loop controller or feedback controller

If we assume the controller C, the plant P, and the sensor F are linear and time invariant (i.e.: elements of their transfer function C(s), P(s), and F(s) do not depend on time), the systems above can be analyzed using the Laplace transform on the variables. This gives the following relations:

$$Y(s) = P(s)\,U(s) \tag{2.1}$$

$$U(s) = C(s)\,E(s) \tag{2.2}$$

$$E(s) = R(s) - F(S)\,Y(S) \tag{2.3}$$

Solving for Y(s) in terms of R(s) gives:

$$\mathrm{Y(s)} = \left(\frac{\mathrm{P(s)C(s)}}{1+\mathrm{F(s)P(s)C(s)}}\right)\mathrm{R(s)} = \mathrm{H(s)R(s)} \qquad (2.4)$$

The expression is referred to as the closed-loop transfer function of the system. The numerator is the forward (open loop) gain from r to y, and the denominator is one plus the gain in going around the feedback loop, the so-called loop gain.

2.4 Types of Motors

The DC motor is one of the first machines devised to convert electrical energy to mechanical power. Its origin can be traced to machines conceived and tested by Michael Faraday, the experimenter who formulated the fundamental concepts of electromagnetism. These concepts basically state that if a conductor, or wire, carrying current is placed in a magnetic field, a force will act upon it. The magnitude of this force is a function of strength of the magnetic field, the amount of current passing through the conductor and the orientation of the magnet and conductor. The direction in which this force will act is dependent on the direction of current and direction of the magnetic field. Electric motor design is based on the placement of conductors (wires) in a magnetic field. A winding has many conductors, or turns of wire, and the contribution of each individual turn adds to the intensity of the interaction. The force developed from a winding is dependent on the current passing through the winding and the magnetic field strength. If more current is passed through the winding, then more force (torque) is obtained. In effect, two magnetic fields interacting cause movement: the magnetic field from the rotor and the magnetic field from the stators attract each other. This becomes the basis of both AC and DC motor design.

2.4.1 AC motors

Most of the world's motor business is addressed by AC motors. AC motors are relatively constant speed devices. The speed of an AC motor is determined by the frequency of the voltage applied (and the number of magnetic poles). There are basically two types of AC motors: induction and synchronous

2.4.2 Induction motors

If the induction motor is viewed as a type of transformer, it becomes easy to understand. By applying a voltage onto the primary of the transformer winding, a current flow results and induces current in the secondary winding. The primary is the stator assembly and the secondary is the rotor assembly. One magnetic field is set up in the stator and a second magnetic field is induced in the rotor. The interaction of these two magnetic fields results in motion. The speed of the magnetic field going around the stator will determine the speed of the rotor. The rotor will try to follow the stator's magnetic field, but will "slip" when a load is attached. Therefore, induction motors always rotate slower than the stator's rotating field.

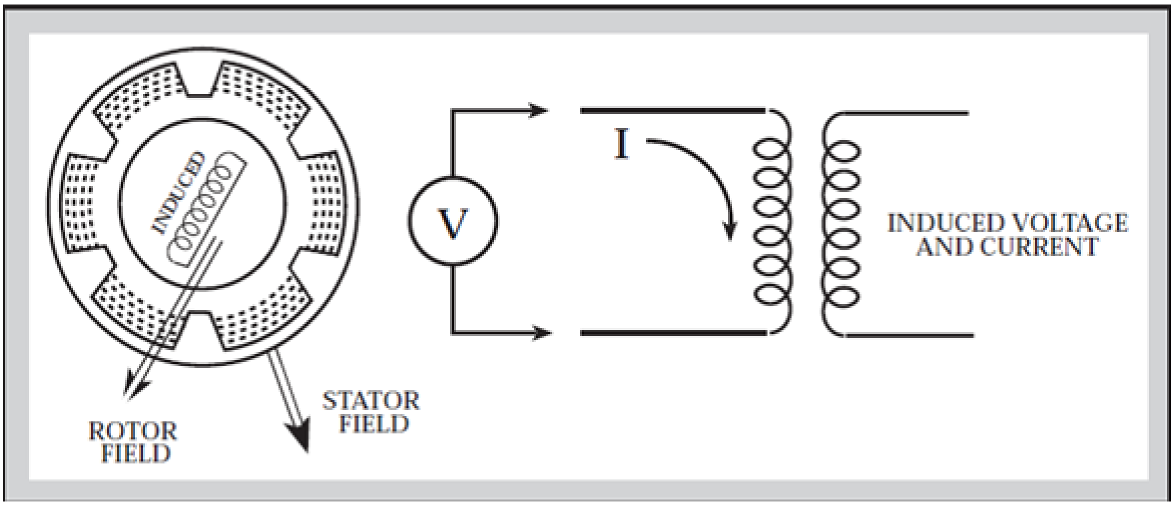

Figure 2.3: Induction motor

Typical construction of an induction motor consists of A stator with laminations and turns of copper wire and A rotor, constructed of steel laminations with large slots on the periphery, stacked together to form a "squirrel cage" rotor. Rotor slots are filled with conductive material (copper or aluminum) and are short-circuited upon themselves by the conductive end pieces. This "one" piece casting usually includes integral fan blades to circulate air for cooling purposes. The standard induction motor is operated at a "constant" speed from standard line frequencies. Recently, with the increasing demand for adjustable speed products, controls have been developed which adjust operating speed of induction motors. Microprocessor drive technology using methods such as vector or phase angle control (i.e. variable voltage, variable frequency) manipulates the magnitude of the magnetic flux of the fields and thus controls motor speed. By the addition of an appropriate feedback sensor, this becomes a viable consideration for some positioning applications.

2.4.3 Synchronous motor

The synchronous motor is basically the same as the induction motor but with slightly different rotor construction. The rotor construction enables this type of motor to rotate at the same speed (in synchronization) as the stator field. There are basically two types of synchronous motors: self-excited (as the induction motor) and directly excited (as with permanent magnets). The self-excited motor (may be called reluctance synchronous) includes a rotor with notches, or teeth, on the periphery. The number of notches corresponds to the number of poles in the stator. Oftentimes the notches or teeth are termed salient poles. These salient poles create an easy path for the magnetic flux field, thus allowing the rotor to "lock in" and run at the same speed as the rotating field. A directly excited motor (may be called hysteresis synchronous, or AC permanent magnet synchronous) includes a rotor with a cylinder of a permanent magnet alloy. The permanent magnets north and south poles, in effect, are the salient teeth of this design, and therefore prevent slip.

2.4.4 DC motor

Most of the world's adjustable speed business is addressed by DC motors. DC motor speeds can easily be varied; therefore, they are utilized in applications where speed control, servo control, and/or positioning needs exist. The stator field is produced by either a field winding, or by permanent magnets. This is a stationary field (as opposed to the AC stator field which is rotating). The second field, the rotor field, is set up by passing current through a commutator and into the rotor assembly. The rotor field rotates in an effort to align itself with the stator field, but at the appropriate time (due to the commutator) the rotor field is switched. In this method then, the rotor field never catches up to the stator field. Rotational speed (i.e. how fast the rotor turns) is dependent on the strength of the rotor field. In other words, the more voltage on the motor, the faster the rotor will turn. The following will briefly explore the various wound field motors and the Permanent Magnet DC (PM) (DC) motors.

2.4.4.1 Shunt wound motor

With the shunt wound, the rotor and stator (or field windings) are connected in parallel. The field windings can be connected to the same power supply as the rotor, or excited separately. Separate excitation is used to change motor speed (i.e. rotor voltage is varied while stator or field winding is held constant). The parallel connection provides a relative flat speed-torque curve and good speed regulation over wide load ranges. However, because of demagnetization effects, these motors provide starting torques comparatively lower than other DC winding types.

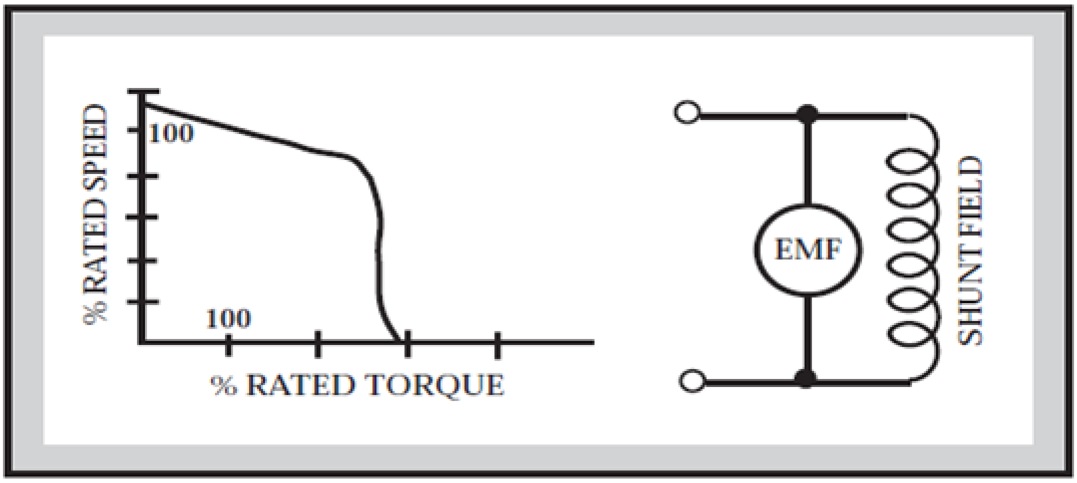

Figure 2.4: Typical speed-torque curve for shunt wound motors

2.4.4.2 Series wound motors

In the series wound motor, the two motor fields are connected in series. The result is two strong fields which will produce very high starting torque. The field winding carries the full rotor current. These motors are usually employed where large starting torques are required such as cranes and hoists. Series motors should be avoided in applications where they are likely to lose load because of the tendency to run away under no-load conditions.

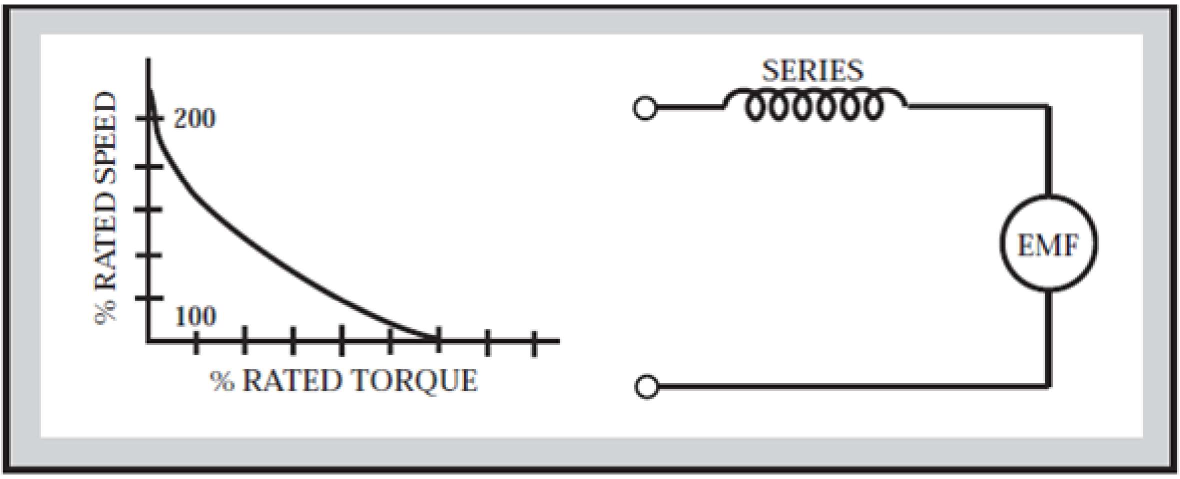

Figure 2.5: Typical speed-torque curve for series wound motors

2.4.4.3 Compound wound motors

Compound motors use both a series and a shunt stator field. Many speed torque curves can be created by varying the ratio of series and shunt fields. In general, small compound motors have a strong shunt field and a weak series field to help start the motor. High starting torques is exhibited along with relatively flat speed torque characteristics. In reversing applications, the polarity of both windings must be switched, thus requiring large, complex circuits.

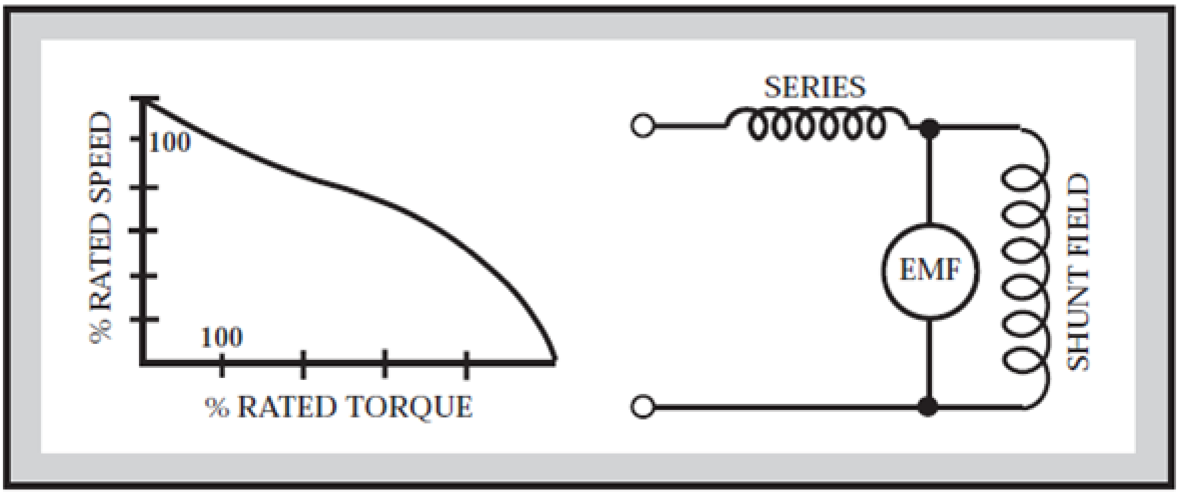

Figure 2.6: Typical speed-torque curve for compound wound motors

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2.5 Proportional –Integral-Derivative Controllers

Other than the BASED controller two types of conventional feedback controllers are used in the present study. One is a Proportional-Integral (PI) controller and the other is a PID controller. Both these servo controllers are used for comparison purposes with the Artificial Neural Network (BASED) based controller. At implementation the controllers were built using a host-target prototyping environment with a compatible data acquisition board. In this study a PMDC motor is adopted as the plant. The idealized equation of a PI controller is

$$u(t) = K\left[e(t) + \frac{1}{T_i}\int_0^t e(t)dt\right] \tag{2.5}$$

in which K is the gain, T_i is the integral time and e(t) is the feedback error; i.e., e(t) =r(t) – y(t). Where r (t) and y (t) are reference input and the plant output respectively The equivalent transfer function in the s-domain is given by

$$U(s) = \left[K\left(1 + \frac{1}{sT_i}\right)\right]E(s) \tag{2.6}$$

For digital control, Equation (2.6) is transformed into its discrete-time (z-domain) equivalent, as given by

$$U(z) = \left[K_p\left(1 + \frac{K_i}{1 - Z^{-1}}\right)\right]E(s) \tag{2.7}$$

Or, in velocity form,

$$U(z) = -K_p Y(z) + K_i \frac{E(z)}{1 - Z^{-1}} \tag{2.8}$$

where

$$K_p = K - \frac{KT_s}{2T_i} \tag{2.9}$$

$$K_i = \frac{KT_s}{T_i} \tag{2.10}$$

and Ts is the sampling interval. The Proportional, Integral, Derivative controller (or the PID controller) is the most popular type of controller used in different engineering applications. The PID controller is a form of control loop that has a feedback mechanism. The PID controller works by calculating the error signal between an output measured value and a reference value, the controller works to minimize the error signal or the difference between the output signal and the reference signal to a minimum value; such that the output measured value will be as close as possible to the input reference signal [1]. The mathematical representation of the PID controller is:

$$U(t) = Kp.e(t) + Ki\int_0^t e(\tau)d\tau + Kd\frac{d}{dt}e(t) \qquad (2.11)$$

Where U(t) is the controller output signal, e(t) is the error signal, K_p is the proportional gain, K_i is the integral gain and K_d is the derivative gain. As shown in Eq. 3.16 above, the PID controller has three parameters, P or Proportional term, I or Integral term and D or Derivative term, each one of these terms has a gain value related to it, and it makes the controller system to react in a different way from the others. The proportional term depends on the present error value, the proportional gain have a direct relationship to the controller sensitivity, the higher P gain value leads to faster change for the systems' output, which makes the controller to be more sensitive [7].

2.6 Tuning of the Proportional-Integral- Derivative Controller

An auto-tuner is a device that automatically computes the parameters of a controller. The goal is to achieve the best control possible given the tuning objectives. The goal is not to replace a human control engineer. The auto-tuner should rather be seen as an aid to improvement [3]. Many single-input single-output industrial control loops are poorly tuned. Tuning of a PID controller refers to the tuning of its various parameters (P, I and D) to achieve an optimized value of the desired response. The basic requirements of the output will be the stability, desired rise time, peak time and overshoot. Different processes have different requirements of these parameters which can be achieved by meaningful tuning of the PID parameters. If the system can be taken offline, the tuning method involves analysis of the step input response of the system to obtain different PID parameters. But in most of the industrial applications, the system must be online and tuning is achieved manually which requires very experienced personnel and there is always uncertainty due to human error. Another method of tuning can be Ziegler-Nichols method. While this method is good for online calculations, it involves some trial-and-error which is not very desirable [3].

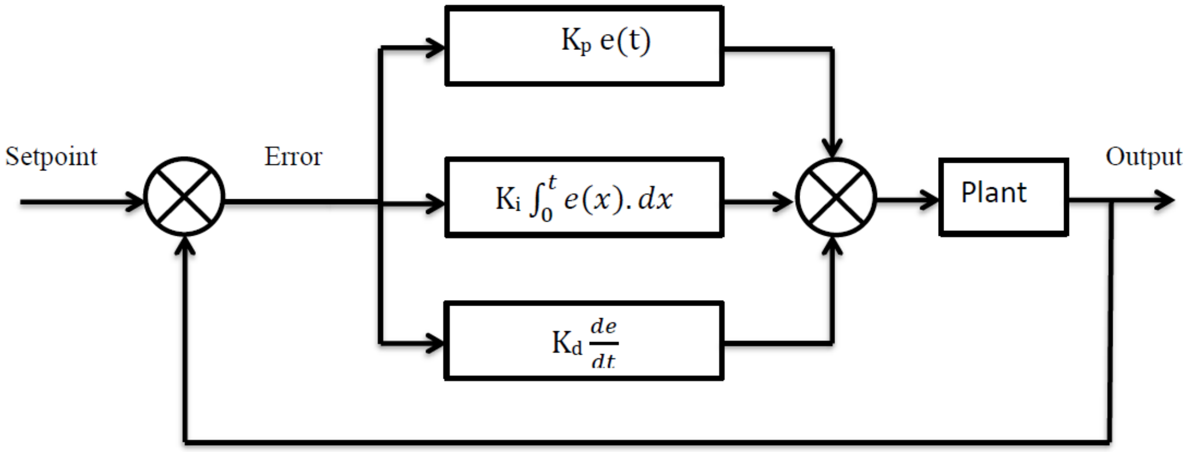

Figure 2.7: Basic block diagram of a conventional PID controller

The PID controller, introduced in the last section, is a standard building block form industrial automation. The popularity of this regulator comes from its robust performance in a wide range of operating conditions, and also from its functional simplicity, which makes it suitable for manual tuning. To account for process changes and ageing, regular retuning is normally required.

Accurate tuning is an operation which, to be done properly, takes considerable time. Since large plants can have hundreds of PID regulators, methods which automate the tuning of the PID compensators are of great practical importance. A large number of methods for PID auto-tuning have been proposed. In this section some of them will be described. To ease the description these methods will be loosely classified into five classes: frequency response based, step response based, on-line parameter estimation based, expert and fuzzy systems based, and neural networks based [3].

CHAPTER THREE

MODELING AND SYSTEM COMPONENTS

3.1 Introduction

As known from the literature, the auto tuning procedure is performed on the demand of the user, or colloquially after a ‘button push’. Thus, it is not performed continuously in the adaptation loop, but rather when the need for tuning or re-tuning arises. This technique reiterates the design steps which the control engineer performs during the design of the controller. Firstly, a simple experiment is performed which determines some characteristics of the process. After that, using the data obtained, the controller parameters are calculated, and the designed controller is started. Such a feature of modern controllers is particularly useful during commissioning of control systems. Besides, auto tuning can also be used for the build-up of the table of controller parameters for gain scheduling [3]. The Ziegler and Nichols [1] methods are the most common PID tuning procedures. These methods are very simple and require few information of the system.

3.2 System Components

In the previous chapter, the current control technologies that have been widely used for speed control to improve the system performance were reviewed. Then, the shortcomings and problems of current control strategies are summarized. These problems limit the use of control strategies for speed control systems. In order to address these issues, future perspectives and approaches to improve the control performance control are discussed and concluded. In this study, PID-controller will be designed for different purposes. The proposed controller design is mainly based on the following considerations: New control approaches may merge both the conventional and advanced control methods. There is a possible way: a method by which individual merits are combined. PID control is usually utilized due to its practicality. But its control performance is mainly based on the PID parameters and improper selection of them will lead to poor control performance. Hence intelligent controller is required to regulate the PID parameters automatically to ensure the optimized control output. The control process that does not require intervention of the users with specific skills or knowledge. Closed-loop, real-time and on-line learning ability. The performance evaluation system could be included to make a control process have the self-learning and modifying ability.

3.3 DC Motor Modeling

A common actuator in control systems is the DC motor. It directly provides rotary motion and, coupled with wheels or drums and cables, can provide translational motion. The electric equivalent circuit of the armature and the free-body diagram of the rotor are shown in the following Figure 3.1. [14]

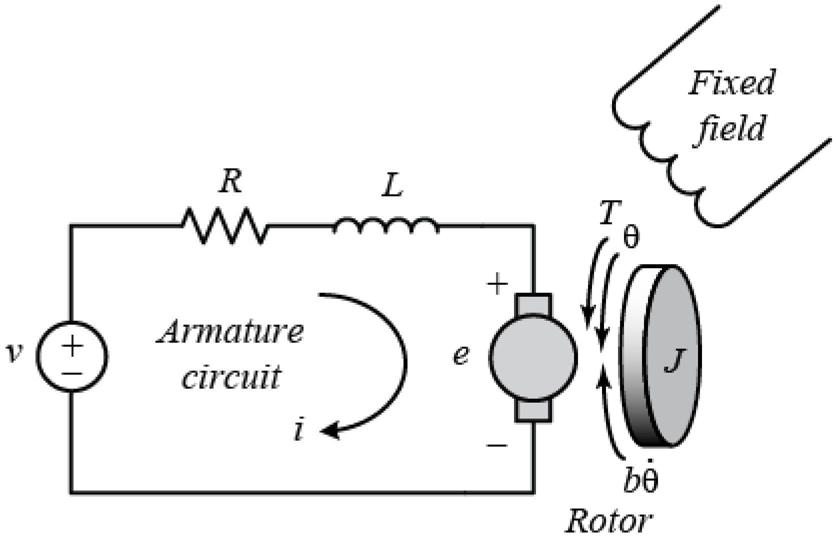

Figure 3.1: Structure of DC motor circuit

For this example, will be assumed that the input of the system is the voltage source (V) applied to the motor's armature, while the output is the rotational speed of the shaft d(theta)/dt. The rotor and shaft are assumed to be rigid. Will be further assumed a viscous friction model, that is, the friction torque is proportional to shaft angular velocity. The physical parameters for our example are:

Symbol	Parameter	Value
J	Moment of inertia of the rotor	0.01 Kg.m^2
b	Motor viscous friction constant	0.1 N.m. s
Ke	Electromotive force constant	0.01 V/rad/sec
Kt	Motor torque constant	0.01 N.m/Amp
R	Electric resistance	1 Ohm
L	Electric inductance	0.5 H

Table 2.1 DC drive data

In general, the torque generated by a DC motor is proportional to the armature current and the strength of the magnetic field. In this example we will assume that the magnetic field is constant and, therefore, that the motor torque is proportional to only the armature current i by a constant factor Kt as shown in the equation below. This is referred to as an armature-controlled motor.

$$T = k_t i \tag{3.1}$$

The back emf, e, is proportional to the angular velocity of the shaft by a constant factor Ke.

$$e = k_e \dot{\theta} \tag{3.2}$$

In SI units, the motor torque and back emf constants are equal, that is, Kt = Ke; therefore, we will use K to represent both the motor torque constant and the back emf constant [14]. From the figure above, we can derive the following governing equations based on Newton's 2nd law and Kirchhoff's voltage law.

$$J\ddot{\theta} + b\dot{\theta} = k\, i \tag{3.3}$$

$$L\frac{di}{dt} + R\, i = V - k\,\dot{\theta} \tag{3.4}$$

3.3.1. S-domain Model

Applying the Laplace transform, the above modeling equations can be expressed in terms of the Laplace variable s.

$$s(Js + b)\theta(s) = K\,I(s) \tag{3.5}$$

$$(Ls + R)I(s) = V(s) - K\dot{\theta}(s) \tag{3.6}$$

We arrive at the following open-loop transfer function 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 [14].

$$P(s) = \frac{\dot{\theta}(s)}{V(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \tag{3.7}$$

3.3.2 State-space model

In state-space form, the governing equations above can be expressed by choosing the rotational speed and electric current as the state variables. Again the armature voltage is treated as the input and the rotational speed is chosen as the output [14].

$$\frac{dy}{dt}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} = \begin{bmatrix}\frac{-b}{J} & \frac{K}{J}\\ \frac{-K}{L} & \frac{-R}{L}\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} + \begin{bmatrix}0\\ \frac{1}{L}\end{bmatrix}V \tag{3.8}$$

$$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} \tag{3.9}$$

3.4 Structure of the PID Controller

Figure 3.1 presents the structure of the proposed PID controller based. It contains two parts: a classic PID controller and Tuning part. The PID controller is used to control the speed of DC motor. The control performance depends on the setting of PID control parameters K_P, K_i and k_d which can be auto tuned. To ensures that the designed neural network is able to calculate the desired PID control parameters for the PID controller. Therefore, in this control approach, by combining the classic PID control and the tuning system output can be tracked with a guaranteed stability.

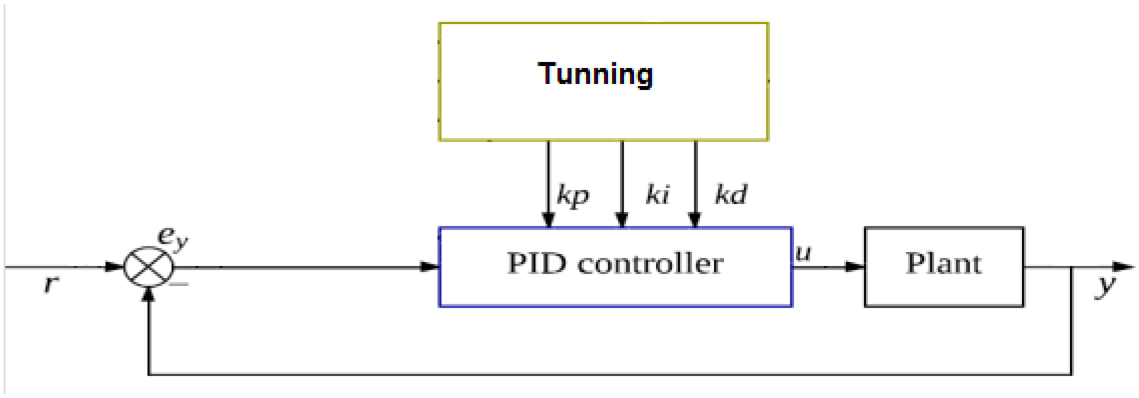

Figure 3.2: PID control scheme

3.5 PID Control Algorithm

The incremental digital PID control algorithm can be expressed as follows [12]:

$$\begin{aligned} u(k) = {} & u(k-1) + k_p\{errro(k) - error(k-1)\} + k_i(k) \\ & + k_d\{error(k) - 2error(k-1) \\ & + error(k-2)\} \end{aligned} \tag{3.10}$$

where u is the output of the PID controller, K_P is the proportional term, K_i is the integral term, K_d is the derivative term and ey is the system error that can be expressed as follows:

$$e(k) = y(k) - r(k) \tag{3.11}$$

Where y is the system actual output and r is the system targeted output.

3.6 Flow Chart

Flow chart showing how to sequence the control process solution in an PID controller.

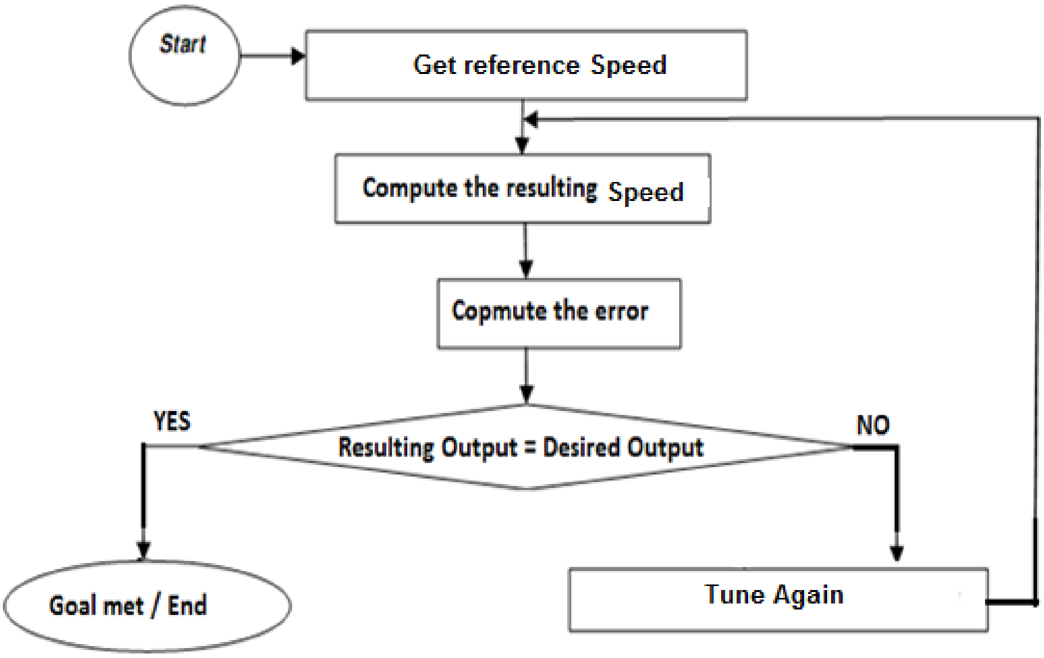

Figure 3.3: Flow chart

CHAPTER FOUR

SYSTEM SIMULATION RESULTS AND DISCUSSION

4.1 Introduction

The detail designs of the proposed controllers were introduced in chapter three. In order to achieve the goal of speed of DC motor to be controlled properly. In this chapter, the performance of the proposed controller is presented. The Simulating tests of the control processes are based on the mathematical models of the DC motor is discussed in chapter three. The simulations have been taken on the platform of MATLAB. The controllers' performance including over shot, response speed, adaptability, robustness and etc. are discussed. Then it analyzed whether the proposed controllers are suitable for their control objects and process. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

4.2 System Results

The simulation test cases as following:

4.2.1 Uncontrolled system response to step input

Figure 4.1 shows the system response without controller.

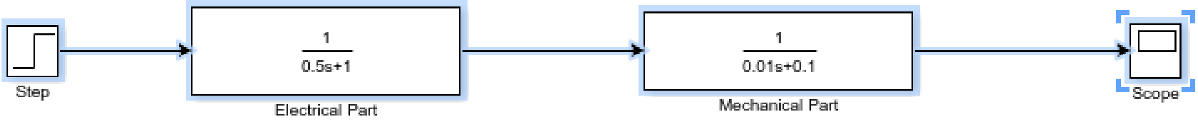

Fig.4.1: Simulink model of uncontrolled system open loop

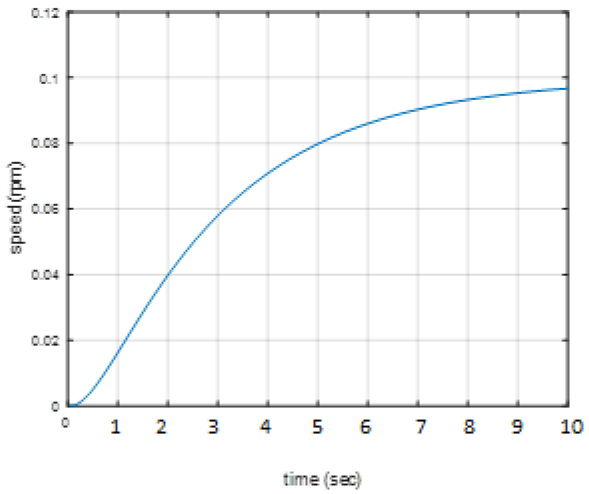

Figure 4.2: Speed response for open loop system

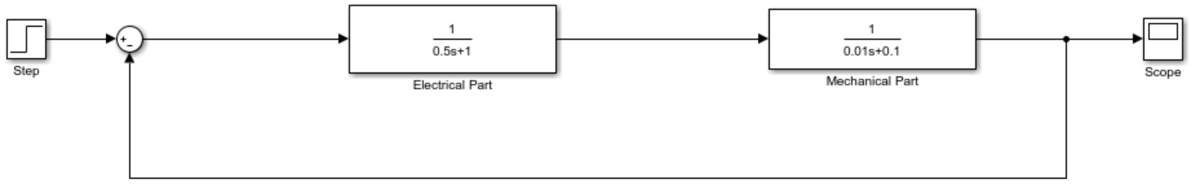

Fig.4.3: Simulink model of uncontrolled system closed loop

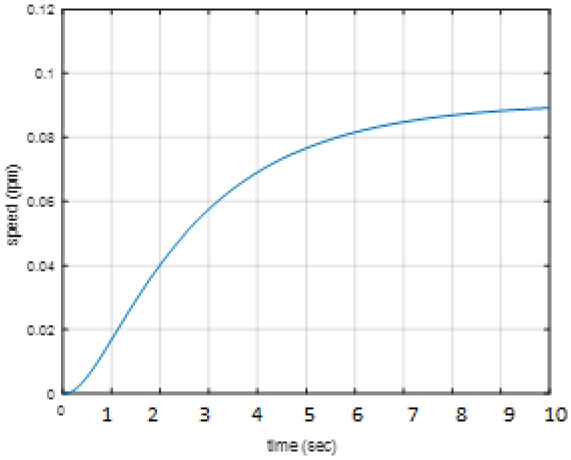

Figure 4.4: Speed response for closed loop system

Fig 4.2 – 4.4 shows the results of uncontrolled open loop and closed loop motor, the figure show the various parameters like settling time, over shoot and steady state error.

4.2.2 System with P Controller

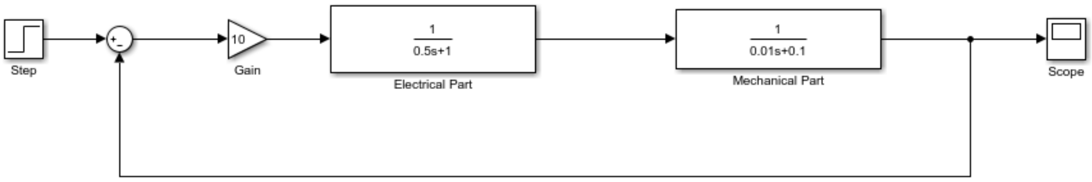

Fig.4.5: Simulink model of P controller system

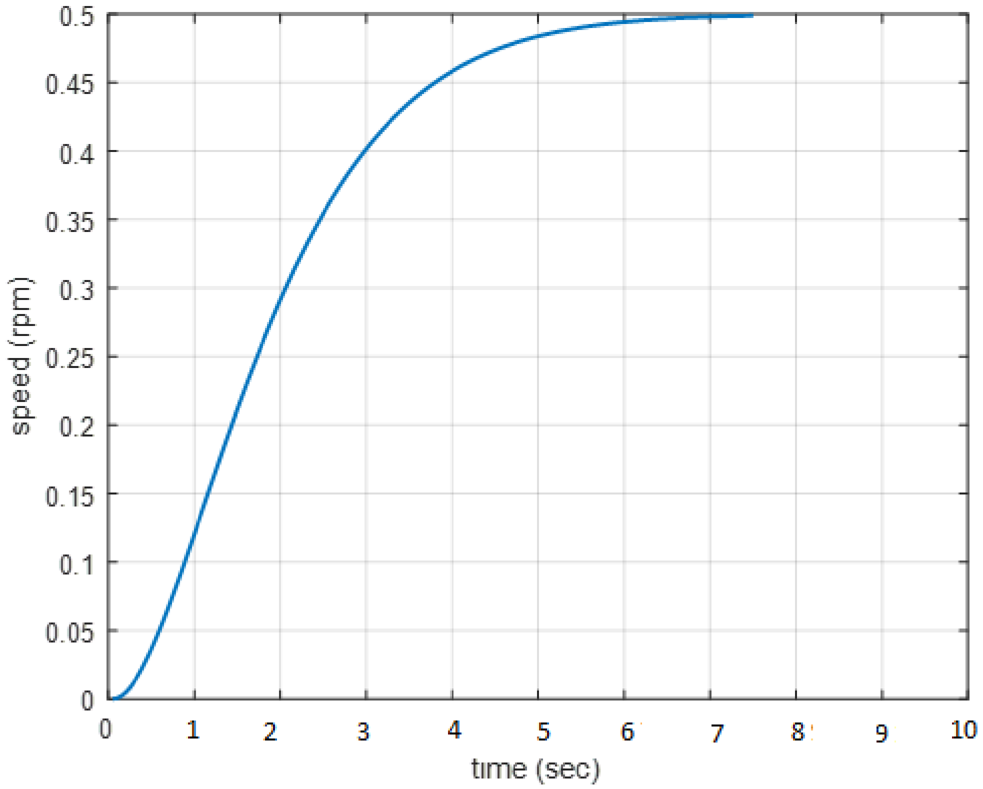

Figure 4.6 Speed response for P controller system

Fig 4.4 shows the results of controlled closed loop motor with P-controller, the figure shows the various parameters like settling time =7.5 seconds, and no over shoot.

4.2.3 System with D controller

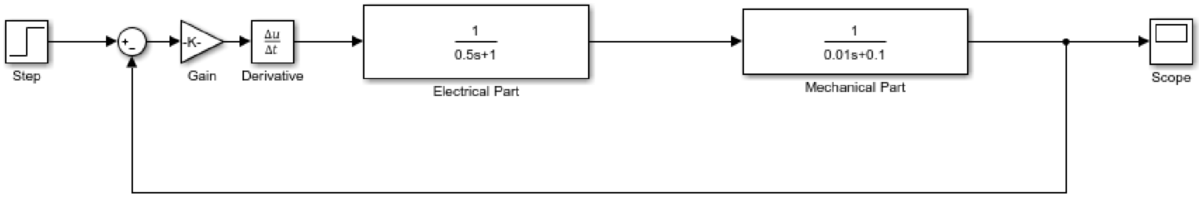

Fig.4.7 Simulink model of D controller system

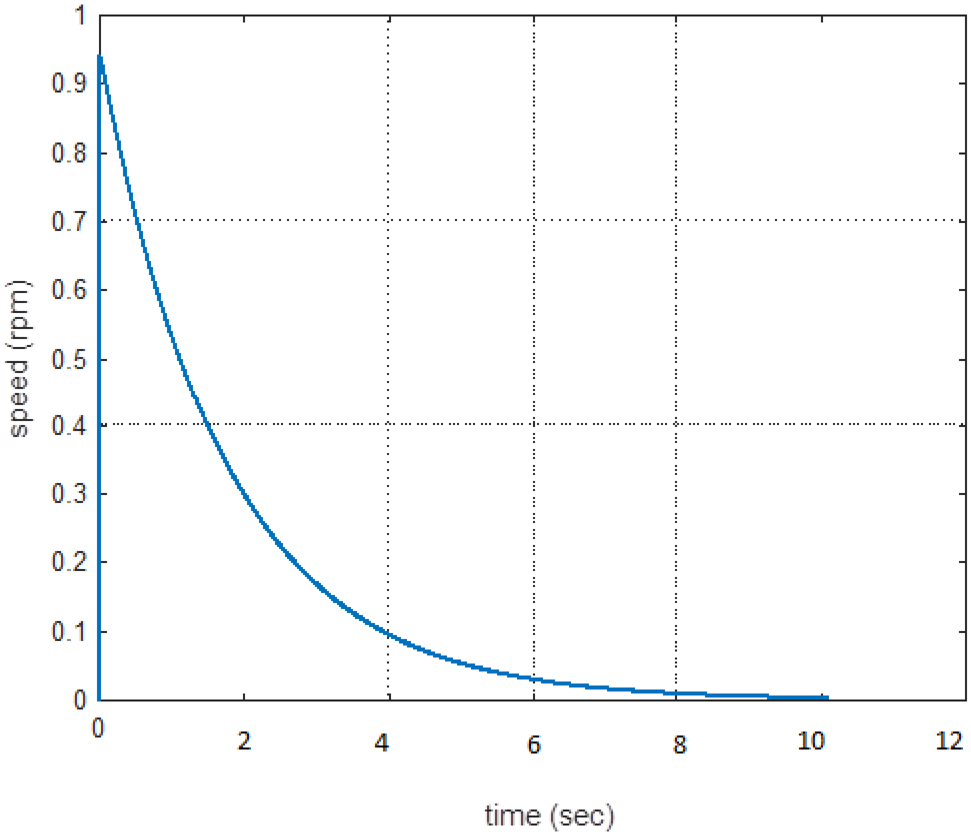

Figure 4.8 Speed response for D controller system

The response od D controller is shown in Fig 4.4, the fig. shows the results of controlled closed loop motor with D- controller, the figure shows the system is unstable.

4.2.4 System with I controller

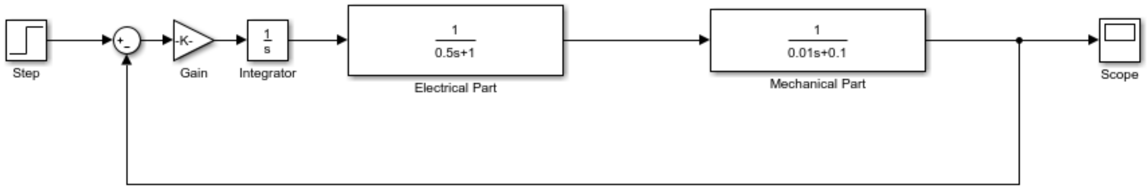

Fig.4.9 Simulink model of I controller system

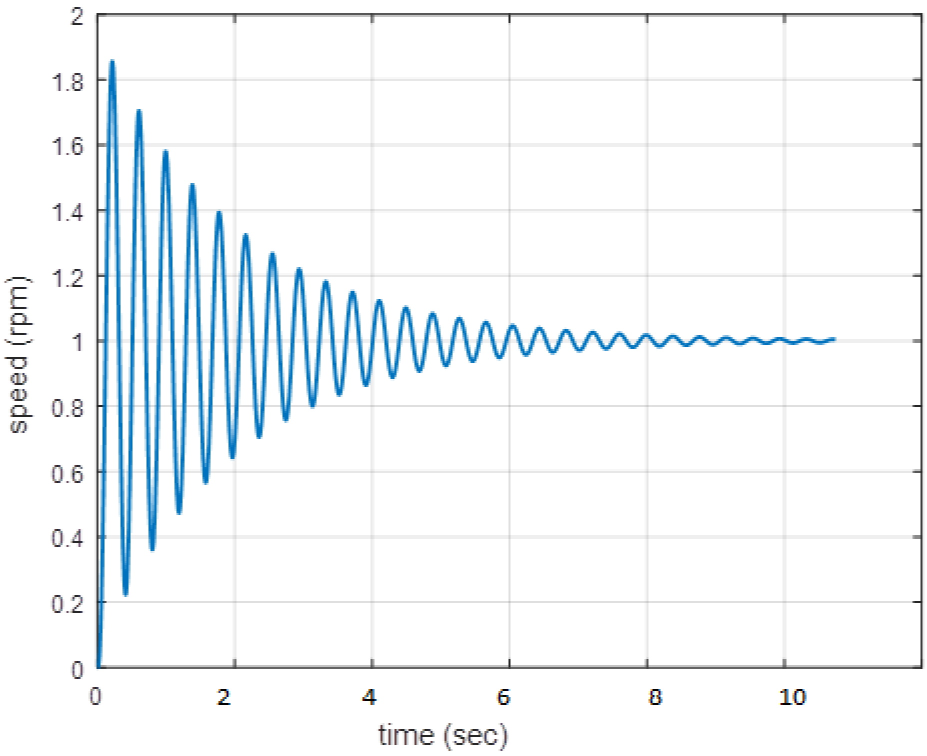

Figure 4.10 Speed response for I controller system

The response of I controller is shown in Fig 4.8, the fig. shows the results of controlled closed loop motor with I- controller, the figure shows the system is stable with about 10 settling time.

4.2.5 System with PI controller

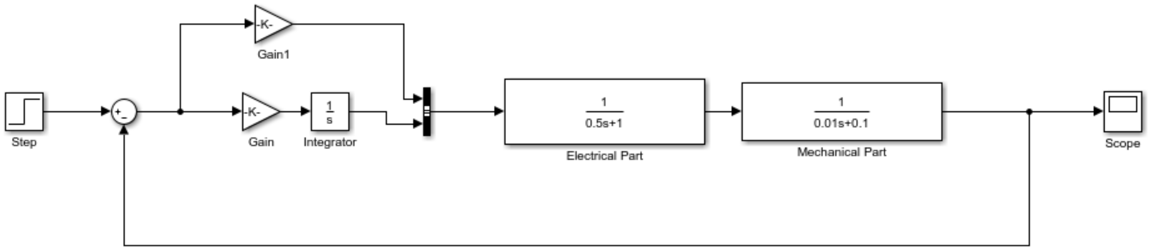

Fig.4.11 Simulink model of PI controller system

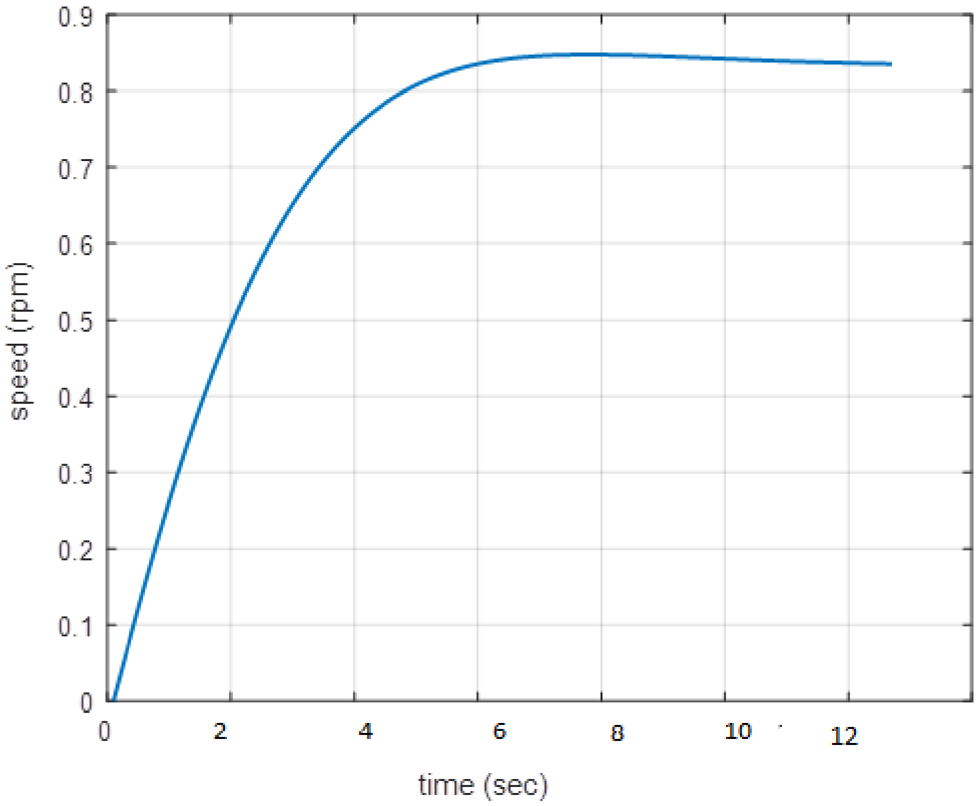

Figure 4.12 Speed response for PI controller system

Fig 4.10 shows the results of controlled closed loop motor with PI-controller, the figure shows the various parameters like settling time = 12 seconds, and no over shoot.

4.2.6 System with PD controller

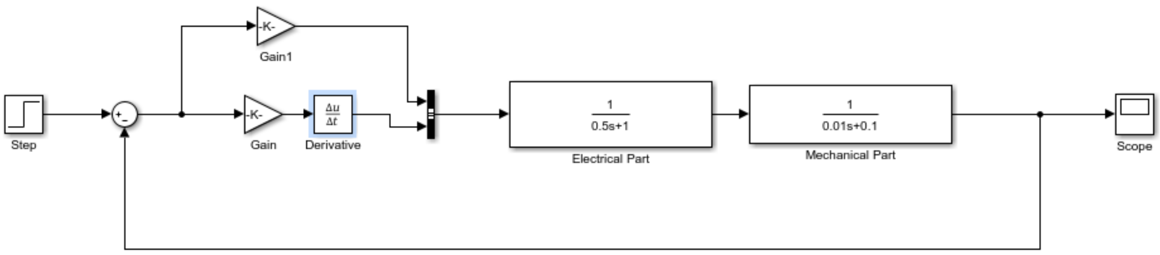

Fig.4.13 Simulink model of PD controller System

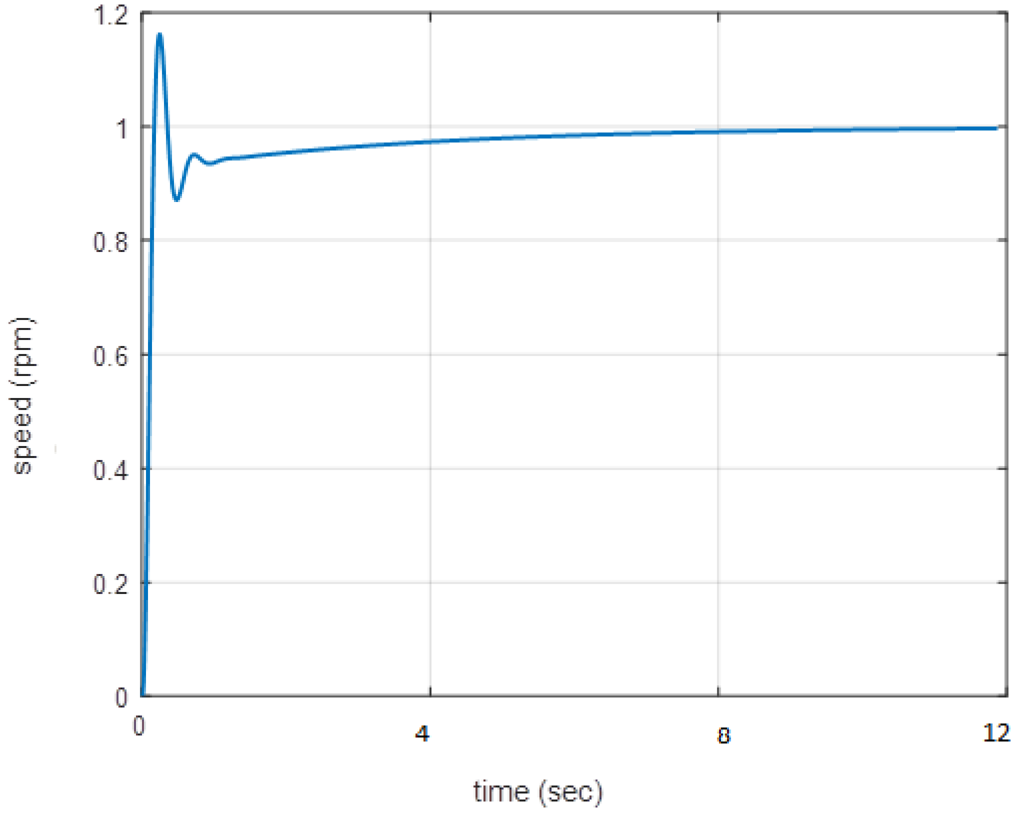

Figure 4.14 Speed response for PD controller system

Fig 4.12 shows the results of controlled closed loop motor with PD-controller, the figure shows the various parameters like settling time = 12 seconds, and over shoot of 18%.

4.2.7 ID controller

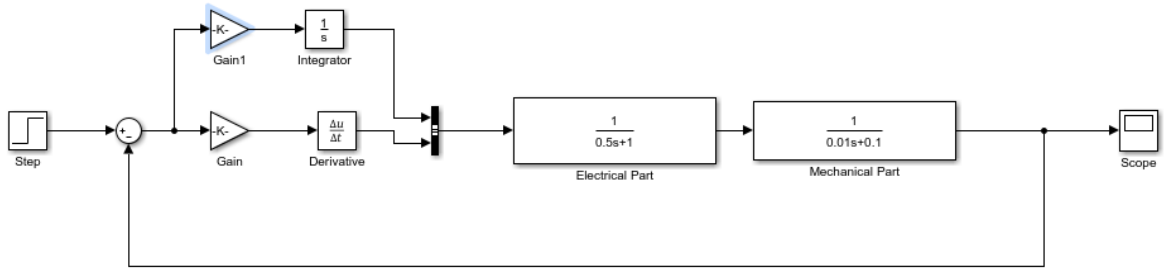

Fig.4.15 Simulink model of ID controller system

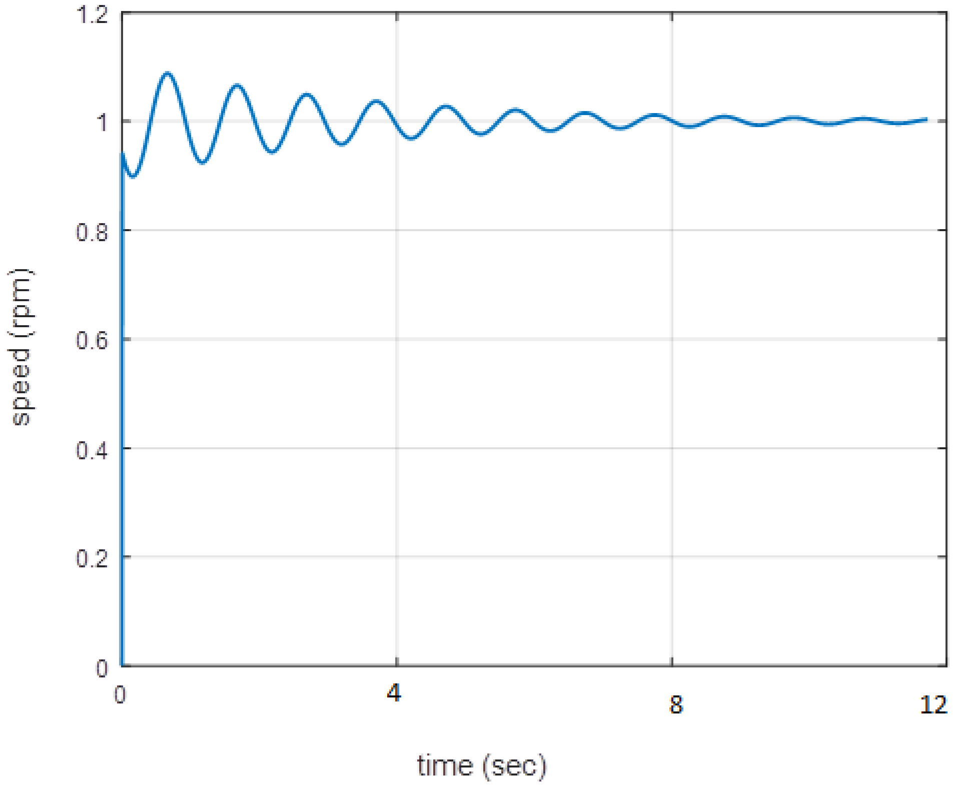

Figure 4.16 Speed response for ID controller system

Fig 4.14 shows the results of controlled closed loop motor with DI-controller, the figure shows the various parameters like settling time = 12 seconds, and over shoot about 10%.

4.2.8 System response with PID controller to step input

As mentioned earlier in chapter two, PID controller is a popular conventional approach. The Figure 4.3 shows the Simulink of DC motor with PID controller and the response of speed. Figure 4.4 shows the system response with PID Controller.

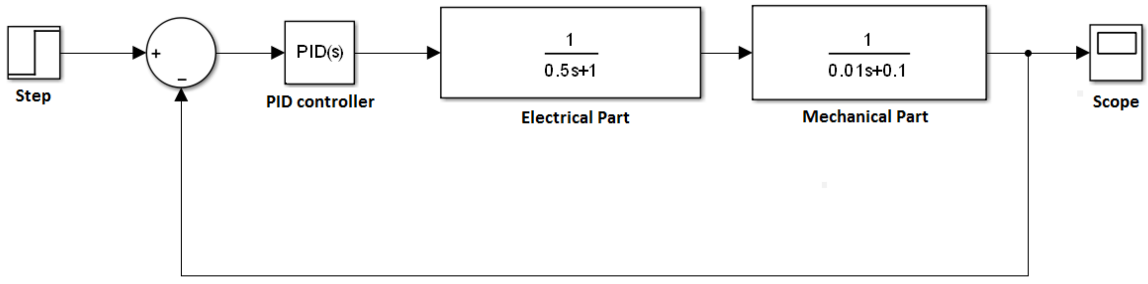

Figure 4.17 Simulink model of DC motor using PID controller

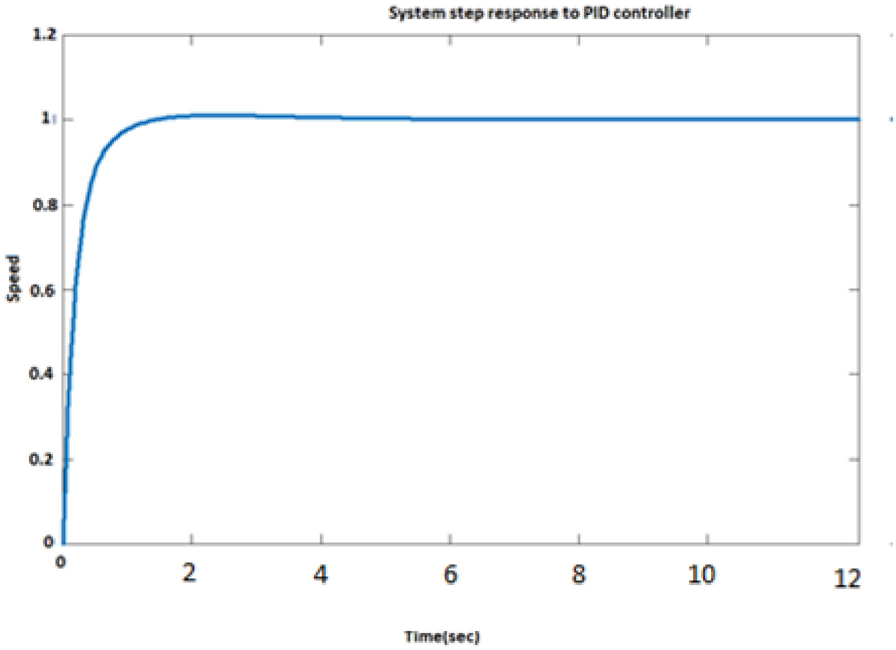

Figure 4.18 Speed response of the system with PID controller

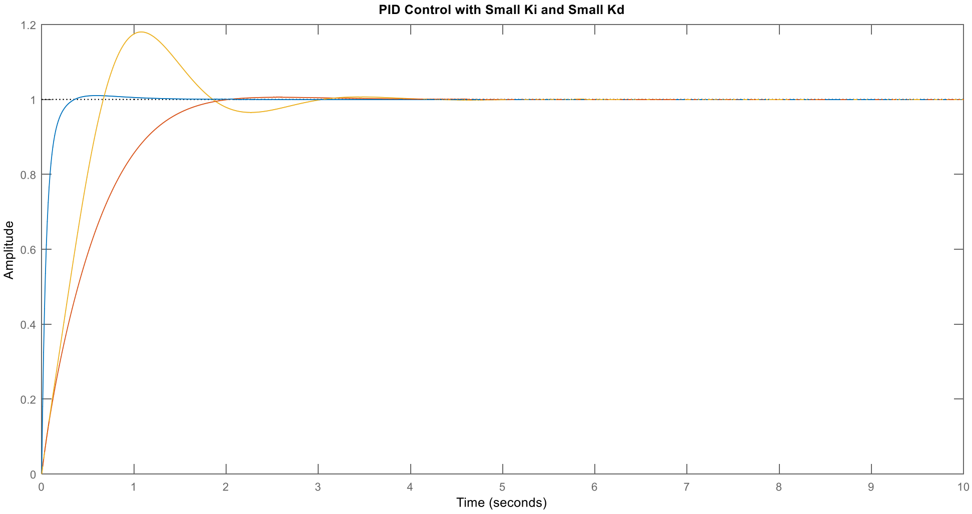

Figure 4.19 PID tuning

From the Table 4.1, it is clear that system without any controller is stable without overshoot, but with conventionality, it becomes stable but overshoot & settling time is relatively high for K_p= 200, K_d = 100 and K_i= 10.With the help of PID system becomes stable and settling time and overshoot becomes too small but rise time of the system increase which is a setback but we can neglect this as our basic requirement is less settling time and less overshoot that is achieved.

Table 4.1: Comparison between various parameters for controller.

Type of Control	**Settling time (second)**	**Overshoot (%)**	**stability**	**Steady state error**
Uncontrolled open loop	120	**0**	Stable	0.9
Uncontrolled closed loop	120	**0**	Stable	0.91
P controller	100	0	Stable	0
D controller	-	-	Un stable	-
I controller	120	83%	Stable	0
PD controller	10	0	Stable	0.15
PI controller	80	18%	Stable	0
ID controller	50	15%	Stable	0
PID controller	0.25	0	Stable	0

CHAPTER FIVE

CONLUSION AND RECOMMENDATIONS

5.1 Conclusion

The current control methods used for speed control systems using PID have been reviewed. The drawbacks of the current control methods are summarized based on the literature review. Then, based on the discussion of the advantages and disadvantages of current control technologies. In this research, PID controller is developed for speed control. Its principles and detailed designs are introduced in Chapter three. These controllers are tested by computational simulation. The simulation is obtained on the platform of MATLAB. The programming codes have been developed to simulate the control strategies and the indoor environment model for testing the controllers ‘performance. The simulation results show clearly that the PID controller is better compared to uncontrolled system. Having very short settling time is an excellent characteristics ant tells that the system will settle to the steady state cast within a very short time and the transient can be ignored.

5.2 Recommendations

- We recommend that the project be implemented in practice
- We recommend that the project be executed with a fuzzy controller and compare results between them

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