PI controller for DC motor speed realized with simulink and practical measurements

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ABSTRACT

This article describes the methodology of speed control by understanding control method of DC motor, definitely, armature and field resistances with additional to armature voltage control methods. The speed of DC motor is controlled PI controller as donor in this work. Using Matlab simulation and practical measurements, Terco DC motor speed control is achieved in this work. The results that obtained from Matlab simulation circuit is appeared approximately similar that obtained by practical connection.

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1. INTRODUCTION

Background, control system is dealing with controlling a portion of an environment called (system plant) in order to emit desired products for society. The designing of an effective control system required prior information of plant. One of the engineering principles applications is DC motor [1]. For a long time, wide speed of DC motors in the industry control area due to many properties such as, high response performance high start torque, linear control.est. [2]. The speed of DC motor is donor by this relationship:

$$N = \frac{V - IaRa}{k\emptyset} \tag{1}$$

From a above equation, the speed is conditional related with the functional voltage V, Φ and Ra. The article designates the Matlab/Simulink of DC motor speed control technique obviously armature control [3]. DC motors are divided into compound wound, series wound, shunt wound, and separately excited DC motors, the last type is the most used at universities [4]. The major methods to have controlled desired speed-torque characteristics of separately excited Dc motor; is to control the armature and field windings fed with variable sources [5]. The motor field winding is ligated to the supply for the speed control. The divers speed, credibility and high performance are three corer properties of an electrical drive system due to the austere control for Dc motor (low horse power) is low coast. By armature and field control, palatial range of variable speed below and above the maximum speed is achieved [6]. Separately exited DC motor is largely use in electrical drives. Many sorts DC motor in the commercial center [7]. PI controller represents 80% of controller applications because it is easy and fluent to understand [8]. DC motor is more adequate appearance used for manifold speed uses after a particular time for the sake of its high simplicity, accurate speed controller and controllable torque [9]. In this article, two problems are appeared. The first problem represented by software (Matlab / Simulink) program and the other problem represented by practical. The software problem is treatment by calculating the best parameters of PI controller and the practical problem is solved choosing the right torque that applied.

A method is proposed to design a PI controller for DC motor speed Matlab programming procedures are used to obtain the optimal response for DC motor with PI controller. The novel method for tuning PI controller is compared with Ziegler-Nichols first method. In order to select the optimum values of PI parameters, this required applying a novel method. This novel method can be dependent as easy to implement, simple concept and computationally efficient [10]. The proposed solution focus on designing the PI controller with DC motor and selecting the optimum parameters of PI controller in order to keep on the actual speed nearly from the reference speed. The motivation of using PI controller comes from the fact that this type of controller will make the error approach to zero (eliminate error).

2. LITERATURE SURVEY

Saleh Ebn Sharif and Anamika Bose [11]. These authors work on separately excited DC motor has parameters (Ra= 1Ω, La= 0.05H, J= 0.01 kgm2/s2, B= 0.00003 Nms, KT= 0.023 Nm/A, Kb= 0.023 Vs/rad) they use many methods to study the DC motor speed response one these methods is PI controller. The transient response values that obtained from PI controller is peak over shoot time (20%), max. time (0.1 sec), rise time (0.01sec) and settling time (1sec).

Ujjwal Kumar, Devendra Dohare [12]. These authors work on separately excited DC motor. They apply three methods of control (Ziegler Nichols response, PI controller and PID controller) and compared between these types and the effect on DC motor speed response curve. The transient response values that obtained from PI controller is peak over shoot time (19%), max. time (1.19sec), rise time (6.01sec) and settling time (34.1 sec).

3. SEPARATELY EXCITED DC MOTOR

3.1. The equivalent circuit.

This motor involves of independent double circuit, armature control and field control. The flux of excitation field is generated by DC motor field winding. The current is flowing into armature rotor across brushes and segments of commentator. The interaction between the segments and the field flux will produce the torque. Figure 1 represents the separately excited DC motor circuit.

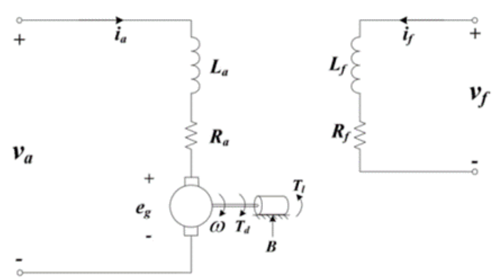

Figure 1. DC motor separately excited circuit.

By exciting the DC separately motor with an ia and if the motor will produce a back E.M.F and providing a balance load torque at a particular speed. Because of armature winding is separated from field winding there for armature current does not depend on the field current. The armature current is higher than the field current [13].

3.2. The mathematical model

Kirchoff's law (KVL) is functional to the armature circuit as shown above it can be seen in Figure 1, the equations can be calculated as [14, 15]:

$$v_a = i_a R_a + L_a \frac{di_a}{dt} + e_g \tag{2}$$

Where,
eg= *Kvifω* leads to:

$$v_a = i_a R_a + L_a \frac{di_a}{dt} + K_v i_f \omega \tag{3}$$

Using Laplace transform for (2) will give

$$V_a(s) = I_a(s) R_a + L_a s I_a(s) + K_v I_f \omega(s) \tag{4}$$

As a result:

$$I_a(s) = \frac{V_a(s) - K_v I_f \omega(s)}{s L_a + R_a} \tag{5}$$

And,

$$T_d = J \frac{d\omega}{dt} + B\omega + T_L \tag{6}$$

4. SPEED CONTROL OF DC MOTOR

PI Controller has a proportional and integral term in the forward path, this controller has the ability to make steady-state error equal zero. The block diagram of PI controller is shown in Figure 2 [16].

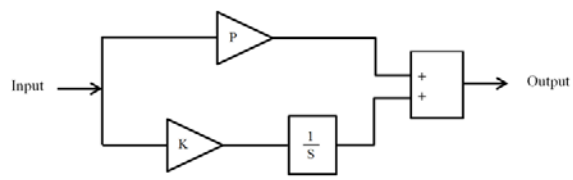

Figure 2. PI- representation

From block diagram a PI controller, one is inner current and second is speed loop. In the speed loop error represents the difference between desired speed and actual speed [17]. According to [18-20], there are four factors must be minimized by the control system:

- Rise time (tr): represents the time period from 10% to 90% of the desired value.
- Overshooting: represents the peak value of the response curve determined from the desired value.
- Settling (tss): represents the time required for actual output in order to reach and stay at percentage (5% or 2%).
- Steady- state error: represents the difference between the actual output value and the desired required output

5. THE CHARACTERISTICS OF PI CONTROLLER

PI controller is using in the areas that have velocity of the system within large scale. The Kp part decreases the rise time, the Ki abolition the steady-state error only but it perhaps be performed to worse transient response. PI controller is mostly used in general applications of DC motors [21].

5.1. Tuning PI controller

The direct way is depending on the process model and the transfer function of the desired closed loop. The interests are that performance takes are incorporated squarely through the description of closed loop transfer function. The standard model is given in Figure 3.

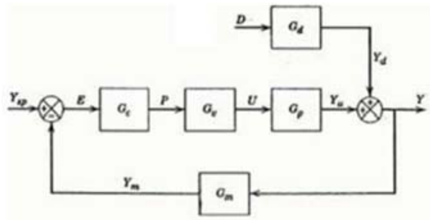

Figure 3. Standard closed-loop representation

The transfer function is depicted as:

$$\frac{Y}{Y_{sp}} = \frac{G_c G_v G_p}{1+G_c G_v G_p G_m} \tag{7}$$

Using Taylor series expansion [22]

$$G_c = \frac{1}{\hat{G}} \frac{e^{\theta s}}{(\tau_c+\theta)s} \tag{8}$$

The time response analysis of a given system can be founded by converting the transfer function equation to the changeable in terms of time by regarding invers Laplace transformations. From the equation, multifarious time domain specification such as peak time, rise time, delay time and settling time can be calculated [23].

6. DC MOTOR CONTROL BASED PI CONTROLLER

PI controller consists of two terms (proportional and integral), the integral term gives this type of controller a characteristic property to eliminate the steady-state error and improving the speed response curve [24, 25]. An adoption with large capabilities call for different PI gains than an adoption which works at a fixed speed [26]. Among six-decades ago, the application of PI controller with DC motors were capacious used than PID controllers [27].

The output of the PI controllers are acting as the modulation index of the converters but its output will give to the DC motor in order to obtain steady-state response for this motor speed and approached from reference value [28, 29]. Figure 4 represents an algorithm of DC motor speed control based PI controller. The proposed PI controller incorporated with DC motor in order to keep on actual speed nearly the reference speed

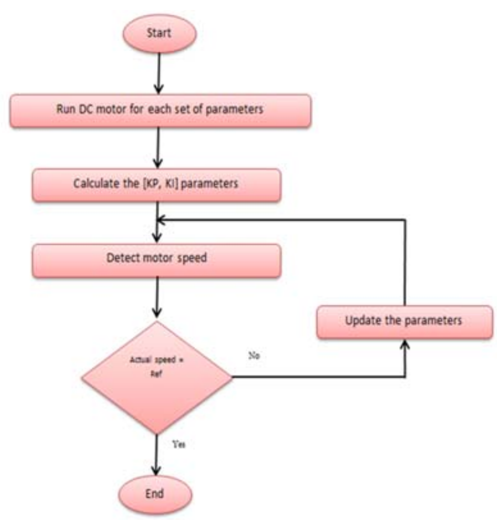

Figure 4. Algorithm process design flowchart

7. MATLAB REPRESENTATION

Figure 5 represents the diagram of the Matlab simulation of PI controller of DC motor.

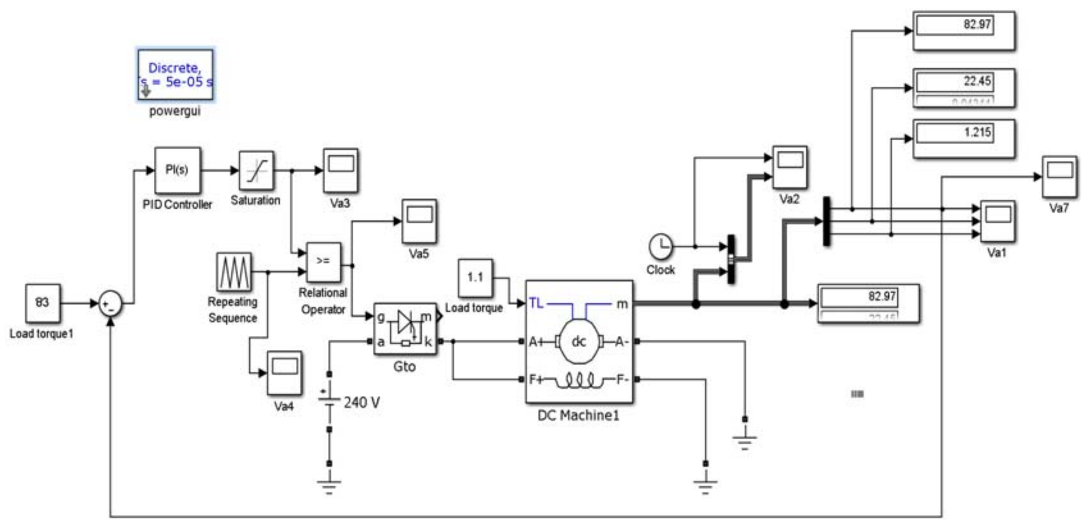

Figure 5. Modeling of DC motor control system

7.1. Open Loop properties

Terco DC motor specification is given in Table 1, the curve fitting is depicted in Figure 6.

Table 1. Description of terco DC motor

Parameters	Standards
Ra	0.25 Ω
La	60.81 mH
Jm	0.012 kg.m^2
Bm	0.0204 N.m.s .rad^{-1}
Kb	10 V.s.rad^{-1}
Rated speed	1500 r.p.m

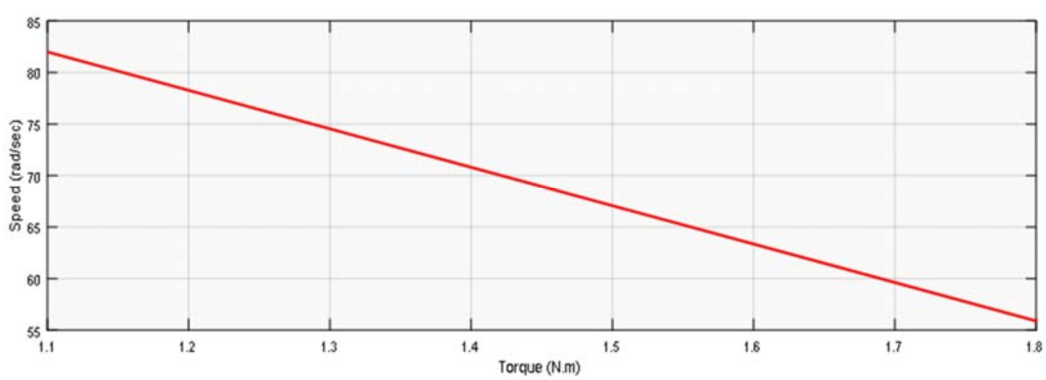

Figure 6. Open loop torque–speed curve.

7.2. Closed loop characteristics

PI factors enhancement the speed response curve. This upgrade can be seen as depicted in Figure 7.

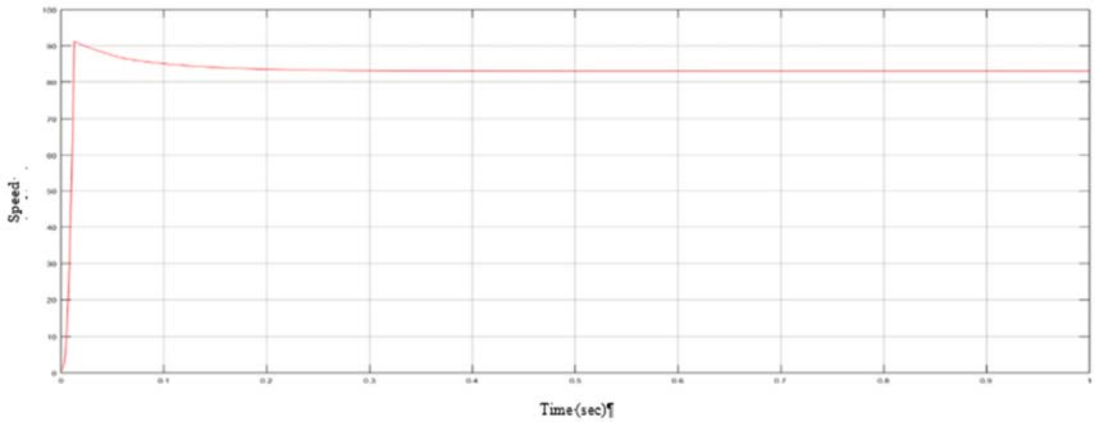

Figure 7. Improvement speed response with time (Kp=7.2, KI=100)

7.3. Practical result

The experimental torque – speed relationship is practically implemented with Terco DC motor as in Figure 8. The relationship between torque and speed for data given in previous is depicted in Figure 9.

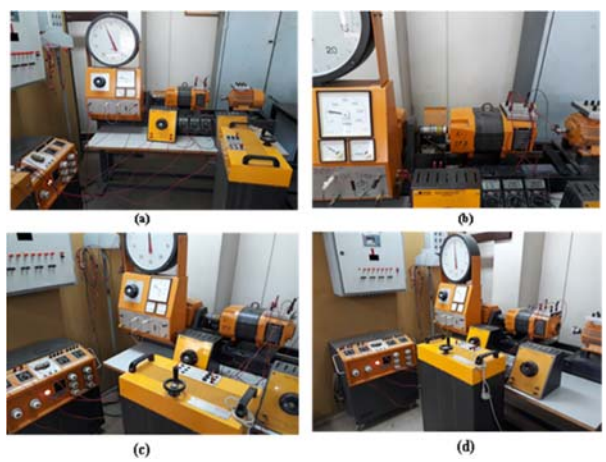

Figure 8(a, b, c, d). Terco system connection.

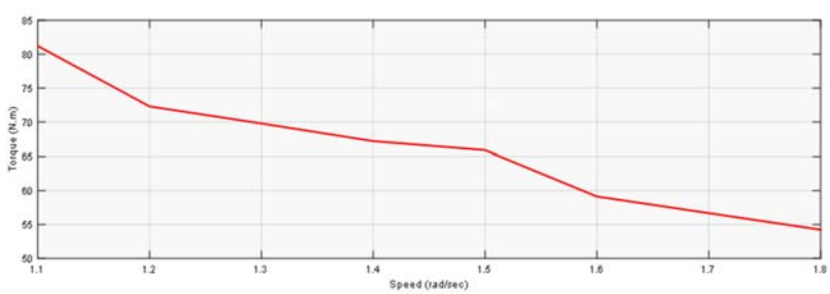

Figure 9. Practical torque–speed characteristics

The relationship between torque and speed is given in Figure 10.

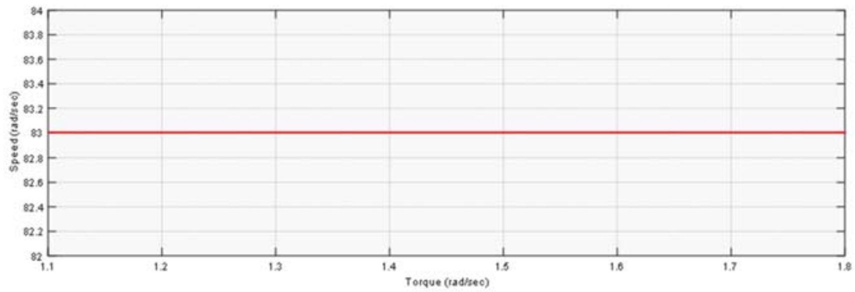

Figure 10. Practical torque – speed curve

8. RESULTS AND DISCUSSION

In this paper, PI controller used to find the suitable performance of DC motor speed control system. Figure (6) illustrates the speed responses of the separately excited DC motor drive with PI controller, the constant of PI controller Kp=7.2 and KI= 100, give the best results for constant speed. The transient performance of this case can be shown in Table 2.

Table 2. Transient performance results

Rise time(s)	Max. time(s)	Overshoot (%)	Settling time
0.01 sec	0.02 sec	9.638 %	0.2 sec

9. CONCLUSION

From the results, the PI-controller solve the problems of large disturbance and noise during operation processer by eradicating enforced oscillations and steady state error subsequent in operation of PI-controller.The simulation results are approximately similar to that obtained from the practical measurements. From the final table the speed values remain constant as respect to increase in the torque values.

Nomenclatures:

V : source voltage (V).
N : speed (rpm)
ia : current of the armature (A).
Ra : resistance of the armature (Ω).
Φ : flux (web).
K : proportional fixed.
if : current of the field (A).
La : self inductance of the armature (H).
eg : back EMF of the armature (V).
ω : angular velocity (rad/s).
Kv : voltage constant (V.s/rad).
Td : total torque (N.m).
Jm : moment of inertia (kg.m2).
Bm : friction factor (N.m/rad/s).

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