Study of State Response of DC Motor Using MATLAB/Simulink

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Abstract— **This thesis describes the 'Study of State Response of DC motor using MATLAB/Simulink'. The speed control method of the DC motor is investigated through open loop system by changing the namely field resistance, armature voltage and armature resistance. The close loop system or feedback system is investigated by using the PI controller and Fuzzy controller. There are two controllers that used to reduce the steady state error between the measured speed motor and the reference speed. The PI controller firstly implemented to investigate the performance of the operating condition. After that the Fuzzy has been used to replace the PI controller to compare the differences of the operating conditions. Finally the Matlab/Simulink models were developed to examine the DC motor. It is developed by using the model of separately excited DC motor.**

Keywords-component — DC motors, software laboratory MATLAB/Simulink, Open Loop System, Close Loop System, Speed Control Method, PI controllers, Fuzzy Logic Controller (FLC).

I. INTRODUCTION

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. In home appliances, washers, dryers and compressors are good examples. In automotive, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these [3]. This thesis is to obtain the knowledge of circuit analysis and synthesis and also to experience the actual behavior of a DC motor. A theory is a general statement of principle abstracted from observation. A model is a representation of a theory that can be used for control. A model is developed by using the MATLAB/Simulink software. MATLAB is software package for high performance numerical computation and visualization. The combination of analysis capabilities, flexibility, reliability, and powerful graphics makes MATLAB the premier software package for all electrical engineers. MATLAB has been enhanced by the very powerful simulink program. Simulink is a graphical mouse-driven program for the simulation of dynamic systems. It enables the user to simulate linear, as well as nonlinear, systems easily and efficiently [4].

II. METHODOLOGY

The simulink implementations are create by using DC motor block power system in MATLAB/Simulink. The DC motor block implements a separately excited DC machine. An access is provided to the field terminals (F+, F-) so that the machine model can be used as a shunt-connected or a series-connected DC machine. The torque applied to the shaft is provided at the Simulink input T_L. The armature circuit (A+, A-) consists of an inductor La and resistor Ra in series with a counter-electromotive force (CEMF) E. The CEMF is proportional to the machine speed [1].

$$E = K_E \omega \quad (1)$$

K_E is the voltage constant and ω is the machine speed.In a separately excited DC machine model, the voltage constant K_E is proportional to the field current I_f:

$$K_E = L_{af} I_f \quad (2)$$

where L_{af} is the field-armature mutual inductance. The electromechanical torque developed by the DC machine is proportional to the armature current Ia.

$$T_e = K_T Ia \quad (3)$$

where K_T is the torque constant. The torque constant is equal to the voltage constant [4].

$$K_T = K_E \qquad (4)$$

The armature circuit is connected between the A+ and A- ports of the DC Machine block. It is represented by a series Ra La branch in series with a Controlled Voltage Source and a Current Measurement block. The control objective is to make the motor speed follow the reference input speed change by designing an appropriate controller. The proportional-integral PI controller is used to reduce or eliminate the steady state error between the measured motor speed (ω) and the reference speed (ωref) to be tracked. The transfer function of PI controller is given by [1]

$$Gc(s) = Kp + Ki / s \qquad (5)$$

where Kp and Ki are the proportional and integral gains. In the feedback control system, the dynamics of the DC motor can be described either by a transfer function or by the following state-space equations:

$$\begin{aligned} X1 &= -\frac{R}{L}x_1 - \frac{Kb}{L}x_2 + \frac{1}{L}u \\ X2 &= -\frac{Kb}{J}x_1 - \frac{B}{J}x_2 + \frac{1}{J}T1 \end{aligned} \qquad (6)$$

where X_1= Ia, X_2 = ω are the armature current and motor speed in rad/s, respectively. u is the voltage input applied to armature circuit, T_1 is the load torque, J is the combined moment of inertia of the load and the rotor; B is the equivalent viscous friction constant of the load and the motor, and Kb is the design constant depending on the construction of the motor [3].

A. Open Loop System

This project discussed about the torque characteristic of DC motor effect by the speed control method. There are three most common speed control methods, Field Resistance Control Method, Armature Voltage Speed Control Method and Armature Resistance Speed Control Method.

a. Field Resistance Speed Control Method

In this method, a series resistance is inserted to the shunt field circuit of the motor to change the flux by controlling the field current. The simulink model is shown in figure 1.

b. Armature Voltage Speed Control Method

In this method the voltage applied to the armature circuit, is varied without changing the voltage applied to the field circuit of the motor. To use armature voltage the motor used is separately excited DC motor. The simulink model is shown in figure 2.

c. Armature Resistance Speed Control Method

In this method, the speed control is achieved by increasing or changing a resistance Ra in the armature circuit. The simulink model is shown in figure 3.

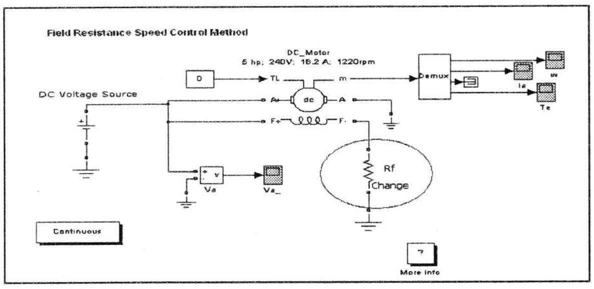

Figure 1: Simulation Design For Namely Field Resistance Control Method.

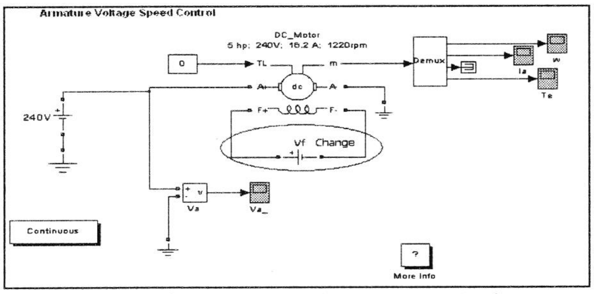

Figure 2:Simulation Design For Armature Voltage Control Method.

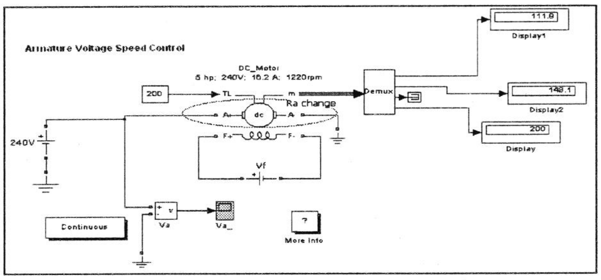

Figure 3 :Simulation Design For Armature Resistance Control Method.

B. Close Loop System

The feedback control concept is to demonstrate the design of controller to achieve desired control goal on torque and speed of DC motor.

a. The different values of PI control gain as shown in figure 4 are used to evaluate the performances different controller and investigate the speed dynamic for close loop DC motor control system.

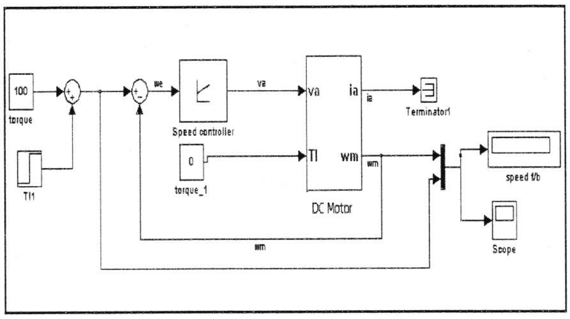

Figure 4: Simulation diagram of Feedback System Using PI Controller.

b. The PI controller is replaced by Fuzzy controller to investigate the effect to the speed control of DC motor. Both controller used has been compared to see which controller is better performance.

III. RESULTS

This section presents simulation results for the control method of open loop system and DC motor close loop control system. The torque-speed curves for system are determined using the simulink models presented in the previous section. The results are obtained from the simulation model and have been plotted. The parameter that used in this model is 5-Horse Power (HP) DC motor of 240 V rating 1220 rpm. The equivalent circuit parameters of the motor are Rf=240 Ω, Lf=120 H, Ra=0.6 Ω [1].

For the field resistance method result, the simulations are run for the value of the load torque TL= 0-500Nm, after that the external resistance is inserted in series with the field resistance to investigate the effect on the DC motor. The value added is Rf = 60Ω as shown in figure 1.The simulations are repeated at the same range of TL= 0-500Nm to determine the steady state value of the speed at each load.

The torque speed characteristic is shown in figure 5.It is clearly shows that at very low speeds (no load condition) , an increase in field resistance will increase the speed of the motor until it reached the rated value which is torque load equal to 300Nm.At torque is greater than 300Nm (TL >300Nm),an increase filed resistance will decrease the speed of the motor.

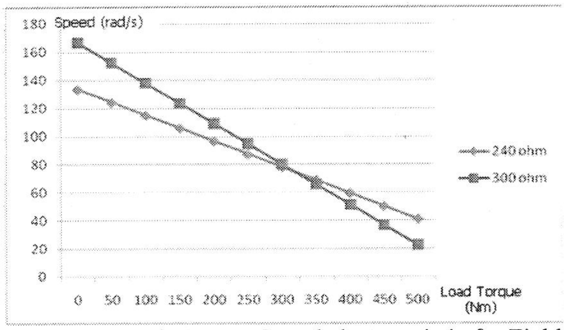

Figure 5: Graph Torque Speed characteristic for Field Resistance Method.

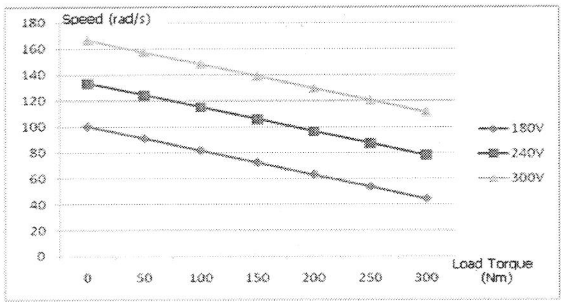

Figure 6: Graph Torque Speed characteristic for Armature Voltage Method.

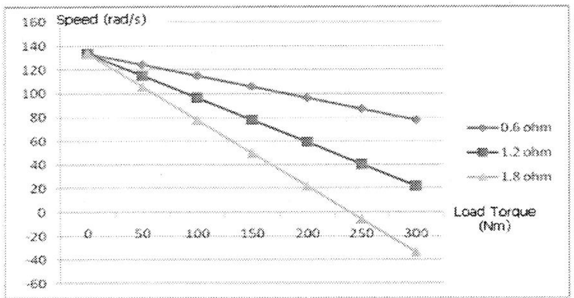

Figure 7: Graph Torque Speed characteristic for Armature Resistance Method.

For the Armature Voltage Control, the armature voltage is adjusted to see the effect on the DC Motor. The model as in figure 2 has been simulate for three different value of armature voltages, Va =180V, 240V and 300V.The field voltage is kept constant while adjusting the Va.

The torque speed characteristic is shown in figure 6.It shows that the slope of the graph is unchanged. Increasing the value of Va make the curve shifted upward that means the speed is increasing.

The last speed control method as shown in figure 3 is simulated. The three difference values are adjusted to see the effect to the speed curve. The values of armature resistance uses are Ra= 0.6Ω, 1.2Ω and 1.8Ω.Simulation result is shown in figure 7.It observe that the Speed is influenced independently by adjusting the armature resistance. An increase in resistance has the effect of increasing the slope of the torque speed characteristic while no-load speed (at zero speed) remains unaffected. This is the expected result.

Figure 8 illustrated the result obtained for the different value of proportional gain, Kp and constant value of integral gain, Ki. Figure 9 show the result obtained for the different value of integral gain, Ki and constant value of proportional integral gain, Kp. The steady state is eliminating by changing the integral gain and constant the proportional gain. It follows the theoretically that a larger value shows that steady state errors are eliminated more quickly. The trade-off is larger overshoot, any negative error integrated during transient response must be integrated away by positive error before reaching steady state [2].

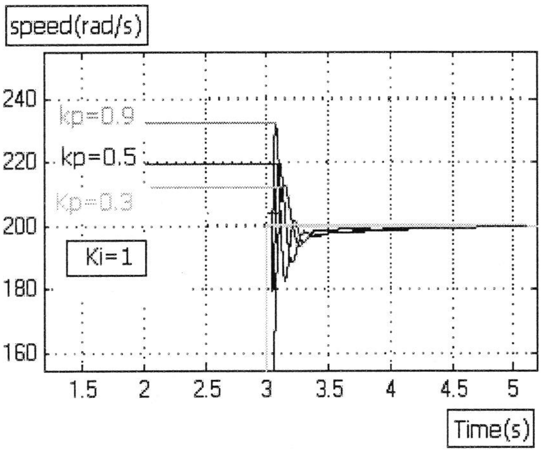

Figure 8: Result of Differences Proportional Gain.

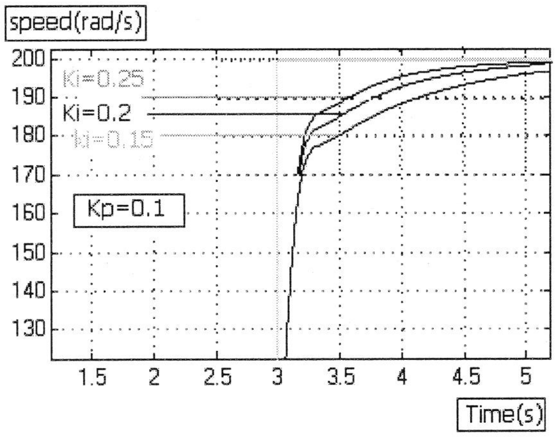

Figure 9: Result of Differences Integral Gain.

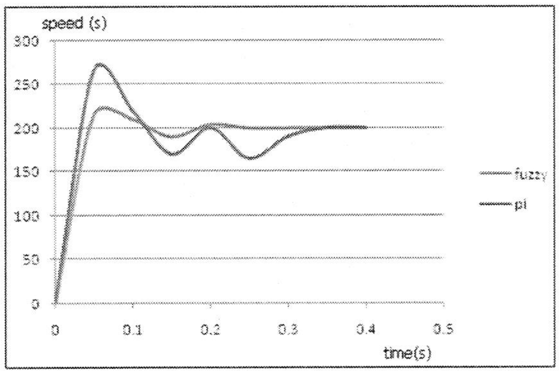

Figure 10: Comparison Result of the system by using PI Controller and Fuzzy Controller.

In this paper the PI controller with the fuzzy logic controller based on the speed controlled have been presented. The simulations have been carried out to investigate the effect of replacing the PI controller with the Fuzzy logic controller. Figure 10 shows the result of the system using PI controller and Fuzzy controller. The Kp and Ki used is equal to 1. The value of the speed for the fuzzy is lower compared to PI controller.

IV. CONCLUSIONS

In this thesis, the block diagram of a DC motor was developed and by using simulink, a toolbox extension of the MATLAB program, the block diagram was simulated with expected waveforms output. Furthermore, by varying the parameters of the DC motor block diagram, the output waveform of the simulation would change accordingly. These parameters include the field resistance, armature voltage and armature resistance.

As expected for the field resistance control method is, an increase of the field resistance will increase the no load speed of motor and in the slope of the torque speed curve.

For the effect of armature voltage control method, when the voltage increases, the no loads speed of the motor increase. The torque speed curve unchanged to kept the flux constant.

For the effect of armature resistance control method, an increase of armature resistance will increase in the slope of the torque speed curve and no load speed remains constant.

For the feedback control system for DC motor drives, the response of the motor speed to a steep increase in the reference speed for difference value of proportional gain (Kp) and the integral gain (Ki) is constant. When the Kp is constant and Ki is varied, the result performance is without the steady state error.

The Result clearly shows that the performance of the Fuzzy logic controller is better than PI controller. The value of the speed for the fuzzy is lower compared to PI controller which is 260rad/s for PI controller and 215rad/s for the Fuzzy controller.

V. REFERENCES

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