

MATLAB as a Substitute for Analysis of Transient Response of Dc Motor without Having Number of Machine.

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Abstract - The aim of this Paper is to introduce the modeling of power components and to use computer simulation as a tool for conducting transient and control studies. Simulation can be very helpful in gaining insights to the dynamic behavior and interactions that are often not readily apparent from reading theory. Next to having an actual system to experiment on. In this Paper, 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 certain parameters of the DC motor block diagram, the output waveform of the simulation would change accordingly. These parameters include the field current, armature circuit resistance and armature voltage. The simulation and modeling of the DC motor also gave an inside look of the expected output when testing the actual DC motor. The results from the simulation were never likely to occur in real-life condition due to the response times and condition of the actual motor. MATLAB/SIMULINK is used because of the short learning curve, its wide distribution, and its general-purpose nature. This will demonstrate the advantages of using MATLAB for analyzing power system steady state behavior and its capabilities for simulating transients in power systems and power electronics, including control system dynamic behavior.

I. INTRODUCTION

The theory of electrical circuit represents one of most important parts of any electrical engineering education. The main aim of this paper is to obtain the knowledge of circuit analysis and synthesis and to experience the actual behavior of a DC motor. This requires a powerful software mathematical tool. 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 engineer. MATLAB has been enhanced by the very powerful SIMULINK program. SIMULINK is a graphical mouse driven program for the simulation of dynamic system. It enables the user to simulate linear, as well as nonlinear, system easily and efficiently.

A theory is a general statement of principle abstracted from observation and a model is a representation of a theory that can be used for control and prediction.

For a model to be useful, it must be realistic and yet simple enough to understand and manipulate. These requirements are not easily fulfilled as realistic model are seldom simple and simple models are seldom realistic.

The scope of the model is defined by what is considered relevant. Feature or behavior that is relevant must be included in the model and those that are not can be ignored. Modeling refers to the process of analysis and synthesis to arrive at a mathematical description that contains the relevant dynamic characteristics of the particular model.

A. Modeling and Simulation

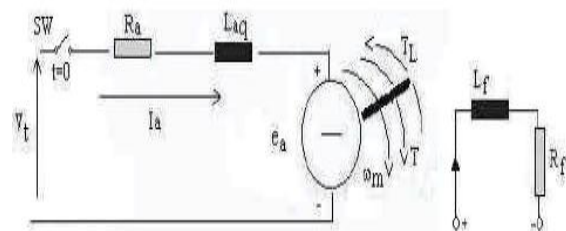
The modeling and simulation of this project helped to generate expected outcomes of the project design. The program used was called SIMLINK, a sub program of the mathematical and simulation software MATLAB. This software is used to provide simulation design and results for evaluation of the transient response of a DC motor.

B. Aim Of Paper

The main aim of this paper is to evaluate the transient response of DC motor using MATLAB/SIMULINK. These can be achieved by changing the setting in MATLAB/SIMULINK to investigate the motor responds to these changes. This would allow future student to use this SIMULINK program to evaluate the transient response of dc motor without having to go to the laboratory to use the actual DC motor.

II. MOTOR MODELING AND SIMULATION

To perform the simulation of a system, appropriate model needs to be established. For this paper, this system contains a dc motor. Therefore, a model based on the motor specification needs to be obtained.



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Assuming magnetic linearity, the basic motor equations are

$$T = K_f i_f i_a = K_m i_a \quad \text{Equation 2.1}$$

$$e_a = K_f i_f \omega_m = K_m \omega_m \quad \text{Equation 2.2}$$

Where $K_m = K_f i_f$ is a constant, which is also the ratio $\frac{e_a}{\omega_m}$

The Laplace transforms of Equation 2.1 and 2.2 are

$$T(s) = K_m i_a(s) \quad \text{Equation 2.3}$$

$$E_a(s) = K_m \omega_m(s) \quad \text{Equation 2.4}$$

Let the switch SW be closed at $t = 0$. After the switch is closed,

$$V_t = e_a + R_a i_a + L_{aq} \frac{di_a}{dt} \quad \text{Equation 2.5}$$

From Equation 2.2 and 2.5

$$V_t = K_m \omega_m + R_a i_a + L_{aq} \frac{di_a}{dt} \quad \text{Equation 2.6}$$

The Laplace transform of Equation 2.6 for zero initial conditions is

$$V_t(s) = K_m \omega_m(s) + R_a I_a(s) + L_{aq} s I_a(s) \quad \text{Equation 2.7}$$

Or

$$V_t(s) = K_m \omega_m(s) + I_a(s) R_a (1 + s \tau_a) \quad \text{Equation 2.8}$$

Where $\tau_a = \frac{L_{aq}}{R_a}$ is the electrical time constant of the armature.

The dynamic equation for the mechanical system is

$$T = K_m i_a = J \frac{d\omega_m}{dt} + B \omega_m + T_l \quad \text{Equation 2.9}$$

The term $B \omega_m$ represents the rotational loss torque of the system.

The Laplace transform of Equation 2.6 is

$$T(s) = K_m i_a(s) = J s \omega_m(s) + B \omega_m(s) + T_l(s) \quad \text{Equation 2.10}$$

From Equation 2.10 and 2.3,

$$\omega_m(s) = \frac{T(s) - T_l(s)}{B(1 + s J/B)} = \frac{K_m I_a(s) - T_l(s)}{B(1 + s \tau_m)} \quad \text{Equation 2.11}$$

where $\tau_m = J/B$ is the mechanical time constant of the system.

From Equation 2.4 and 2.8,

$$I_a(s) = \frac{V_t(s) - E_a(s)}{R_a(1 + s \tau_a)} = \frac{V_t(s) - K_m \omega_m(s)}{R_a(1 + s \tau_a)} \quad \text{Equation 2.12}$$

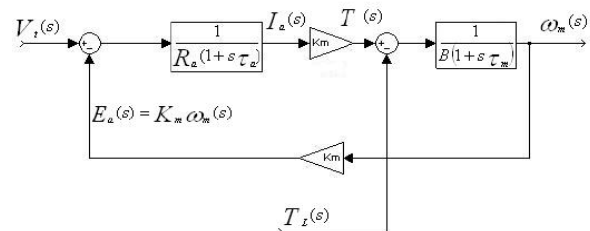


Figure 1. Block Diagram Representation Of Self Excited DC Motor.

1. LAB WORK:

Table I
Specification of Motor

Frame	180 M
Winding	Shunt
Armature voltage	230 V
Armature current	29 A
Power	7.5 HP
RPM	1000 RPM

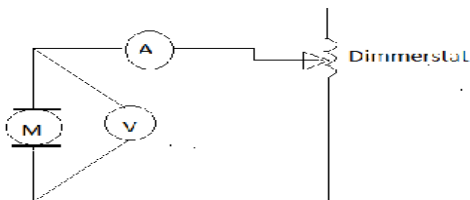


Figure 2. Circuit diagram for finding inductance (L) and Resistance (Ra) (Ra) = 1.9

TABLE II.
Observations

Sr. No	V	I	Z=V/I	X=(Z ² -R ²) ^{1/2}	L=X/2π F
1	5.74	1	5.74	5.37	0.0171
2	4.60	0.82	5.60	5.27	0.0168
Avg	5.17	0.91	5.67	5.32	0.017

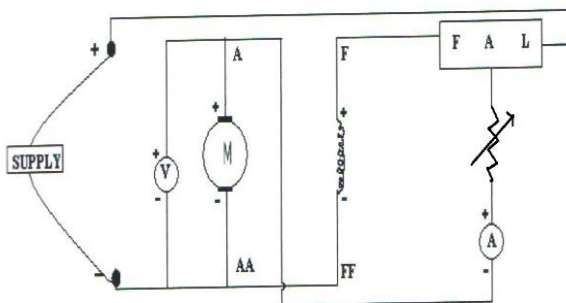


Fig. Ckt Diagram For calculating Torque, Speed & Current

Looking at the mechanical equation, equation 2.9:

$$K_m I_a = J \frac{d\omega_m}{dt} + B \omega_m + T_l$$

$$J \frac{d\omega_m}{dt} = K_m I_a - B \omega_m - T_l$$

At steady state both I_a and ω_m stabilized,

$$\frac{d\omega_m}{dt} = 0$$

$$K_m I_a - B \omega_m - T_l = 0$$

Since $P = 7.5 \text{ hp}$, $I_a = 29 \text{ A}$, $K_m = 2.19$, $n = 1000 \text{ rpm}$

As the speed is in term of N, so the unit is rpm. We need to convert it to rad/s

by using the following formulae.

$$W_m = 2\pi n / 60$$

$$W_m = 2\pi * 1000 / 60 = 104.66 \text{ rad/sec}$$

$$T_l = P / W = 7.5 * 746 / 104.66$$

$$(1 \text{ HP} = 746 \text{ WATT}) = 53.46 \text{ NM}$$

Therefore,

$$(2.19 * 29) - B (104.66) - T_l = 0$$

$$(2.19 * 29) - B (104.66) - 53.46 = 0$$

$$B = 0.096$$

For the value of rotor inertia J (in Kg m^2), It is assumed to be 0.04 Kg m^2

Table III
Specification of Motor DC Motor

SR. NO.	INTERNAL EMF Ea(VOLT)	SPEED(DRPM)	CURRENT Ia (RPM)	$\omega_m=2\pi n/60$ (Rad/sec)	$K_m = E_a/\omega_m$
1	183	870	2.55	91.10	2.0
2	170	780	2.40	81.68	2.08
3	160	750	2.25	78.53	2.03
4	150	720	2.10	75.39	1.98
5	140	670	1.90	70.16	1.99
AVG	160.06	758	2.24	79.37	2.19

With required specification of DC motor, a model of the DC motor was developed using SIMULINK. The DC motor was modeled using the characteristics. Transfer function of the electrical and mechanical of the motor as shown in figure.

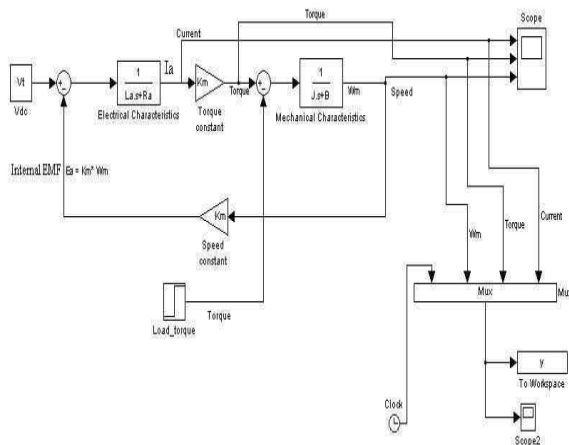
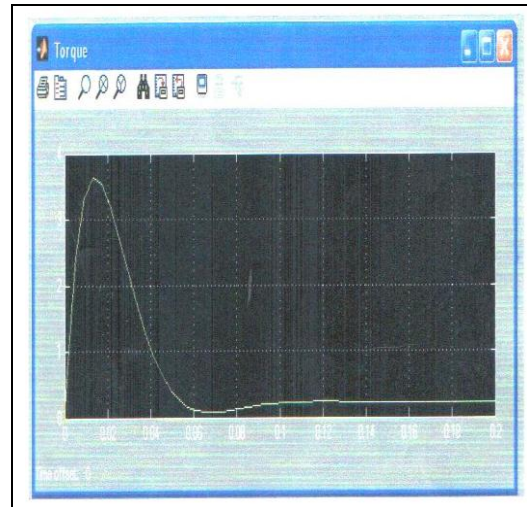


Figure 3. DC motor Block Diagram

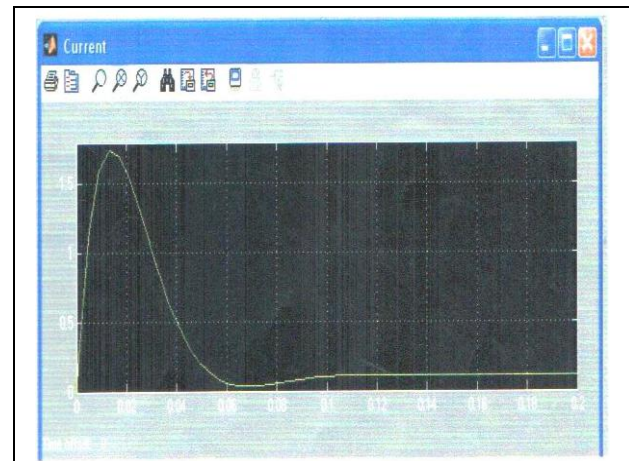
Figure 3. shows the DC motor input armature voltage (V_c) summed with the internal EMF. The result is then fed into the electrical characteristics transfer function block to produce the armature current (I_a). It is then passed through a torque constant to produce torque. This is then summed with a torque load, giving an output torque which is then fed into the mechanical characteristics transfer function block. The output power is the rotor speed (ω_m), which is fed back into the speed constant providing the constant EMF.

III. SIMULATION RESULT

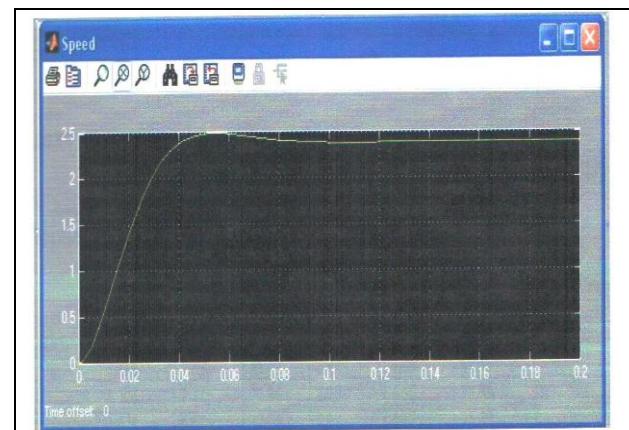
The result from simulation of motor model in Simulink is shown in figure.



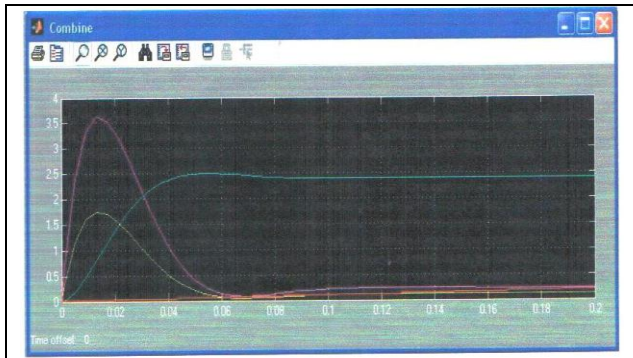
Screen Shot 1. Simulation Result Torque.



Screen Shot 2. Simulation Result Current.



Screen Shot 3. Simulation Result Speed.



Screen Shot 4. Simulation Result Combine all Above.

IV. SIMULATED RESULT VS MEASURED RESULT

For different values of applied voltage in the block diagram and simulated to get the following. Tests were also done on the actual DC motor using a workbench to get the armature current, torque and rotor speed-readings.

Table IV
Simulated Result Vs Measured Result

Voltage applied	Simulated			Measured		
	Armature current	Torque	Rotor speed	Armature current	Torque	Rotor speed(Wm)
183	4.239	8.435	87.91	2.55	5.12	91.10
170	3.938	7.836	81.67	2.40	4.99	81.68
160	3.706	7.375	76.86	2.25	4.58	78.53
150	3.474	6.914	72.06	2.10	4.17	75.39
140	3.243	6.453	67.26	1.90	3.79	70.16

From the results, it can be seen that the simulated readings were slightly similar to the measured readings. The difference could be put down to not having accurate initial parameter for the simulation and due to assumption of J. Thus the simulation of DC motor has been performed and the transient response is obtained with the help of MATLAB.

V. CONCLUSION

Actual experimentation on bulky power component can be expensive and time consuming. But simulation offers a fast and inexpensive means to learn more about this component. In this project, 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 waveform output. Furthermore, by varying certain parameter of the DC motor block diagram, the output waveform of the simulation would change accordingly. This parameter includes the field current, armature circuit resistance and armature voltage. The simulation and modeling of the DC motor also gave an inside look of the expected output when testing the actual DC motor. The results from the simulation were never likely to occur in real life condition due to the response times and condition of actual motor.

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