ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 2, February 2017

Simulation of Transient Behaviour of Dc Motor Using MATLAB/Simulink

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ABSTRACT: The aim of this paper is to introduce the modelling 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 behaviour and interactions that are often not readily apparent from reading theory motor. Using these simulation results we can get information regarding motor behaviour under different operating conditions which are helpful in designing more advanced protective devices precautionary equipments. In this Paper, the block diagram of a DC motor is developed and by using SIMULINK, the block diagram is simulated, For simulation of motor, some data is also required like torque constant which is obtained by experimental investigations. By varying certain parameters of the DC motor simulink block, the output waveform of the simulation would change accordingly. These parameters include the field current, armature circuit resistance and armature voltage. The simulation and modelling of the DC motor also gave an inside look of the expected output when testing the actual DC motor.

KEYWORDS: Transient response, Dc motor, motor modelling

I.INTRODUCTION

The main aim of this paper is to obtain the knowledge of circuit analysis and synthesis and to experience the actual behaviour of Electrical machines under transient conditions. Transients in electrical machines arise from changes in the voltages at machine terminals and the sudden change of load on the shaft, machine parameters, during connection of a machine to or its disconnection from the bus, etc. In real conditions, transients can naturally occur during a simultaneous variation of a few factors. Such a response of the electrical machine during this state is referred as the “transient response”. There are large varieties of transients which are much more complex than steady state responses. By their importance and the influence they have on the operation of the machines, the transients can be divided into the responses brought about during Starting, Reversing, and Restarting and. Load variation. These responses can appear at symmetric and asymmetric voltages in symmetric and asymmetric machines. There arises harmonics during the transient state. These harmonics are never safe. These transients could be 3-8 times rated values. The heavy currents and voltages produced during this transient state can damage these machines sometimes. These heavy currents sometimes produces disturbance to the other machines connected across the supply, hence there is a great need to suppress them. Transients long for only small time if their amplitude is sufficiently enough they can damage any type of machine. Study of these transient currents and voltages cannot be measured for studied using conventional methods. Only possible solution for the study of these transients is simulation.

A good simulation requires a good machine model which can exactly represent the machine behaviour. Using these simulations we can design more advanced protective devices precautionary equipments. The modelling and simulation of this thesis helped to generate expected outcomes of the project design. The program used was called SIMULINK, 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. A great number of research studies have been done on the subject prior to this study. The transient analysis and output characteristics of DC motors powered by photovoltaic systems was discussed where it was concluded that when the DC machine is operated at the specified conditions, the steady-state values are in conformity in both cases of entirely illuminated photovoltaic cells and preset terminal voltage and at light loads with photovoltaic cells and full illumination, the responses of the machines are greater as the voltage supplied is greater. The evaluation of the transient response of a DC motor was analyzed and it was

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inferred that by varying certain parameters of the DC motor system, the output waveform of the simulation would change accordingly and the simulation and modelling of the DC motor also gave an insight on the estimated output when testing the definite DC motor and the results from the simulation were never likely to occur in real-time conditions due to the response times and condition of the actual motor. An appraisal of the transient response of a DC motor using MATLAB/SIMULINK under no-loading and full-loading conditions was analyzed where a conclusion was drawn that simulation can be a very helpful tool in studying the dynamic behaviour of D.C shunt motor and its interaction, with reading experiment. It was also shown that the simulation model correctly predicts the effect of the field resistance on the torque-speed characteristic of the D.C shunt motor.

II. MOTOR MODELING

To perform the simulation of a system, an appropriate model needs to be established .For this paper; the system contains a DC motor. Therefore, a model based on the motor specifications needs to be obtained. Assuming magnetic linearity, the basic motor equations are

$T = K_f \; i_f \; i_a = K_m \, i_a$

$e_a = K_f \, i_f \, \omega_m \; = K_m \, \omega_m$

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

Laplace transform of the Equations are

$T(s) = K_m \, i_a(s)$ $e_a = K_m \, \omega_m(s)$

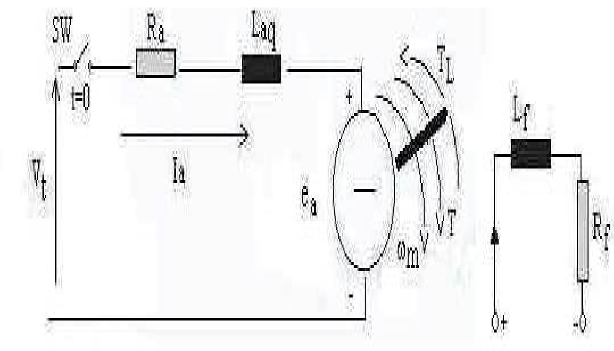

Figure1: Schematic diagram of Armature controlled DC Motor

Let the switch SW be closed at T=0,After switch is closed

$$V_t = e_a + R_a i_a + L_{eq} \frac{di_a}{dt}$$

From equation above mentioned

$$V_t = K_m \omega_m + R_a i_a + L_{eq} \frac{di_a}{dt}$$

The Laplace transform of the above Equation for zero initial conditions.

$V_t(s) = K_m \, \omega_m(s) + R_a \, i_a(s) + L_{eq} \; s \; i_a(s)$ $V_t(s) = K_m \, \omega_m(s) + I_a(s) \, R_a \; (1+ s\tau_a)$

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

The dynamic equation for the mechanical system is

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$$T = K_m i_a = J\frac{dw_m}{dt} + B\omega_m + T_l$$

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

The Laplace transform of above Equation is

$T(s) = K_m i_a(s) = Js\omega_m(s) + B\omega_m(s) + T_l(s)$

This gives
$$\omega_m(s) = \frac{(T(s) - T_L(s))}{B(1 + s\tau_m)} = \frac{K_m i_a(s) - T_L(s)}{B(1 + s\tau_m)}$$

Where τ_m= J/B is the mechanical time constant of the system hence $I_a(s)$ is given by

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

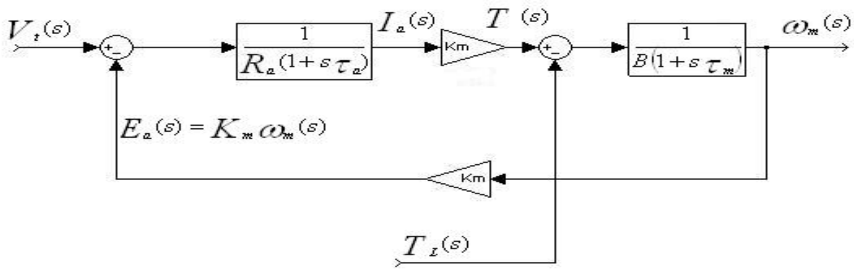

Figure 2: Block diagram representation of a separately excited DC motor

Speed control in a DC machine can be achieved by the following methods:

1. Armature voltage control (V_t)
2. Armature resistance control (R_a).
3. Field control (I_f)

Therefore, speed in a DC machine increases as V_t increases and decreases as Ø or R_a increases.

III.PARAMETER EXTRACTION

To produce a good design, there needs to be some amount of modeling or simulations done to avoid aimless trial and error techniques with the actual equipment (the DC motor).For this purpose , a number of specifications are needed to be obtained and established. The specifications of the DC motor like Voltage, Current, Power, Field Voltage, Field Current are noted from the name plate details.

Specifications:

Type	Shunt
Voltage	220v
Current	19A
Power	5 H.P
Field Voltage	220V
Field Current	3A
Insulation	B

Table 1: Name plate details of a DC Motor

There is other specification that is required for the modelling of the DC motor and it is measured using test equipments in the laboratory and through mathematical calculations.

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Testing the Armature Side of the Dc Motor

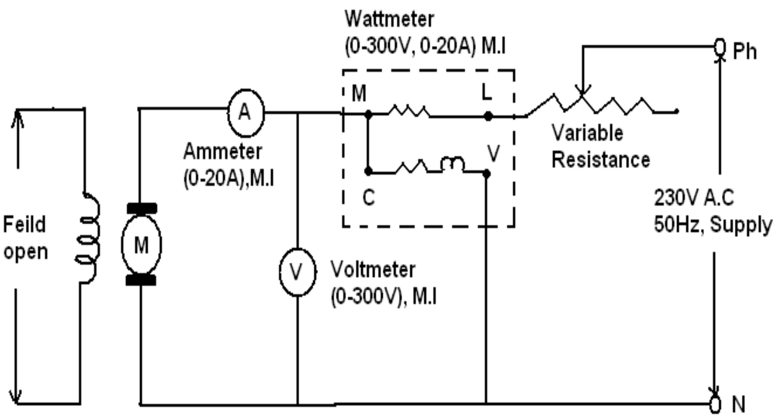

Figure3: Experimental setup for testing the Armature side

Observations from test:
Power (W) =22.95 W
Voltage (V) = 22.5V
Current (A) = 3A
Phase angle (Φ) = cos-1(W/(V*I))= 70.07
Impedance (Z) = (V/I)= 7.5 ohms
Resistance (R) = (W/I^2) = 2.55 ohms
reactance (X) = $\sqrt{Z^2 - R^2}$ = 7.053 ohms
inductance (L) = $\frac{X}{2\Pi f}$ = 0.0225 Henry

Test for Finding Torque Constant (K_m)

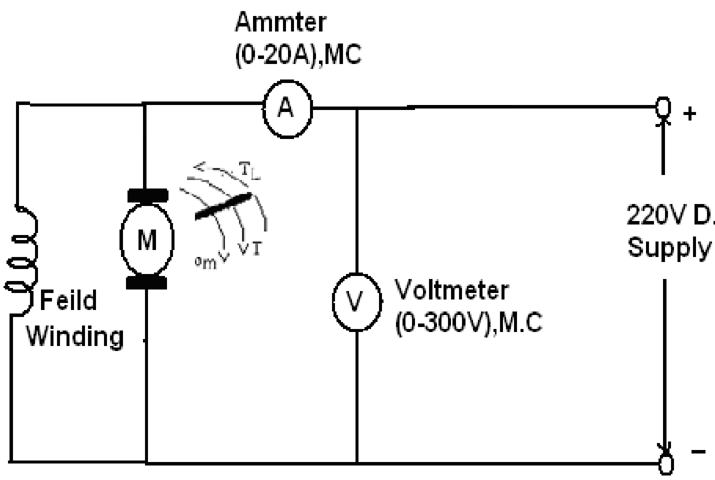

Figure 4 Circuit for finding K_m of DC motor

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Table 2: To find the Average Torque constant of DC motor

Terminal Voltage, V_t (Volts)	Internal EMF, E_a (Volts)	Load Current, I_L (Amps)	Speed, N(rpm)	Speed, W_m in (rad/s)	Torque constant, $K_m=E_a/W_m$
220	216.2	1.5	1410	147.56	1.465
220	213.9	2.4	1399	146.49	1.460
220	211.6	3.3	1394	145.92	1.450
220	210.8	3.6	1384	144.89	1.455

By using above data and equations ,Coefficient of viscous friction includes all rotation losses like friction and windage losses (B) and the moment of inertia of the motor (J) is calculated .and value of B and J is found to be

B=0.0251

J= 0.0759

IV. SIMULINK MODEL

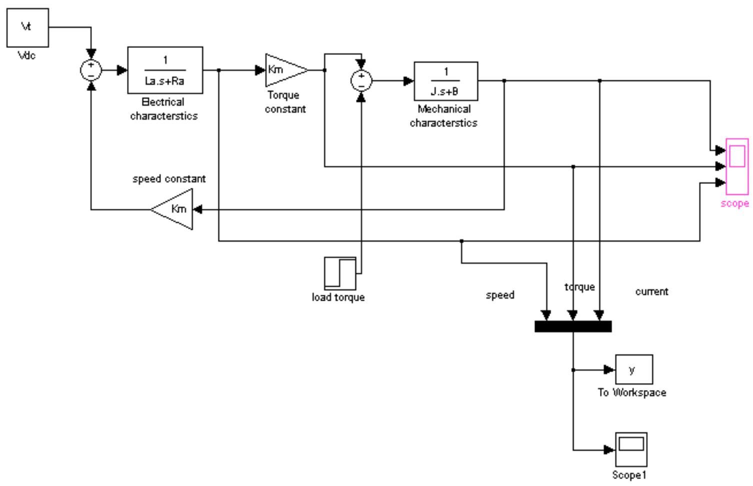

Figure 5 Simulink Model of Dc Motor

With required specification of DC motor, a model of the DC motor was developed using SIMULINK. The DC motor was modelled using the characteristics. Transfer function of the electrical and mechanical of the motor as shown in Figure5. Figure5. Shows the DC motor input armature voltage (V_t) 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 pass through a toque 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 (W_m), which is fed back into the speed constant providing the constant EMF.

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V SIMULATION RESULTS

A. *SIMULATION WITH INITIAL CONDITIONS AND WHEN ARMATURE VOLTAGE IS INCREASED*

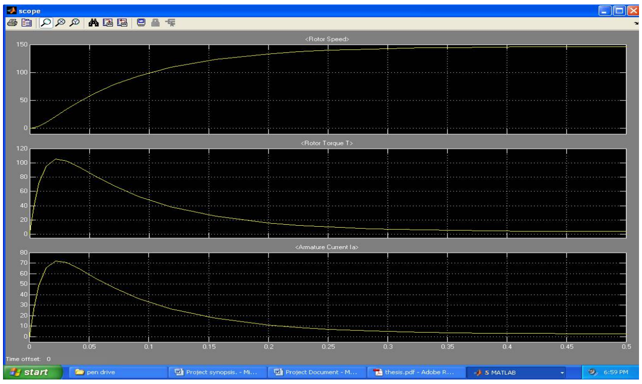

Figure: 6 Armature Current, torque and rotor speed

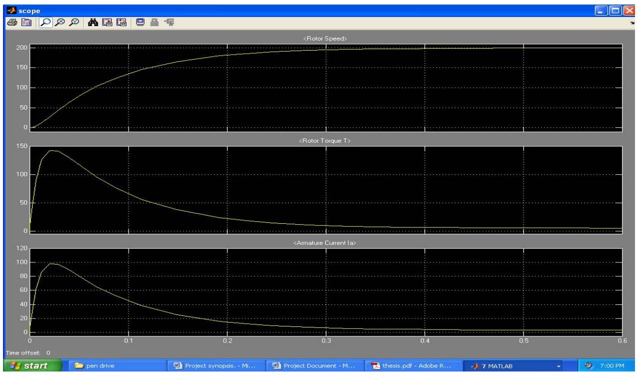

Figure: 7 Armature current, torque and rotor speed

In Figure 7, the armature terminal voltage is increased to simulate armature voltage control. The output waveform shows a large increase in the armature current, torque and rotor speed when compared to the initial output in Figure 6

A. SIMULATION RESULTS WHEN ARMATURE VOLTAGE IS DECREASED AND WHEN ARMATURE RESISTANCE IS INCREASED

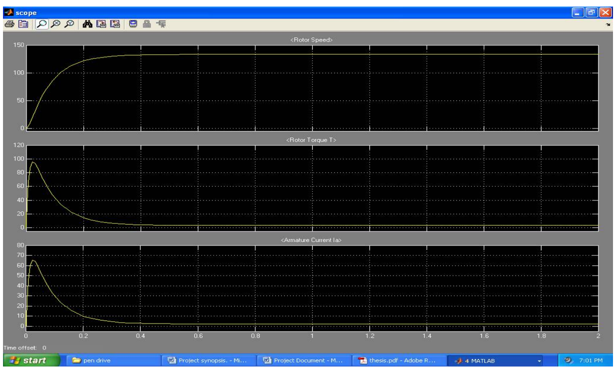

Figure: 8 Armature current, torque and rotor speed

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In Figure 8, the armature terminal voltage is decreased to simulate armature voltage control. The output waveform shows a drop in the armature current, torque and rotor speed when compared to the initial output in Figure 6.

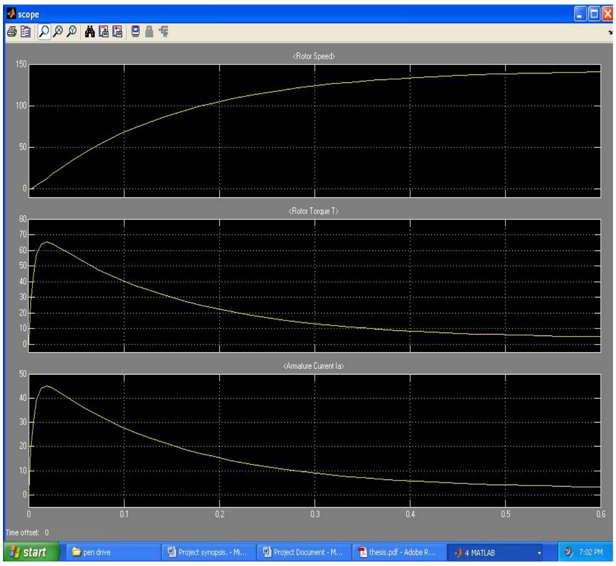

Figure: 9 armature current, torque and rotor speed

From Figure 9, the armature resistance is increase to simulate armature resistor control. The output waveform shows a large drop in the armature current, torque and rotor speed when compared to the initial output in Figure 6. And all the output waveforms took a longer time to reach steady state.

B. SIMULATION RESULTS WHEN FULL LOAD TORQUE APPLIED TO THE MOTOR SUDDENLY

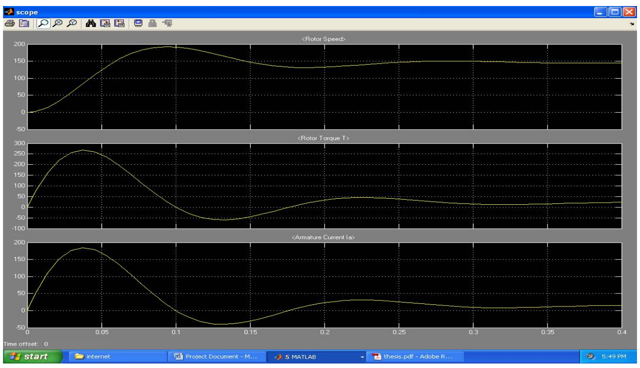

Figure: 10 Armature current, torque and rotor speed

From Figure 10, the armature resistance is decrease to simulate armature resistor control. The output waveform shows a large increase in the armature current, torque and rotor speed when compared to the initial output in Figure 6. All three output waveforms show an under damped response.

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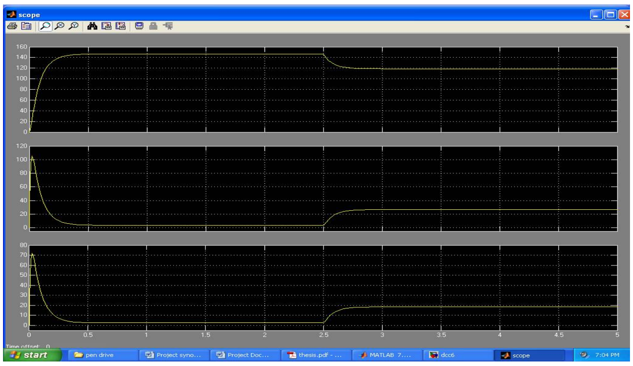

Figure: 11 When Full Load Torque Applied

From the simulation results of the DC motor in Figure 11, it shows the DC motor running at no-load condition at start up. After the motor has reached steady-state, if a mechanical load is suddenly applied to the shaft, the small no-load current does not produce enough torque to carry the load and the motor begins to slow down. This causes the counter EMF to diminish, resulting in a higher current and a corresponding higher torque. When the torque developed by the motor is exactly equal to the torque imposed by the mechanical load, and then the speed will remain constant.

VI. 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. These parameter includes the field current, armature circuit resistance and armature voltage. The simulation and modelling 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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