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Evaluation of the Transient Response of a DC motor

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Abstract: *The objective of the present work 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, simulation is often chosen by engineers to study transient and control performance or to test conceptual designs. 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.*

Keywords: *Boost converter, Power factor correction, Active filter, non-linear loads.*

1. Introduction

The theory of electrical circuits represents one of most important parts of any electrical engineering education. The objective of this project is to obtain the knowledge of circuit analysis and synthesis and to experience the actual behaviour 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 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.
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 models are seldom simple and simple models are seldom realistic.

The scope of a model is defined by what is considered relevant. Features 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.

2. Basics of DC Motor

Construction of DC Motor
The stator of the DC motor has poles, which are excited by DC current to produce magnetic fields. The rotor has a ring-shaped laminated iron-core with slots. Coils with several turns are placed in the slots. The distance between the two legs of the coil is about 180 electric degrees.

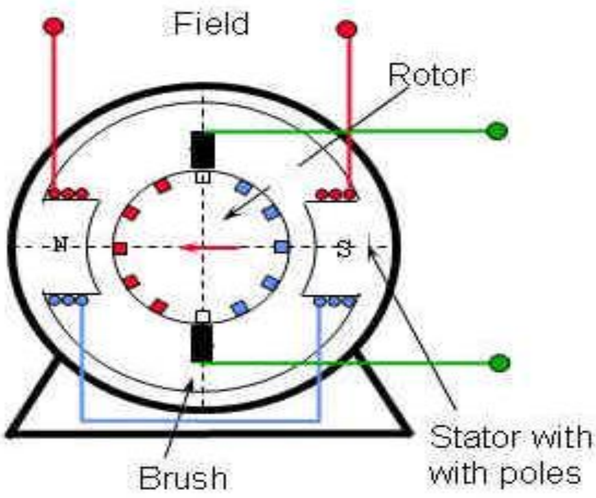

Figure:2.1 Construction of DC motor

The coils are connected in series. To keep the torque on a DC motor from reversing every time the coil moves through the plane perpendicular to the magnetic field, a split-ring device called a commutator is used to reverse the current at that point. The above figure: 2.1 show the construction of DC motor.

3. Principle of Operation

In any electric motor, operation is based on simple electromagnetism. A current carrying conductor generates a magnetic field which when placed in an external magnetic field; it will experience a force proportional to the current in the conductor and to the strength of the external magnetic field. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

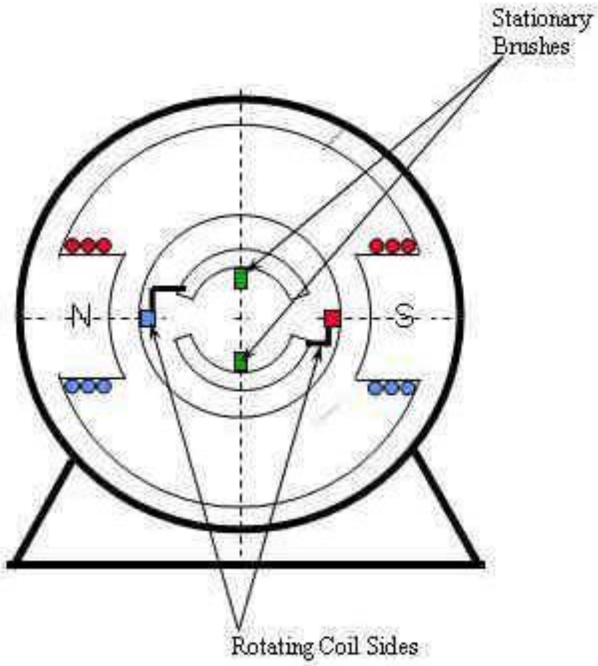

Figure:3.1 Concept of DC motor operation

4. Mathematical Model

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 is discussed where it is 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 is analyzed and it is inferred that by varying certain parameters of the DC motor system, the output waveform of the simulation would change accordingly and the simulation and modeling of the DC motor also give an insight on the estimated output when testing the definite DC motor and the results from the simulation are 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 is analyzed. where a conclusion is drawn that simulation can be a very helpful tool in studying the dynamic behavior of D.C shunt motor and its interaction, with reading experiment. It is 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. To perform the simulation of a system, an appropriate model needs to be established. For this thesis, the system contains a DC motor. Therefore, a model based on the motor specifications needs to be obtained.

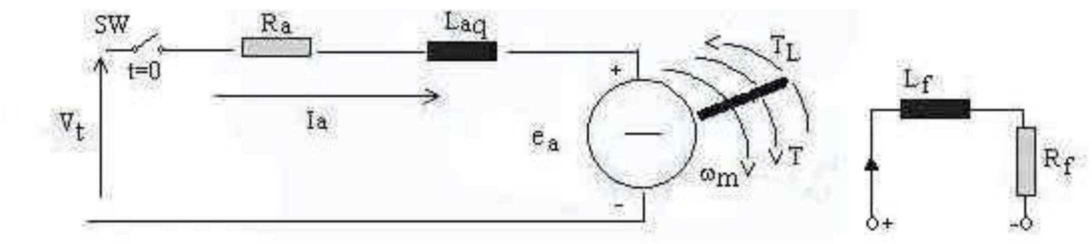

Figure: 4.1 Schematic diagram of a separately excited dc motor

Assuming magnetic linearity, the basic motor equations are,

$\mathbf{T = K_f i_f i_a = K_m i_a}$ (4.1)

$\mathbf{e_a = K_f i_f \omega_m = K_m \omega_m}$ (4.2)

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

By taking the Laplace transformation of equations 5.1 and 5.2, we get

$\mathbf{T_{(s)} = K_m i_a(s)}$ (4.3)

$\mathbf{E_a = K_m \omega_m(s)}$ (4.4)

The switching operation is done at t=0 time. Therefore, the switch is made ON (Closed) at that time.

$\mathbf{V_t = e_a + R_a i_a + L_{aq} \frac{di_a}{dt}}$ (4.5)

Now, putting the value of equation 5.2 in to above expression 5.5, we get

$\mathbf{V_t = K_m \omega_m + R_a i_a + L_{aq} \frac{di_a}{dt}}$ (4.6)

Using the zero initial condition in the above expression will give,

$\boldsymbol{V_t(s) = K_m \omega_m(s) + R_a I_a(s) + L_{aq} s I_a(s)}$ (4.7)

Now, the electrical time constant is given by,

$$\boldsymbol{\tau_a = L_{aq}/R_a}$$

$\boldsymbol{V_t(s) = K_m \omega_m(s) + I_a(s) R_a (1 + s\tau_a)}$ (4.8)

For the mechanical system, the dynamic equation is given by

$\boldsymbol{T = K_m i_a = J \frac{d\omega_m}{d_t} + B\omega_m + T_L}$ (4.9)

The term $\boldsymbol{B\omega_m}$ in the above expression represents the rotational loss torque of the system. Now, taking the Laplace transformation of the above equation, we get

$\mathbf{T(s) = K_m i_a(s) = J s \omega_m(s) + B \omega_m(s) + T_L(s)}$ (4.10)

From expressions 5.3 and 5.10 (after further simplification), we get

$\mathbf{\omega_m(s) = \frac{T(s) - T_L(s)}{B(1 + sJ/B)} = \frac{K_m I_a(s) - T_L(s)}{B(1 + s\tau_m)}}$ (4.11)

Here, the mechanical time constant of the system is given by

$$\tau_m = J/B$$

From expressions 5.3 and 5.10 (after further simplification), we get

$$I_a(s) = \frac{V_t(s)-E_a(s)}{R_a(1+s\tau_a)} = \frac{V_t(s)-K_m\omega_m(s)}{R_a(1+s\tau_a)} \qquad (4.12)$$

The Figure 4.2 given below shows the block diagram representation of Equations 4.10 and 4.11.

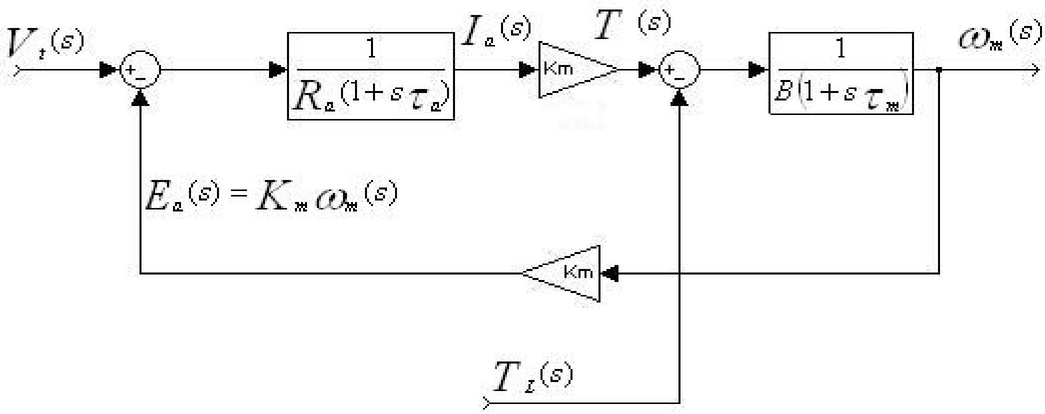

Figure: 5.2 Block diagram representation of a separately excited DC motor

The program used to complete the modelling and simulation is called SIMULINK, a sub program of MATLAB. From the above block diagram mathematical modelling can be done and various simulated results can be achieved which will be used for the next part of the project work. By complete modeling of DC motor in MATLAB, it is possible to get different results of speed controlling methods and the same will be done on actual DC motor. Furthermore, we will have the evaluation of transient response of DC motor.

5. Simulation Model

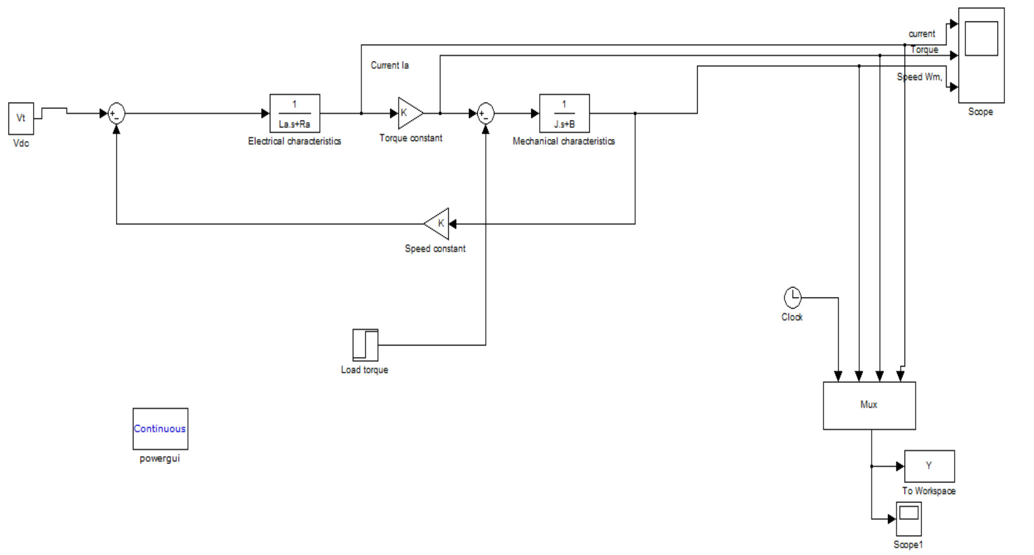

Figure:5.1 SIMULINK Model the separately excited DC motor

The result is then fed into the electrical characteristics transfer function block to produce the armature current (Ia). It is then pass thru 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 is the rotor speed (Wm), which is fed back into the speed constant providing the constant EMF.

6. Simulation Result

The result from the simulation of the motor model in SIMULINK is shown in Figure 6.1

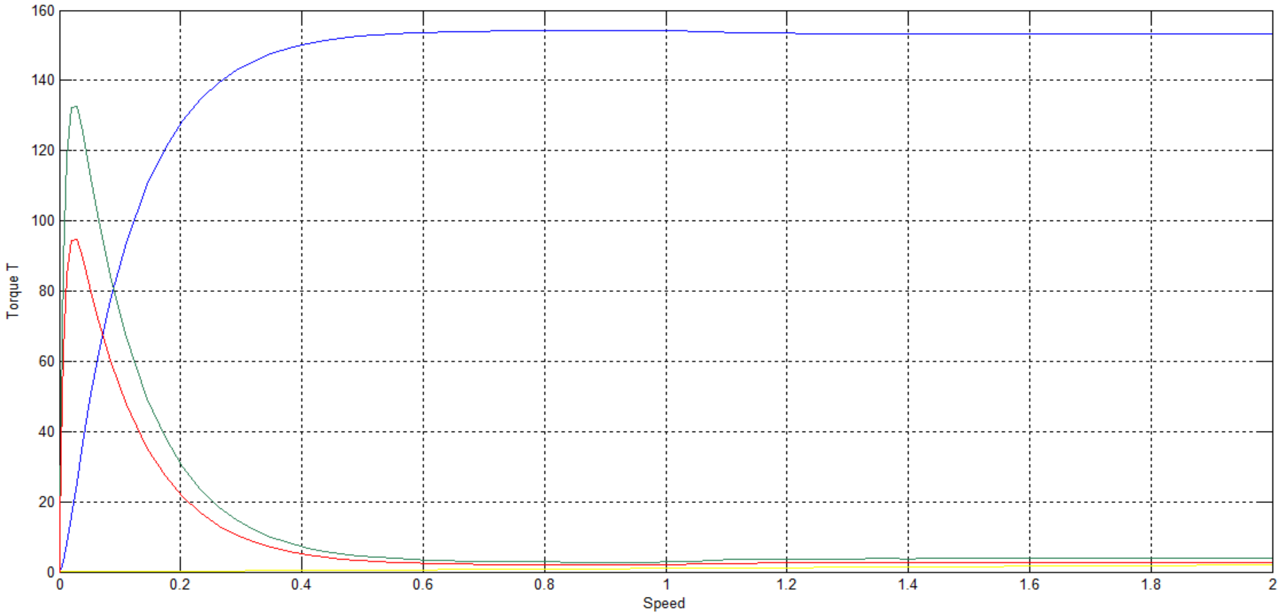

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Figure: 6.2 simulated outputs for the armature current, torque and rotor speed for initial conditions.

7. Future Scope

The simulation of different speed control methods of DC motor will be done. The same will be done on actual DC motor on no load and on load conditions to get more accurate results. Including other resistors into the armature circuit when starting of the simulation to decrease the high starting current.

8. Conclusion

Actual practical on bulky power components can bulky and time taking. But simulation gives a speedy and less costly means to know much about these elements. The simulation and modeling of the DC motor give an inside look of the better output when testing the perfect DC motor. The responses from simulation are never expected to done in real-life condition due to response times and situation of the real motor. By complete modeling of DC motor in MATLAB, it is possible to get different results of speed controlling methods and the same will be done on actual DC motor. Furthermore, we will have the evaluation of transient response of DC motor.

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