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Evaluation of Speed and Torque in Armature Controlled DC Motor

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ABSTRACT

This study presents the MATLAB perception of field resistance and armature voltage for dc motor drive as dc motor speed control methods. It is possible to forecast the behavior of a DC motor under various circumstances by simulating it using the appropriate model. As a result, we measured the dc motor parameters and then suggested a dc motor model in the Simulink software based on the findings.Simulink is used to simulate the entire drive system, with the speed being controlled via back emf detection.Using the proper model, it is possible to simulate DC motor operation and forecast how the motor will behave under certain circumstances. Consequently, we measured the DC motor parameters and, based on the findings, we suggested a DC motor model in the Simulink software.Armature voltage and torque all affect a DC motor's speed. In this study, the armature voltage is modified to produce the appropriate output speed.The suggested system maintains constant output voltage despite fluctuations in input voltage. As a result, a sizable decrease in overshoot is seen, increasing the motor's effectiveness.A DC motor whose speed and supply voltage have an inverse relationship. The known relationship between speed and supply voltage is used in this study to explore the impact of various loads and inputs that affect how the armature controlled direct current motor responds to its output. The goal is to find the link between load torque and DC motor speed at various voltages. There were two stages to the study's execution. The system is initially mathematically simulated, and the second stage centers on a simulation of an armature driven direct current motor. The incorporation of feedback improves the armature-controlled DC motor's transient reaction capabilities, according to an analysis of the modelling system's functioning. The findings further demonstrate that the load torque and DC motor speed have an inverse relationship for various input voltages.

Keywords: DC Motor, Dynamic Model, MATLAB, Modeling.

1. INTRODUCTION

When electrical energy from a source is converted into mechanical energy, a DC motor acts as an actuator (for load). These motors are widely used for electrical traction, cutting tools, robotic manipulation, etc.(Pratyusha Biswas Deb, 2017). Because a huge load is not required, the motor achieves a relatively high speed and low torque with a light load. In contrast, A motor will run at a lower speed and provide greater torque to accommodate a heavier or more challenging-to-move load if one is present.

STATOR:The DC motor generates torque, which causes it to rotate, using electricity and a magnetic field. Two magnets with diametrically opposed poles, an electric coil that acts as an electromagnet, and other components(Ibtihal Akram, 2021), and other components. The magnets' electromagnetic forces of attraction and repulsion produce the torque that turns themotor (Priyadarshini, 2017). Additionally, it consists of a single set of coils inside a single set of permanent magnets known as the stator. The stator's windings can be organized into two connections, known as the Star and Delta connections. Speed is low when the stator windings are disconnected, but torque is strong when they are connected in a star arrangement. A few interlinked coils that are inserted into one or more of the stator slots make up these windings. Low torque and low speed result from the winding only receiving half of the input voltage through a delta connection.(Priyadarshini, 2017). The armature moves when a voltage is delivered to the coils, which creates a torque. Current, I, will circulate through a coil when its two ends are connected in opposition to a DC voltage source. A force is created on the coil by the interaction of the electric current and magnetic field. Due to the force operating on the coil's two sides, the coil begins to move in the direction of the force.

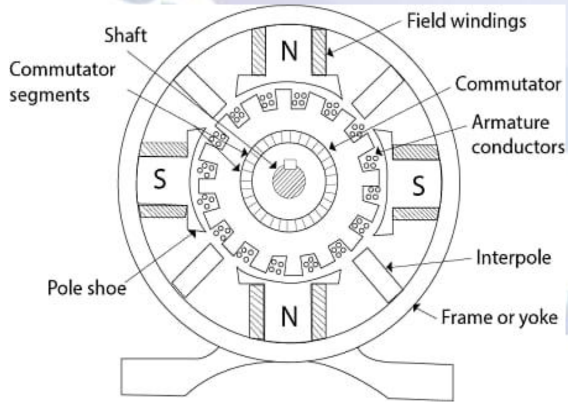
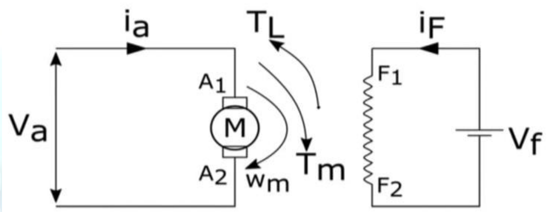


Figure 1: DC motor

ROTER: Coils are wound on the rotor of a DC motor, (as shown in figure1) and when force is applied to them all, the rotor rotates. Because of the greater force produced, the wire moves more quickly the higher the current in the wire or the stronger the magnetic field. As the conductors move in a magnetic field, torque is created concurrently. An electromagnetic force (emf) is produced when the flux connected to it varies at several locations. This voltage is occasionally referred to as a counter-voltage or back emf since it is the opposite of the voltage at which a conductor experiences current flow.

The discrepancy between the voltage that is being applied and the counter-voltage controls the amount of current flowing through the armature. Lenz's law states that the current generated by this counter-voltage typically works against the cause of it. The outcome is that the rotor slows down until the force of the magnetic field and the force of the load pushing on the shaft are equal. After that, the system moves at a constant speed.

2. MATHEMATICAL MODELLING



V_a=Voltage source in armature winding.

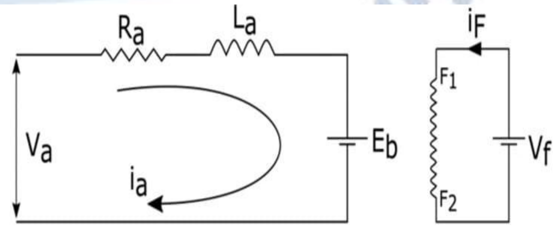
V_f= Voltage source in field winding.

T_m= Motor Torque, T_l= Load Torque.

i_a=Current flow in armeture winding.

i_f=Current flow in field winding.

Armature Control method: In this method we keep field voltage (V_f) constant and we will vary the armature voltage (V_a)to do speed variation. By doing armature control method we only can control the speed below the base speed.



$R_{a=}$ Resistance in the armeture winding.

$L_{a=}$Armature inductance.

$E_{b=}$Back EMF.

The field voltage is kept constant. Field will therefore remain constant. Mathematically,$(K_e\emptyset)$ = Constant

So the governing equations are:-

$V_a = i_a R_a + L_a \frac{di_a}{dt} + E_b$

$E_b = (K_e \emptyset)\omega_m$, $T_m = (K_e \emptyset) L_a = T_l + J\frac{dw_m}{dt} + B\omega_m$

[where J=Moment of inertia& ω_m =Angular velocity of motor& B=Viscous friction coefficient.]

Taking Laplace Transforms:

$V_a(s) - E_b(S) = L_a(S)\,[R_a + SL_a]$

$L_a S = \frac{V_a(S) - E_b(S)}{[R_a + SL_a]} = \frac{V_a(S) - (K_e\emptyset)\omega_m(S)}{R_a(1+S\frac{L_a}{R_a})}$

$[\frac{L_a}{R_a} = \tau_a]$, Where, τ_a is the armature circuit's time constant hence, the armature current is

$L_a S = \frac{V_a(S) - E_b(S)}{R_a(1+S\tau_a)} = \frac{V_a(S) - (K_e\emptyset)\omega_m(S)}{R_a(1+S\tau_a)}$

$T_m(S) - T_l(S) = \omega_m(S)[B+SJ]$

$\omega_m(S) = \frac{T_m(S) - T_l(S)}{B+SJ}$

$\omega_m(S) = \frac{T_m(S) - T_l(S)}{B(1+S\frac{J}{B})}$

$[\frac{J}{B} = \tau_m]$, Where, τ_m is a motor's mechanical time constant. hence, the motor speed is

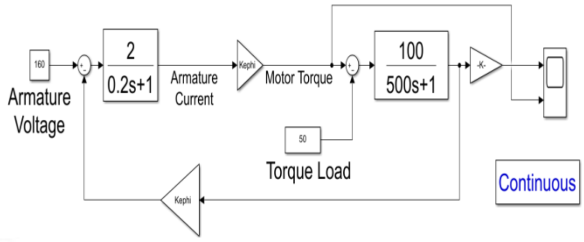
$\omega_m(S) = \frac{T_m(S) - T_l(S)}{B(1+S\tau_m)} = \frac{(K_e\emptyset)L_a(S) - T_l(S)}{B(1+S\tau_m)}$

By altering the armature circuit's applied voltage (Va) rather than the field voltage, as well as the armature voltage control technique can change the voltage. motor's electrical system circuit. Consequently, in order to use armature voltage control, the motor must be powered separately. The no-load voltage increases as the armature voltage does. the motor's speed rises as the gradient of the Since the flux, the torque-speed curve has remained unaltered, Maintains constancy.

3. SIMULATION& RESULTS

Most often used for programming, computation, and numerical visualization, MATLAB is a high-level programming language with an interactive interface. The creator was MathWorks. Plotting of functions and data, the construction of user interfaces, and matrix manipulation are some of MATLAB's fundamental capabilities. A model is merely a depiction of how some systems of interest are built and function. A model resembles the system it portrays but is less complex. Making a model is the process of modelling. It requires using known input circumstances to run the model and comparing the outcomes to those of the system(Channid4, 2021).

These are the values that we have put into the simulation diagram:



Block Diagram of simulation

R_a= Resistance in the armeture winding =0.5ohms,L_a=Armature inductance =0.1Henry, J=Moment of inertia =5 Kg-m/S^2, V_a= Voltage source in armature winding =160 volts,T_l= Load Torque= 50, tau_a =L_a/R_a, B=Viscous friction =0.01, tau_m = J/B.

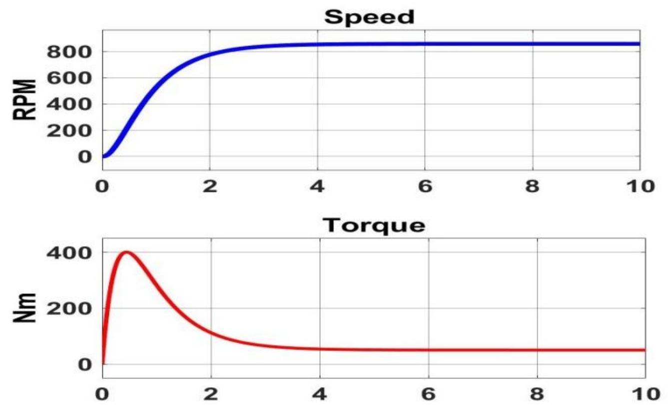


Diagram 1: with Constant Armature voltage & torque load in simulation.

In this simulation, (According to diagram 1) the armature voltage is 160 v & the torque load is 50. We can see that the motor speed increases gradually from 0-850 rpm in 4 seconds, after that it remains constant. The torque reaches its maximum value of 0-400 Nm in 1 second, and after 5 seconds it remains constant at 50 Nm.

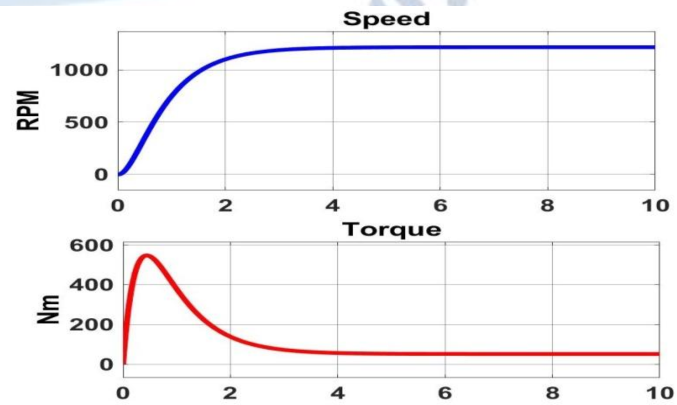


Diagram 2: simulation by veering Armature voltage.

The armature voltage in this simulation is 220 v, and the torque load is 50 Nm. We can observe that the increased armature voltage caused the motor speed to increase to 1200 rpm. Additionally, torque rose by 550 Nm.

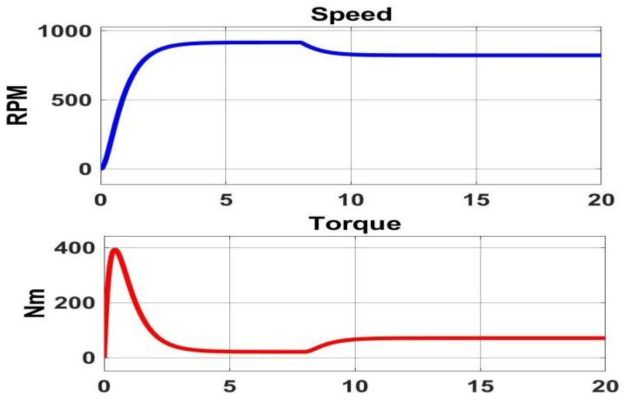


Diagram 3: simulation by using step value of torque load.

The armature voltage in this simulation is 160 volts, the initial torque load is 20 nm, and the final torque load after 8 seconds is 70 nm.(According to diagram 3) Before the first eight seconds, the motor is running at 870 RPM at load 20, but drops to 800 RPM at torque load of 70 Nm. Thus, the relationship between the motor speed and the torque load is inverse. Additionally, both the motor speed and torque load stay constant at 820RPM and 70Nm, respectively.

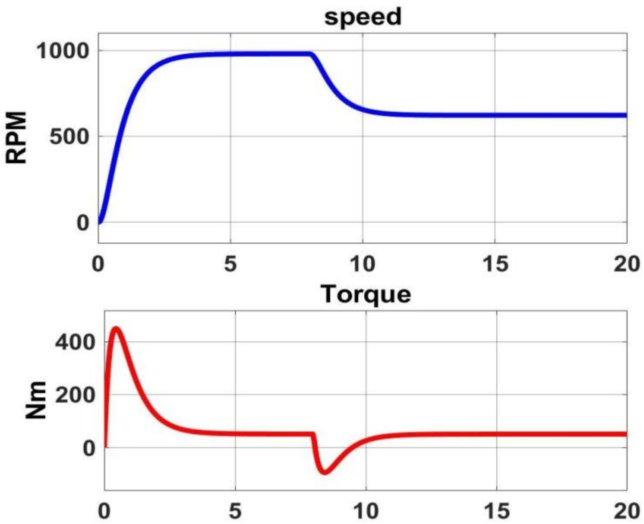


Diagram 4: simulation by using step value of Armature voltage.

In this scenario, the armature voltage starts off at 180 volts and drops to 120 volts after 8 seconds due to the 50 Nm torque load. Here, we can observe that the motor's first speed is 980 RPM and its initial torque load is 50Nm. appropriate motor operation However, the torque load brakes after 8 seconds, and the motor speed decreases as a result of the negative value. (According to diagram 4). Thus, the torque load and motor speed are inversely proportional to each other and rely on the armature voltage.(Ayasun, 2017).

4. CONCLUSION

For DC motor drives, MATLAB has been used to create DC motor speed control methods and feedback control systems simulation models. It has been demonstrated that the offered simulation models are reliable predictors of the resistance and armature voltage effects based on the torque-speed relationship of the DC motor.The properties of the armature-controlled dc motor's torque-speed and armature voltage-speed are properly predicted by the simulated motor. Additionally, the investigation's findings indicate a direct correlation between the DC motor's armature voltage and speed.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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