

## ***Computer-Aided Pedagogy of DC Motor for Undergraduates***

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### ***Abstract***

#### ***Background***

*Computer technology has become inevitable in the era of technological advancement, use. To boost pedagogy techniques the need of the hour is to integrate software tools in engineering curriculum. Electrical engineering along with simulations software is a great help to undergraduates. Operation of high voltages and heavy currents should be handled with care. Appropriate control is the only viable solution which could be well designed control if engineers have the knowledge of associated waveforms. Tedious procedure is involved while plotting manually. Simulation aids helps us understand steady state of system resulting in better performance. In this paper computer, aided pedagogy of DC motor is carried out using MATLAB/Simulink. The pedagogy includes starting of DC motor and Speed control.*

***Keywords: -MATLAB/Simulink, DC Motor, Speed Control, Pedagogy***

### **INTRODUCTION**

An inevitable part of classroom lectures and practical experiments in electric machinery education [1] has been resulted due to the trending advent of low cost personal computers and easily accessible open source software packages.

Elucidation of steady state operation of motor under various loading conditions easily enables the instructor to culminate modern pedagogy techniques [3]. Enhancement of laboratory sessions by undergraduate students are boosted via computer aided tools assists students i.e.

verifying hardware counterparts with simulation. Hardware limitations are well understood via comparative study of hardware as well as software [2]. The error bridge between hardware and software simulations is due to the assumption made in simulation. This elucidates the fact that hardware experiments can't be replaced exactly by simulation. Simulation software used in the following work is MATLAB/Simulink. With their associated merits and demerits software's such as MAPLE and MathCAD can be used in electrical engineering [5]. Easy accessibility of MATLAB in undergraduate courses in Institution culminates the use of MATLAB in pedagogy [6]. The simulation performed in this paper is for starting of speed control of DC Motor along with speed control of a DC motor using field resistance control method and armature voltage control

method with associated DC motor characteristics.

## **DC MOTOR STARTING**

### ***Three Point Starter***

While starting a resistance is added in series with armature winding. Resistance is gradually cut out from the armature circuit as the lever is moved further. As the lever reaches the final position armature gets directly connected across the supply and all the resistance is cut out from the armature circuit. When there is low or no voltage the electromagnet releases the lever to the initial position. The decrease in shunt current is very negligible as the value of starter resistor is very small compared to shunt resistance. The following is the apparatus showing three point starter from MITRC electrical department laboratory Fig. 1



***Figure 1: Laboratory Setup Demonstration***

### Simulink Diagram for Three Point Starter

The following is the Simulink diagram shown for the implementation of three point starter in MATLAB/Simulink Fig. 2.

In the following figure along with DC supply a staircase generator and resistance in series along with breaker is used to emulate the system of three point starter. These breakers are designed with some time lag simulating the changing or addition of resistance gradually. The left over circuit is basically connection of DC motor for its characteristics. The use of motor has the specification as 5 HP, 240V DC motor. The use of workspace and XY

graph block is to plot the characteristics and observe the respective waveforms.

### FIELD RESISTANCE CONTROL

The speed of the DC shunt motor is given by the following expression:

$$N = \frac{V_a - I_a R_a}{K \cdot \phi}$$

In (1), the voltage applied across the armature is denoted by  $V_a$  and  $\phi$  denotes number of flux per pole that is proportional to the field current  $I_f$ . Armature current is decided by mechanical load present in shaft. Therefore, the armature voltage speed can be varied with variations of armature field current. For speed control of the DC motor using field resistance is illustrated in Fig. 3

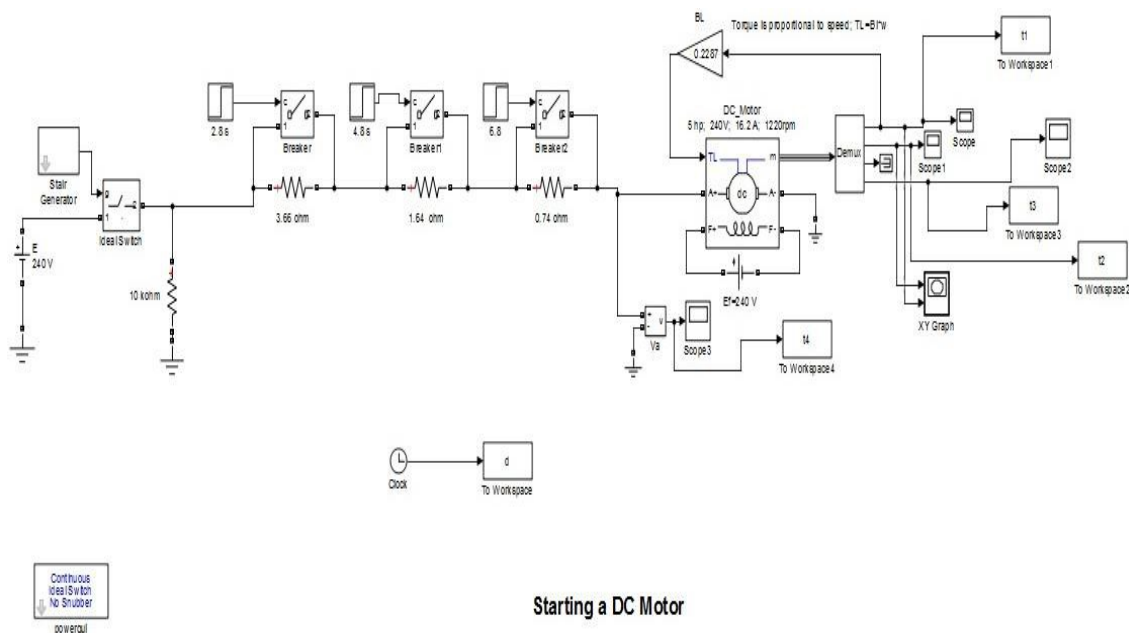


Figure 2: Simulink Diagram for Three point starter of DC Motor

To control the speed of a DC shunt motor, field circuit resistance is varied. If we vary field current  $I_f$ , flux  $\phi$  will change which would result in the variation of speed. To bring a change in the field current, an external resistance is connected in the series with the field windings. The resistance acts as shunt field regulator, rated flux is produced by a field coil when no external resistance is connected and

rated voltage is applied across the field coil.

### A. Field Resistance Control Using Simulink

The DC motor speed control is implemented using field resistance control is shown in Fig. 4 [7].; 5 HP, 240V, 1750RPM is the specification of the DC motor used having a field voltage of 300V and load torque of 160N-m.

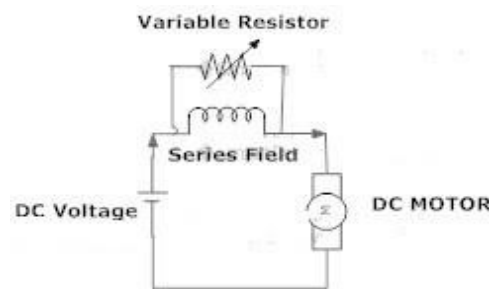


Figure 3: Speed control of DC Motor Using Field Resistance

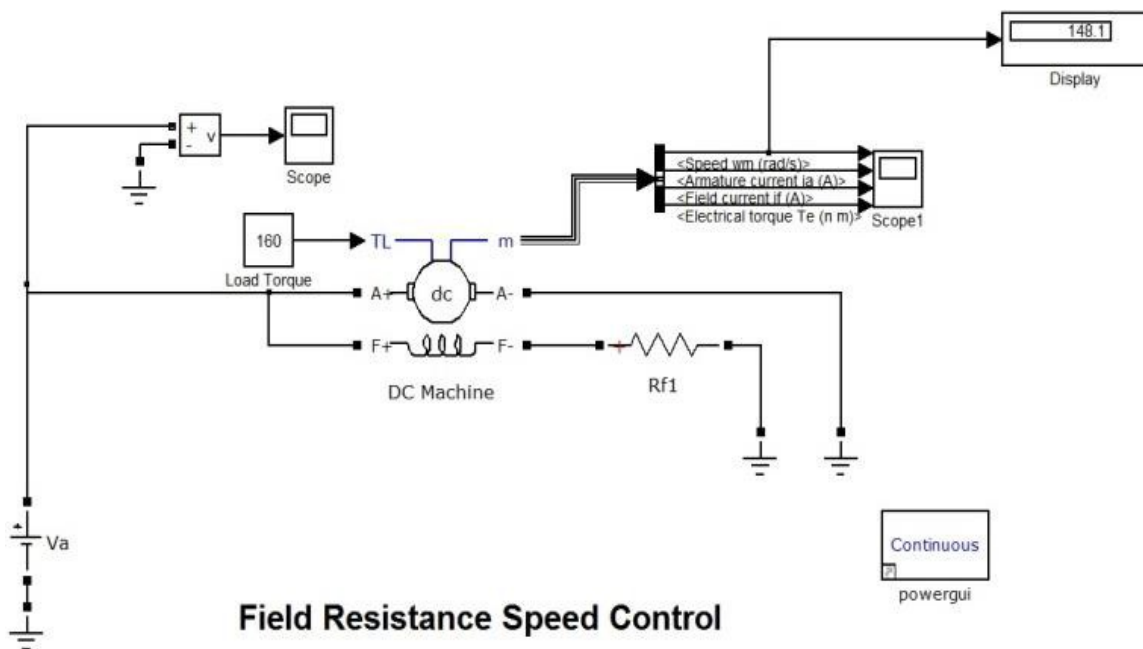


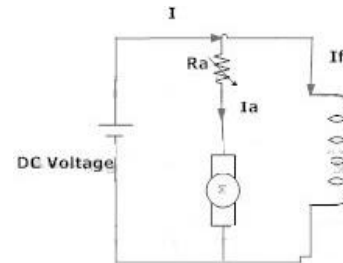
Figure 4: Speed Control of DC Motor Using Field Circuit (Simulink Model)

Insertion of series resistance for changing flux via regulating field current in shunt field circuit of the model [7]. R-L circuit ( $R_f$  and  $L_f$  in series) and connected between the ports (F+ and F-) illustrates the field circuit [7]. An inductor  $L_a$  and resistor  $R_a$  in the series with an electromotive force  $E_a$  and is connected between the ports (A+, A-) illustrates armature circuit [7]. External resistance  $R_{f1}$  is inserted in the series with the field circuit to realize the field resistance speed control [7]. The experimental setu for the speed control at MITRC laboratory is as shown in Fig. 1.

### ARMATURE VOLTAGE CONTROL

Here at the armature, circuit voltage is applied without varying the applied voltage to the field circuit of motor  $V_a$  is varied [7]. Hence for armature voltage

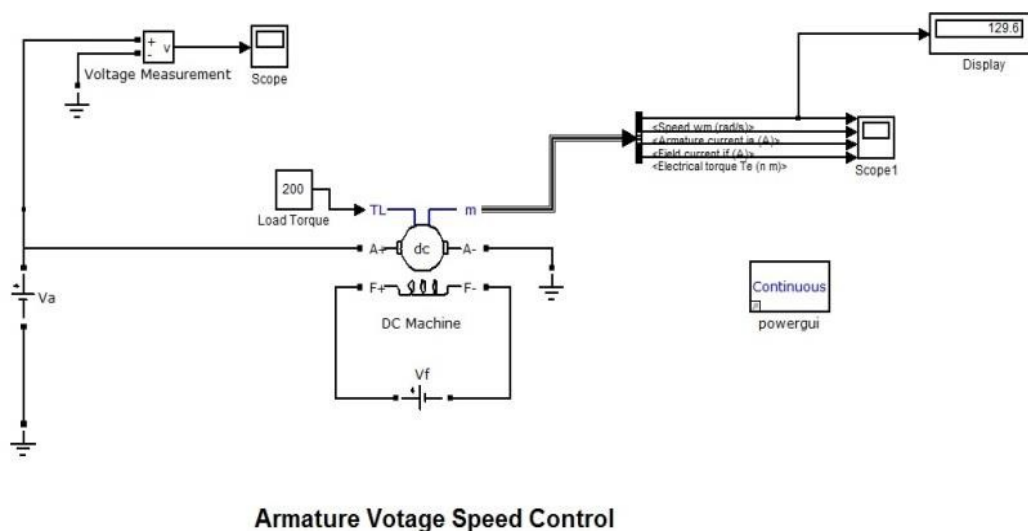
control method separately excited must be used [7]. The circuit diagram used for armature voltage control can be depicted as in Fig. 5.



**Figure 5: Armature Voltage Control Experimental Setup**

### A. Armature Voltage Control Using Simulink

5HP, 240V, 1750RPM having a field voltage of 300V and load torque of 160 N-m, these parameters are used for modeling DC motor for armature voltage control. The Simulink model used for this purpose is shown in Fig. 4 [7].



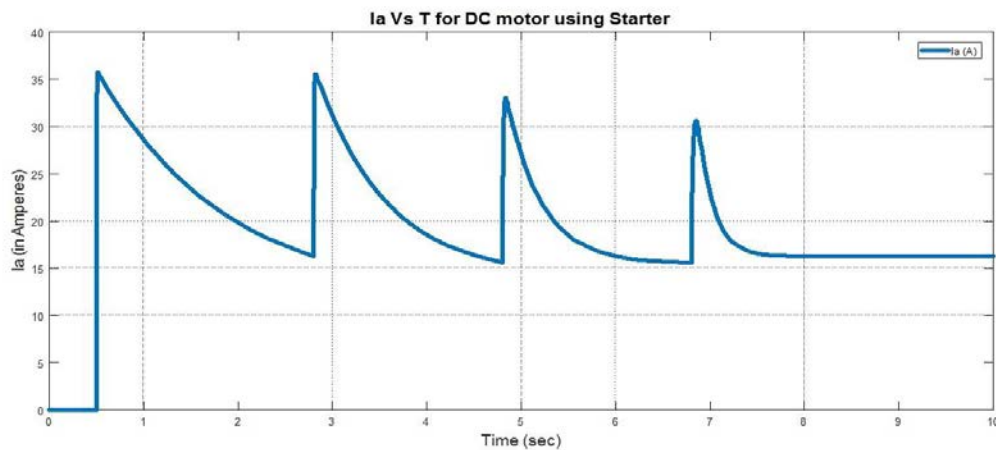
**Figure 6: Simulink Model for Armature Voltage Control**

The method which is in seldom used is usually called armature resistance method. In which external resistance is used in series with armature circuit.

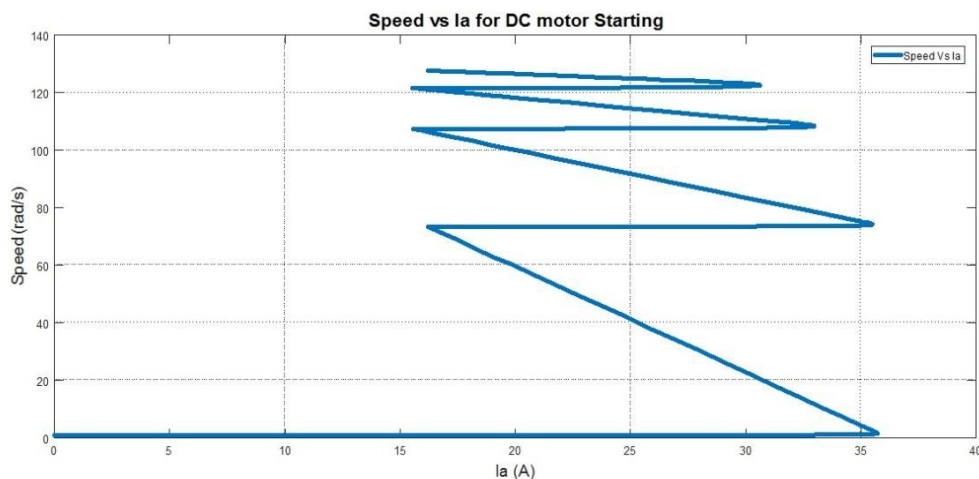
## RESULTS

The following section presents the simulation and analyses of the speed control method of a DC motor. The characteristics of DC motor while starting is shown from Fig. 7 to Fig. 10. A 5HP, 240V, 1750 RPM, having a field voltage

of 300V DC motor is used in the simulation for plotting of torque speed characteristics. Field resistance control, is performed initially, with value of the resistance  $R_F=240\Omega$  nominal is selected and simulations are run for the range of  $T_L=0-500$  N-m of load torque, to determine the steady state value of the speed at each load level. Raising the field resistance causes effect in torque speed characteristics which is illustrated in Fig. 11.



*Figure 7: Armature Current Vs Time for DC motor Starter*



*Figure 8: Speed Vs Armature Current for DC Motor Starting*

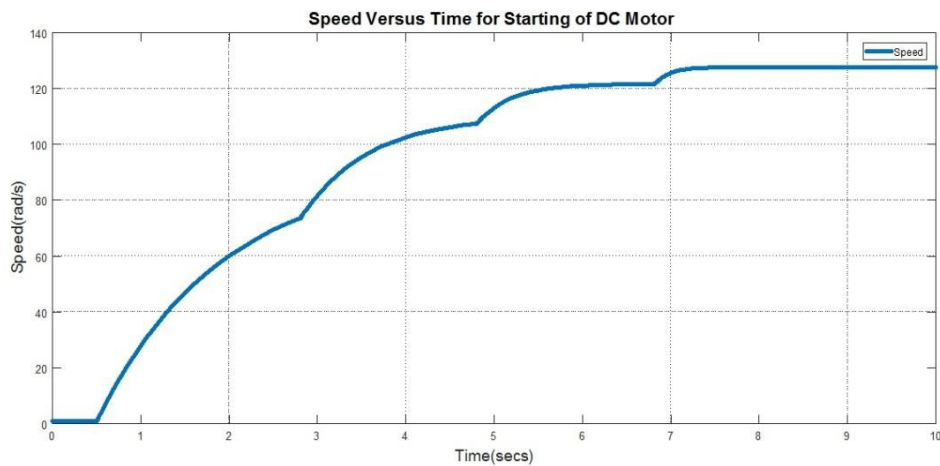


Figure 9: Speed Vs Time for DC motor Starting

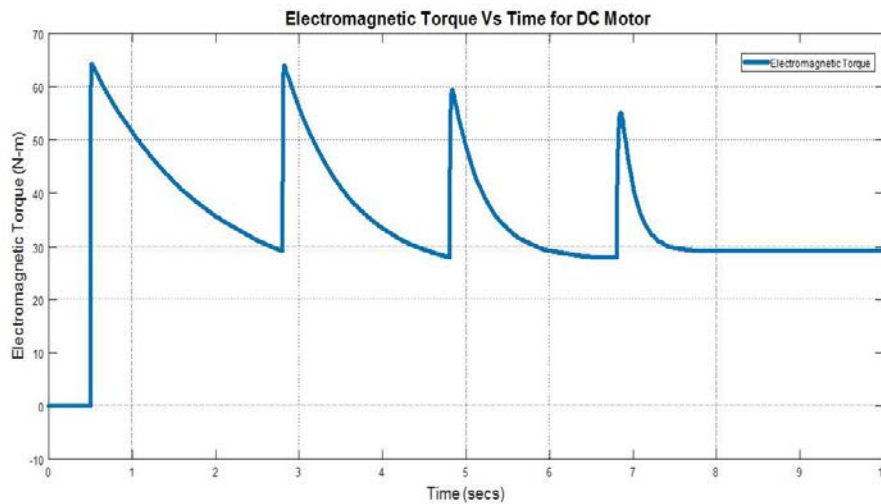


Figure 10: Electromagnetic Torque Vs Time for DC Motor

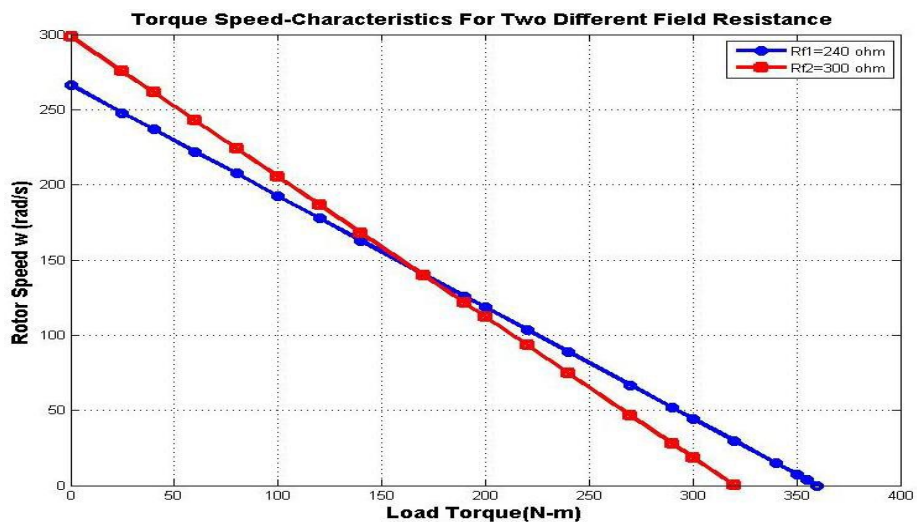


Figure 11: Torque Speed Characteristics (Under Different Field Resistance)

Fig. 11 shows that the slope of curve as well as no load speed of the DC motor increases w.r.t rise in field resistance. An increase in field resistance causes an increase in the motor speed over a range from no load to full load conditions. An increase in field resistance will decrease the speed of the motor, at a lower speed, on the contrary [7].

Using the model shown in Fig. 6, with different armature voltages 180V, 240V and 300V, respectively, and the applied

voltage to the field circuit is kept constant at a nominal value of 240V armature voltage control simulation are performed. Fig. 12 torque speed characteristics are compared. The torque speed curve is shifted upwards by increasing the armature voltage, while the slope of curve remains unchanged as is theoretically expected. This is clearly illustrated in Fig. 12.

Further speed time characteristics for field resistance control for a DC motor are as shown in Fig. 13.

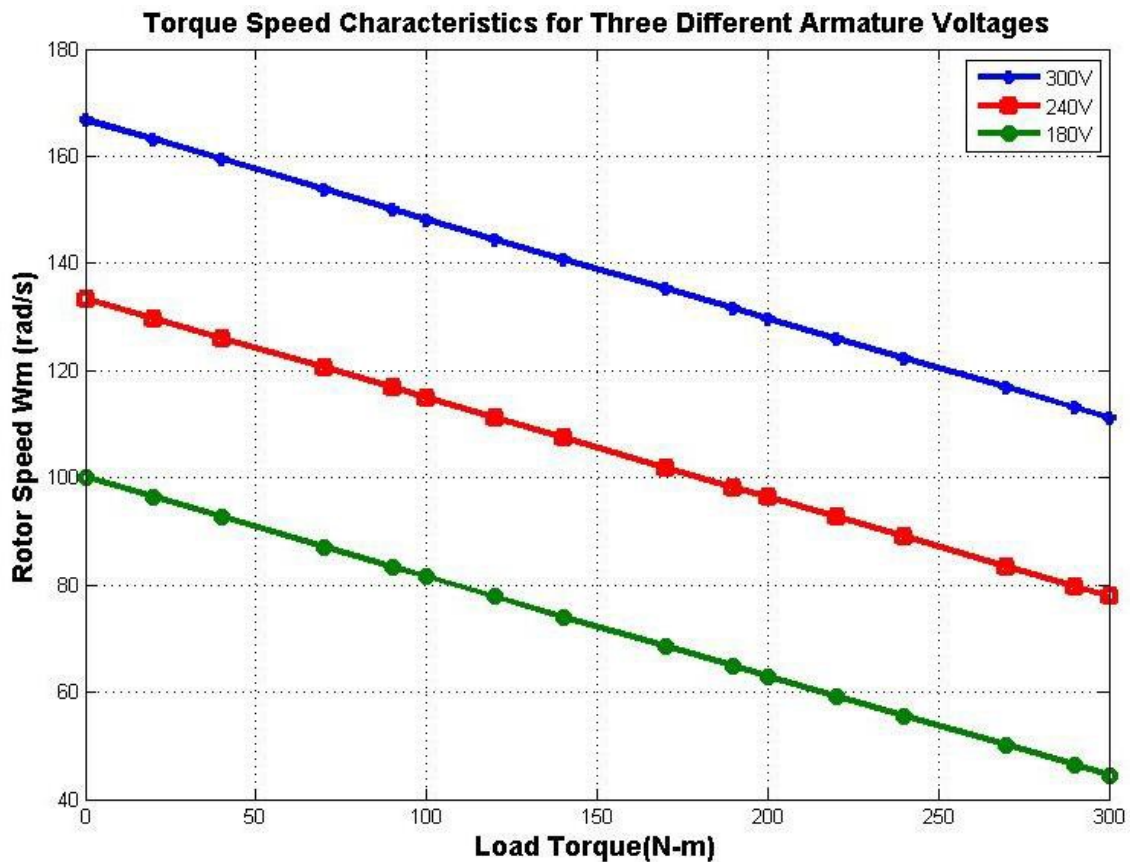
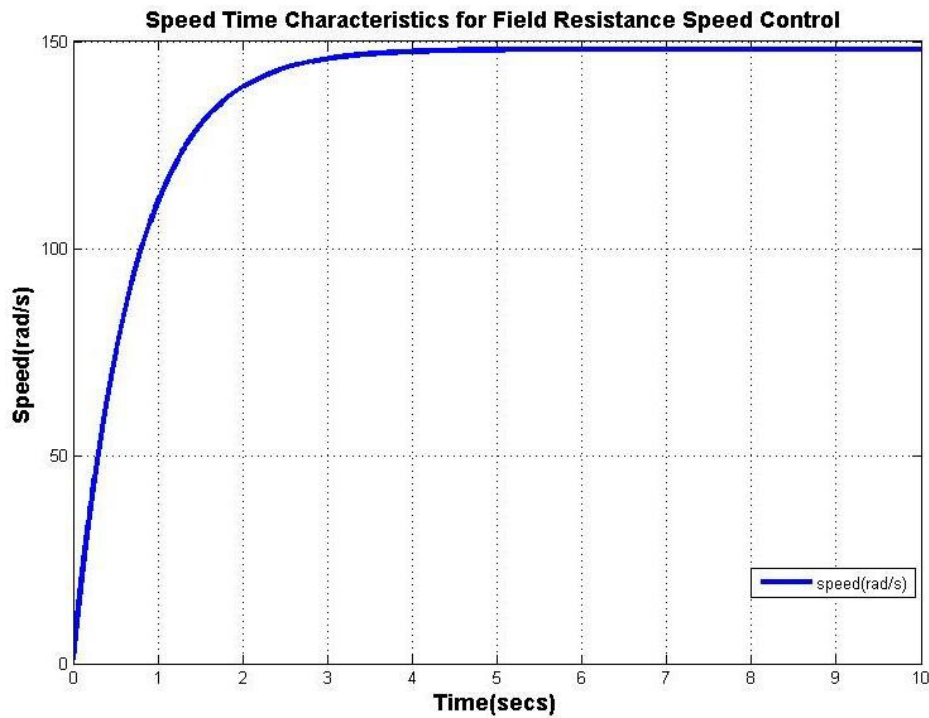
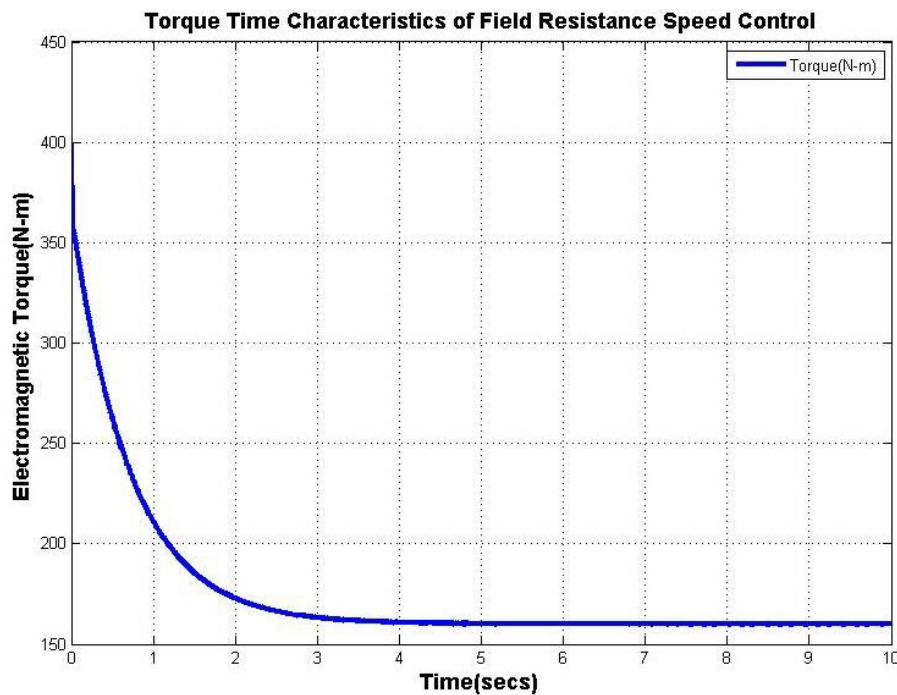


Figure 12: Torque Speed Characteristics (Different Armature Voltages)



*Figure 13: Speed Time Characteristics(Field Speed Control)*

The torque time characteristics of field resistance control and armature voltage control is illustrated in Fig. 14 and Fig 16 respectively.



*Figure 14: Torque Time Characteristics (Field Resistance)*

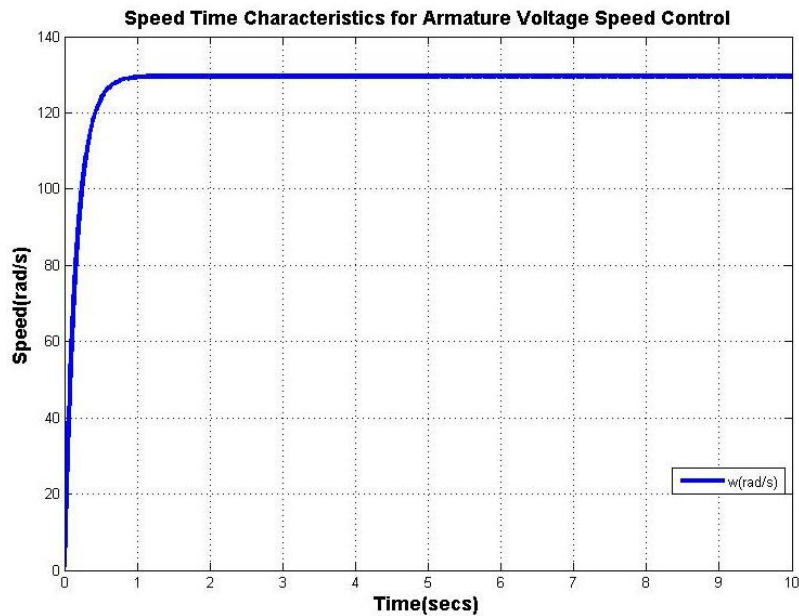


Figure 15: Speed Time Characteristics (Armature Voltage Speed Control)

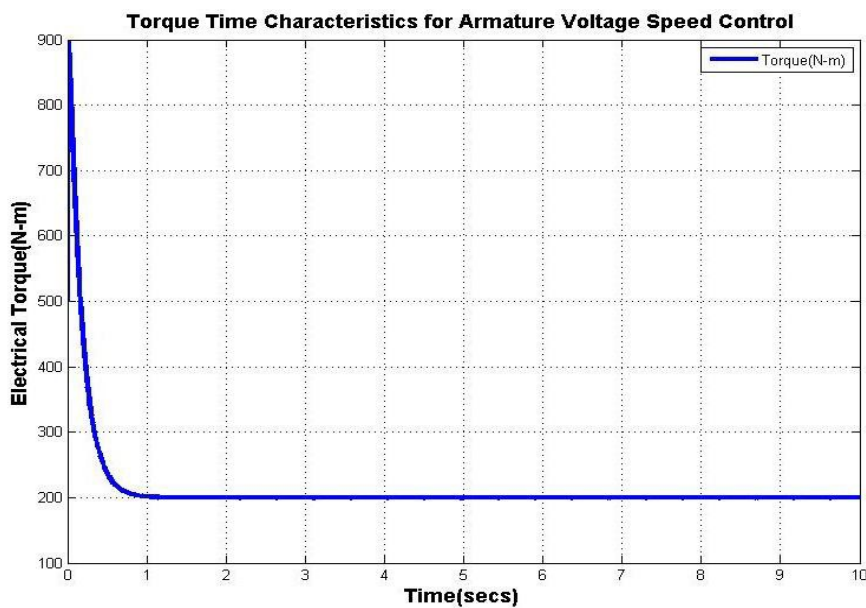


Figure 16: Torque Time Characteristics (Armature Voltage Speed Control)

DC motor speed increases at initial instant of time, after reaching the steady state it remains constant, which could be elucidated from the above figures. Whereas torque at initial instant of time

then reaches a constant value at steady state.

### CONCLUSION

It was observed that increase in field resistance concluded in an increase of the

no load speed of the motor and in the slope of the torque speed curve while analyzing DC motor speed control methods. A significant increase in the slope of the torque speed characteristics of the motor is elucidated with an increase in armature resistance, while the no load speed remains constant. The study aims implementing teaching aids on interactive and learning basis i.e. aiding laboratory experiments with MATLAB Simulink models. A clearer view of the characteristics of a DC motor speed control is elucidated at variable parameters. It is not possible to fully replace hardware with simulation due to modelling assumptions this could be elucidated while evaluating the bridge between software and hardware. Hence, the virtual environment could be used as a tool for running a final check on a circuit diagram and then applying to a real time system, and thus avoid dangerous mishaps in the laboratory due to errors in circuit connections.

## REFERENCES

- I. SIMULINK, Model-based and system-based design, Using Simulink, MathsWorks Inc., Natick, MA, 2000.
- II. Sim Power Systems for use with Simulink, user's guide, Math Works Inc., Natick, MA, 2002.
- III. M.H. Nehrir, F. Fatehi, and V.Gerez, "Computer modeling for enhancing instruction of electric machinery", IEEE Transaction on Education 38 (1995), 166-170.
- IV. W.M. Daniels and A.R. Shaffer, "Reinventing the electrical machines curriculum", IEEE Transaction on Education 41(1998), 92-100.
- V. C.M. Ong, "Dynamic Simulation of Electrical Machinery using MATLAB/Simulink, Prentice Hall, Upper Saddle River, NJ, 1998.
- VI. K.L. Shi, T.F.Chan, Y.K. Wong and S.L. Ho, "Modelling and simulation of three phase induction motor using Simulink", International Journal on Electrical Engineering Education 36(1999), 163-172.
- VII. Saffet Ayasun, Gultekin Karbeyaz, "DC Motor Speed Control Methods Using MATLAB/Simulink and Their Integration into Undergraduate Electric Machinery Courses", Computer application on Engineering Education, 15:347, 2007.