

Modern Pedagogy Techniques for DC Motor Speed Control

Rajesh Kumar, Roopali Dogra, Puneet Aggarwal

Abstract—Based on a survey conducted for second and third year students of the electrical engineering department at Maharishi Markandeshwar University, India, it was found that around 92% of students felt that it would be better to introduce a virtual environment for laboratory experiments. Hence, a need was felt to perform modern pedagogy techniques for students which consist of a virtual environment using MATLAB/Simulink. In this paper, a virtual environment for the speed control of a DC motor is performed using MATLAB/Simulink. The various speed control methods for the DC motor include the field resistance control method and armature voltage control method. The performance analysis of the DC motor is hence analyzed.

Keywords—Pedagogy techniques, speed control, virtual environment, DC motor, field control, voltage control.

I. INTRODUCTION

WITH the trending advent of low cost personal computers and easily accessible open source software packages, modern pedagogy technique has become an inevitable part of classroom lectures and practical experiments in electric machinery education [1]. Modern pedagogy technique enables the instructor to illustrate steady state operation of motor under various loading conditions easily [3]. Computer aided tools assists students to enhance their laboratory session i.e. verifying their hardware counterparts with simulation. Since simulation does not give the exact results as hardware, it helps students to understand hardware limitations [2]. The error bridge between hardware and software simulations is due to the assumption made in simulation. This realizes the fact that we cannot substitute actual hardware experiments with simulation exactly. Simulation software used in the following work is MATLAB/Simulink. Following the circuit diagram, respective block diagrams are connected with reference to circuit elements portrayed in the circuit diagram and simulating it for the respective simulation time [4]. Other software such as Maple and MathCAD, are commonly used in electrical engineering education with their advantages and disadvantages [5]. The reason MATLAB, with its toolbox is selected, is that it is the main software package used in almost all undergraduate courses in institutions as a computation tool; therefore, students can easily access it [6]. The simulation performed in this paper is for the speed control of a DC motor

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using field resistance control method and armature voltage control method along with DC motor characteristics.

II. FIELD RESISTANCE CONTROL

The speed of the DC shunt motor is given by:

$$N = \frac{V_a - I_a r_a}{k\phi} \quad (1)$$

V_a is the voltage applied across the armature and ϕ is flux per pole and is proportional to the field current I_f . The mechanical load present on the shaft decides the armature current. Therefore, by varying the field current, the armature voltage speed can be varied. For speed control of the DC motor using field resistance, the circuit is shown in Fig. 1.

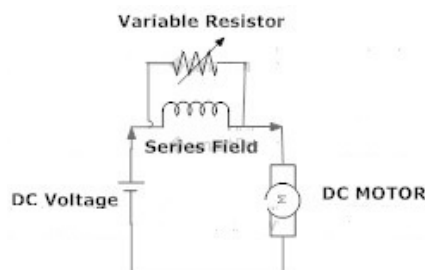


Fig. 1 Set Up For Field Resistance Control

To control the speed of a DC shunt motor, field circuit resistance is varied. If we vary field current I_f , flux ϕ 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

Implementing the DC speed control using field resistance control is shown in Fig. 2 [7]. A DC motor, with the specifications; 5 HP, 240V, 1750RPM having a field voltage of 300V and load torque of 160N-m, is used.

In the shunt field circuit of the motor, a series resistance is inserted in order to change flux by regulating the field current [7]. The field circuit is illustrated by an R-L circuit (R_f and L_f in series) and is connected between the ports (F+ and F-) [7]. The Armature circuit can be illustrated as inductor L_a and resistor R_a in the series with an electromotive force E_a and is connected between the ports (A+, A-) [7]. External resistance R_{f1} is inserted in the series with the field circuit to realize the

field resistance speed control [7].

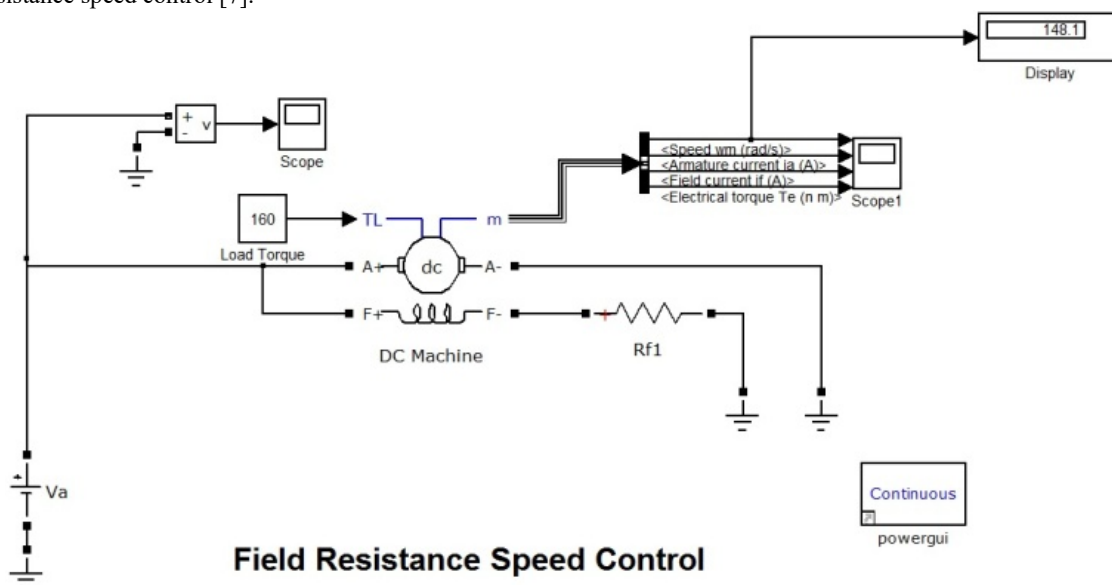


Fig. 2 Field Resistance Speed Control Using SIMULINK

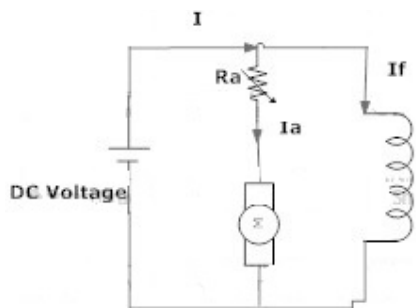


Fig. 3 Experimental Setup for armature voltage control

III. ARMATURE VOLTAGE CONTROL

Here at the armature, circuit voltage is applied without changing the applied voltage to the field circuit of motor V_a is varied [7]. Separately, the excited motor must be therefore used for armature voltage control method [7]. The circuit diagram used for armature voltage control can be depicted as in Fig. 3.

A. Armature Voltage Control Using Simulink

For performing DC motor speed control using armature voltage control method, the DC machine block is modeled with parameters 5HP, 240V, 1750RPM having a field voltage of 300V and load torque of 160 N-m. The Simulink model used for this purpose is shown in Fig. 4 [7].

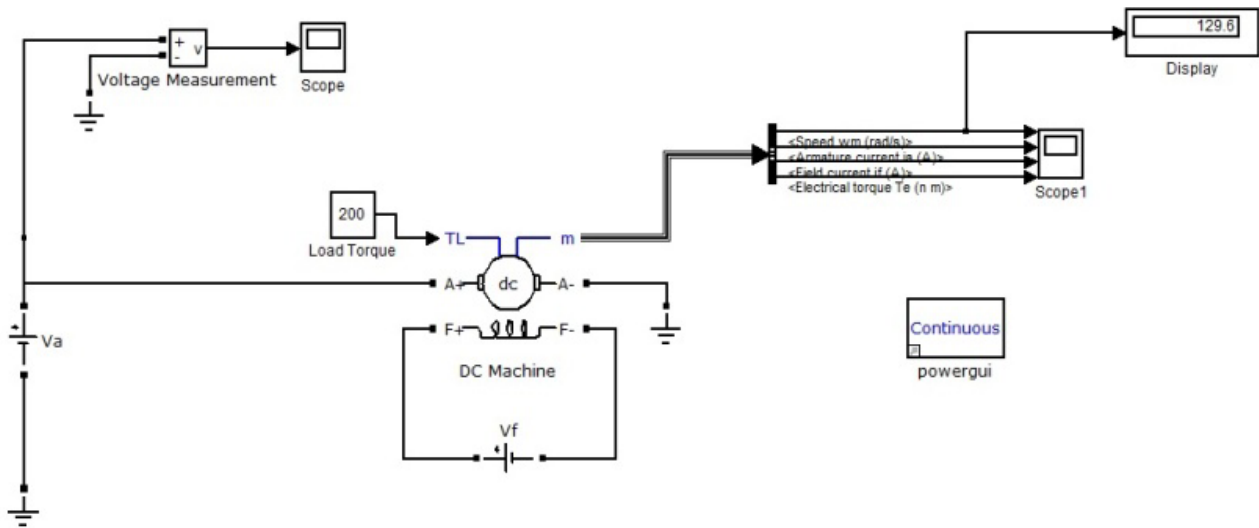
The method in which an external resistance is inserted in series with the armature circuit, i.e. armature resistance method, and it is less commonly used method for speed control.

IV. RESULTS

The following section presents the simulation and analyses of the speed control method of a DC motor. For plotting of torque speed characteristics, a 5HP, 240V, 1750 RPM, having a field voltage of 300V DC motor is used in the simulation models. To perform field resistance control, initially, the nominal value of the resistance $R_F=240\Omega$ is selected and simulations are run for several values of load torque in the range of $T_L=0-500$ N-m, to determine the steady state value of the speed at each load level. Effect of increase in the field resistance on the torque speed characteristics is investigated. The torque speed curves for both resistance values are shown in Fig. 5.

Fig. 5 shows an increase in the slope of the curve as well as the no load speed of the motor with respect to an increase in the field resistance. Over a range from no load to full load conditions, an increase in field resistance causes an increase in the motor speed. On the contrary, at a lower speed, an increase in field resistance will decrease the speed of the motor [7]. To perform armature voltage control simulation are performed using the model shown in Fig. 4, 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. Fig. 6 compares the torque speed characteristics. It is clearly illustrated from Fig. 6 that the torque speed curve is shifted upwards by increasing the armature voltage, while the slope of curve remains unchanged as is theoretically expected.

Further speed time characteristics for field resistance control for a DC motor are as shown in Fig. 7.



Armature Voltage Speed Control

Fig. 4 Armature Voltage Speed Control Using Simulink

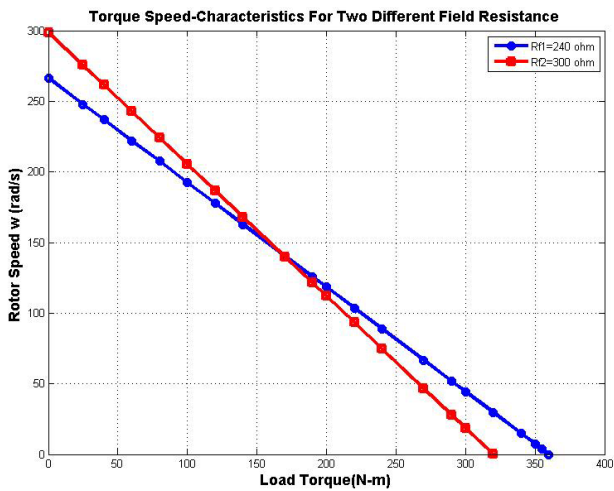


Fig. 5 Torque- speed characteristics for two different field resistances

Armature current time characteristics and torque time characteristics for field resistance speed control is plotted in Figs. 8 and 9, respectively.

The speed time, armature current time, and torque time characteristics for armature voltage control are plotted in Figs. 10, 11 and 12, respectively.

From the above, it can be noticed that the speed of the DC motor increases at initial instant of time, after reaching the steady state it remains constant whereas torque and armature current drops at initial instant of time then reaches a constant value at steady state.

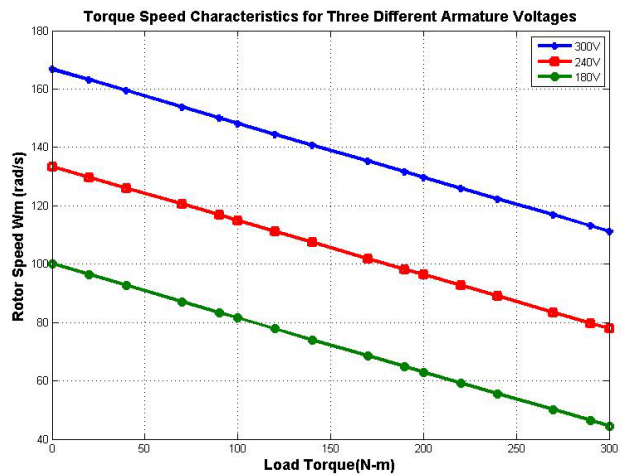


Fig. 6 Speed Torque Characteristics for three different armature voltages

V.CONCLUSIONS

While analyzing DC motor speed control methods, 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. An increase in armature resistance results in significant increase in the slope of the torque speed characteristics of the motor, while the no load speed remains constant. The simulation presented here, attempted to make teaching aid and pedagogy more interactive i.e. aiding laboratory experiments with MATLAB Simulink models. A clearer view of the characteristics of a DC motor speed control can be observed at variable parameters. While evaluating the bridge between software and hardware, it was concluded that it is not possible to fully replace hardware with simulation due

to modelling assumptions. 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.

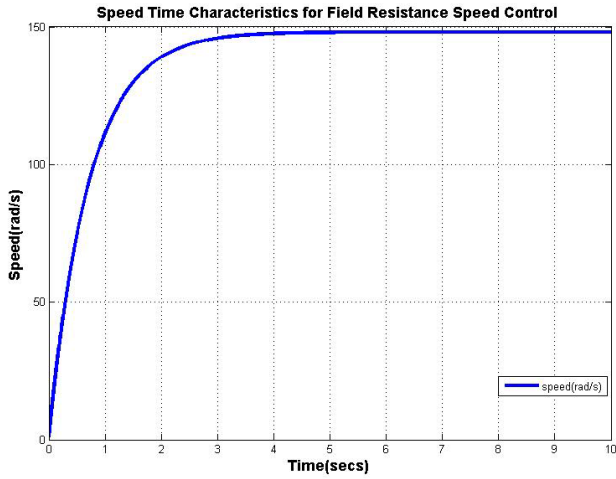


Fig. 7 Speed Time Characteristics for Field Resistance Speed Control

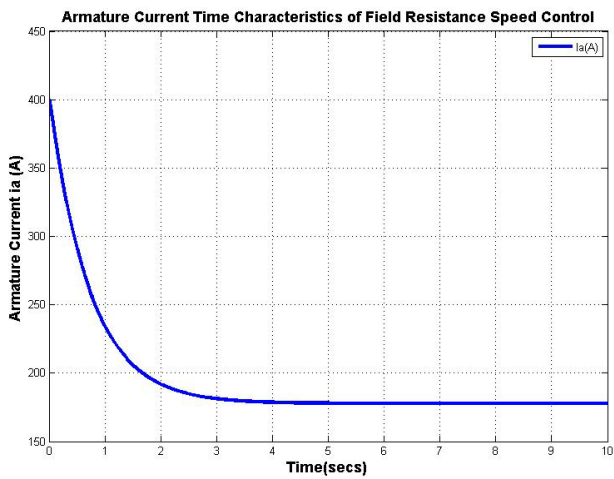


Fig. 8 Armature Current Time Characteristics of Field Resistance Speed Control

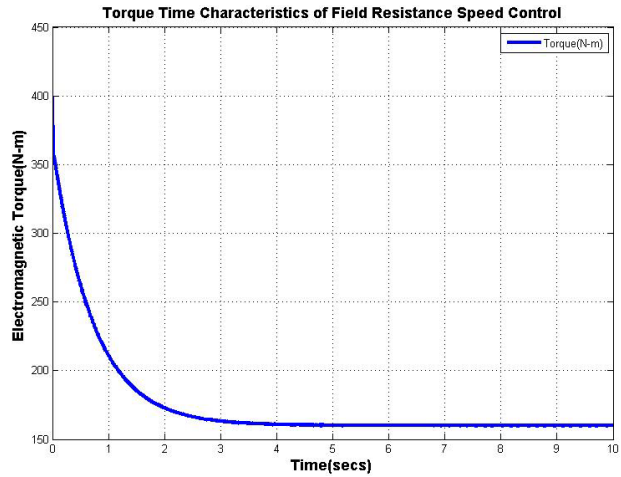


Fig. 9 Torque Time Characteristics of Field Resistance Speed Control

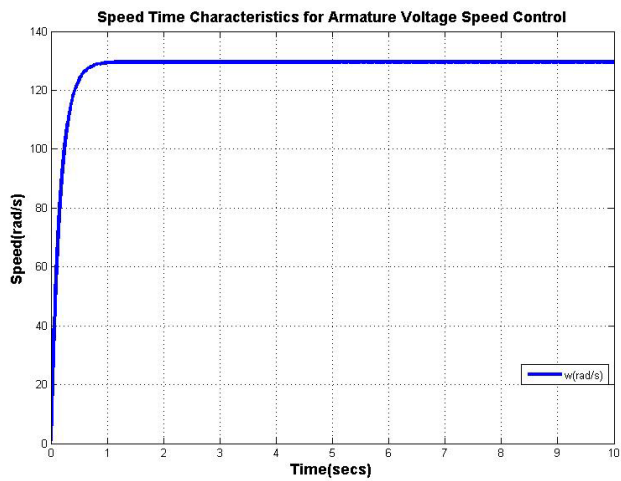


Fig. 10 Speed Time Characteristics for Armature Voltage Speed Control

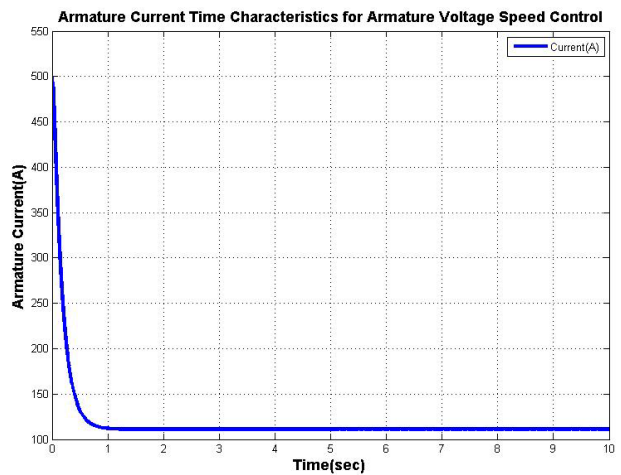


Fig. 11 Armature Current Time Characteristics for Armature Voltage Speed Control

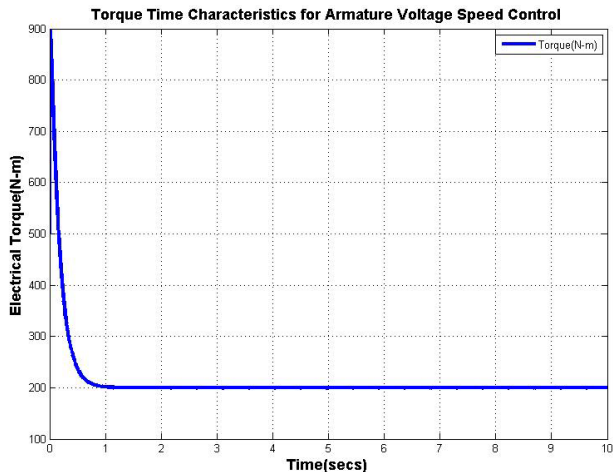


Fig. 11 Torque Time Characteristics for Armature Voltage Speed Control

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