Control Panel for Speed Control of D.C Series Motor Using Armature Control and Flux Control Method

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Abstract : The DC series motors are also very popular in industry like traction, crane, lifts, and rolling mills because of their high starting torque and variable speed nature. Yet, DC series motors are difficult to control in terms of speed due to the fact that the relationship between the armature current and the magnetic flux is not linear. The paper is about speed control of DC series motor by armature control and flux control. The armature control technique is where the speed of the motor is controlled by changing the applied armature voltage whereas the flux control technique is where the speed is controlled by changing the field flux with field diverter arrangements. The efficiency, torque characteristics, power losses, and speed regulation are the parameters applied to analyze the performance of both control techniques. The findings show that armature control is workable at lower speeds that are less than the rated, whereas flux control is applicable in attaining higher speeds that are above the rated value. The solution proposed can offer a solution to industrial DC motor speed control in an efficient and economical way

Key Words - DC Series Motor, Speed Control, Armature Control Method, Flux Control Method, Electric Drives, Industrial Applications.

1. Introduction

The use of direct current (DC) motors in industrial applications is extensive because of their ease of construction, large starting torque and easy speed regulation. The DC series motor makes up a variety of DC motors, and is often applied in electric traction systems, cranes, hoists, and elevator systems that need a high level of starting torque. Nonlinear dependence between armature current and magnetic flux makes the control of the speed of a DC series motor difficult though.

The speed of the DC motors is controlled in various ways, and some of these are the armature control and the flux control methods. In armature control technique, armature voltage or

armature resistance is varied to change the motor speed whereas in flux control technique field flux is varied to change the motor speed. These are effective ways of speed controlling DC series motors in various industrial processes.

2. Literature Review

One of the most popular topics of the DC motor control is the speed control because it is an essential aspect of industrial usage (electric traction system, cranes, and elevators). Various methods are established in order to have effective speed control and enhance the efficiency of DC motors.[1]

Bimal K. Bose stated that electric drive systems employ a number of control techniques to control the speed of DC motors, such as armature voltage control and field flux control. With these techniques, there is effective speed variation and better motor performance in industrial drives.[2]

According to P. C. Sen, armature control is normally utilized in controlling the motor speed that are less than the rated value and flux control is utilized in the achievement of speeds that are greater than the rated speed. These techniques are also used in electric drive systems since they offer smooth and reliable control of speed.[3]

According to research studies by Stephen J. Chapman, DC series motors are appropriate in the process of using high starting torque and variable speed nature. Efficiency, reduction of power losses, and stability of motor operation are achieved by proper speed control methods.[4]

Additional research by Ned Mohan and M. H. Rashid indicates the significance of power electronic control methods to enhance the performance of a motor and to give some better speed regulation in modern electrical drive systems.[5]

3. Methodology

The two control mechanisms of the proposed system are the armature control method and the flux control method to control the speed of a DC series motor. Under the armature control technique, the armature voltage determines the speed of the motor. As the armature voltage is raised, the motor speed is also raised and the opposite also applies.
The flux control method uses the magnetic flux of the motor field winding to control the speed. This is carried out by parallel connection of the field winding and a variable resistor. The resistance can be altered to change the field current that has an impact on the flux and consequently motor speed.
The motor is supplied by a DC power supply and this is fed on the control circuit. The value of the voltage, current and speed of the motor are measured by appropriate measuring equipment. To investigate the performance of the motor in various conditions, the readings are recorded and analyzed. The techniques contribute to effective and easy regulation of the motor speed to various uses.

4. Circuit Diagram Explanation

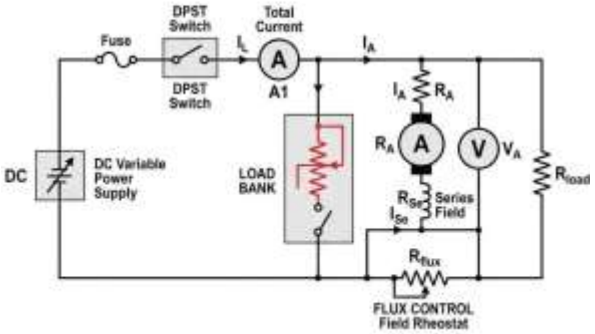

Fig.1. Schematic Circuit Diagram (Functional)

The schematic circuit diagram shows the setup used for controlling the speed of a DC series motor using armature control and flux control methods. A DC variable power supply is used to provide the required voltage to the motor. A fuse and DPST switch are connected in the supply line to provide protection and to control the power supply to the circuit.
An ammeter (A1) is used to measure the total current flowing in the circuit. The armature current is measured using another ammeter connected in series with the armature winding, while a voltmeter is connected across the armature to measure the applied voltage.
A load bank is connected to the motor to apply different load conditions during the experiment. For flux control, a field rheostat is connected in the series field circuit to adjust the field current and magnetic flux. By varying the armature voltage and field resistance, the speed of the DC series motor can be effectively controlled.

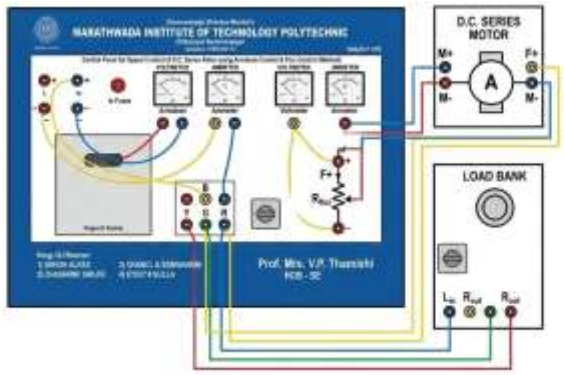

FIGURE 2: PANEL WIRING DIAGRAM (PHYSICAL CONNECTIONS)

Panel Wiring Diagram Explanation

The panel wiring diagram shows the physical connections used in the experimental setup for controlling the speed of a DC series motor. The control panel consists of measuring instruments such as voltmeters and ammeters to measure the armature voltage, field voltage, and current flowing in the circuit.
The DC supply is connected to the control panel through input terminals and protective fuses. From the control panel, the armature terminals (M+ and M−) are connected to the DC series motor. The field terminals (F+ and F−) are connected through a field rheostat, which is used to control the magnetic flux in the field winding.
A load bank is connected to the motor to apply different load conditions during the experiment. By adjusting the armature voltage and field rheostat from the control panel, the speed of the DC series motor can be controlled and the corresponding voltage and current readings can be observed using the meters.
Thus, the panel wiring diagram represents the actual physical connections of the control system used for performing the speed control experiment.

5. Working principle

The principle of operation of a DC series motor is simple, as when electrical current passes through the armature and the field windings, a magnetic field is created. When this magnetic field is placed in contact with the conductors of the armature carrying the current, it produces electromagnetic torque which makes the motor shaft turn.
A DC motor primarily depends on the supply voltage, resistance in the armature, current through the armature and the magnetic flux generated by the field winding in determining the speed of the motor. The speed of the motor can be changed depending on the requirement through regulation of these parameters.
Examples of speed control in the armature control method include the speed through different voltage applied to the armature circuit. This is done by putting a variable resistance across the armature. This resistance can be changed to cause a change in the voltage across the armature, which causes a change in motor speed.

The flux control method has the motor operating on varying magnetic flux that is generated in the field winding to control the speed of the motor. The field circuit has an attached field rheostat to control the field current. The less the field current the less the magnetic flux and as a result, the higher the speed of the motor.
As such, the effective and smooth speed control of the DC series motor in varied operating conditions can be attained by varying the armature voltage and field flux control in a DC series motor.

Motor Speed Equation

The speed of a DC motor depends on the back electromotive force (EMF) generated in the armature and the magnetic flux produced by the field winding.

The back EMF of a DC motor is given by:

$Eb = V - IaRa$

Where:
Eb = Back EMF (V)
V = Supply voltage (V)
Ia = Armature current (A)
Ra = Armature resistance (Ω)

The speed of the motor is directly proportional to the back EMF and inversely proportional to the magnetic flux. Therefore, the speed equation of a DC motor can be expressed as:

$N \propto Eb / \Phi$

Substituting the value of back EMF:

$N \propto (V - IaRa) / \Phi$

This equation shows that the speed of the motor increases with an increase in supply voltage and decreases with an increase in magnetic flux. Therefore, by controlling the armature voltage and field flux, the speed of the DC motor can be effectively controlled.

Calculation Analysis

In order to understand the performance and speed characteristics of the DC series motor,calculations are performed using standard motor equations. These calculations help in analyzing parameters such as back EMF, speed variation, and armature voltage drop. The following demonstrate the relationship between voltage, current, resistance, and speed of the DC series motor used in the experimental setup.

Formula:

Back EMF

$Eb = V – Ia \times Ra$

(Armature resistance Ra is usually very small.
If not given in practical, we assume Ra=1 Ω for calculation.)

Motor Input Power

$P=V \times Ia$

Torque

$T = 9.55 \times P / N$

CALCULATIONS

Reading 1 (Load = 2.4 kW)

Motor Voltage = 225.6 V
Motor Current = 15.9 A
Speed = 1682 rpm

Power

$P=225.6\times15.9$

P= 3587.04 W
Back EMF (Assuming Ra =1Ω)
$Eb=225.6- (15.9\times1)$
$Eb=225.6- 15.9$
Eb=209.7 V

Torque

T=9.55×3587.04\1682
T=34256.23\1682
T=20.36 Nm

Reading 2 (Load = 2 kW)

Voltage = 234.1 V
Current = 14.3 A
Speed = 1788 rpm

Power

$P=234.1\times14.3$
P=3347.63 W

Back EMF
$Eb=234.1-14.3$
Eb=219.8 V

Torque

T=9.55×3347.63\1788
T=17.88 Nm

Reading 3 (Load = 1.8 kW)

Voltage = 234.7 V
Current = 13.25 A
Speed = 1864 rpm

Power

$P=234.7\times13.25$

P=3114.78 W

Back EMF

Eb=234.7−13.25
Eb=221.45 V

Torque

T=9.55×3114.78\1864
T=15.96 N\m

Reading 4 (Load = 1.6 kW)

Voltage = 235.8 V
Current = 12.06 A
Speed = 1950 rpm

Power

P=235.8×12.06
P=2843.75 W

Back EMF

Eb=235.8−12.06
Eb=223.74 V

Torque

T=9.55×2843.75\1950
T=13.93 N\m

Armature current Ia = 20 A

Formula:
Eb = V − Ia(Ra + Rse)

Calculation:
Eb = 220 − 20(0.5 + 0.3)

Eb = 220 − 20(0.8)

Eb = 220 − 16

Eb = 204 V

Result:
The Back EMF of the DC series motor is 204 V.

Final observation table

Load	Power (W)	Back EMF (V)	Torque (N.M)
2.4kw	3587.04	209.7	20.36
2kw	3347.63	219.8	17.88
1.8kw	3114.78	221.45	15.96
1.6kw	2843.75	223.74	13.93

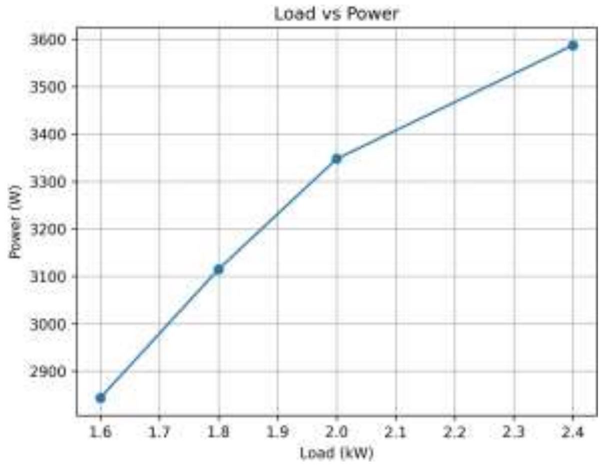

Fig.3. Graph of load vs power of dc series motor

The graph of load vs power illustrates that the power increases with the increase in the load. As the load is changed to 2.4 kW, the power changes to 3587.04 W as well whereas the power was 2843.75 W. It means that the DC series motor will need increased electrical power to offer higher load.

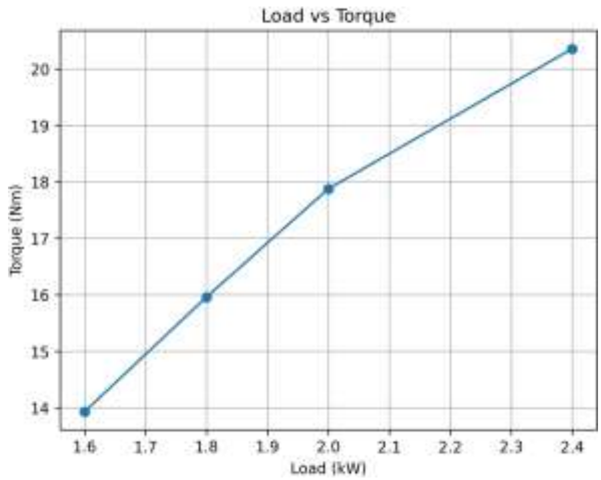

Fig.4. Graph of load vs torque of dc series motor

The graph on Load vs Torque indicates that torque valve is directly proportional to the load. The torque rises to 13.93 N 3 m at 1.6 kW to 20.36 N 3 m at 2.4 kW. Such a characteristic is characteristic of a DC series motor, in which the torque increases with the load and current.

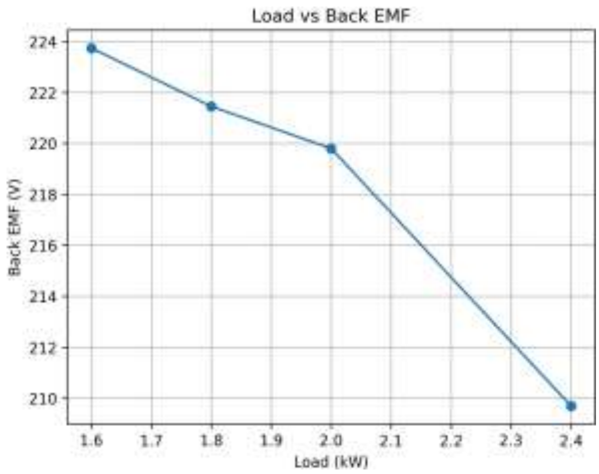

Fig. 5. Graph of load vs back EMF of dc series motor

According to the graph of Load vs Back EMF, there is a slight decrease in the back EMF with increase in load. With the load of 1.6 kW, the back EMF is 223.74 V and with the load of 2.4 kW it reduces to 209.7 V. This is because as the load rises, the motor attracts more current thus reducing the back EMF.

6. Final view of Project

7. Result and Discussion

The experiment conducted on the armature voltage control and flux control clearly shows speed control attributes of the DC series motor. Based on the graph of voltage on armature versus motor speed, it can be noted that the speed of the motor rises almost linearly with the increase in armature voltage and the flux is held constant. Such action is in accordance with the DC motor speed equation $N = V - I_a R_a / k\Phi$ according to which speed is directly proportional to the armature voltage applied. Experimental measurements indicate that acceleration was smooth and stable over the rated range indicating that good speed regulation could be achieved through this method. Under flux control method, the field current against speed graph proves that when the field current is lower, the flux also lowers and the motor speed increases sharply. As speed is an inverse proportion of flux ($N=1/\phi$) weakening the flux will cause an increase in the speed operation beyond the rated speed. But a large cut off of flux can cause bad commutation and even overheating. In general, the practical findings are similar to that of the theoretical analysis and both techniques are able to regulate the velocity of the DC series motor with armature voltage control being appropriate when the speed is below-rated and flux control being appropriate when the speed is above-rated.

8. Conclusion

The current project has managed to prove the control speed of a DC series motor through armature voltage control as well as flux control. Observations made experimentally and by graphic analysis verify that the speed of the motor rises as the voltage of the armature rises and falls as the magnetic flux rises. Armature control method is used to give a smooth and stable control of the speed within a lower range of the rated speed, and the flux control method is applicable in attaining the speed beyond the rated speed. The experimental findings are much consistent with the theoretical formulas of the working of a DC motor. Both of the methods are, thus, reliable and can be applied in the industry where they are needed to regulate the speed of action.

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