1 Experiment No. 6

2 Experiment Title

Speed control of DC Shunt Motor

3 Objective

The objectives of this lab are as follows:

- To compare and contrast the armature control method and field control method for speed adjustment in DC shunt motors.
- To explore the effects of adjusting armature resistance on the armature current and consequently the motor speed.
- To investigate how field current adjustment influences the magnetic flux and motor speed, particularly in high-speed applications.

4 Theory

Speed Control of DC Shunt Motor

The speed S of a DC shunt motor can be controlled by manipulating either the armature current I_a or the field flux Φ, as shown in the following formula:

$$S = \frac{V_T - I_a R_a}{K\Phi}$$

where:

- V_T is the terminal voltage supplied to the motor.
- I_a is the armature current, which flows through the armature winding.
- R_a is the resistance of the armature winding.
- K is a constant related to the motor's construction.
- Φ represents the magnetic flux per pole, which depends on the field current I_f flowing through the field winding.

Speed Control Methods

There are two main methods to control the speed of a DC shunt motor:

1. Armature Control Method

This method involves changing I_a, the armature current.

- By adjusting the resistance in the armature circuit, the voltage drop across R_a can be modified, thereby changing I_a and consequently the speed S.
- This method is generally used when controlling the speed below the motor's rated speed.

2. Field Control Method

This method involves changing Φ by adjusting I_f, the field current.

- Decreasing Φ (by reducing I_f) increases the speed since Φ is in the denominator of the speed equation.
- This method is suitable for controlling the speed above the motor's rated speed.

Field Control Method

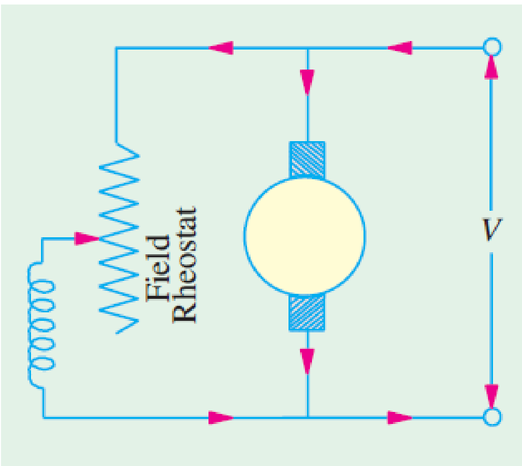
The Field Control Method is used to achieve speeds above the motor's base speed. This method controls the speed by adjusting the field current I_f that flows through the field winding, thereby changing the magnetic flux Φ. Field control is commonly used in high-speed applications such as centrifugal pumps, blowers, and pumps.
The back EMF (E_b) in a DC motor is given by:

$$E_b = K\Phi S$$

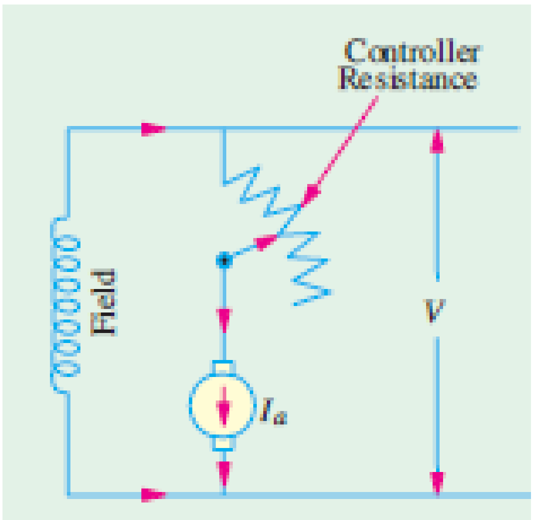
where K is a constant, Φ is the flux, and S is the speed.
Rearranging this, we find that:

$$S \propto \frac{1}{\Phi}$$

This indicates that the motor speed is inversely proportional to the magnetic flux.
To decrease Φ and increase speed, a variable resistor R_f is added in series with the field winding. By increasing R_f, we reduce I_f (the field current), which reduces Φ (the flux).
When the field resistance R_f is increased, the field current I_f decreases, reducing the magnetic flux Φ. Since speed is inversely related to flux $\left(S \propto \frac{1}{\Phi}\right)$, a decrease in Φ results in an increase in speed S.
Therefore, increasing the field resistance allows the motor to achieve speeds above its base speed.



(a) Field Control I_f Method



(b) Armature Control I_a Method

Armature Control Method

The current in the armature I_a is given by:

$$I_a = \frac{V_T - E_b}{R_a + R_{ar}}$$

where:

- E_b is the back EMF (Electromotive Force) generated by the rotation of the armature in the magnetic field.
- R_a is the internal resistance of the armature winding.
- R_{ar} is the external resistance added to the armature circuit for control purposes.

By adjusting R_{ar}, we change the total resistance in the armature circuit, which affects I_a and subsequently the speed S of the motor.
When R_{ar} is increased, the overall resistance in the armature circuit rises. This causes I_a to decrease, leading to a reduction in the torque T, as:

$$T \propto I_a$$

Since torque T is proportional to the armature current I_a, a decrease in torque means less force to drive the motor, resulting in a drop in the speed S of the motor.
Therefore, increasing the armature resistance decreases the motor's speed below its base speed.

5 Required Apparatus

1. Variable Resistor (Ratings: Resistance: $5000\,\Omega$, Current: 0.31 A)
2. Variable Resistor (Ratings: Resistance: $200\,\Omega$, Current: 1.58 A)
3. Fixed DC Power Supply (Ratings: Voltage: 220 V)
4. DC Multimeter (Ratings: Voltage: 600 V, Current: 20 A)
5. DC Motor (Ratings: Power: 300 W, Voltage: 220 V, Speed: 2500 rpm)
6. Tachogenerator (Ratings: Current: 0.07 A max, Speed: 5000 rpm max)

6 Circuit Diagrram

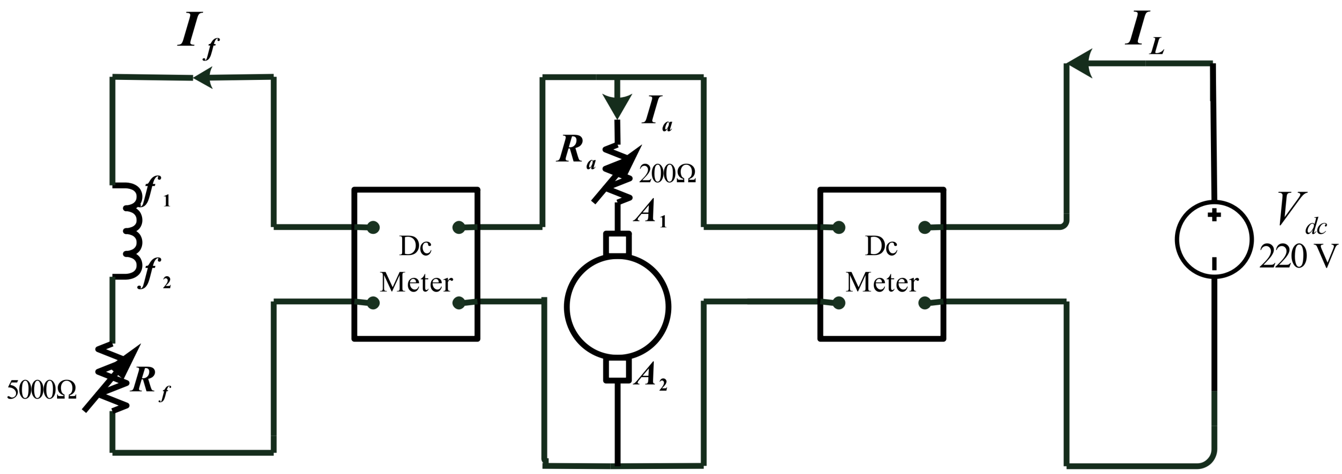


Figure 2: Required Circuit Diagram

7 Data Table

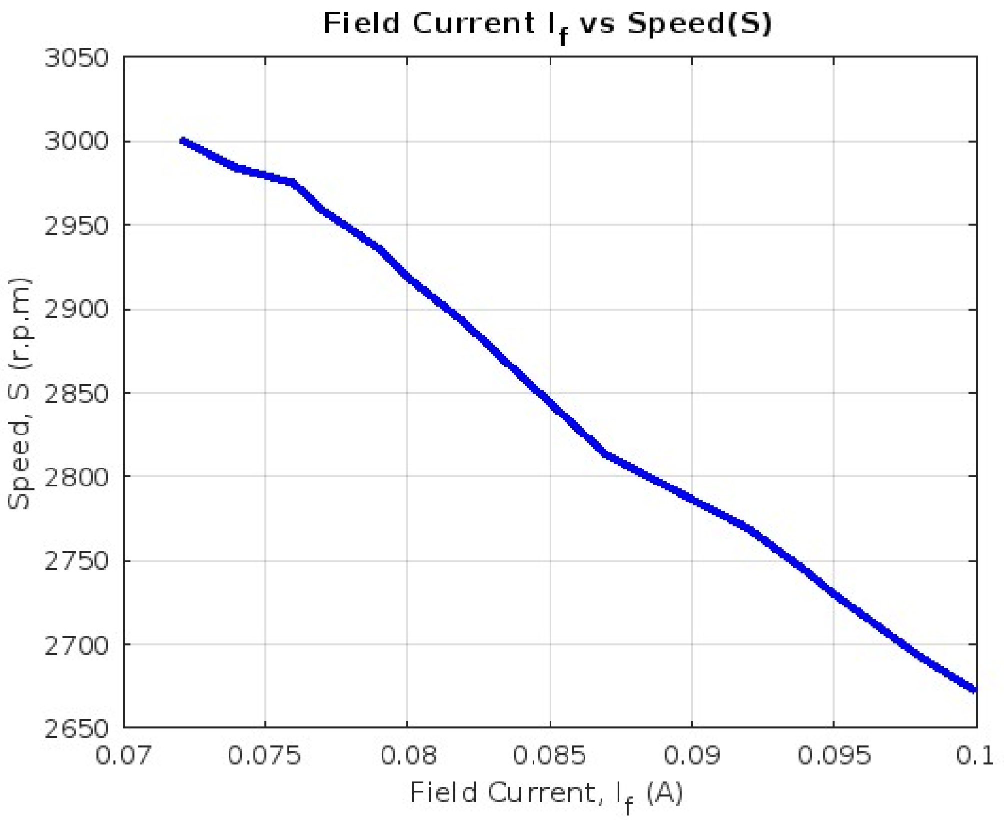
SI	**Field Current,** $I_f(A)$	**Speed ,** $S(r.p.m)$
1	0.1	2672
2	0.098	2693
3	0.095	2730
4	0.094	2744
5	0.092	2769
6	0.087	2813
7	0.084	2860
8	0.082	2892
9	0.08	2919
10	0.079	2936
11	0.077	2959
12	0.076	2975
13	0.074	2984
14	0.072	3001

(a) Data table of Field current (I_f) and Motor Speed (S)

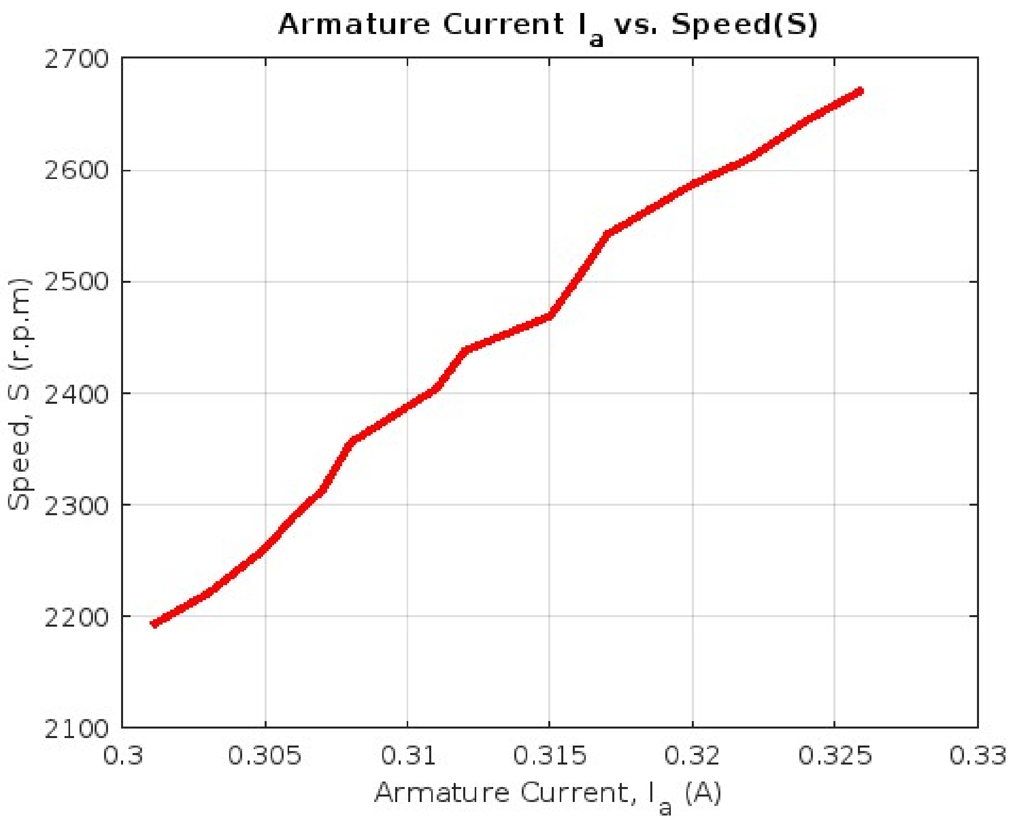
SI	**Armature Current ,** $I_a(A)$	**Speed ,** $S(r.p.m)$
1	0.326	2672
2	0.324	2644
3	0.322	2610
4	0.320	2587
5	0.317	2542
6	0.316	2504
7	0.315	2469
8	0.312	2438
9	0.311	2404
10	0.308	2356
11	0.307	2313
12	0.306	2290
13	0.305	2261
14	0.303	2221
15	0.301	2192

(b) Data table of Armature current (I_a) and Motor Speed (S)

8 Graph



(a) I_f vs. Speed Graph (S)



(b) I_a vs. Speed Graph (S)

9 Discussion

The experiment was conducted to investigate the speed control of a DC shunt motor. The relationship between the motor speed S and armature current I_a and field flux Φ was analyzed. The relationship was described by the equation:

$$S = \frac{V_T - I_a R_a}{K\Phi}$$

It was observed that as the field resistance increased, I_f was decreased, which resulted in an increase in speed. Conversely, in the armature control method, the armature resistance was increased, causing I_a to decrease, leading to a reduction in speed. A fixed DC power supply of $220\,\mathrm{V}$ was provided for the experiment. For careful motor startup, the armature resistance was initially maximized while the field resistance was minimized. After the motor started, the armature resistance was returned to a minimal setting to maintain the base speed.