D-C Shunt-motor Operation

INTRODUCTORY INFORMATION

Characteristics of a D-C Shunt Motor

Because d-c motors lend themselves readily to electronic control, and because of their desirable speed and torque characteristics, their use in industry has increased appreciably. The d-c shunt motor can be operated as a variable-speed motor with good regulation and good torque characteristics within its range. Moreover, electronic control units available for use with these motors make possible automatic operation over a wide range of speeds.

Let us briefly review the operation of d-c shunt-wound motors. This type of motor consists of a rotating armature, slotted to accommodate the armature winding. This winding is connected to a cylindrical commutator, which is part of the armature assembly. Armature current is supplied from an external d-c source, through carbon brushes which make contact with the copper commutator bars as they move beneath the brushes. The stationary shunt field winding on the motor frame is also supplied from a d-c source.

Figure 22-1*a* shows the connections to the armature and field of a shunt motor. We see that the circuit branch containing the field winding is in parallel with the branch containing the armature winding and R_1. Thus the armature current is separate from and in shunt with the field current.

Let us now consider the characteristics of the field and armature windings of a d-c shunt motor, and let us note how these characteristics affect the operation of the motor. The field coils have a relatively high resistance. This high resistance limits the current through the field winding and makes it possible to connect the field coil directly across the line. The field winding is not affected by changes in armature current.

The armature winding has a relatively low resistance. When power is first applied to the armature, only the ohmic resistance of the winding limits the current through it. However, as the armature begins to turn, its conductors cut the lines of magnetic force about the field winding. This action induces a counter-emf in the armature winding which acts in opposition to the d-c voltage applied to the armature. As a result the voltage which causes current to flow through the armature is the difference between the applied voltage and the counter-emf. As the motor warms up and speed increases, the counter-emf rises and the armature current decreases. The counter-emf can never rise to the applied voltage since the armature current would then drop to zero.

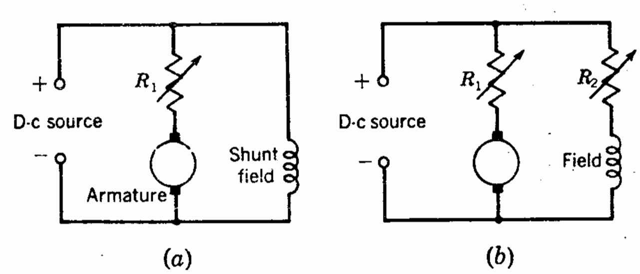

Fig. 22-1. Armature and field connections to d-c shunt motor.

Varying Speed of a D-C Shunt Motor

It is possible to change the speed of a d-c shunt motor by changing the field or armature current. Figure 22-1*b* shows the connections for this arrangement. The rheostats R_1 and R_2 may be used to adjust the armature and field voltage, respectively. We will find that within the range of operation of the motor, its speed may be increased by increasing the armature voltage, or by decreasing its field voltage. Let us see how this generalization applies to a specific motor.

The manufacturer's specifications sheet lists the characteristics of a motor, including its "base speed." This is the speed at which the motor operates under load, when the "rated" voltages are applied. For example, Fig. 22-2 shows that the base speed of a particular motor is 1,800 rpm when 220 volts

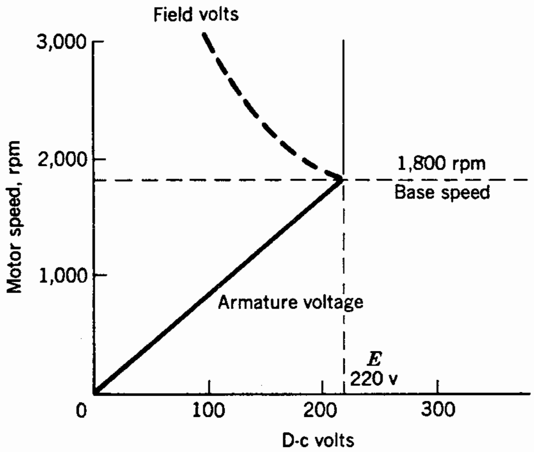

Fig. 22-2. D-C motor-speed control by varying armature or field excitation.

are applied to both the armature and field windings. The graph indicates that we may *increase* the motor speed beyond the base speed by reducing the field voltage while keeping the armature voltage constant, or that we can *decrease* the motor speed below the base speed by reducing the armature voltage while keeping the field voltage constant.

Using a rheostat in the armature circuit to vary the speed of a motor is limited by the *IR* drop across the rheostat. For as the load on the motor is increased, armature current tends to increase, increasing the voltage drop across the rheostat. The increased *IR* drop across the rheostat reduces the voltage applied to the armature, and the motor tends to slow down.

Safe operation requires that the field voltage be operated within specified limits. It should not be reduced below a predetermined value to prevent excessive motor speed. Nor should the field voltage be increased beyond its maximum value.

In the circuit of Fig. 22-1 are shown the connections for a motor which derives armature and field current from a single d-c source. However, the armature- and field-voltage requirements of motors will vary, depending on the design of the motor. Thus there are motors whose field-voltage rating is different from the armature-voltage rating. For example, the motor you will be using in this job is rated at 230 volts field voltage, 140 volts armature voltage.

Certain precautions must be observed in starting and stopping a d-c shunt motor. The motor should be started with full field voltage, but with low armature voltage. Armature voltage is increased slowly to increase motor speed. This is accomplished by starting the motor with a resistance in series with the armature winding, and by reducing the resistance gradually as the motor speeds up.

In stopping a d-c shunt motor with separate field and armature sources, power should be removed from the armature circuit first.

Measuring Counter-EMF of a Motor

It is possible to determine the counter-emf which is generated in the armature winding. The circuit of Fig. 22-3

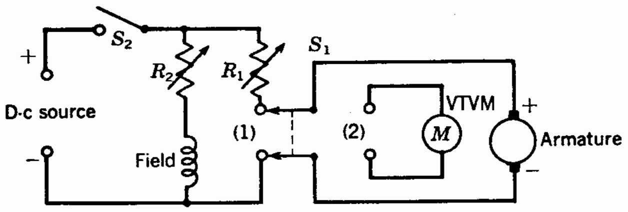

Fig. 22-3. Circuit for measuring counter-emf of a motor.

shows how this back emf may be measured experimentally. A switch S_1 is used either to apply power to the armature winding or to remove power from the armature. A voltmeter is connected in parallel with the winding. In the closed position of the switch, shown in Fig. 22-3, direct current is applied to the armature circuit and the motor starts, building up a counter-emf. After the motor is running, the counter emf generated in the armature winding may be measured by opening S_1, removing power from the armature. The voltage read on the voltmeter after the switch is open is the counter-emf. The counter-emf decreases as the motor slows down.

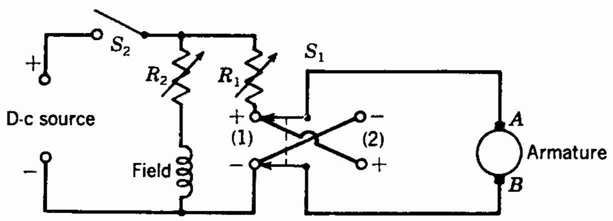

Fig. 22-4. Reversing the direction of rotation of a d-c shunt motor.

Reversing Direction of Rotation

The direction of rotation of the motor is determined by the polarity of the voltage applied to the armature and field windings. We can reverse the direction of rotation of the motor by reversing the armature connections, as in the circuit of Fig. 22-4. With S_1 in position (1) shown, the armature winding terminals *A* and *B* receive a d-c voltage whose polarity is respectively plus and minus. Assume that the motor turns in a clockwise direction. Now when S_1 is thrown to position (2), the polarity of d-c voltage applied to terminals *A* and *B* is reversed, and the motor turns in the opposite direction, that is, counterclockwise. While the simple switch S_1 illustrates the method of reversal, in commercial practice more complex arrangement employing relays is used. The details of one such arrangement will be discussed in Job 25.

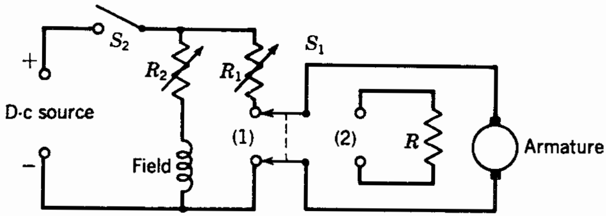

Fig. 22-5. Method of dynamic braking.

Dynamic Braking

It is possible to stop a motor rapidly by the method of dynamic braking, illustrated in Fig. 22-5. In position (1) of switch S_1, power is applied to the armature winding and the motor is operative. In position (2) of the switch, voltage is removed from the armature and a load R is thrown across the armature winding. The field-winding circuit is not affected and remains on the line. The motor cannot stop instantly with removal of power from the armature, because of its inertia. The turning motor, therefore, acts as generator and forces current to flow through the braking resistance R. The value of R determines how quickly the motor will stop. The lower the value of braking resistance, the higher is the braking current which will flow in the circuit, and the more rapidly will the motor stop. Maximum braking current occurs at the instant the "brake" is applied. As the motor slows down, the generated voltage drops, and the braking current and braking effect is reduced.