SHUNT, SERIES, COMPOUND EXCITED DIRECT CURRENT MACHINE

PREPERATION QUESTIONS

1) What are the types of DC motors according to their excitation method? Explain their application areas

2) Draw the equivalent circuits of series, shunt, and compound DC motors..

3) What are the windings of a DC motor and what are their functions?

4) Explain the magnetic fields in a DC machine..

5) Why must brushes be placed in the neutral position?
6) Explain the armature reaction.
7) Why are DC motors started with a starter, and what are the starting methods?

EQUIPMENTS

One general purpose direct current machine, one salient pole generator, two adjustable dc sources, tachometer, Volt meters, Ammeters, moment meter, single phase Wattmeter, connection cables.

1. GENERAL INFORMATION

Direct current (DC) machines operate based on the principle that the induced current generated in conductors moving within a constant magnetic field is rectified by means of the commutator–brush system and delivered to the external circuit. The excitation method determines the classification of DC Machines. Most DC machines employ electromagnetic excitation and, according to the excitation method, are categorized as Shunt, Series, or Compound machines.

A DC machine is an energy conversion device and operates either as a motor or a generator depending on the input energy.

Figure 1 presents the cross-sectional view of a two-pole DC machine equipped with interpoles and compensation windings. Small machines contain only the armature winding and the field winding. In larger machines (several kW), an interpole winding or both an interpole winding and a compensation winding are included. In addition, a series field winding is used to improve commutation characteristics. The ampere-turns of this winding correspond to approximately 5–10% of the series or shunt field winding. The series field ensures stable operating points when performing speed control over a wide range by regulating the magnetic field along the pole region.

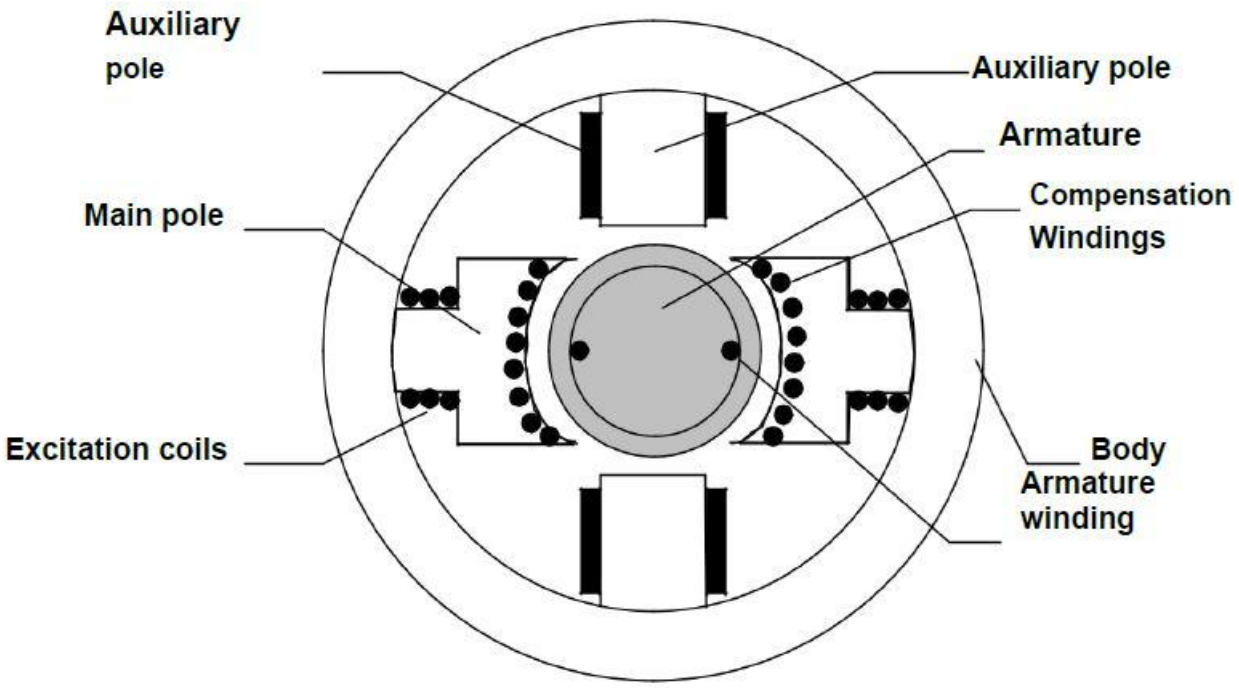


Figure 1. Cross-section of a bipolar DC motor.

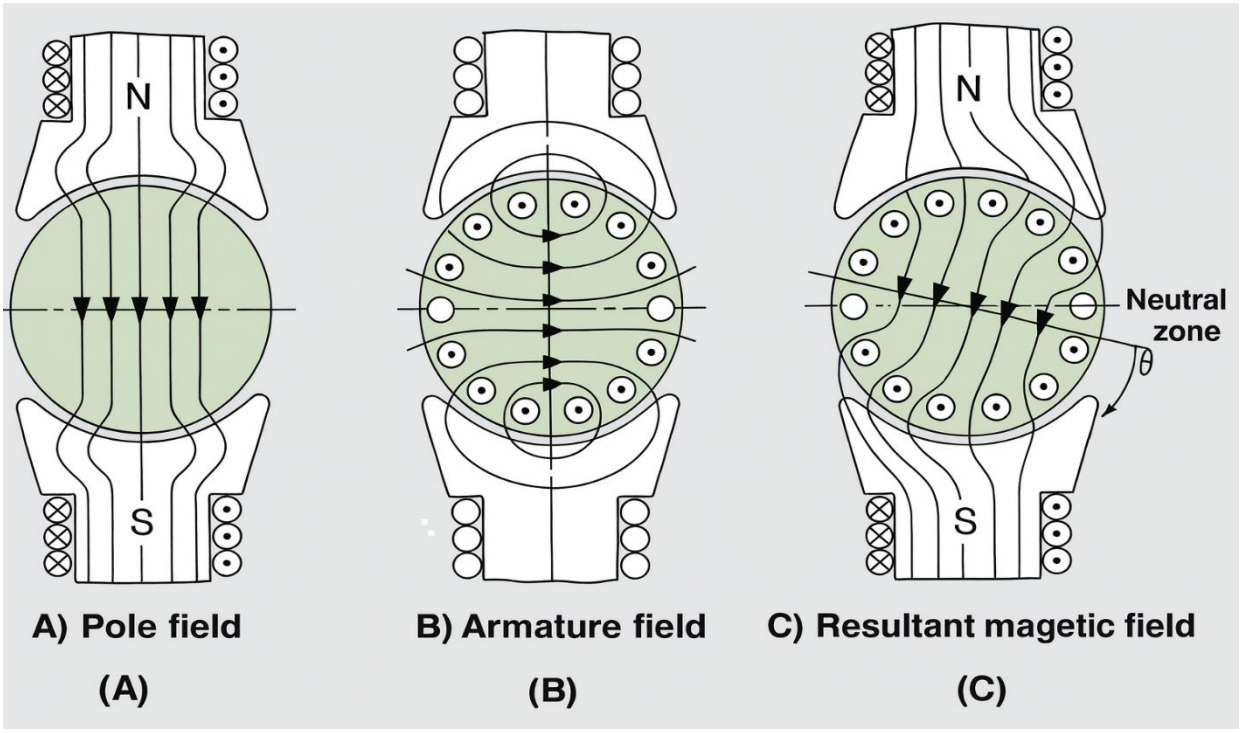


Fig. 2. Magnetic fields in a DC machine

In modern direct current (DC) machines, the pole field is produced by electromagnets. The windings inside the stator (field system) constitute the pole field windings. This magnetic field completes its path through the armature core.

The armature field, on the other hand, is generated by the current flowing through the conductors of the armature. When current flows through parallel conductors in the same direction, each conductor produces a magnetic field, and these magnetic fields combine. This magnetic field has the characteristic of distorting and weakening the pole field.

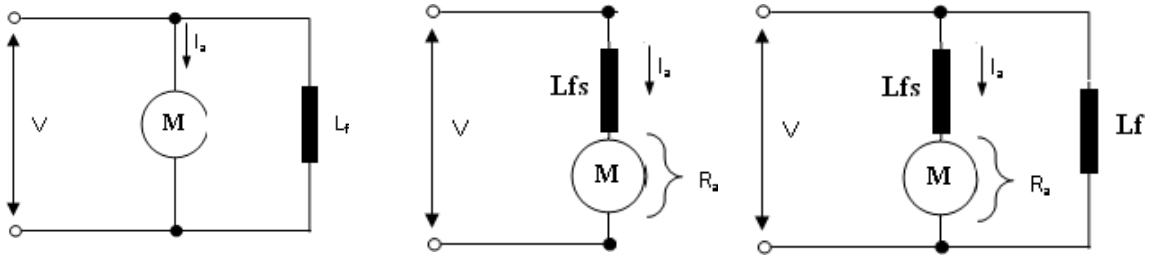
The pole field and the armature field together form the resultant magnetic field of the machine.

1.1 DC Motor

DC shunt machines are manufactured in two types: self-excited and separately excited.
In self-excited shunt machines, the field winding and the armature winding are supplied from the same DC voltage source.
In separately excited machines, the armature and field windings are supplied by two independent DC voltage sources.

In DC series machines, the armature and field windings are connected in series. Since the total operating current flows through the field windings in these machines, the resistance of both the armature and field windings must be low.
The current drawn by a DC series machine, particularly during starting, is very high. Therefore, a starting mechanism must be used to limit the initial current.

In DC compound machines, both series and shunt field windings are present simultaneously. Therefore, compound machines exhibit the combined characteristics of both series and shunt machines.



(a) (b) (c)

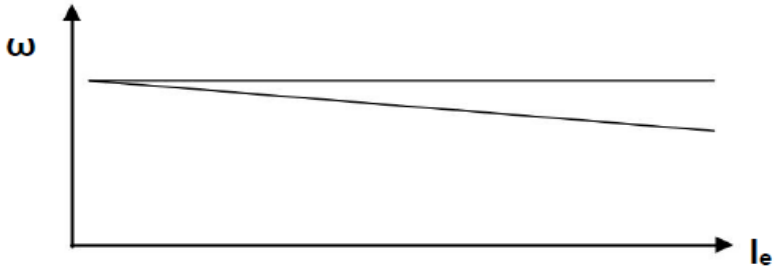
Figure 3. (a) Shunt, (b) Series, (c) Compound Motor Equivalent Circuit

$$V = E + I_a R_a \qquad (1)$$

Armature terminal voltage supply
E: Armature induced voltage
Ia: Armature current
Ra: Armature resistance
E = kωΦ (k is a constant)

$$E = V - I_a R_a \quad ve \quad \omega = \frac{V - R_a I_a}{k\Phi}$$

The term IaRa is generally smaller than %5 of V, so ω approximately equal tı V/kΦ. The ω depending on armature current Ia is illustrated below.



The power equation is obtained by multiplying V with Ia:

VIa = EIa + I_a^2 Ra

Here,

VIa : The electrical power of motor

EIa : The power transfered to the armatüre (Some portion of this power is consumed as core and friction losses.)

EIa = ω T (i.e. Po = ωT)

T ∝ Φ Ia = k Φ Ia , but Φ∝ If

Under shunt and constant armature voltage operation, Φ is constant, torque changes varies with the armature current. This variation can be seen in Figure 4.

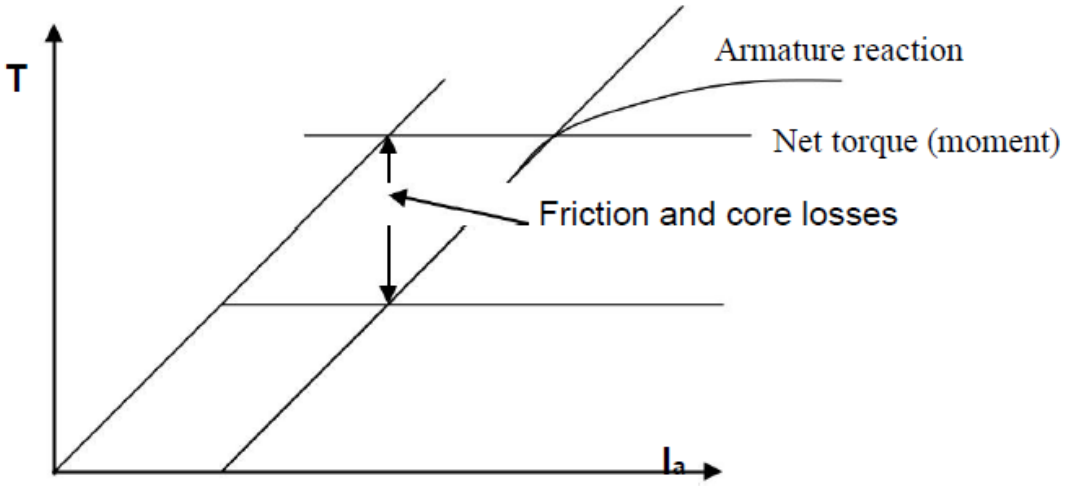


Figure 4. Torque-Armature current graphics

The armature current Ia depends on speed hence there is a relation between speed and moment.

$$I_a = \frac{V - E}{R_a} = \frac{1}{Ra}(V - k\omega\Phi)$$

So;

$$T = \frac{k\Phi}{R_a}(V - k\omega\Phi)$$

If Φ is constant then torque linearly varies quickly and maximum torque is produces when ω = 0.

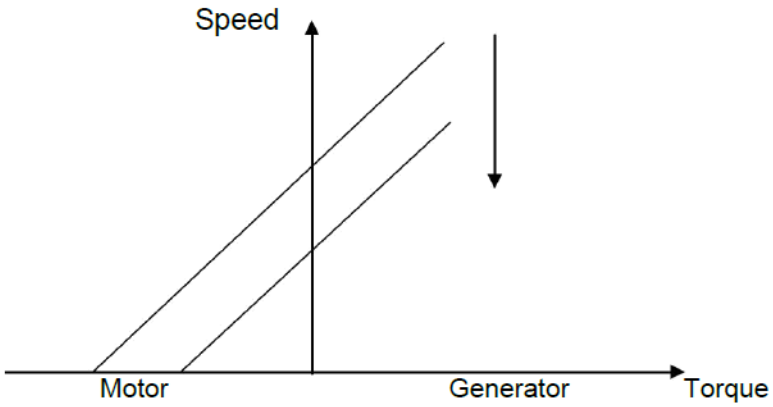


Figure 5. Speed - torque graph

Experiment 1: No-Load Speed Characteristic of a DC Shunt Motor

Objective of the experiment:
To operate the DC shunt motor under no-load conditions and analyze the relationship between motor current (Im), motor voltage (Um), field current (Iu), and motor speed (n), in order to obtain the speed characteristic curve and gain knowledge and practical skill on the subject.

Experiment Connection Diagram Y-036/001

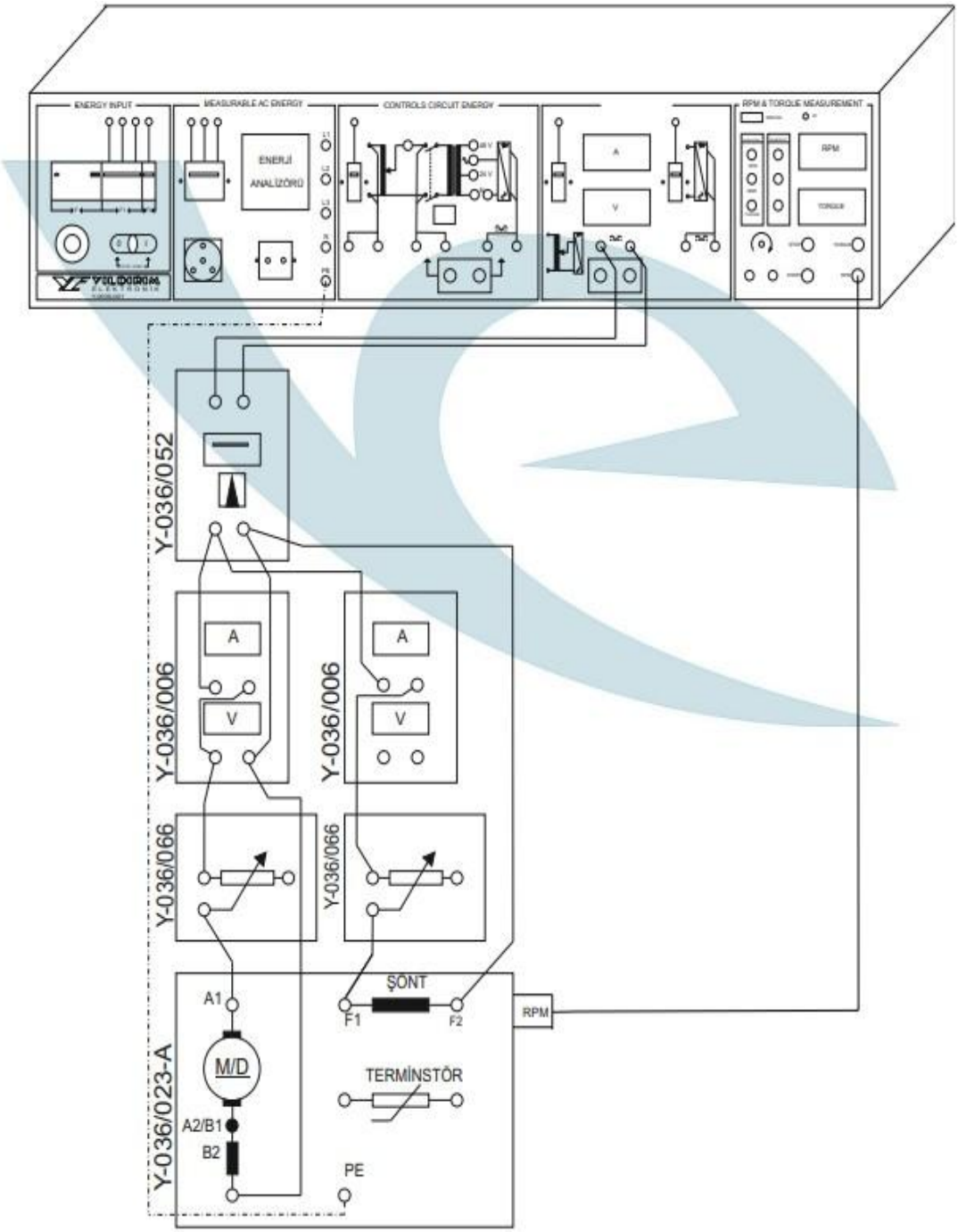


Figure 1.1: Experimental connection diagram of the DC shunt motor under no-load operation.

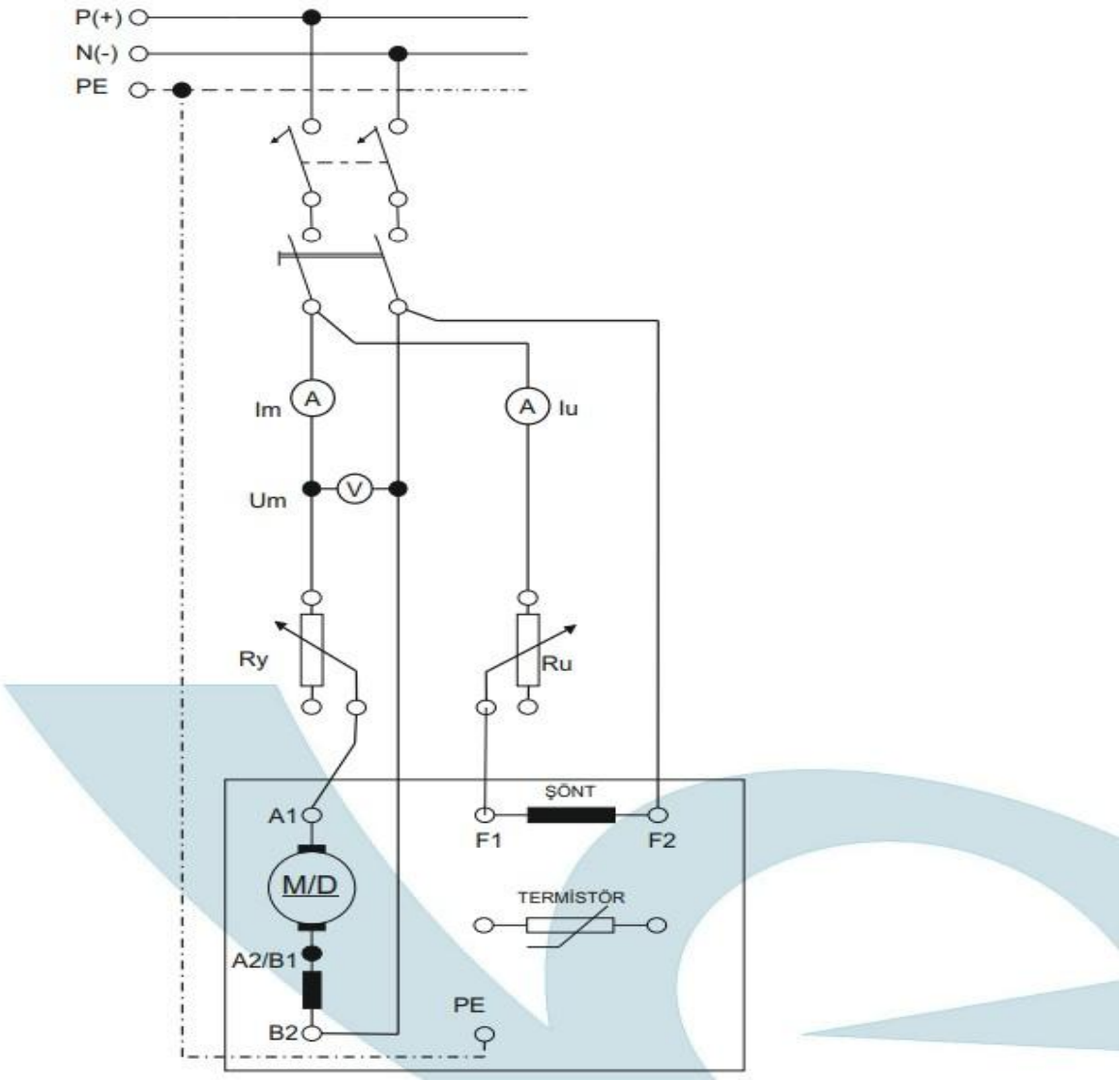


Figure 1.2: Circuit diagram of the DC shunt motor under no-load operation.

Experimental Procedure

Note:
• Instead of the starting (LRM) rheostat, a 50 Ω, 1000 W adjustable rheostat is used; in the excitation circuit, a 100 Ω, 500 W adjustable rheostat is employed.
• A wider adjustment range can be achieved by using a second adjustable DC supply (Y-036/002) in the excitation circuit.
• Examine the nameplate (rated) values of the DC shunt machine.

1. Establish the experimental connections shown in Figures 1.1 and 1.2.
2. Ensure that the excitation resistance (Ru) is at zero (excitation rheostat short-circuited) and the starting rheostat (Ry) is set to its maximum value.
3. Apply the nominal DC motor voltage (200 V) to the circuit and start the motor. Record the values of Im, Um, Iu, and n.

4. Gradually introduce the excitation resistance in steps to adjust the motor speed. Keep the motor supply voltage at its nominal value at each step. Record Im, Um, Iu, and n at every step.
5. Increase the motor speed to 25%, 50%, and 100% of nominal speed. Short-circuit the excitation rheostat and record Um, Im, Iu, and n.
6. When the motor reaches 100% nominal speed, reduce the applied motor voltage below its nominal value. Record Im, Um, Iu, and n.
7. Turn off the main switch of the first stage and disconnect the motor supply; observe and record the value indicated by Um in the armature circuit.
8. Cut the power and terminate the experiment.

Experiment 2: Load Operation of the DC Shunt Motor – External Characteristic

Objective of the experiment:
To observe the relationship between the motor current (Im) and the rotational speed (n) during the load operation of the DC shunt motor, and to analyze the decrease in speed as the motor current (Im) increases.

Experiment Connection Diagram Y-036/001

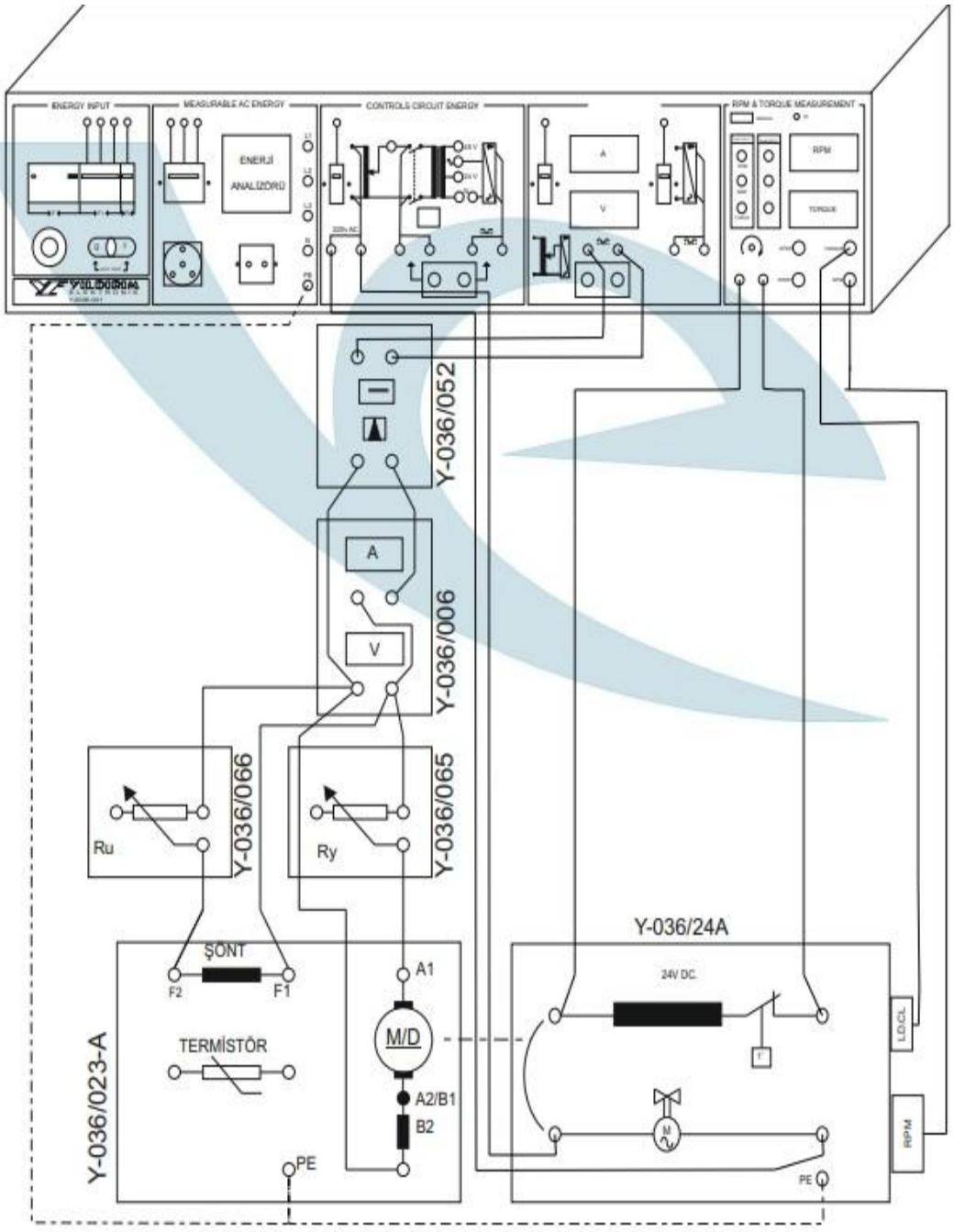


Figure 2.1: Experimental connection diagram of the DC shunt motor under load operation.

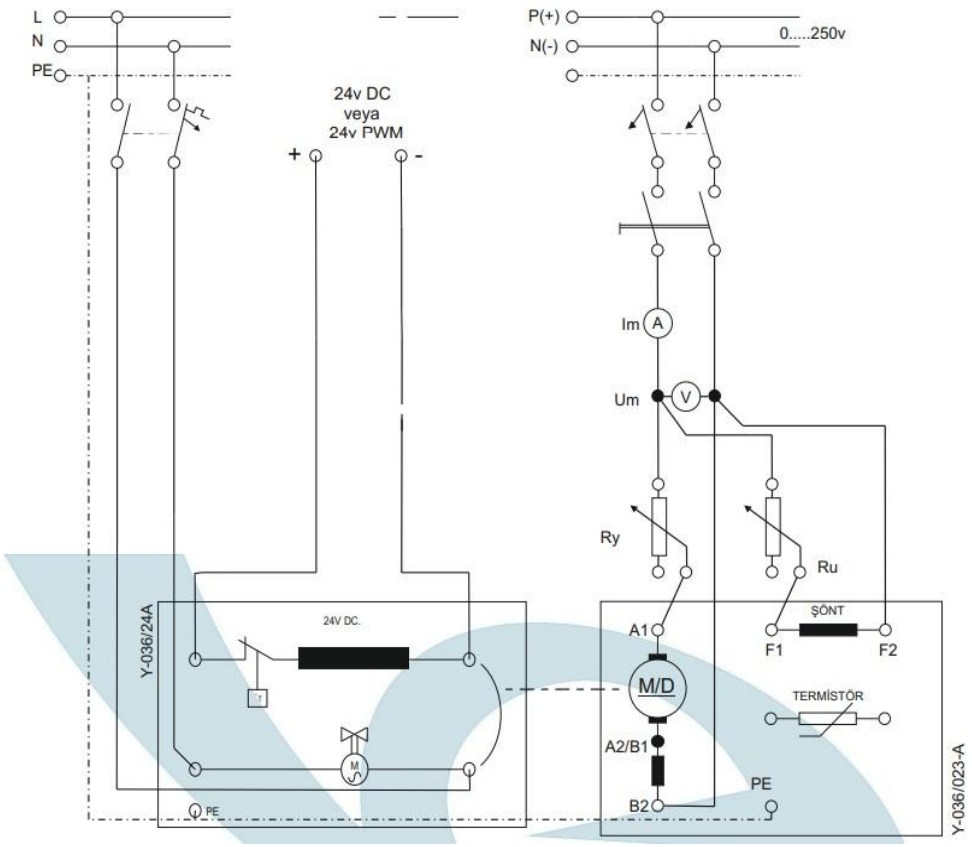


Figure 2.2: Circuit diagram of the DC shunt motor under load operation.

Experimental Procedure

Note:

• Examine the nameplate of the magnetic powder brake; thermal protection is activated if it operates above its nominal rating for an extended period.

• Examine the nameplate (rated values) of the DC shunt machine.

• Before energizing the DC shunt motor, ensure that the starting rheostat (Ry) is at its maximum value and the excitation rheostat (Ru) is at minimum or zero resistance (Ru short-circuited).

1. Establish the experimental connections shown in Figures 2.1 and 2.2.
2. Set the Y-036/001 DC supply or adjustable source to 200 V.
3. Energize the DC shunt motor and start it using the starting rheostat (Ry).
4. Adjust the DC shunt motor to its nominal speed using the excitation rheostat (Ru), and record Um, Im, Iu, and n.
5. Load the DC shunt motor using the magnetic powder brake (dynamic load) by applying 0–24 V DC or a PWM driver. Bring the motor terminal voltage (Um) to its nominal value. Record Im, n, and torque.
6. Increase the DC voltage applied to the magnetic powder brake (dynamic load) in steps and load the DC shunt motor up to its nominal power. At each step, keep the applied motor voltage (Um) at its nominal value and record Im, Iu, n, and torque.
7. Load the DC shunt motor up to 1.2 times its nominal power using the magnetic powder brake. Keep the applied voltage at its nominal value and record Im, n, magnetic powder brake readings, and torque.

8. Disconnect the power and terminate the experiment.

Experiment 3: Starting and Load Operation of the DC Series Motor

Objective of the experiment:

To start the DC series motor, change its direction of rotation, and analyze the relationship between load current and rotational speed, thereby gaining knowledge and practical skills related to the operation of the DC series motor

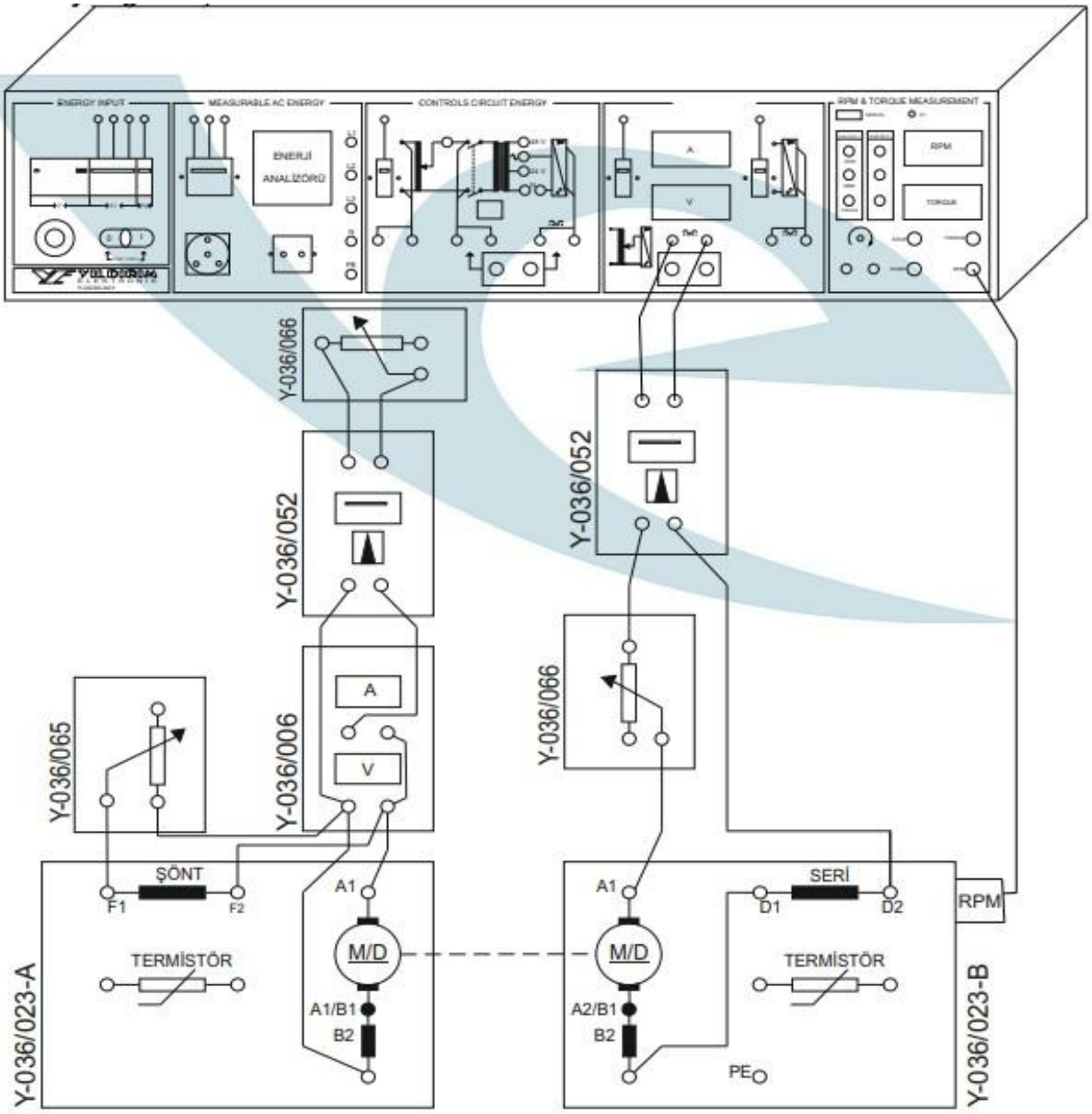


Figure 3.1: Connection Diagram for Starting and Load Operation of the DC Series Motor

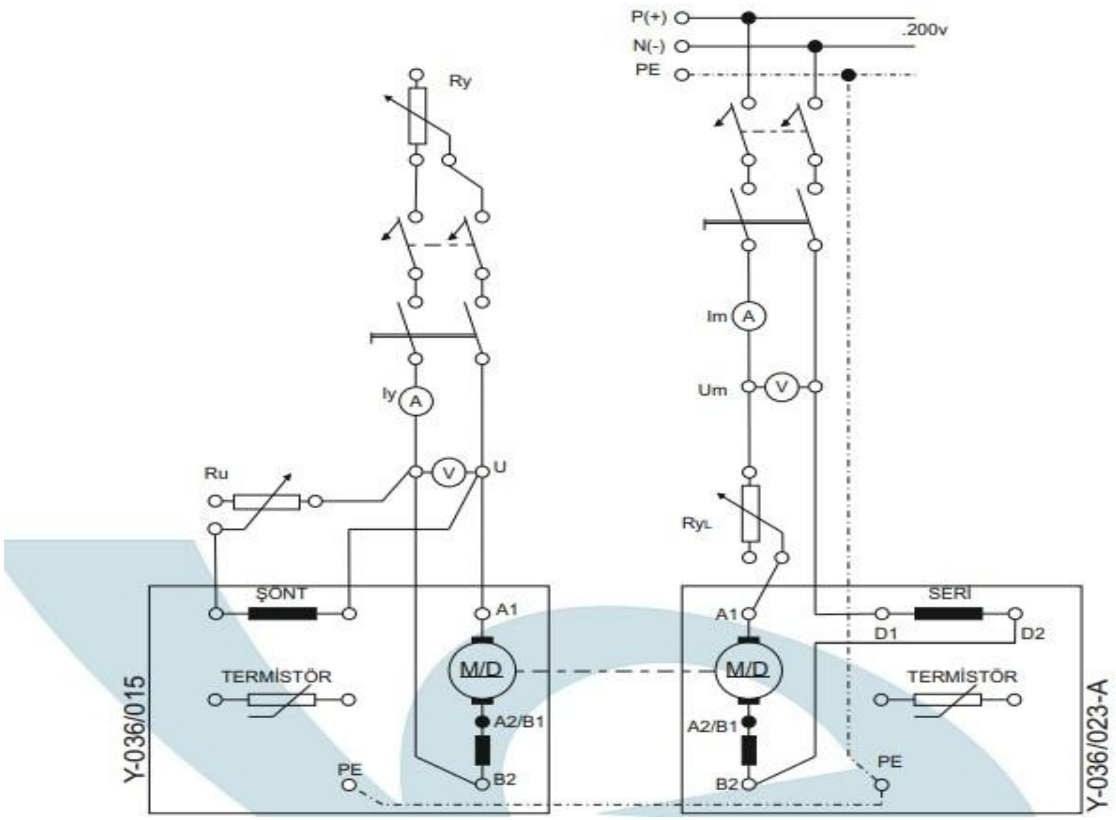


Figure 3.2: Circuit diagram for starting and load operation of the DC series motor.

Experimental Procedure

Note:
• Take into account the rated values of the DC shunt and DC series machines.
• Do not operate the DC series motor under no-load conditions; do not start it directly.
• When loading the DC shunt dynamo, use a lamp bank if necessary.
• For loading the DC series motor, an additional experiment may be performed using the Y-0036/24-A magnetic powder brake unit.

1. Establish the experimental connections shown in Figures 3.1 and 3.2.
2. Adjust the dynamo to produce its nominal voltage, close the fuse switch, and set it to absorb approximately 50% load.
3. With the starting rheostat (RyL) at its maximum value, set the adjustable supply to apply the nominal voltage (200 V) to the DC series motor and close the fuse switches.
4. Start the motor using the starting rheostat (RyL). Check whether the dynamo generates voltage; if it does not, change the direction of rotation of the motor to ensure generation.
5. Load the DC series motor by loading the dynamo in steps up to 1.2 times its nominal value, and record Iy,U,Im,Um,n at each step.
6. Reduce the load until the motor speed (n) reaches approximately twice its nominal value, and record Iy,U,Im,Um,n.
7. Disconnect the power and terminate the experiment.

Experiment 4: Measurement of Armature and Field (Excitation) Resistance

Objective of the experiment:
To become familiar with the components of DC machines and to measure the armature and field (excitation) resistances of the DC shunt (D/M) machine.

Experiment Connection Diagram: Y-036/001

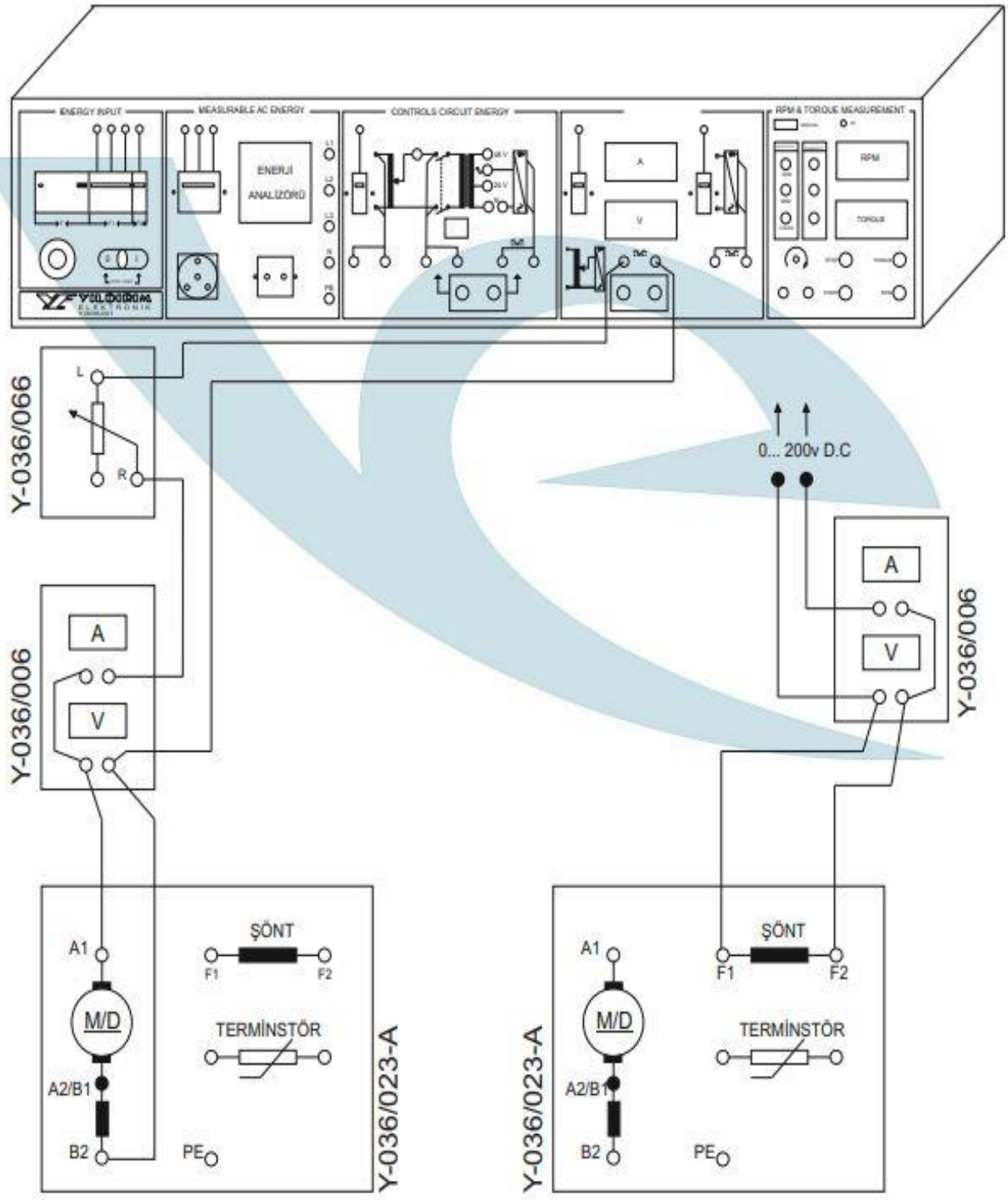


Figure 4.1: **Armature resistance measurement** experiment connection diagram

Figure 4.2: Field resistance measurement **experiment connection diagram**

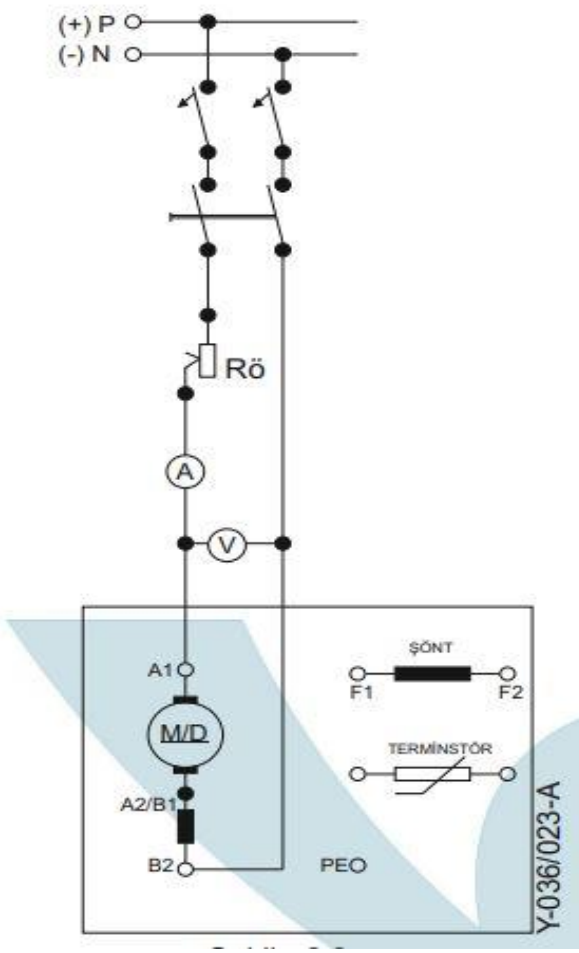


Figure 4.3:Armature resistance measurement Cicuit diagram

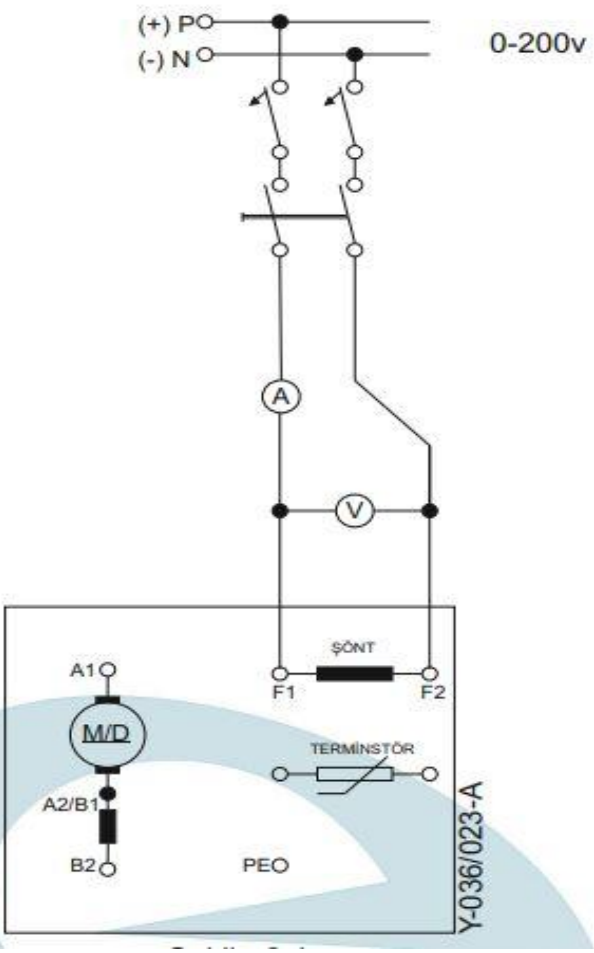


Figure 4.4:Field resistance measurement circuit diagram

Note:

• In DC series machines, the series field winding resistance must be connected in series with an adjustable resistor (Rö) when measuring the armature resistance.
• The shunt field winding (excitation winding) resistance can be measured using a suitable ohmmeter.

Experimental Procedure

Note:
• Examine the nameplate values of the DC machine used in the experiment. Pay attention to the nominal voltage–current–speed (U–I–rpm) ratings.

Measurement of Armature Resistance

- Make the connections shown in Figures 4.1 and 4.3.
- Set the adjustable series resistor Rö to its maximum value.
- Apply the nominal armature voltage to the circuit.
- Adjust the series resistance to allow the nominal armature current to flow through the circuit.

- Record the U–I values from the DC measurement unit.
- Slowly rotate the armature (machine shaft) by hand and record the U–I values at each position.
- Using Ohm's law, calculate the armature resistance as R=U/I (take the average if different values are obtained).
- **If the armature starts rotating when voltage is applied, continue the experiment and record the U–I values.**
- **Cut the power, stop the experiment, reverse the polarity of the DC supply (+/–), and repeat the measurement; in this case the armature should not rotate. Record the U–I values.**
- Analyze the results of the last two steps if both conditions occur.
- Check the temperature of the DC machine.
- Disconnect the power and terminate the experiment.

Measurement of Field (Excitation) Resistance

- Make the connections shown in Figures 4.2 and 4.3.
- Follow the warning regarding the series field winding.
- Apply the nominal voltage to the field winding.
- Record the U–I values from the DC measurement unit.
- Apply field voltages below nominal and record the corresponding U–I values.
- Using Ohm's law, calculate the field resistance as R=U/I.
- Shortly after completing the field-resistance measurement, proceed to the armature-resistance experiment; the effect of friction on the armature shaft may be observed.
- Disconnect the power and terminate the experiment.

Measured Values:

(Values vary depending on the DC machine used.)

Armature Resistance Measurement

- 40 V — 3.2 A
- 42 V — 4 A
- 58 V — 4 A *(Armature rotating)*

Field Resistance Measurement

- 160 V — 0.8 A
- 200 V — 4 A