SİVAS UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND NATURAL SCIENCES

ELECTRICAL MACHINES EXPERIMENTS MANUAL REPORT

SİVAS

Experiment 1: Measurement of Armature and Field Winding Resistance in D.C. Machines

1. Objective of the Experiment

To recognize the internal components of a D.C. shunt motor and to measure the resistances of the armature (rotor) and field (stator/exciter) windings.

2. Theoretical Background

In D.C. machines, resistance measurements of the armature and the field windings are fundamental for diagnostic purposes and performance evaluation.

- The **armature resistance** affects voltage drop and power loss during operation.
- The **field winding (shunt winding)** creates the main magnetic field. Its resistance impacts field current and thus the magnetic flux.

Ohm's Law R= U/I is used to calculate resistance from measured voltage and current.

For accurate armature resistance measurement:

- A **series resistor (Rö)** is connected to limit the current and prevent overheating.
- The **armature** must be turned manually or slowly by supply to observe EMF effects.

Field winding resistance is measured under nominal voltage conditions with the machine at rest to avoid induced EMF effects.

3. Materials Used

- D.C. Shunt Motor (Y-036/023-A)
- Energy-supplied lab bench (Y-036/001)
- D.C. Measurement Unit (Y-036/006)
- Adjustable resistor (0–500 W, Y-036/066)
- Analog ammeter and voltmeter
- IEC Power cables
- Rail-mounted motor base (Y-036/003)

4. Procedure

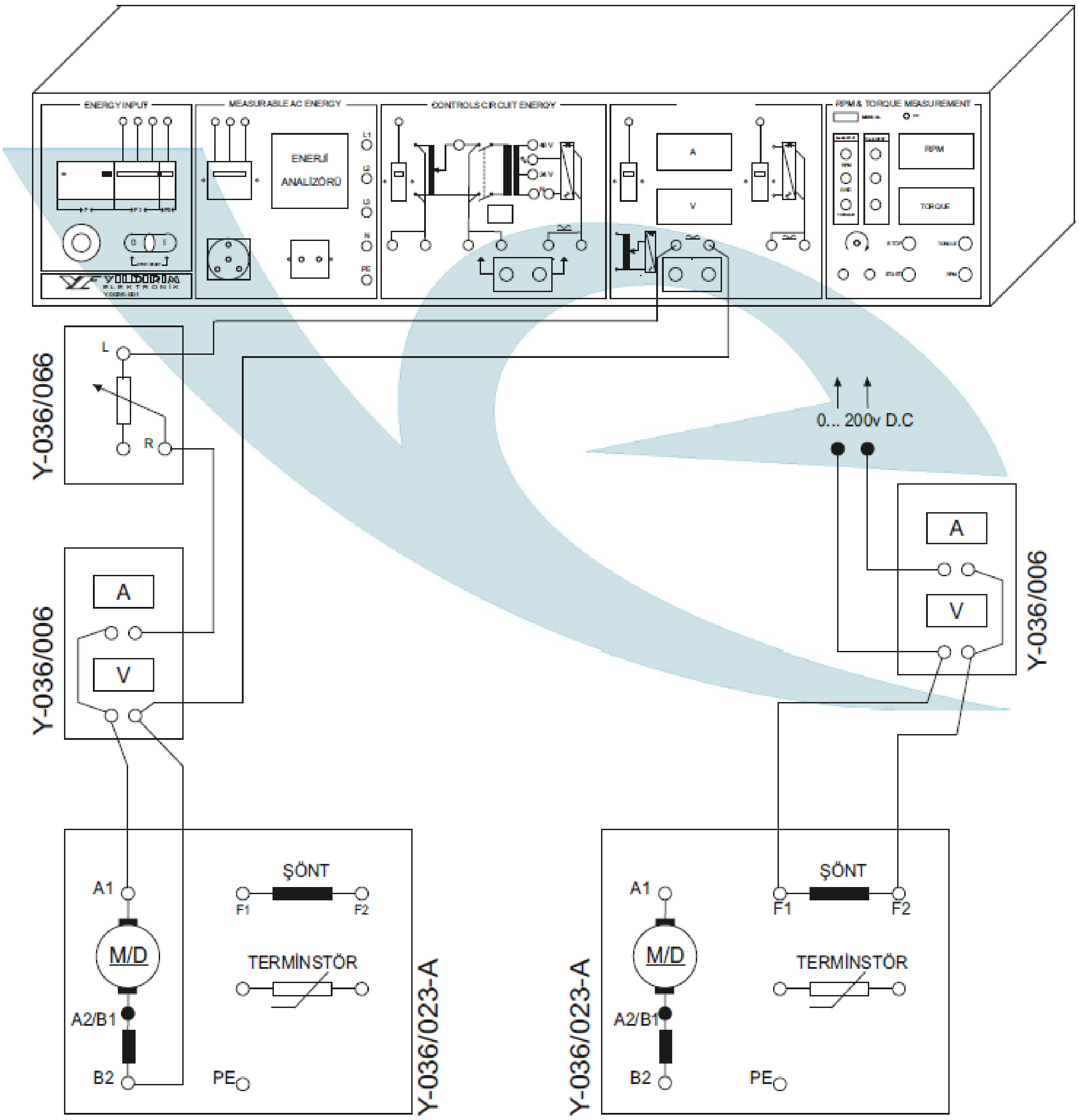

Fig 2.1

Fig 2.2

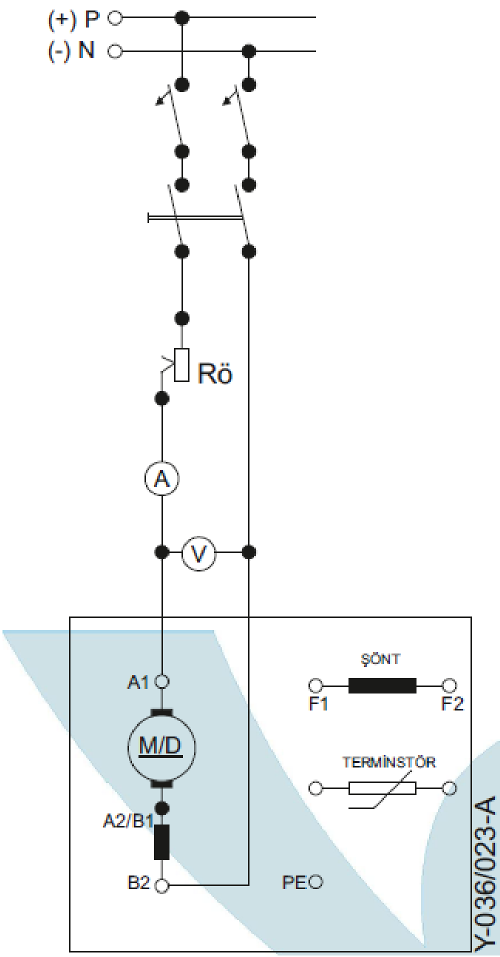

Fig 2.3

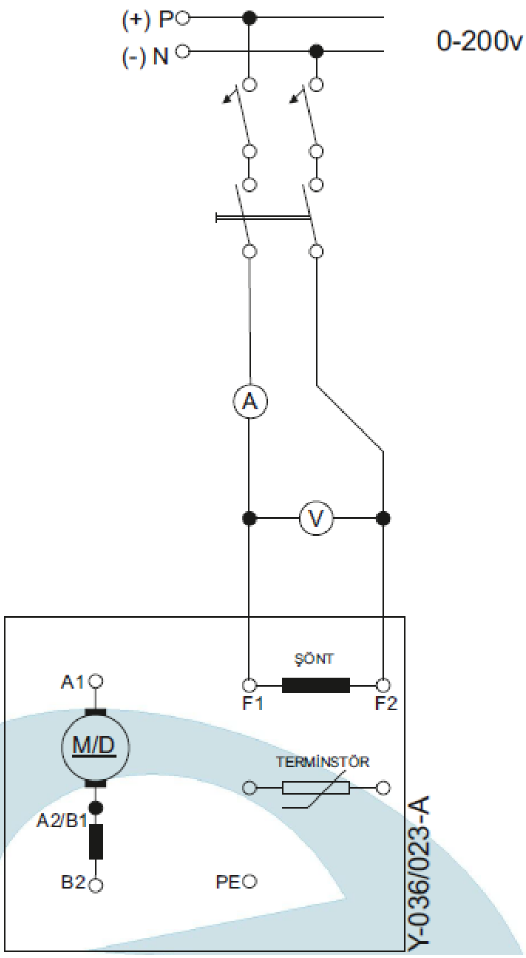

Fig 2.4

4.1 Armature Resistance Measurement

1. Connect the circuit as shown in Figures 2.1–2.3.
2. Set the adjustable resistor Rö to maximum value.
3. Apply nominal D.C. voltage gradually.
4. Adjust Rö to allow nominal armature current.
5. Record voltage (U) and current (I) using the measurement unit.
6. Calculate R_armature=U / I.
7. If the armature begins to rotate, note the U-I values under motion as well.
8. Repeat measurement by switching polarity to observe induced voltage differences.
9. Stop the experiment and disconnect the circuit.

4.2 Field Resistance Measurement

1. Connect the circuit as shown in Figures 2.2 and 2.4.
2. Apply nominal field voltage without exceeding the limit.
3. Record voltage and current from the D.C. measurement unit.
4. Calculate R_field U / I.
5. Stop the experiment and disconnect the setup.

5. Evaluation of Results

- Calculate and tabulate resistance values.
- Analyze the influence of machine motion on U-I values for the armature.
- Comment on the difference between static and rotating conditions.
- Example data:
  - Armature Resistance:
    - 40 V / 3.2 A → 12.5 Ω
    - 58 V / 4.0 A (rotating) → 14.5 Ω
  - Field Resistance:
    - 200 V / 0.4 A → 500 Ω

6. Safety Precautions

- Never short-circuit the supply during resistance measurement.
- Adjust Rö gradually to prevent current spikes.
- Ensure all equipment is de-energized before rewiring.
- Do not exceed nominal voltages of the D.C. machine.

7. References

- Laboratory Manual: D.C. Machines
- Manufacturer datasheet for D.C. Motor (Y-036/023-A)
- “Electrical Machines” by Fitzgerald, Kingsley, Umans
- Ohm’s Law and Basic Electrical Measurement Principles

Experiment 2: Determination of Brush Position and Neutral Axis Shift in D.C Machines

1. Objective of the Experiment

To understand the importance of the neutral axis in D.C. machines and analyze the problems caused by brush misalignment from the neutral axis under load conditions.

2. Theoretical Background

In DC machines, the neutral axis is the position where no electromotive force (EMF) is induced in the armature coil. Proper brush positioning on this axis minimizes sparking and maximizes commutation efficiency.

When the machine is loaded, the magnetic field distribution within the machine can become asymmetrical due to armature reaction, causing the neutral axis to shift. If the brushes remain at the original no-load neutral axis position, sparking and increased wear occur.

The experiment demonstrates how brush position affects the commutation process and how misalignment causes arcing (şerare) and voltage drops.

3. Materials Used

- Energy-supplied experiment table (Y-036/001)
- Adjustable rail motor bench (Y-036/003)
- D.C. shunt machine (Y-036/023-A)
- 3-phase asynchronous motor (Y-036/015)
- 3-phase asynchronous motor controller (Y-036/006)
- D.C. measurement unit
- 2-phase fuse switch (Y-036/052)
- Adjustable load rheostat, 50–1000W (Y-036/066)
- Tachometer (speed sensor)
- Open-end wrench set
- Plug and IEC cables

4. Procedure

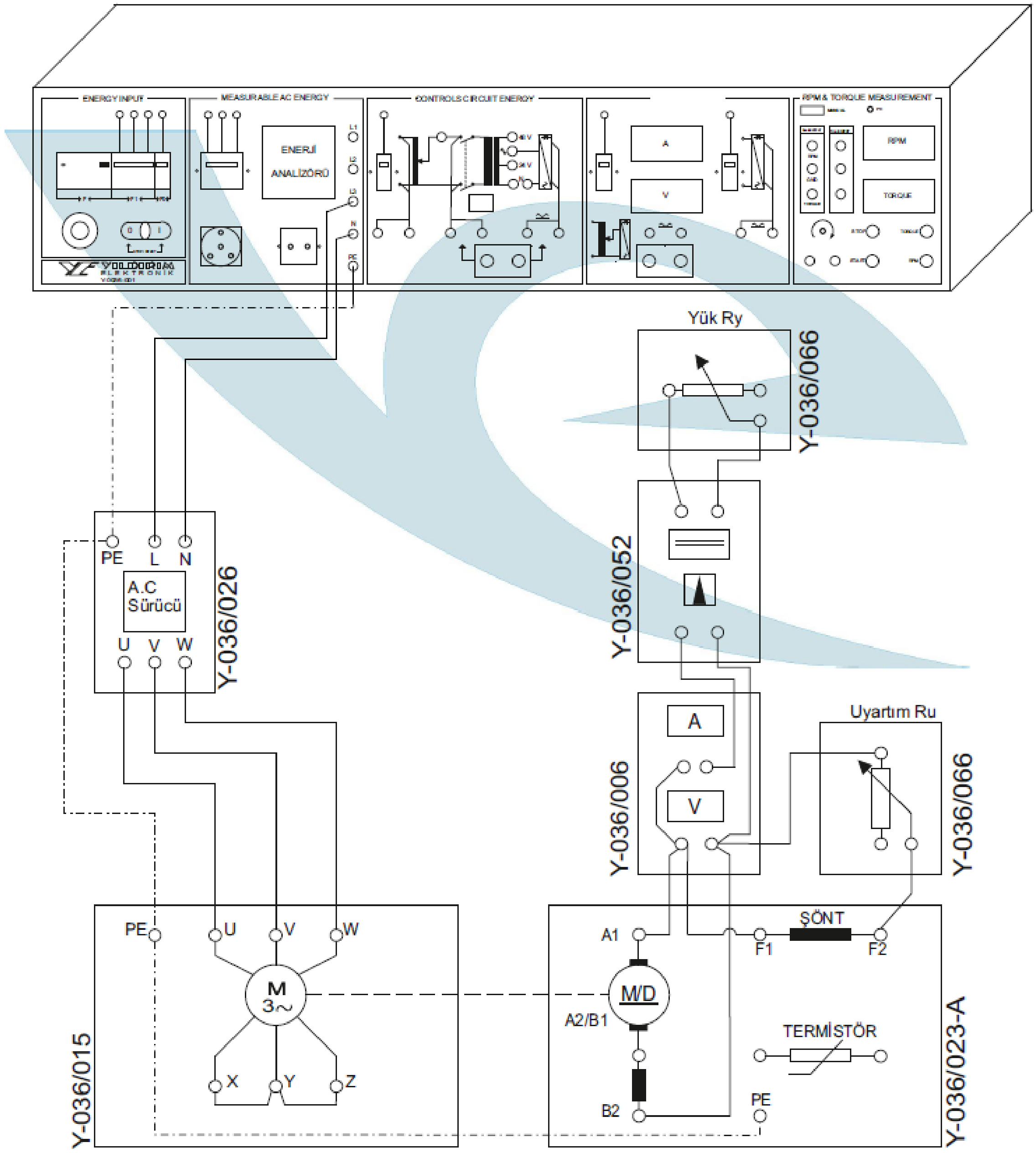

Fig 3.1

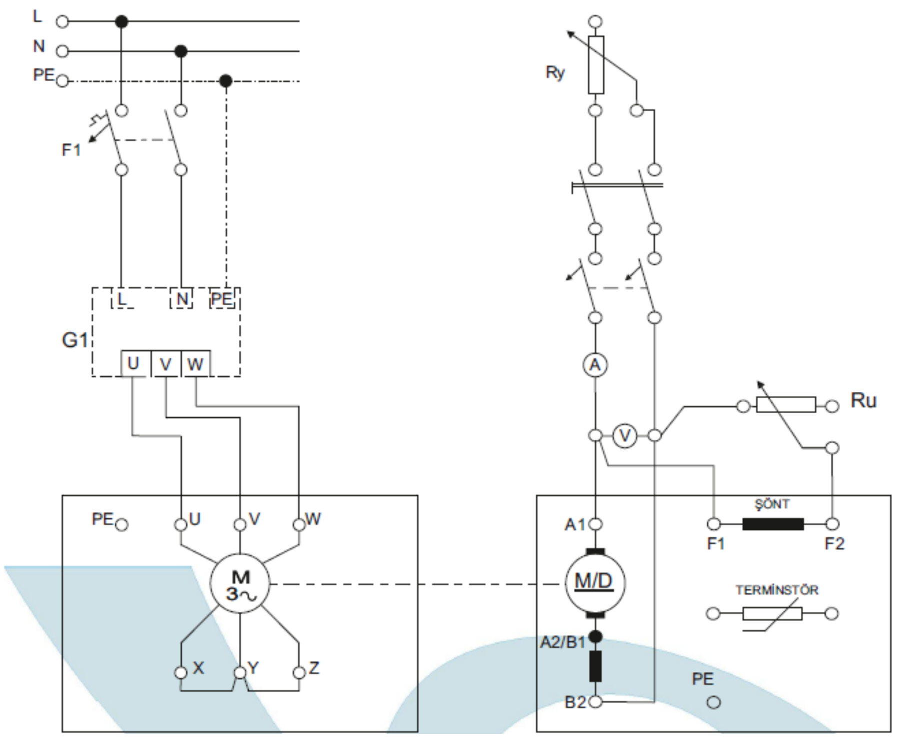

Fig 3.2

1. Connect the circuit as shown in Figure 3.1 and 3.2.
2. Ensure all units are grounded via PE (Protective Earth) banana sockets.
3. Adjust load rheostat (Ry) and excitation rheostat (Ru) to max resistance.
4. Set brush position to neutral axis; start the asynchronous motor and rotate D.C. shunt motor to nominal speed (1500 rpm).
5. Adjust excitation (Ru) and record the unloaded U-I-rpm values.
6. Load the generator by decreasing Ry; record U-I-rpm values again.
7. Stop the system, shift brushes from neutral axis using brush holder screws.
8. Repeat steps with shifted brush position; record data and observe sparking between commutator and brushes.
9. Determine new brush-neutral position by rotating the holder until sparking is minimal and voltage is maximized.

Brushes on the Neutral Axis					Brushes offset from the Neutral Axis				
	U	I	Rpm	Sparking		U	I	Rpm	Sparking
No-Load					No-Load				
Loaded					Loaded				

5.Evaluation of Results

The experiment demonstrates that improper brush alignment leads to sparking and poor voltage regulation. Through shifting and realigning the brushes, the correct neutral axis can be experimentally determined where sparking ceases and voltage is maximized.

Students compare data between brush-on-neutral and brush-off-neutral conditions for both no-load and load scenarios to evaluate the impact of brush placement on DC machine performance.

6. Safety Precautions

- Ensure all power is disconnected before adjusting brush holders.
- Handle brushes and commutator carefully to avoid mechanical damage.
- Use insulated tools and wear gloves when operating live circuits.
- Monitor current and voltage levels to prevent overloading the system.

7. References

- D.C Machine Laboratory Manual
- Electrical Machinery by Fitzgerald, Kingsley & Umans
- IEC Wiring Standards
- Manufacturer Datasheets: Y-036 series equipment

Experiment 3: No-Load Test of Separately Excited D.C Shunt Generator

1. Objective of the Experiment

To observe the remanent voltage of a separately excited DC shunt generator and to analyze the relationship between excitation voltage Uu and generated voltage Ub. The experiment aims to obtain and characterize the no-load characteristic curve of the dynamo.

2. Theoretical Background

A separately excited DC shunt generator has its field winding powered by an external DC source, allowing independent control of excitation current. When the rotor is driven at nominal speed, it produces a small voltage due to residual magnetism. Applying excitation increases magnetic flux, which induces a voltage in the armature winding as per Faraday's Law:

$$Ub = k \cdot \phi \cdot n$$

Where:

- Ub: Generated voltage
- k: Machine constant
- ϕ: Magnetic flux (depends on field current Iu)
- n: Rotational speed

As field current increases, the flux ϕ increases until magnetic saturation limits further voltage increase. The no-load characteristic Ub vs. Iu (or Uu) is nonlinear due to the magnetization curve of the machine.

3. Materials Used

- Y-036/001: Energy Unit Lab Bench
- Y-036/003: Rail-mounted Motor Bench
- Y-036/023-A: D.C Shunt Generator
- Y-036/015: 3-Phase Asynchronous Motor
- Y-036/066: Asynchronous Motor Driver
- Y-036/066: D.C Measurement Unit
- Y-036/066: 500 Ω to 1000 Ω Adjustable Rheostat
- Tachometer (for speed measurement)
- IEC Plugged Power Cable

4. Procedure

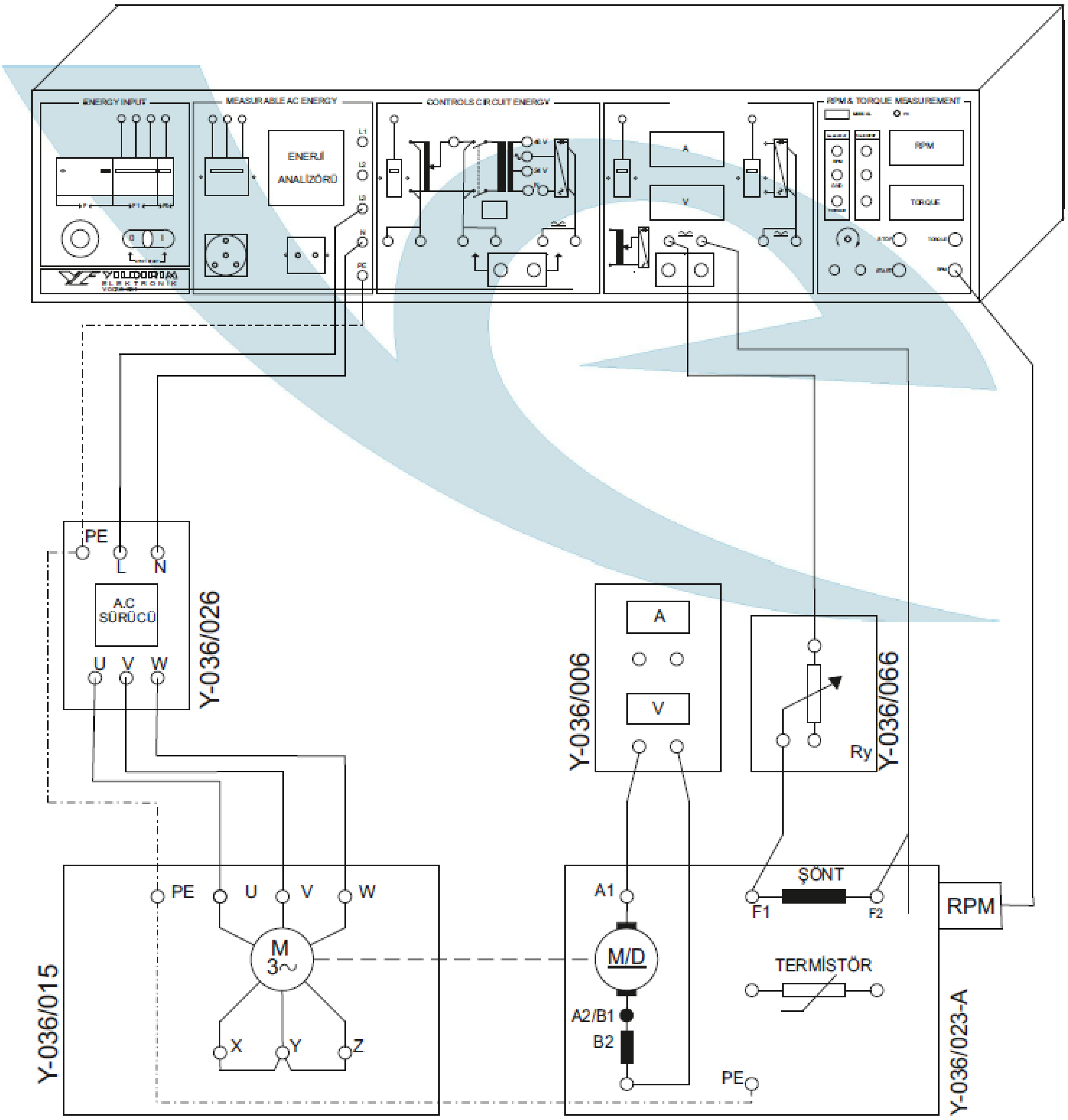

Fig 4.1

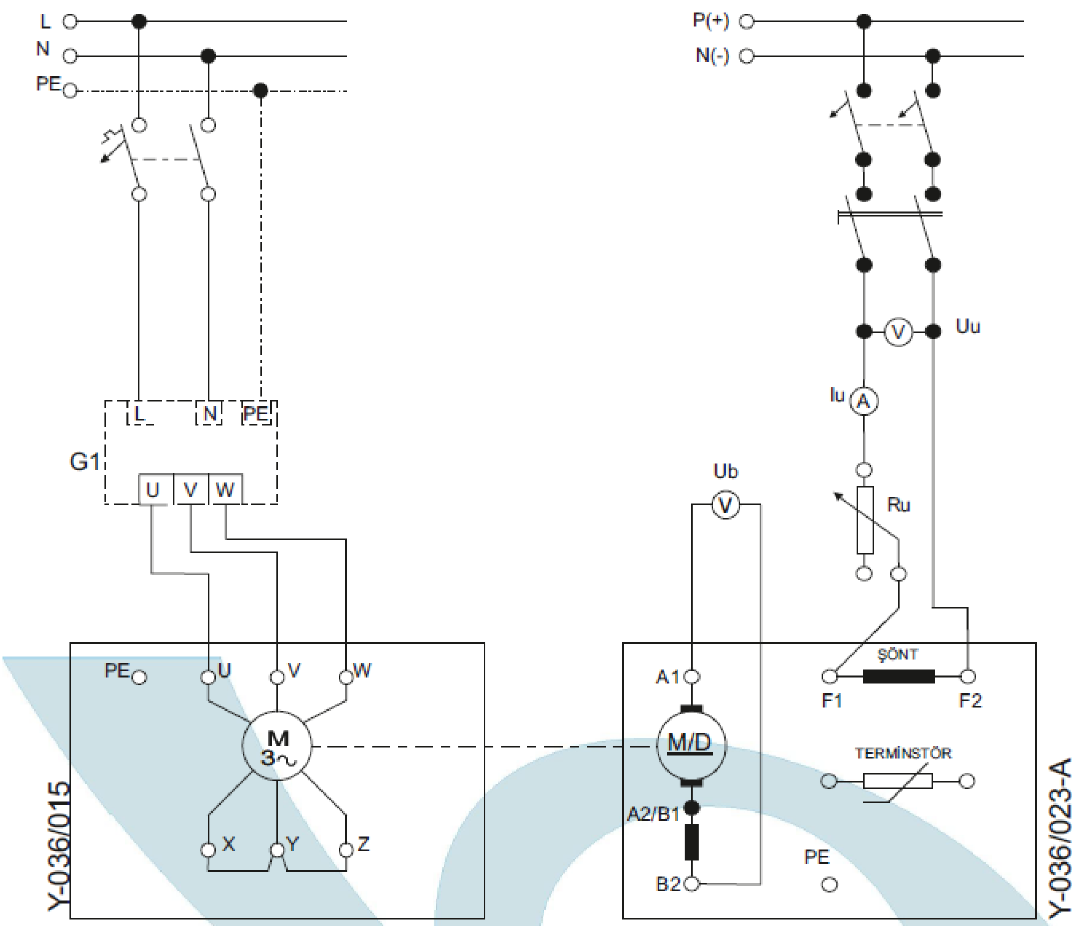

Fig 4.2

1. Set up the experimental wiring as shown in the connection diagrams (Şekil 4.1 ve Şekil 4.2).
2. Set the DC voltage on the energy unit to **220 V**.
3. Start the asynchronous motor to drive the dynamo at **nominal speed (≈1500 rpm)** and record the residual voltage Ub.
4. Apply maximum excitation through the rheostat and measure Uu, Ub, and Iu.
5. Gradually decrease excitation resistance (increase Iu), record Ub, Uu, and Iu at each step.
6. Stop reducing resistance once Ub reaches nominal value (≈200 V).
7. Increase Uu by 10%, record data.
8. Gradually reduce Uu back to zero, ensuring Iu=0 at the end.
9. Stop excitation and record the final Ub value.
10. Turn off all power to conclude the experiment.

5. Evaluation of Results

Using the table below, fill in the values recorded during the experiment. Plot the Ub–Iu and Ub–Uu curves to analyze the no-load characteristics.

Speed(rpm)	Ub	Uu	Iu	Position
n= 1486 rpm (constant)				

Discussion Questions:

1. What is the measured Ub without excitation?
2. Is Ub's increase linear with increasing Iu? Why/why not?
3. Why does Ub not increase significantly after a certain Iu?
4. What is the excitation current Iu when Ub= 200V? What % of nominal?
5. Without Ry, how else could excitation be supplied?
6. Summarize your observations from the experiment.

6. Safety Precautions

- Ensure all wiring is checked before powering on the system.
- Do not touch live terminals.
- Stop the system immediately in case of abnormal noises or overheating.
- Use appropriate PPE (gloves, goggles).

7. References

- Electrical Machines Lab Manual, Sivas University of Science and Technology
- IEEE Std. 11-2000: DC Machines
- Fitzgerald, Kingsley & Umans: *Electric Machinery*
- Laboratory-provided datasheets for Y-036 components

Experiment 4: Loaded Operation of Separately Excited D.C. Shunt Generator

1. Objective of the Experiment

The objective of this experiment is to operate a separately excited D.C. shunt generator under load and analyze the relationship between speed, load current, generated voltage, excitation current, and output voltage across the load.

2. Theoretical Background

A separately excited D.C. shunt generator has its field winding energized by an external voltage source independent of the armature circuit. When a prime mover (in this case, a 3-phase asynchronous motor) drives the armature, voltage is induced due to the rotating magnetic field. The load on the generator affects the armature voltage and current. As the load increases, the voltage typically drops due to armature reaction and internal resistance.

The generated voltage Ud, excitation voltage Uu, armature current Iu, and excitation current Iy are monitored under different loading conditions. This allows for understanding the performance characteristics of the generator under real operational conditions.

3. Materials Used

- Y-036/001: Energy unit experimental bench
- Y-036/003: Rail-type motor bench
- Y-036/023-A: D.C. shunt generator
- Y-036/015: Three-phase asynchronous motor
- Y-036/026: Three-phase asynchronous motor driver
- Y-036/006: D.C. power supply
- Y-036/066: 10–25000 Ω variable rheostat
- Y-036/052: 2-pole fuse switch
- Y-036/052: Tachometer (RPM meter)
- IEC plug cable

4. Procedure

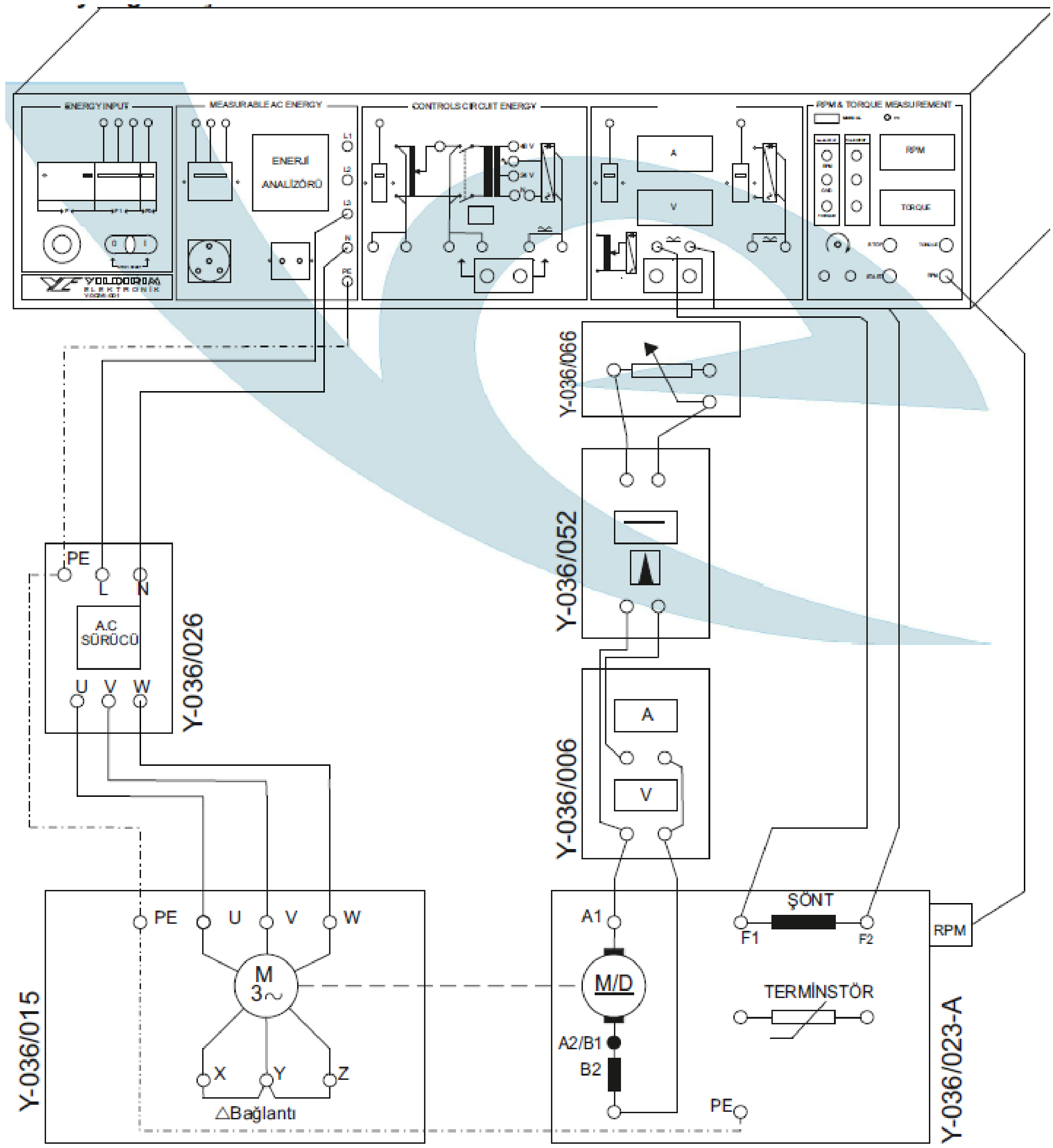

Fig 5.1

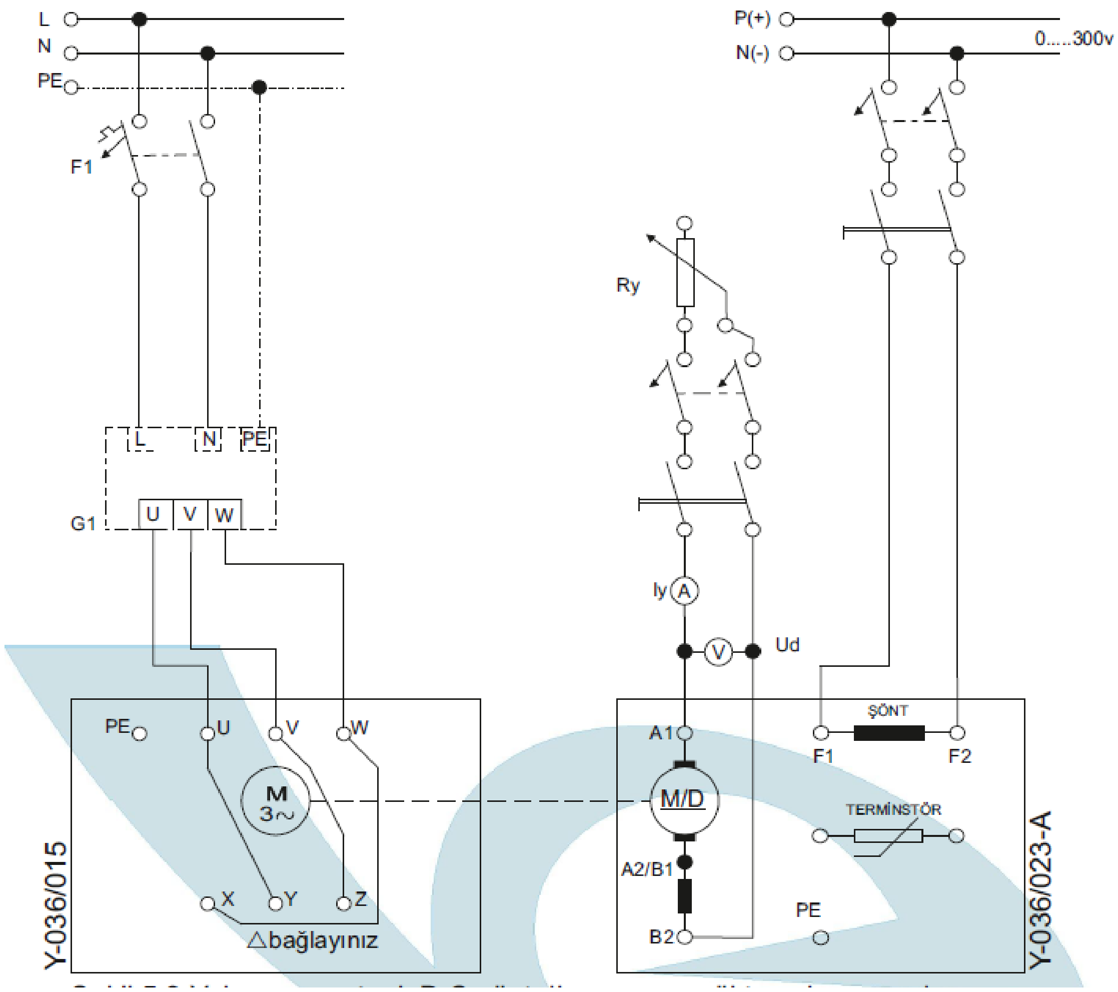

Fig 5.2

1. Set the frequency of the A.C. motor controller to nominal value (100 Hz) for rated RPM.
2. Run the asynchronous motor and generator setup to reach the rated speed.
3. Adjust the excitation voltage so that the D.C. generator reaches its no-load rated voltage. Record Ud,Iy,Uu,Iu.
4. Apply load in four incremental steps using the variable resistor:
   - 1st load: ~0.5× rated current
   - 2nd load: ~1.0× rated current
   - 3rd load: ~1.2× rated current
   - 4th load: same as 3rd, but short circuit the load momentarily to observe max drop Record values for each load case.
5. Maintain the motor speed constant using the asynchronous motor controller.
6. After each load step, record:
   - Generator Voltage Ud
   - Field Current Iy
   - Excitation Voltage Uu
   - Armature Current Iu
   - Speed n

5.Evaluation of Results

n	Ud	Iy	Uu	Iu	Explanation

- Plot the terminal voltage Ud vs load current Iu to observe the external characteristic curve.
- Analyze how Ud decreases with increasing Iu.
- Interpret changes in excitation current Iy and excitation voltage Uu under varying load.
- Use Ohm’s law to estimate internal resistance from observed voltage drops.
- Determine if generator behavior aligns with theoretical expectations of a separately excited D.C. generator.

6. Safety Precautions

- Do not operate the generator without load for prolonged periods.
- Avoid short circuiting the generator for more than a few seconds.
- Ensure all switches and cables are rated for the expected current.
- Use goggles and gloves during the experiment.
- Check all connections before energizing the system.

7. References

- Chapman, S.J., *Electric Machinery Fundamentals*, McGraw-Hill.
- Fitzgerald, A.E., *Electric Machinery*, McGraw-Hill.
- Laboratory Manual for Electrical Machines, Sivas University of Science and Technology.
- Manufacturer manuals of Y-036 series devices.

Experiment 5: No-Load Test of Self-Excited D.C. Shunt Generator

1. Objective of the Experiment

The objective of this experiment is to run the D.C. shunt generator under no-load condition and observe the remanent voltage. The relationship between the excitation current (Iu) and the terminal voltage (Ub) is analyzed to determine the no-load characteristic curve of the self-excited D.C. shunt generator.

2. Theoretical Background

Self-excited D.C. shunt generators utilize residual magnetism in the poles to initiate voltage generation. As the generator rotates, a small voltage (remanent voltage) appears across its terminals, causing a small current to flow through the shunt field winding. This current strengthens the magnetic field, resulting in higher generated voltage—a process known as cumulative excitation.

The no-load characteristic (also called open-circuit characteristic) is the relationship between the field current (Iu) and the terminal voltage (Ub) at constant speed. The shape of this curve depends on:

- Magnetic saturation of the core material
- Field resistance
- Speed of rotation

Understanding this characteristic helps in designing and evaluating excitation systems for generators.

3. Materials Used

- Energy unit test bench (Y-036/001)
- Rail motor base (Y-036/003)
- D.C. shunt generator (Y-036/023-A)
- Three-phase asynchronous motor (Y-036/015)
- Three-phase motor controller (Y-036/026)
- D.C. measurement unit (Y-036/006)
- Adjustable rheostat (50 Ω 10.000 W, Y-036/065)
- Tachometer (rpm measurement)
- Standard IEC plug cable, banana plugs

4. Procedure

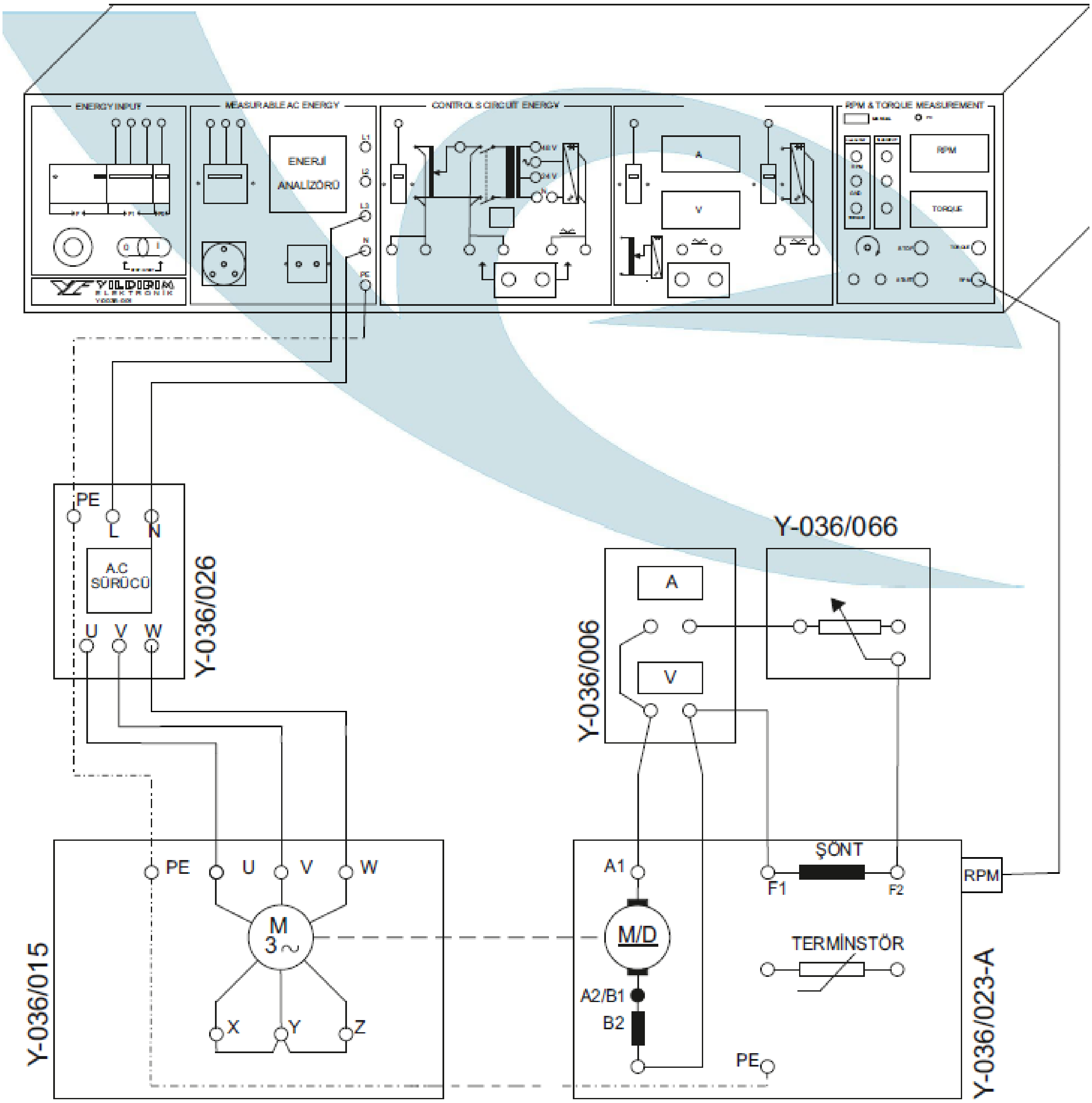

Fig 6.1

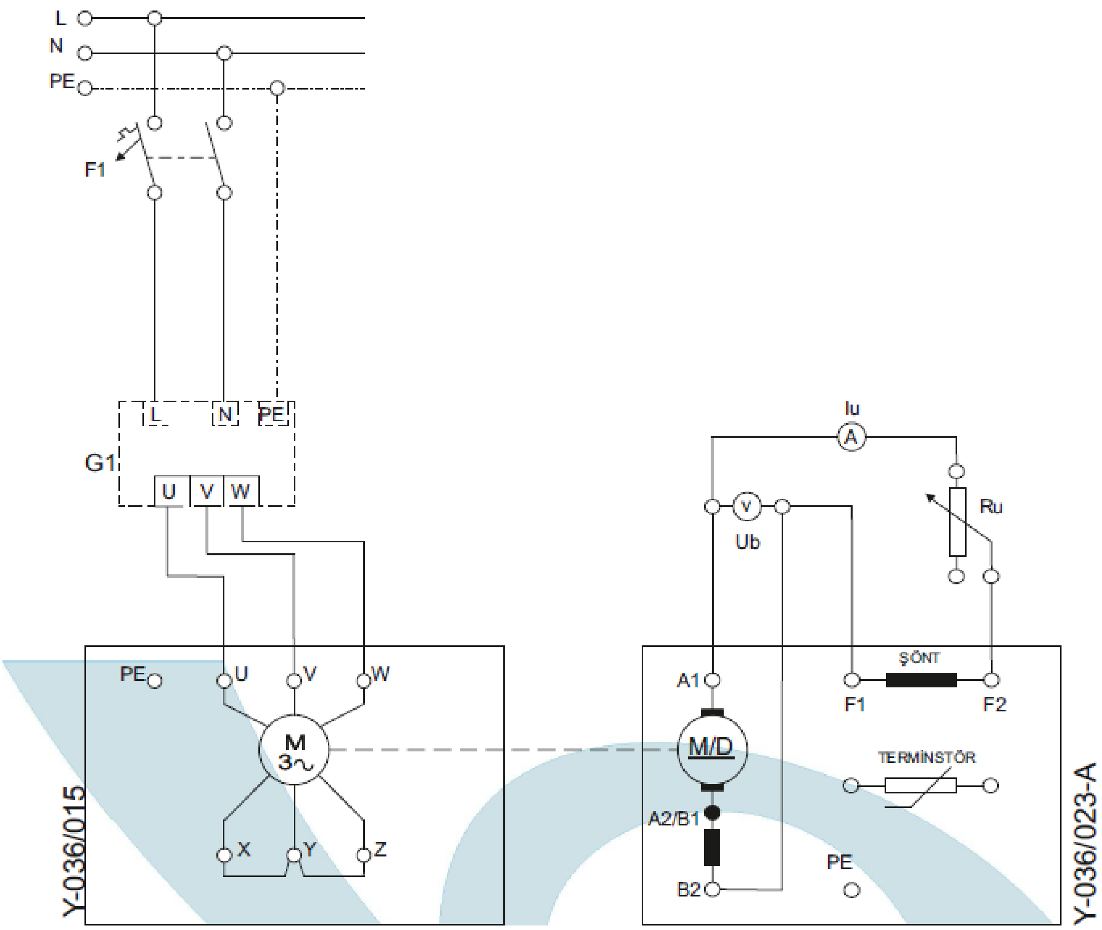

Fig 6.2

1. Connect the circuit as shown in Figure 6.1 and Figure 6.2.
2. Ensure the field rheostat is set to **maximum resistance** (open field circuit).
3. Run the three-phase induction motor using the motor controller and set the frequency to drive the generator at 1500 rpm.
4. Observe and record remanent voltage (Ub), excitation current (Iu = 0), and speed (n).
5. Gradually reduce the field rheostat resistance and record Ub, Iu, and n values for each step.
6. If the voltage begins to decrease unexpectedly, reverse the excitation current direction and repeat the measurements.
7. Continue until the field rheostat is at its **minimum resistance** (maximum field current).
8. Record final values and switch off the system.

5. Evaluation of Results

n(rpm)	Ud	Iu(A)	Explanation

- Plot the no-load characteristic curve: **Ub vs. Iu**
- Analyze how the excitation current affects the terminal voltage
- Determine the point of magnetic saturation
- Interpret the effect of residual magnetism on self-excitation
- Compare nominal values with observed behavior

6. Safety Precautions

- Ensure all connections are correctly made before energizing the circuit
- Do not touch live terminals during operation
- Handle the rheostat with care to avoid overheating
- Use appropriate PPE (goggles, gloves)
- Disconnect power supply before changing the circuit configuration

7. References

- Electrical Machines Laboratory Manual
- "Principles of Electric Machines and Power Electronics" by Wildi
- IEC Standards for Electrical Machines
- Manufacturer manuals for devices: Y-036/001, Y-036/015, etc.

Experiment 6: Loaded Operation of a DC Shunt Motor with a DC Controller

1. **Objective of the Experiment**

The objective of this experiment is to understand the structure and operation of a DC shunt motor controlled by a DC motor controller. The experiment aims to analyze the relationship between load, current, voltage, and rotational speed during loaded operation. By performing practical connections and measurements, students will gain hands-on experience in controlling a DC motor and interpreting its performance under load conditions.

2. Theoretical Background

A A DC shunt motor is a type of direct current motor in which the field winding is connected in parallel (shunt) with the armature winding. This configuration allows the motor to maintain a nearly constant speed under varying load conditions, making it suitable for applications requiring stable speed control.

In this experiment, a DC motor controller is used to regulate the voltage supplied to the motor, thereby controlling its speed and torque. The controller typically operates by adjusting the average voltage using techniques such as Pulse Width Modulation (PWM). By varying the duty cycle of the PWM signal, the effective voltage across the motor terminals changes, allowing precise speed control.

During loaded operation, the motor experiences an increase in torque demand, which causes a corresponding increase in current drawn by the armature. The motor's speed may slightly decrease due to increased load, but the shunt configuration helps mitigate this variation.

Key electrical parameters such as voltage (V), current (I), speed (N), and torque (T) are interconnected through fundamental DC motor equations. The mechanical power output $P=T\cdot\omega$, and the electrical power input $P=V\cdot I$, are monitored to evaluate motor efficiency and performance.

Understanding the dynamic behavior of the motor under different load conditions provides valuable insight into the design and operation of DC motor-driven systems.

3. Materials Used

- Experiment desk with integrated power supply unit (Energy Unit) – Y-036/001
- Rail-mounted motor platform – Y-036/003
- DC shunt machine – Y-036/023-A
- Magnetic powder brake – Y-036/024-A
- DC motor controller – Y-036/025
- DC measurement unit – Y-036/006
- Power cables with jack and IEC connectors

4. Procedure

1. Review the user manual of the DC motor controller and enter the necessary parameters as per the experimental setup. The controller should be pre-programmed for this experiment.
2. Do not exceed the rated (nominal) values of the DC motor for extended periods during loading.
3. Set up the experimental circuit as shown in Fig.6.1 and Fig.6.2.
4. Start the DC shunt motor using the DC motor controller. Adjust the motor to its nominal speed using the speed potentiometer (speed control knob).
5. Press the DISP/Fn button on the controller to view and monitor the motor speed and current on the display. Record these values.
6. Gradually apply mechanical load to the motor using the magnetic powder brake (dynamic load). Increase the load up to 25%–50% above the motor's rated power or current.
7. Observe and record the motor speed, armature current, and torque (Nm) under load.
8. At the final load point, cut off the load energy and observe the motor parameters immediately. Record the values.
9. Turn off the power supply and safely terminate the experiment.

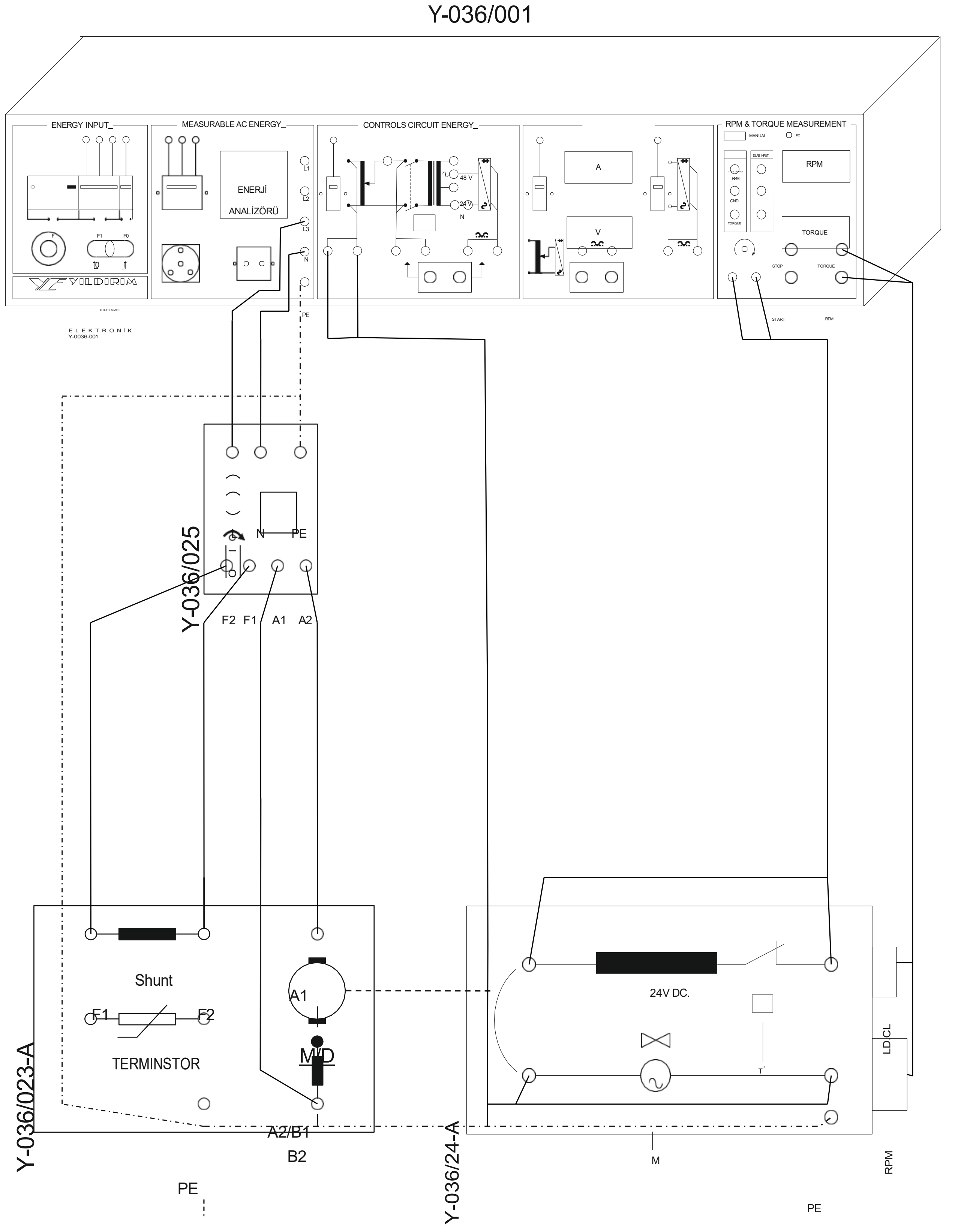

Fig.6.1: Experimental connection diagram for the loaded operation of a DC shunt motor with a DC controller.

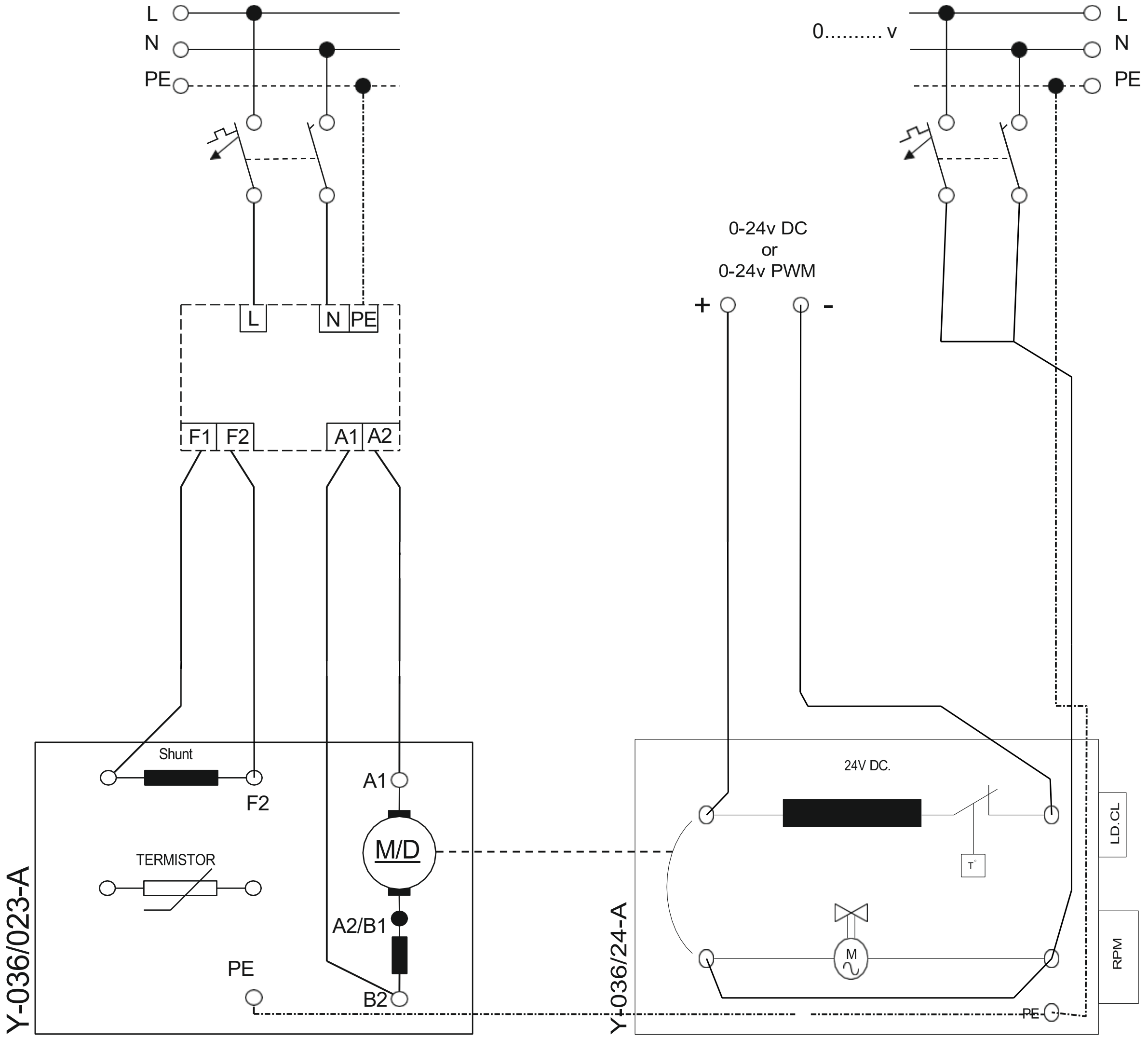

Fig.6.2: Loaded operation circuit diagram of a DC shunt motor with a DC motor controller.

5.Evaluation of Results

Tabulate the data obtained during the tests.

From Driver Display		Measured n (rpm)	Nm	Description
n (rpm)	I(Amp)			

Question 1: Explain the operating principle of the DC motor controller.

Question 2: What is the relationship between rotational speed (n) and load current (Im)? Explain the factors that influence this relationship.

Question 3: What are the advantages and disadvantages of using a DC motor controller? Explain.

Question 4: Change the acceleration and deceleration parameters in the controller, operate the motor both under load and no-load conditions, and explain your observations.

Question 5: What are the protection-related parameters defined in the controller? Identify and explain them.

Question 6: Explain your observations at the end of the experiment.

6. Safety Precautions

- Ensure that all electrical connections are properly made before powering on the system to prevent short circuits or equipment damage.
- Never touch live terminals or conductive parts while the system is energized. Always wait until the power is completely turned off before making any adjustments.
- Before modifying connections or changing motor/controller parameters, switch off the main power supply.
- Do not exceed the rated voltage, current, or speed of the DC motor during operation to avoid overheating or permanent damage.
- Use properly rated measuring instruments and place probes securely to prevent accidental contact or short circuits.
- Avoid prolonged operation at loads higher than the motor’s nominal values, as this may lead to overheating or mechanical failure.
- Keep hands dry and the working area free of liquids to reduce the risk of electric shock.
- Verify the settings of the DC motor controller (e.g., acceleration, deceleration, overload protection) before starting the experiment.
- Do not operate the equipment unattended during load testing or high-speed operation.
- In case of abnormal noise, excessive heat, or vibration, immediately shut down the system and inspect the motor and controller.

Experiment 7: No-Load Operation of a Single-Phase Transformer and Determination of the Transformation Ratio

1. Objective of the Experiment

The objective of this experiment is to analyze the no-load operation of a single-phase transformer, to understand the associated no-load losses, and to calculate the transformation (turns) ratio. Through this experiment, students will develop knowledge and practical skills related to transformer behavior under no-load conditions and the determination of its voltage ratio.

2. Theoretical Background

A transformer is an electrical device used to transfer electrical energy between two or more circuits through electromagnetic induction. In single-phase transformers, the primary and secondary windings are wound on a common magnetic core. When an alternating voltage is applied to the primary winding, it creates a time-varying magnetic flux that induces a voltage in the secondary winding according to Faraday's Law.

The no-load test (also known as the open-circuit test) is performed to evaluate the core losses (iron losses) of the transformer, which include hysteresis and eddy current losses in the core material. During this test, the secondary winding is left open, and the rated voltage is applied to the primary winding. Since there is no load connected to the secondary, the transformer draws only a small no-load current I_0, which consists of:

The magnetizing component I_m, which produces the magnetic flux in the core.The core loss component I_c, which accounts for the iron losses.

The power consumed during this test reflects the no-load losses of the transformer and is mostly due to the core. These losses are important for determining transformer efficiency.

Additionally, the transformation ratio (or turns ratio) k is defined as the ratio of primary voltage U_1 to secondary voltage U_2 under no-load conditions:

$$k = \frac{U_1}{U_2}$$

In Fig.7.1 and Fig.7.2, the experimental setup and circuit diagram show the measurement of input voltage U_1, input current I_0, and output voltage U_2 using a voltmeter, ammeter, and energy analyzer. This setup enables observation of transformer behavior without load and allows calculation of the transformation ratio and analysis of core losses.

3. Materials Used

- Experiment desk with integrated power supply unit (Energy Unit) – Y-036/001
- Rail-mounted motor platform – Y-036/003
- DC shunt machine – Y-036/023-A
- Magnetic powder brake – Y-036/024-A
- DC motor controller – Y-036/025
- DC measurement unit – Y-036/006
- Power cables with jack and IEC connectors

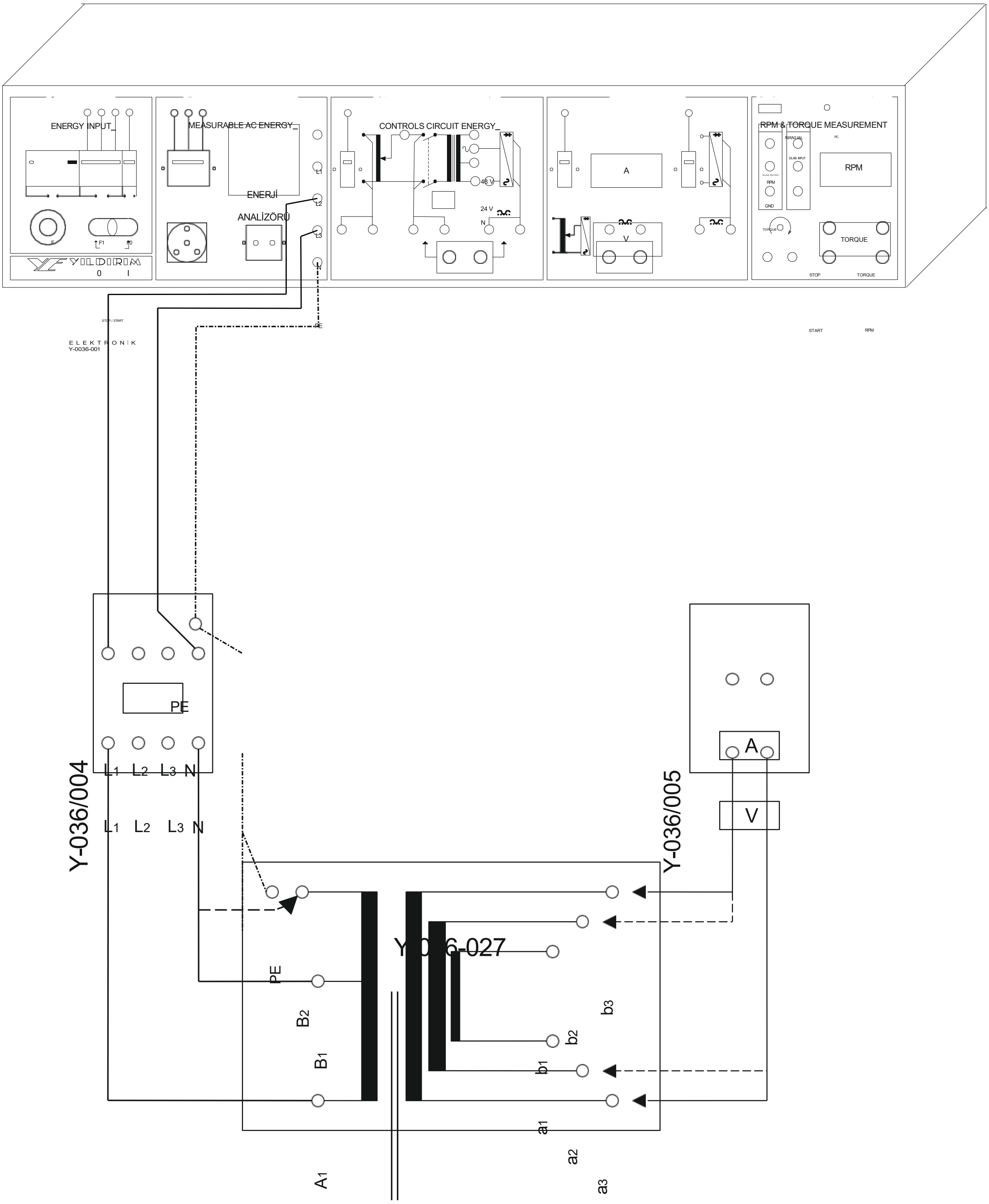

Fig.7.1 Experimental connection diagram for the no-load test of a single-phase transformer.

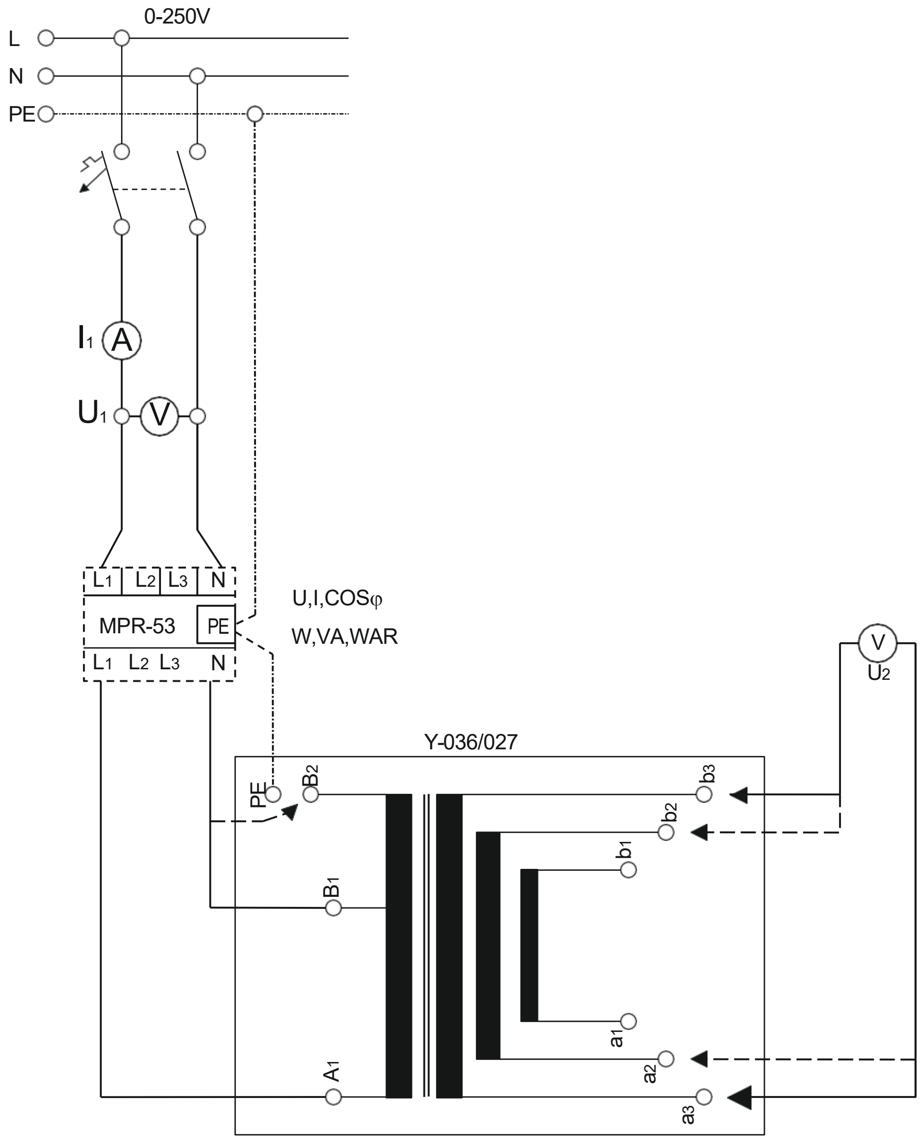

Fig.7.2 Circuit diagram of the no-load operation of a single-phase transformer.

4. Procedure

1. Check the nameplate (rating label) values of the transformer before starting the experiment. Note that if the transformer has two primary voltage ratings, the corresponding secondary voltage values are valid for the higher primary input voltage. The secondary voltage will vary depending on the primary voltage applied.
2. Set up the experimental connections as shown in Fig.7.1 and Fig. 7.2.
3. Close the switch and fuse in the primary circuit, then gradually apply AC voltage to the primary winding, starting from 0 V and increasing in steps up to the rated (nominal) voltage of the transformer.
4. At each voltage step, record the measurements.
5. Use a multimeter with milliampere (mA) sensitivity if the current or power factor readings are not visible on the energy analyzer due to low no-load current.
6. If the adjustable AC voltage from unit Y-036/001 is not sufficient to reach the required transformer primary voltage, use unit Y-036/002 as an alternative power source.
7. Note the measured values in a results table for each voltage step. These values will be used later to calculate the transformer's transformation ratio and analyze no-load performance.
8. After completing all measurements, switch off the power supply and safely disconnect the system.

5. Evaluation of Results

Tabulate the data obtained during the tests.

U_1	I_1	U_2	Energy Analyzer						Description
			U	I	cosφ	W	VA	VAR	

Question 1: When the nominal voltage U1 is applied to the primary side of the transformer and the secondary side is unloaded, what power is observed on the energy analyzer? Define and explain.

Question 2: Based on the measured values of U1 and U2, calculate the transformation (turns) ratio of the transformer.

Question 3: Using the measured values of voltage U, current I1, and the data from the energy analyzer, plot the no-load characteristic curve of the transformer.

Question 4: How can the number of turns (windings) of a transformer be determined? Explain.

Question 5: Explain the operating principle of a transformer.

Question 6: Describe your observations at the end of the experiment.

6. Safety Precautions

- Ensure that all electrical connections are properly made before powering on the system to prevent short circuits or equipment damage.
- Never touch live terminals or conductive parts while the system is energized. Always wait until the power is completely turned off before making any adjustments.
- Before modifying connections or changing motor/controller parameters, switch off the main power supply.
- Do not exceed the rated voltage, current, or speed of the DC motor during operation to avoid overheating or permanent damage.
- Use properly rated measuring instruments and place probes securely to prevent accidental contact or short circuits.
- Avoid prolonged operation at loads higher than the motor's nominal values, as this may lead to overheating or mechanical failure.
- Keep hands dry and the working area free of liquids to reduce the risk of electric shock.
- Verify the settings of the DC motor controller (e.g., acceleration, deceleration, overload protection) before starting the experiment.
- Do not operate the equipment unattended during load testing or high-speed operation.
- In case of abnormal noise, excessive heat, or vibration, immediately shut down the system and inspect the motor and controller.

Experiment 8: Measurement of the Primary and Secondary Winding Resistances of a Single-Phase Transformer

1. **Objective of the Experiment**

The objective of this experiment is to gain knowledge and practical skills related to measuring the winding resistances of the primary and secondary circuits of a single-phase transformer using a DC source. Through this measurement, students will understand the importance of resistance values in transformer performance and efficiency.

2. **Theoretical Background**

A transformer consists of two or more windings (coils) wound around a magnetic core. These windings—primary and secondary—are typically made of copper or aluminum wire, and like any conductor, they possess a certain amount of electrical resistance. This winding resistance causes copper losses (I^2R losses) during transformer operation, which reduce the overall efficiency of the device.

To determine these resistances, a direct current (DC) source is used. Unlike alternating current (AC), which induces impedance due to inductance, DC flows uniformly and allows for the pure ohmic resistance of the winding to be measured without the influence of inductive reactance.

In this experiment, a low-voltage adjustable DC power supply is connected across the winding being tested (either primary or secondary). The voltage (V) across the winding and the current (I) passing through it are measured using a voltmeter and an ammeter, respectively. The resistance R is then calculated using Ohm's Law: R=IV

For accurate results:

- The voltage should be increased gradually, and measurements should be taken at low current levels to prevent heating of the windings.
- The resistance values measured in this way reflect only the DC resistance of the copper wire and do not account for core losses or impedance effects.

The measurement is performed separately for both the primary and secondary windings, and for transformers with multiple secondary taps, each tap must be tested individually. This data is essential for analyzing transformer losses, temperature rise, and performance during load operation.

3. **Materials Used**

- Energy-integrated experimental bench – Y-036/001
- DC measurement unit – Y-036/006
- Single-phase transformer – Y-036/027 or Y-036/028
- Banana plug cables and IEC plug cable
- Multimeter (Avometer)

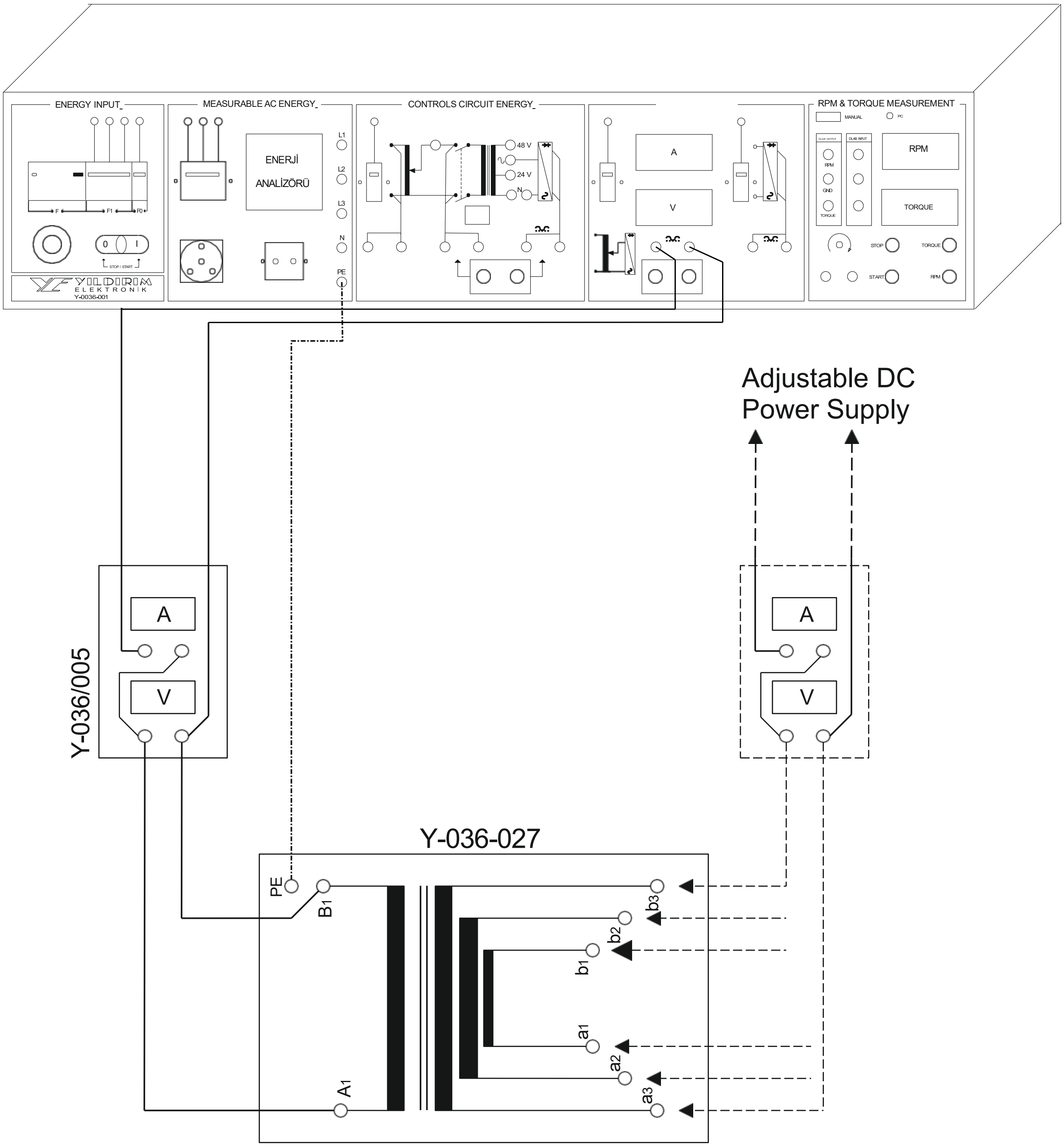

Fig.8.1 Experimental connection diagram for measuring the primary and secondary winding resistances of a single-phase transformer.
∗ The experimental connection will be applied first to the primary and then to the secondary in sequence.

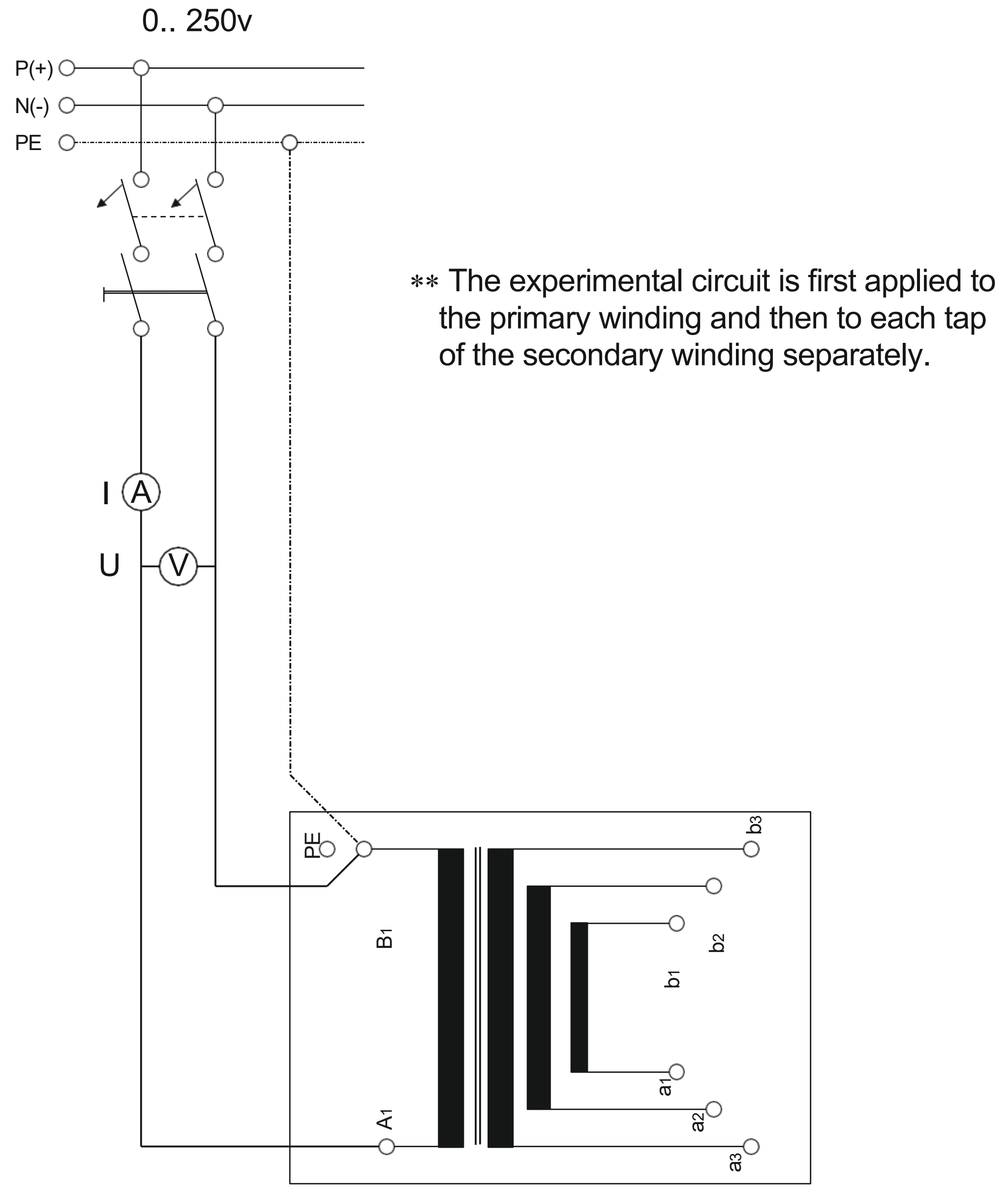

Fig.8.2 Circuit diagram for measuring the primary and secondary winding resistances of a single-phase transformer

4. Procedure

1. Caution: Do not allow the current through the primary or secondary windings to exceed their rated (nominal) DC current values. Avoid operating at nominal current levels for extended periods.
2. Set up the experimental circuit as shown in Fig.8.1 and Fig.8.2.
3. Connect the adjustable DC power supply to the transformer windings with the output voltage set to 0 V.
4. Gradually increase the voltage in steps from 0 V, and observe the current passing through the primary winding. Continue increasing the voltage until the nominal current value is reached.
5. At each step, observe and record the voltage U and current I values accurately.
6. After reaching the target values, turn off the power supply and safely disconnect the circuit.
7. Repeat all of the above steps individually for each tap (terminal) of the secondary winding. For each tap, gradually apply DC voltage and observe the current behavior.
8. At every position and tap, record the corresponding voltage U and current I measurements.
9. Once all measurements are completed, turn off the DC supply.
10. Using an ohmmeter, measure the DC resistance of each tap in the primary and secondary windings separately, and record the resistance values.

5. Evaluation of Results

Tabulate the data obtained during the tests.

PRIMARY				SECONDARY				Description
U_1	I_1	Calculated R	Measured R	U_2	I_2	Calculated R	Measured R	

Question 1: Why was a DC power supply used in the winding resistance measurement experiment? What would happen if an AC source were used instead? Explain.

Question 2: Considering the nominal current ratings of the windings for AC operation, why was current limitation applied when using DC? What would happen if the nominal operating voltage were applied directly as DC? Explain.

Question 3: Using the measured voltage U and current I values from the experiment, calculate the winding resistances of the transformer using the formula $R = U/I$

Question 4: What would the winding resistances be if AC were applied to the transformer? What causes the change in resistance under AC? Explain.

Question 5: What is the difference between the resistance values measured with an ohmmeter and those calculated from $R = U/I$during the experiment? Explain the reasons for any differences.

Question 6: Describe your observations at the end of the experiment.

7. Safety Precautions

- Ensure that all electrical connections are properly made before powering on the system to prevent short circuits or equipment damage.
- Never touch live terminals or conductive parts while the system is energized. Always wait until the power is completely turned off before making any adjustments.
- Before modifying connections or changing motor/controller parameters, switch off the main power supply.
- Do not exceed the rated voltage, current, or speed of the DC motor during operation to avoid overheating or permanent damage.
- Use properly rated measuring instruments and place probes securely to prevent accidental contact or short circuits.
- Avoid prolonged operation at loads higher than the motor's nominal values, as this may lead to overheating or mechanical failure.
- Keep hands dry and the working area free of liquids to reduce the risk of electric shock.
- Verify the settings of the DC motor controller (e.g., acceleration, deceleration, overload protection) before starting the experiment.
- Do not operate the equipment unattended during load testing or high-speed operation.
- In case of abnormal noise, excessive heat, or vibration, immediately shut down the system and inspect the motor and controller.

7. References

Experiment 9: Determination of the Polarity of a Single-Phase Transformer

1. **Objective of the Experiment**

The objective of this experiment is to gain knowledge and practical skills related to identifying the terminal markings of a single-phase transformer and understanding the importance of polarity. The experiment focuses on determining the correct winding polarities through voltage addition and subtraction methods, which are essential for parallel operation and proper transformer connection.

2. **Theoretical Background**

In single-phase transformers, polarity refers to the relative instantaneous direction of the voltages in the primary and secondary windings. Correct polarity is essential in applications where transformers are connected in parallel or in specific phase relationships, such as in multi-phase systems. Improper polarity can result in short circuits, phase opposition, or malfunctioning of the system.

Transformers have winding terminals that are often marked (e.g., A1–B1 for primary, a1–b1 for secondary). However, in some cases—especially for older or unidentified transformers—these markings may be missing or incorrect. Therefore, polarity testing becomes necessary to identify the correct terminal pairs and confirm whether the winding polarities are additive or subtractive.

Two common methods used to determine polarity are:

Additive Polarity (U_1 + U_2): When the voltages of the primary and secondary windings are in phase, the measured voltage across a series-aiding connection (primary and secondary in series) will be the sum of the two voltages.

Subtractive Polarity (U_1 – U_2): When the voltages are out of phase, the measured voltage across the same configuration will be the difference between the two voltages.

In this experiment:

The nominal AC voltage is applied to the primary winding.

The secondary voltage (U_2) is measured for each tap (U_{21}, U_{22}, U_{23}).

By connecting the secondary in series with the primary and measuring the resulting voltage using a voltmeter, polarity is determined based on whether the result is U1 +U2 or U1−U2.

Fig.9.1 and Fig.9.2 illustrate both the additive and subtractive configurations and help visualize how the voltage behavior indicates winding polarity.

3. **Materials Used**

- Energy-integrated experimental bench – Y-036/001
- A.C. measurement unit – Y-036/005
- Single-phase transformer – Y-036/027 or Y-036/028
- Banana plug cables and IEC plug cable
- Avometer (Ohmmeter / Multimeter)

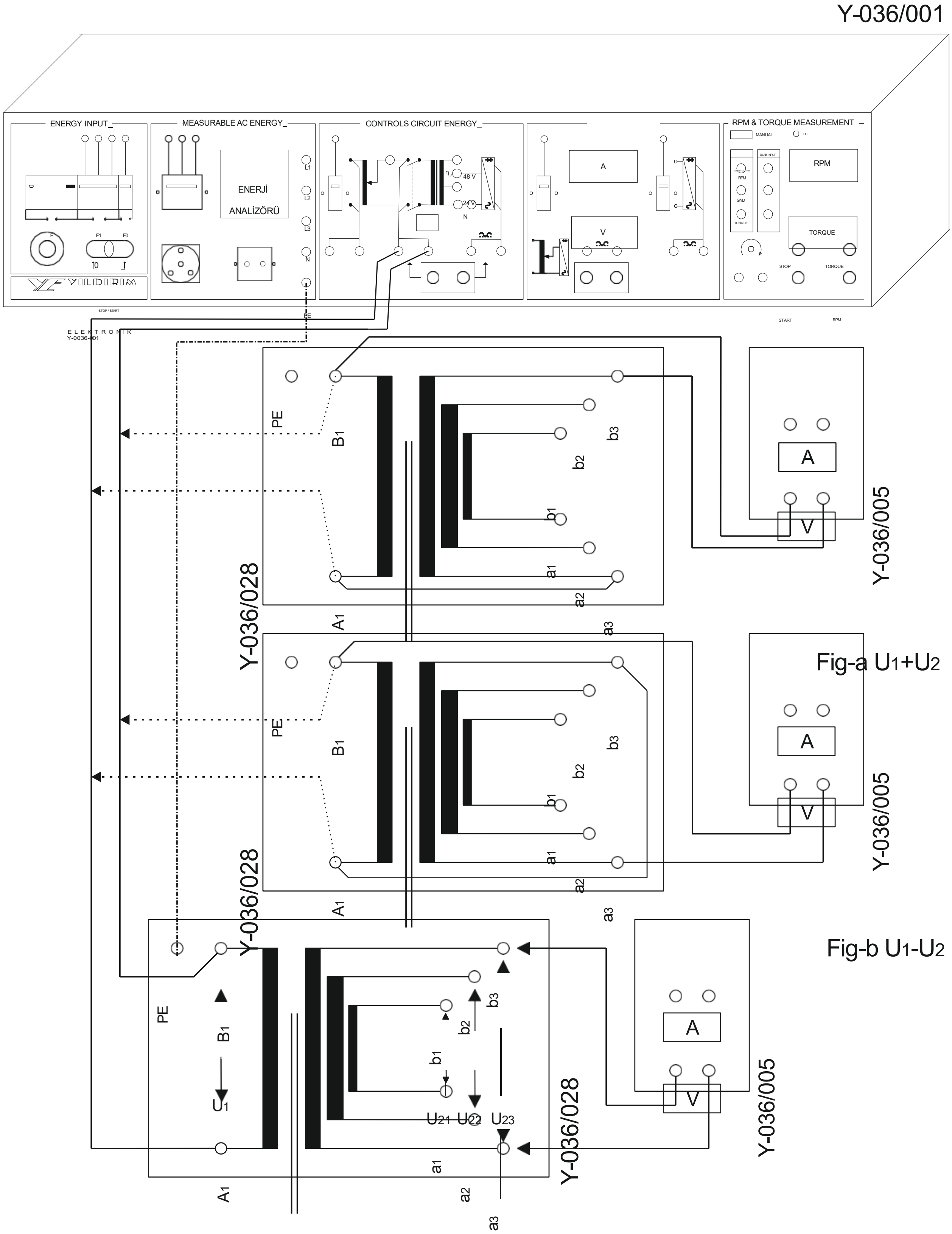

Fig.9.1 Experimental connection diagram for determining the polarity of a single-phase transformer.

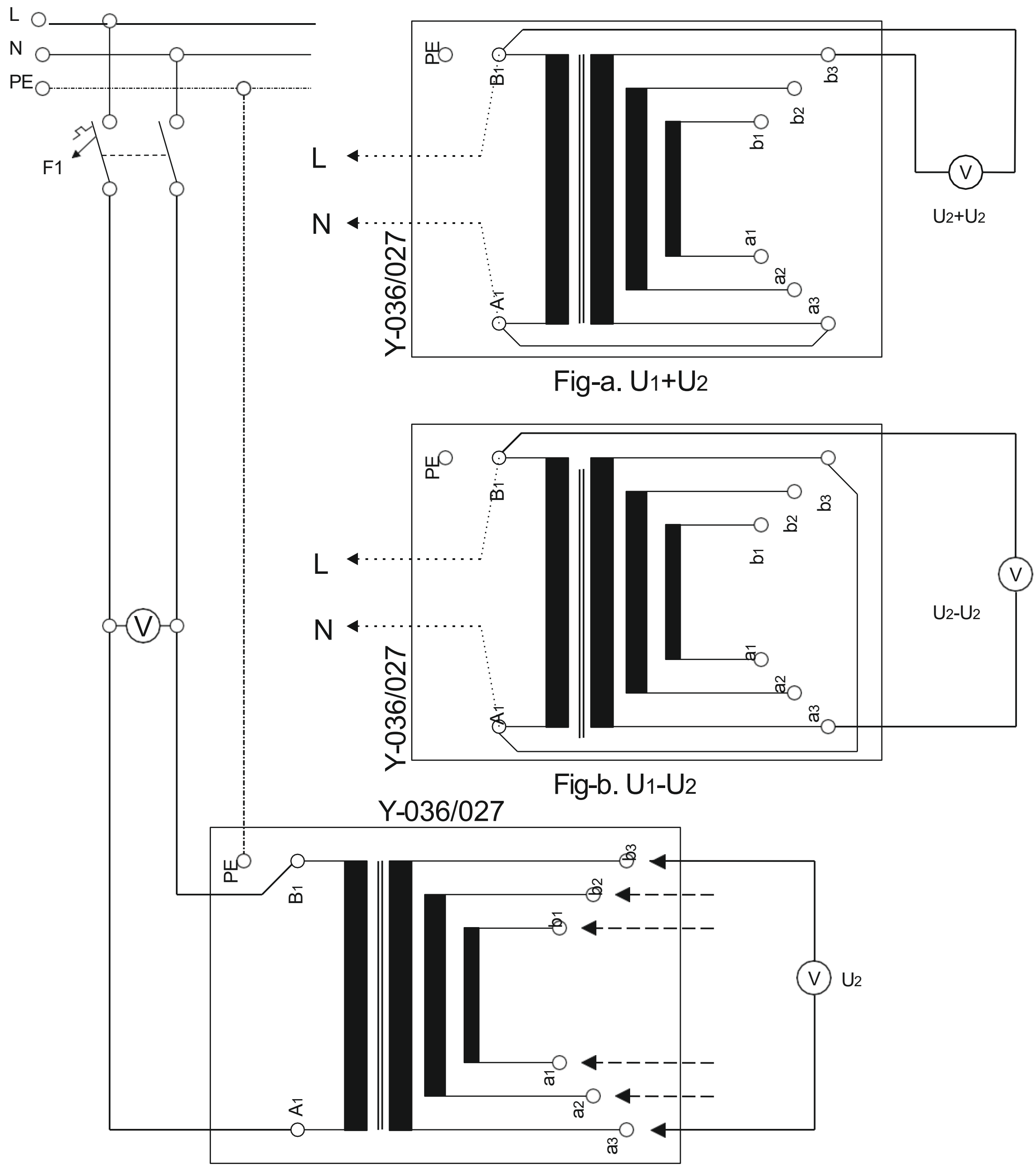

Fig.9.2 Circuit diagram for determining the polarity of a single-phase transformer.

4. Procedure

1. Note: In polarity testing, the marked terminals on the transformer panel may be incorrect or the transformer may be unmarked. Always verify polarity manually. Use an adjustable power supply for controlled voltage application.
2. Set up the experimental circuit as shown in Fig.9.1 and Fig.9.2.
3. Apply the nominal AC voltage to the primary winding of the transformer using the adjustable power source. Measure and record the input voltage U1.
4. Measure and record the output voltages from each secondary tap separately as U21 , U22, and U23.
5. Configure the circuit as shown in Fig. 9.1a (Additive: U1 +U2). Energize the transformer and measure the voltage shown on the voltmeter. Record the value.
6. Repeat the additive polarity configuration for each secondary tap separately. Record the measured voltmeter values for each configuration.
7. Based on the results from step 6, determine the transformer winding polarities by identifying whether the measured voltage is additive (U1 +U2) or not. Use this to confirm the correct terminal pairings (e.g., A1–B1, a1–b1, a2–b2, a3–b3).
8. Reconfigure the circuit according to Fig.9.1b (Subtractive: U1 −U2), and repeat the same steps as done for the additive configuration.

9. Observe and compare the measured voltages to further validate winding polarities.
10. Once all measurements are completed, switch off the power supply and safely disconnect the system.

5. Evaluation of Results

Tabulate the data obtained during the tests.

U_1	U_{21}	U_{22}	U_{23}	U_1+U_2	U_1-U_2	Description

Question 1: In the configurations shown in Fig-a and Fig-b, did the voltmeter display any readings? Analyze the values that were observed.

Question 2: Based on the results of the experiment with the connection in Fig-a, identify the primary and secondary winding input/output terminals of the transformer (A1–B1 and a1–b1, a2–b2, a3–b3).

Question 3: Based on the experiment performed using the connection in Fig-b, identify the primary and secondary winding input/output terminals of the transformer.

Question 4: Do the terminal pairs identified in Question 2 match those in Question 3? Explain whether they are consistent. If not, discuss the possible reasons for the discrepancy.

Question 5: Where are the results obtained from transformer polarity identification used in practice? What are the benefits of knowing transformer polarity? Explain.

Question 6: Describe your observations at the end of the experiment.

6. Safety Precautions

- Ensure that all electrical connections are properly made before powering on the system to prevent short circuits or equipment damage.
- Never touch live terminals or conductive parts while the system is energized. Always wait until the power is completely turned off before making any adjustments.
- Before modifying connections or changing motor/controller parameters, switch off the main power supply.
- Do not exceed the rated voltage, current, or speed of the DC motor during operation to avoid overheating or permanent damage.
- Use properly rated measuring instruments and place probes securely to prevent accidental contact or short circuits.
- Avoid prolonged operation at loads higher than the motor's nominal values, as this may lead to overheating or mechanical failure.
- Keep hands dry and the working area free of liquids to reduce the risk of electric shock.
- Verify the settings of the DC motor controller (e.g., acceleration, deceleration, overload protection) before starting the experiment.
- Do not operate the equipment unattended during load testing or high-speed operation.
- In case of abnormal noise, excessive heat, or vibration, immediately shut down the system and inspect the motor and controller.

7. References

Experiment 10: Examination of the Autotransformer

1. **Objective of the Experiment**

The objective of this experiment is to examine the no-load and loaded operation of an autotransformer and to develop knowledge and practical skills related to its performance. The experiment also aims to compare the advantages and disadvantages of autotransformers with conventional two-winding transformers.

2. **Theoretical Background**

An autotransformer is a type of transformer that shares part of its winding between the primary and secondary circuits. Unlike two-winding transformers, autotransformers use a single continuous winding that acts as both the primary and the secondary, with a tapping point that defines the secondary output. The key benefits of autotransformers include:

- Smaller size and lighter weight for the same power rating
- Higher efficiency due to reduced copper losses
- Cost-effectiveness in applications requiring small voltage differences

However, their disadvantages are:

- Lack of electrical isolation between input and output
- Reduced safety in certain fault conditions

In this experiment, both no-load and loaded operations are investigated. Measurements include voltages, currents, power factor, and power (active, reactive, and apparent) at both the input and output sides, using energy analyzers. The effect of loading is observed through an adjustable rheostat. Fig.10.1 and Fig.10.2 show the experimental setup and circuit schematic for testing the autotransformer.

3. **Materials Used**

- Experiment Energy-integrated experimental bench – Y-036/001
- A.C. measurement unit – Y-036/005
- Three-phase autotransformer – Y-036/031
- Energy analyzer – Y-036/004
- Double-pole fused switch – Y-036/052
- Adjustable rheostat (50 Ω, 1000 W) – Y-036/066
- Banana plug cables, IEC plug cable, Avometer

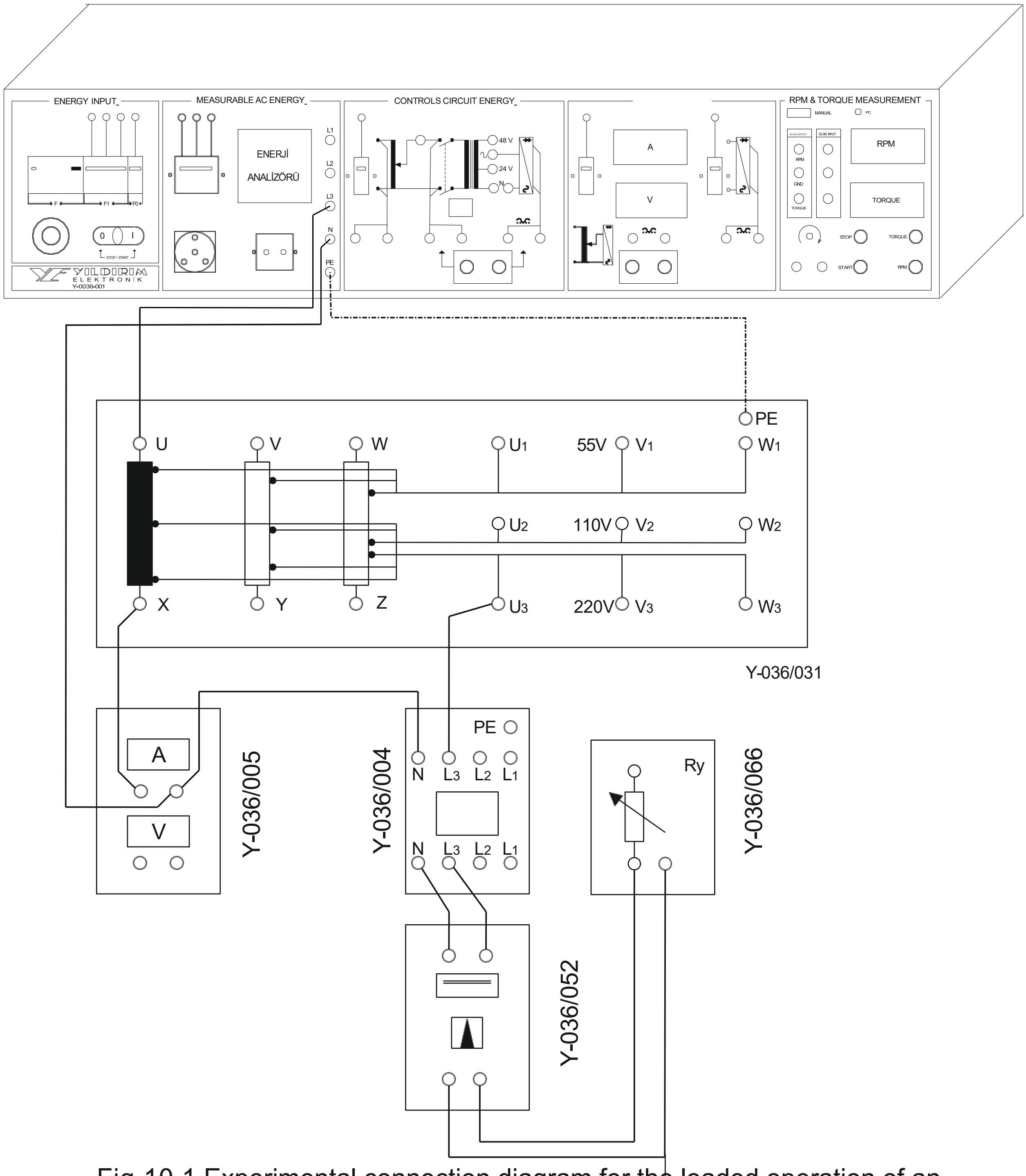

Fig.10.1 Experimental connection diagram for the loaded operation of an autotransformer.

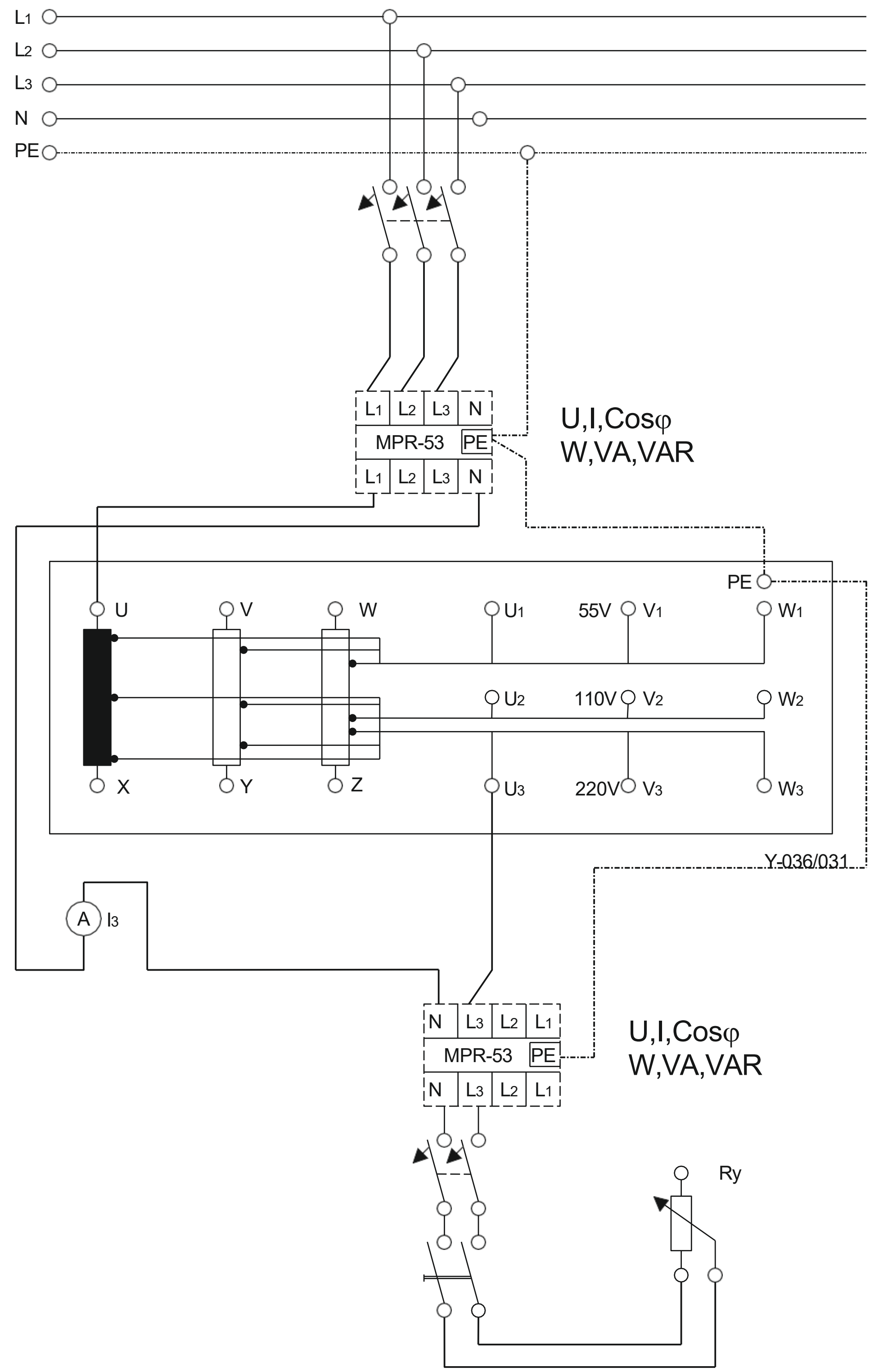

Fig.10.2 Circuit diagram of the autotransformer under load operation.

4. **Procedure**

1. Note: The transformer used in this experiment is a three-phase autotransformer (Y-036/031). You may analyze the entire three-phase structure using star (Y) connection, or only one phase as shown in the diagrams.
2. Connect the circuit as shown in Fig.10.1 and Fig.10.2.
3. Apply nominal voltage to the input of the autotransformer while the double-pole switch is open and the transformer is under no-load condition.
4. Observe and record the following:
   4.1. Input energy analyzer readings: $U_1, I_1, \cos\phi_1, W_1, VA_1, VAR_1$
   4.2. Output energy analyzer readings: $U_2, I_2, \cos\phi_2, W_2, VA_2, VAR_2$
   4.3. Current I_3

5. Close the double-pole switch and load the autotransformer using the adjustable rheostat (Ry).
6. Gradually increase the load up to 125% of the nominal power rating of the autotransformer.
7. At each load level, record the same parameters listed above from both input and output sides, as well as the current I3.
8. After completing the measurements, set the load to zero, switch off the power, and safely terminate the experiment.

5. Evaluation of Results

Tabulate the data obtained during the tests.

Input Energy Analyzer						Output Energy Analyzer						I_3	Description
U_1	I_1	$Cos\varphi_1$	W_1	VA_1	VAR_1	U_2	I_2	$Cos\varphi_2$	W_2	Va_2	VAR_2		

Question 1: Define the autotransformer and briefly explain its working principle.

Question 2: What are the advantages and disadvantages of an autotransformer? Explain.

Question 3: What is the relationship between the currents I_1, I_2, and I_3 observed in the experiment? Explain.

Question 4: Is the equality $P_1 = P_2$ valid? Explain the reason.

Question 5: Describe your observations at the end of the experiment.

6. Safety Precautions

- Ensure that all electrical connections are properly made before powering on the system to prevent short circuits or equipment damage.
- Never touch live terminals or conductive parts while the system is energized. Always wait until the power is completely turned off before making any adjustments.
- Before modifying connections or changing motor/controller parameters, switch off the main power supply.
- Do not exceed the rated voltage, current, or speed of the DC motor during operation to avoid overheating or permanent damage.
- Use properly rated measuring instruments and place probes securely to prevent accidental contact or short circuits.
- Avoid prolonged operation at loads higher than the motor’s nominal values, as this may lead to overheating or mechanical failure.
- Keep hands dry and the working area free of liquids to reduce the risk of electric shock.
- Verify the settings of the DC motor controller (e.g., acceleration, deceleration, overload protection) before starting the experiment.
- Do not operate the equipment unattended during load testing or high-speed operation.
- In case of abnormal noise, excessive heat, or vibration, immediately shut down the system and inspect the motor and controller.