



KARABÜK ÜNİVERSİTESİ

MÜHENDİSLİK VE DOĞA BİLİMLERİ FAKÜLTESİ

ELEKTRİK-ELEKTRONİK MÜHENDİSLİĞİ

ELECTROMECHANICAL ENERGY CONVERSION LABORATORY EXPERIMENT SHEETS

WEEK 1

LABORATORY GENERAL RULES AND OCCUPATIONAL SAFETY

LABORATORY GENERAL RULES AND OCCUPATIONAL SAFETY

Purpose

This sheet has been prepared to provide a safe and efficient working environment for the Electromechanical Energy Conversion Laboratory course.

Laboratory General Rules

- Maximum attention and care must be shown in all work carried out with electrical energy in the laboratory.
- Direct contact with energized circuits must be strictly avoided. All connections must be made while the energy is disconnected, and energy must not be applied until the accuracy of the connections is confirmed by the laboratory supervisor.
- Necessary safety distances must be maintained when approaching equipment carrying high voltage or high current.
- When any electrical failure, abnormal situation (burning smell, smoke, sparks, excessive heating, etc.) or dangerous situation is detected, the laboratory supervisor must be informed immediately.
- Extreme caution must be exercised when working with rotating machinery in the laboratory. Loose clothing, long hair, or jewelry can get caught in the rotating parts of machines and cause serious injuries. Attention must be paid to this matter.
- It is strictly prohibited to touch or interfere with moving parts while machines are running.
- Laboratory work areas must be kept neat and clean at all times. At the end of experimental work, all equipment used must be returned to their proper places.
- It is strictly prohibited to consume food and beverages, chew gum, or keep any food items in the laboratory environment.
- Personal items (bags, coats, etc.) are strictly not allowed to be kept on the experiment set or experiment work table.
- Before coming to experiments, the relevant week's experiment sheet must be examined. The purpose of the experiment, equipment to be used, connection diagrams and measurement methods, and theoretical knowledge about the experiment must be studied.
- No work is allowed in the laboratory without the supervision of the laboratory supervisor.

- Damaged, faulty, or equipment whose functionality is in doubt must not be used, and the laboratory supervisor must be informed.
- All operations that may cause physical or electrical damage to equipment must be avoided.
- Students who are not in the laboratory within the first 5 minutes from the start of the laboratory class will not be admitted to the class. This application will be implemented to maintain the integrity of the course and to ensure attention and discipline in the classroom.”
- Each student is obliged to have the experiment sheet for the relevant week's experiment with them during laboratory classes. Students who do not bring their sheets will not be admitted to the experiment.”

Every student in the laboratory environment must comply with the rules stated above without exception. Failure to comply with these rules may result in accidents that may lead to serious consequences or disciplinary penalties”



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WEEK 2: INTRODUCTION TO LABORATORY EQUIPMENT

Laboratory Equipment

Purpose: Introduction of equipment to be used in experiments.



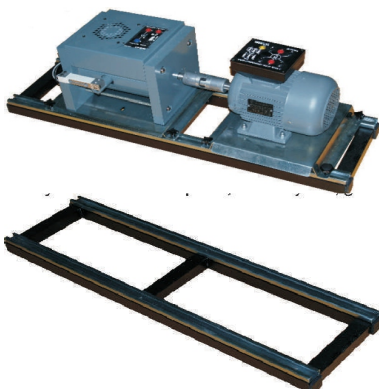
“Energy Unit Experiment Table”

- The experiment table energy unit consists of five sections. After energizing with the energy input section and protection and control, each section is used independently from each other.
- The experiment table energy unit is multifunctional with necessary power sources, measurement and control units.
- Can be used by placing modules or motor stands on the table.



3-Phase Portable Energy Unit

- Energy unit with fuse-protected adjustable AC/DC energy output.
- 3 -phase adjustable AC 0-435V measured output
- Adjustable DC 0-520V measured output



Rail Motor Stand

- Rail motor stand suitable for use on experiment table
- Suitable for use of all compatible sledge motors in the training set
- Suitable for coupled use of two motors or dynamos.



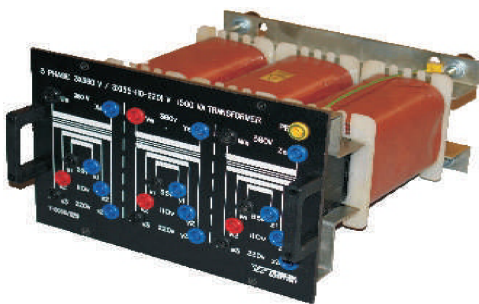
Monofaze Transformatör

P=300 vA
Input = 220-380v 50/60 Hz
Output = 12 - 24 - 36v 50/60 Hz



Monofaze Transformatör

- P=1500 vA
Input = 380v 50/60 Hz
Output = 55 - 110 - 220v 50/60 Hz



Trifaze Transformatör

P= 1500 vA
Input = 3x380v 50/60 Hz
Output = 3x(55 - 110 - 220v) 50/60 Hz



Magnetic Powder Brake

- U= 0-24 VDC, I=1.2 A, 30 Nm, n=4000 rpm, 220v 50/60 Hz
- "With 4-pulse speed sensor holder"
- Suitable for use with sledge motor base and rail motor stand.



AC Measure

-220-240 V 50/60 Hz
AC beslemeli
- 0-15A AC measure
- 0-750V AC measure



DC measure

- 220-240 V 50/60 Hz
- AC supply
- 0-15A DC measure
- 0-750V DC measure



Trifaze Asenkron Motor

- $P = 1.1 \text{ kW}$, $U = 220-380 \text{ V}$, $f = 50 \text{ Hz}$, $n = 1380 \text{ rpm}$
- $I = 4.6/2.7 \text{ A}$ $\cos\phi = 0.8$
- With 4-pulse speed sensor holder
- Suitable for use with sledge motor base and rail motor stand



AC Motor Sürücü

- Supply : L-N $U = 220-240 \text{ V}$ 50/60 Hz AC
- Output : L-L $U = 200-240 \text{ V}$ AC 3 Faz
- Parameter input via driver.
- Parameter and control position monitoring from LCD screen
- Speed (frequency), torque, motion and brake control
- PC communication
- PC driver control with D-LAB interface

NOTE: In this experiment week, introduction of all other equipment in the laboratory will also be made in addition to the equipment to be used in experiments.



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ENERJİ ÜNİTELİ DENEY MASASININ TANITIMI

WEEK 3: INTRODUCTION TO ENERGY UNIT EXPERIMENT TABLE

Purpose:

Introduction of the sections of the energy unit experiment table and demonstration of its use.

Energy Unit Experiment Table



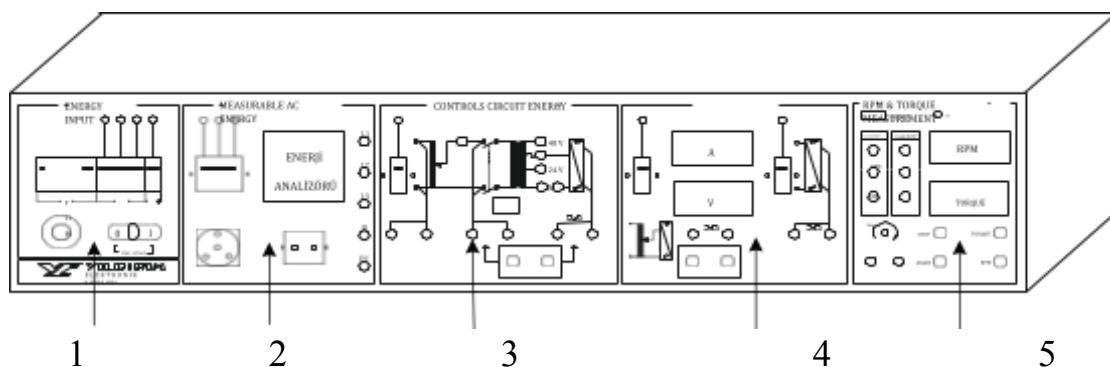
The main unit of the electrical machines training set, supplied with 380-415 V, 50-60 Hz and 3-phase AC energy. The AC/DC energies required in all experiments are used in various values; fixed adjusted, protected and measured with banana socket 1-3 phase and IEC socket. RPM and torque measurement are also performed in the unit.

The unit will be examined in 2 parts:

- A) Energy Unit Sections
- B) Use of the Energy Unit and Table

A) Energy Unit Sections:

The energy unit consists of 5 sections. Usage and features are given with explanations.



1-Energy Input: Leakage current protection relay, three-phase main fuse, control circuit fuse protected. With emergency stop button, control twin start-stop button, energy available and running signal lamps. For the system to operate, the 3-phase energy plug is plugged into the appropriate socket, and the fuse and control elements are brought to the ON (operating) position to energize the entire unit.

2-Measured AC Energy: Three-phase fuse protected, signal lamp, energy analyzer with current transformer (U, I, $\cos\phi$, W, VA, VAR, THD, etc.) measured, banana socket, three-phase and single-phase socket output. When energy is given to the system without relation to other sections, it is used by bringing its fuse to the ON position.

3-Control Circuit Energy: Single-phase fuse protected, signal lamp, banana socket output. 0-250 V AC adjustable banana socket output, adjustable AC input 0-24-48 V AC banana socket output. Also 0-24-48 V DC selectable adjustable banana socket output. When energy is given to the system without relation to other sections, any fixed and adjustable energy part can be used simultaneously by bringing the fuse to the ON position.

4-DC Energy: Fuse protected, signal lamp, 0-250 V DC adjustable banana socket output, fuse protected, signal lamp 250 V DC fixed banana socket output. When energy is given to the system without relation to other sections and fuses are brought to the ON position, they can be used independently or simultaneously.

5-RPM and Torque Measurement: ON/OFF lighted switch, PC-manual selector switch magnetic brake control, torque and speed measurement outputs, signal inputs banana socket and connector. When energy is given to the system without relation to other sections, direct speed measurement is made with the speed sensor structure in all machines in the training set. Also, magnetic powder brake (dynamic load) control and torque measurement are made with the help of the load cell on it.

B) Use of the Energy Unit and Table:

- All sections in the energy unit are used after energy input is made and the energy input section is in the ON position.
- Each section is controlled with its own fuse protection, switch button, etc. command.
- Measurement sections in the sections only concern their own sections, not used as measurement units for other sections.
- Energy of the same or different value and structure cannot be given to any of the sections in the energy unit under any circumstances. It causes serious accidents and damage.
- According to the experiment to be performed, necessary modules are placed in module carriers. In this placement, modules should be placed considering the connection of cables without confusion.
- IEC sockets at the bottom of the energy unit should generally be used for digital measuring device supply, small power devices can also be supplied when necessary.
- Do not put motors directly on the table surface of the energy unit, always connect motors on sledge stands and use them by installing the protection part. You can also use suitable modules on the table.
- You can mount and use the cable hanger in the energy unit on the side you want.



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WEEK 4: FINDING POLARITY AND TRANSFORMATION RATIO IN SINGLE-PHASE TRANSFORMERS

FINDING POLARITY AND TRANSFORMATION RATIO IN SINGLE-PHASE TRANSFORMERS

Experiment Purpose

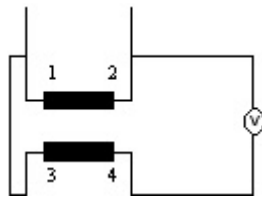
To gain skills in determining the winding terminals of a single-phase transformer, understanding the importance of polarity and finding it, and calculating the transformation ratio.

Theoretical Information

The polarity of a transformer indicates the instantaneous directions of coil voltages. Knowing the polarity of a transformer provides great benefit in connecting transformers to each other or connecting various windings of a transformer among themselves. If primary and secondary terminals carrying separate indices are mounted side by side, this transformer is called "negative (-) polarity"; if primary and secondary terminals carrying the same index are brought out diagonally, these transformers are called "positive (+) polarity" transformers.

"(+) Polarity / (-) Polarity Method"

In this method, one terminal each of the primary and secondary windings of the transformer is connected, and the other terminals are connected to the voltmeter as shown in the figure. If the value read from the voltmeter is the difference between primary and secondary voltages, terminal No. 1 is named P1, terminal No. 2 P2, terminal No. 3 S1, and terminal No. 4 S2. This is called (-) polarity. If the value read from the voltmeter is the sum of primary and secondary voltages, in this case, terminal No. 1 is named P1, terminal No. 2 P2, terminal No. 3 S2, and terminal No. 4 S1. This is called (+) polarity. In both polarity situations, the terminals of the transformer are found.



Şekil 1. Polarite tespiti

Process Steps:

- Apply the nominal voltage to the primary circuit of the transformer (U_1) and record the primary voltage.
- Make the connection in Figure 2.a, energize the transformer and record the value shown by the voltmeter.
- Determine the terminals (A1-B1- and a1-b1-, a2-b2, a3-b3) of the transformer used in the experiment as a result of applying the additive (U_1+U_2) polarity in Figure 2.a.

	U₁	U₂	U₃	Polarite
1				
2				
3				
4				



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WEEK 5: NO-LOAD TEST IN SINGLE-PHASE TRANSFORMERS

Open Circuit Test Purpose

Finding core losses in single-phase transformers and examining the variation of magnetizing current and iron losses with voltage.

Theoretical Information

Open circuit test; is called core loss test, iron loss test, no-load operation test or idle operation test. This test is performed to determine core losses and magnetizing reactance under rated conditions. In this test, rated voltage at rated frequency is applied to the primary winding and the secondary winding terminals are left open (no-load). Voc, Ioc and Poc values are measured from the primary side.

$$\begin{aligned} PF &= \cos \theta = \frac{P_{oc}}{V_{oc} I_{oc}} \\ \theta &= \cos^{-1} \frac{P_{oc}}{V_{oc} I_{oc}} \\ Y_E &= G_c - jB_M \\ G_c &= \frac{1}{R_c} \\ B_M &= \frac{1}{X_M} \end{aligned}$$

	V _{oc}	I _{oc}	P _{oc}	R _c	cosQ	X _m
1						



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WEEK 6: SHORT CIRCUIT TEST IN SINGLE-PHASE TRANSFORMERS

Short Circuit Test Purpose

Finding copper losses of primary and secondary windings of a single-phase transformer and determining short circuit voltage.

Theoretical Information

Short circuit test is called impedance or copper loss test. The purpose of this test is to determine power losses (copper losses) and impedances of windings in the transformer. Winding losses affect the efficiency of the transformer, leakage impedance affects short circuit current and output voltage. Since the input voltage is very small during the short circuit test, a negligible current flows from the excitation branch. If the excitation current is neglected, the entire voltage drop in the transformer is associated with the series elements in the circuit.

$$\begin{aligned} PF = \cos\theta &= \frac{P_{sc}}{V_s I_{sc}} \\ Z_{SE} &= \frac{V_s}{I_{sc}} = \frac{V_s I_{sc} \cos\theta}{I_{sc}^2} \\ Z_{SE} &= R_{eq} + jX_{eq} \end{aligned}$$

	V_{sc}	I_{sc}	P_{sc}	R_{eq}	Cos Q	X_{eq}
1						
2						
3						
4						
5						

Hesaplamalar



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*WEEK 7: STRUCTURE OF ASYNCHRONOUS MOTORS, EXAMINATION OF NAMEPLATE VALUES
AND DELTA-STAR CONNECTIONS*

Experiment Purpose

Definition of structure, parts, operating principle of asynchronous motors, delta-star connections and examination of motor nameplate values.

Theoretical Information

Asynchronous motors rotate by applying two-three phases to the windings in their stators to obtain a rotating magnetic field. For this, windings belonging to each phase are placed in stator slots at 120° angles. If there is a 120° phase difference between the currents applied to these windings (three-phase alternating current), a moving rotating magnetic field is created on the inner surface of the stator. The speed of this rotating field depends on the number of poles of the stator and the frequency of the applied current. This rotating field is called synchronous speed n_s

$$n_s = \frac{120 \times f}{2P}$$

In asynchronous motors, the speed at which the stator rotating field rotates is called synchronous speed n_s . The rotor never rotates at synchronous speed. Because when the stator rotating field and rotor bars are in the same direction, the rotor conductor bars will not be cut by the stator field, EMF will not be induced in the rotor bars, and therefore no torque will occur. For this reason, the rotor speed will lag behind the synchronous speed. Therefore, the rotor must rotate at a speed less than the speed of the rotating field.

Slip in terms of speed: $-S = n_s - n_r$

Slip in percentage : $\% S = \frac{n_s - n_r}{n_s} \cdot 100$



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*WEEK 8: CHANGING ROTATION DIRECTION OF 3-PHASE ASYNCHRONOUS MOTORS AND
CHANGING MOTOR SPEED VIA DRIVE*

Experiment Purpose

To change the rotation direction in 3-phase asynchronous motors and enable motor speed adjustment via drive.

Theoretical Information

The rotation direction of 3-phase asynchronous motors depends on the direction of the rotating magnetic field formed in the stator windings of the motor. The rotation direction of this magnetic field is determined according to the phase sequence of the 3-phase voltage feeding the motor. To change the rotation direction of the motor, this phase sequence needs to be reversed. This process is usually done by changing the places of any two phases from the 3-phase line going to the motor. For example, if the motor works in the forward direction according to the R-S-T phase sequence, it is sufficient to change the places of the R phase and S phase (S-R-T) to run it in the reverse direction.

The speed of 3-phase asynchronous motors depends on the speed of the rotating magnetic field formed inside the motor. The speed of this magnetic field is directly determined by the frequency of the electricity feeding the motor. Since the electricity coming from the grid usually has a constant frequency (for example 50 Hz), the motor speed is also constant. Drives (VFD) convert the fixed frequency electricity they receive from the grid into variable frequency and variable voltage according to the motor's needs. When a drive increases the output frequency, the motor's rotating magnetic field moves faster and the motor speed also increases. Conversely, when it decreases the frequency, the magnetic field slows down and the motor also slows down.



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WEEK 9: MEASUREMENT OF STATOR PHASE RESISTANCE VALUES IN 3-PHASE ASYNCHRONOUS MOTORS

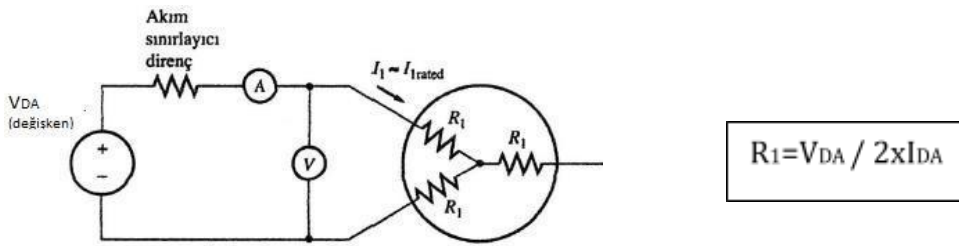
Experiment Purpose

Finding stator phase resistances of 3-phase asynchronous motors in delta and star connections.

Theoretical Information

Another method for finding stator resistances is the measurement method with ohmmeter. This method will be used in the experiment.

DA Deneyi



Şekil 1. DA deney şeması

V _{DC}	I _{DC}	R ₁



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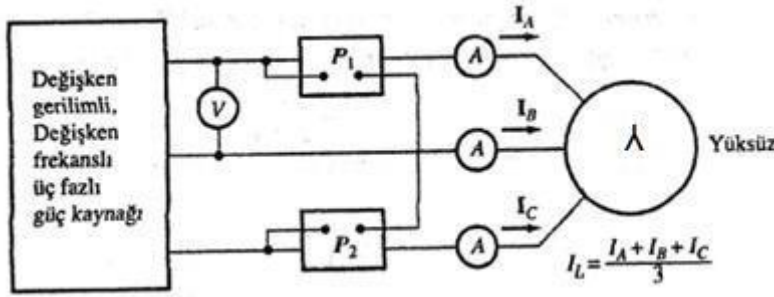
WEEK 10: NO-LOAD OPERATION TEST OF 3-PHASE ASYNCHRONOUS MOTORS

Experiment Purpose

To find core losses and core parameters in 3-phase asynchronous motors.

Theoretical Information

Nominal voltage is applied during no-load operation of the motor. In asynchronous motors, slip is very small during no-load operation. During no-load operation, the motor draws current of 15%-50% of the nominal current from the grid depending on the motor structure. The no-load operation test of the motor measures the rotational losses of the motor and provides information about the magnetizing current. In this test, the input power measured by measuring instruments should be approximately equal to rotational losses and stator copper losses. Since rotor current I_2 is quite small, rotor copper loss can be neglected.



$$P_{SCL} = 3I_L^2 R_1$$
$$P_{in} = P_{SCL} + P_{core} + P_{FW} + P_{misc}$$
$$Z_{eq} = \frac{V}{I_L \phi_{nl}}$$
$$Z_{eq} \cong X_1 + X_m$$

I_A	I_B	I_C	V_T	P_{in}



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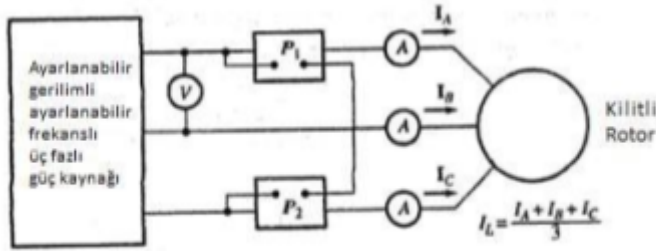
SHORT CIRCUIT (LOCKED ROTOR) TEST OF 3-PHASE ASYNCHRONOUS MOTORS

Experiment Purpose

Finding copper losses and equivalent circuit parameters in 3-phase asynchronous motors.

Theoretical Information

In the locked rotor test, the rotor is kept stationary (blocked) to prevent the rotor from moving. A voltage is applied to the motor from an adjustable voltage source until the rated current value is reached, and current, voltage and power values are measured. In this test, since the rotor does not move, the slip is 1.



$$PF = \cos\theta = \frac{P_{in}}{\sqrt{3}V_T I_L}$$
$$Z = \frac{V_\phi}{\underline{I}} = \frac{V_\phi}{\sqrt{3}I_L} = R_{LR} + jX_{LR}$$
$$R_{LR} = R_1 + R_2$$
$$X_{LR} = X_1 + X_2 \quad (X_1 = X_2)$$

I _A	I _B	I _C	V _T	P _{in}