SAFETY RULES

1. Please don’t touch any live parts.
2. Never use an electrical tool in a damp place.
3. Don’t carry unnecessary belongings during performance of practicals (like water bottle, bags etc).
4. Before connecting any leads/wires, make sure power is switched off.
5. In case of an emergency, push the nearby red color emergency switch of the panel or immediately call for help.
6. In case of electric fire, never put water on it as it will further worsen the condition; use the class C fire extinguisher.

Fire is a chemical reaction involving rapid oxidation (combustion) of fuel. Three basic conditions when met, fire takes place. These are fuel, oxygen & heat, absence of any one of the component will extinguish the fire.

If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, otherwise you might make the problem worsen.

The letters and symbols are explained in left figure. Easy to remember words are also shown.

Don’t play with electricity, Treat electricity with respect, it deserves!
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<td>3. Dahlander Motor</td>
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<td>10</td>
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<td>Operation and Characteristics of:</td>
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</tbody>
</table>
LAB SESSION 01

OBJECTIVE
To determine the turns ratio of a transformer, also determine the polarity of transformer windings for their parallel operation.

APPARATUS
✓ Two Single Phase Transformers (T1 & T2)
✓ Ammeter
✓ Voltmeter

THEORY

Turns Ratio:
Transformers provide a simple means of changing an alternating voltage from one value to another, keeping the apparent power $S$ constant.

For a given transformer, the turns ratio can be found out using the relation.

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P} = a$$

If $a > 1$; The transformer is step down, otherwise step up.

Transformer Polarity:
When we speak "the polarity" of transformer windings, we are identifying all of the terminals that are the same polarity at any instant of time. "Polarity marks" are employed to identify these terminals. These marks may be black dots, crosses, numerals, letters, or any other convenient means of showing which terminal are of the same polarity. In our case, we use black dots. The black dots, as shown in the figure, indicate that for a given instant in time: when 1 is positive with respect to 2, then 3 is positive with respect to 4.
The identification of polarity becomes essential when we operate the two transformers in parallel. Otherwise if terminals of unlike polarity connected to the same line, the two secondary windings would be short circuited on each other with a resulting excessive current flow.

Suppose we have two transformers T1 & T2, having terminals H1, H2 (HV) & X1, X2(LV) as shown in figure 2. The transformers in fig 2 are so marked that if the H1’s are connected to one primary line and the H2’s to the other primary line then the X1’s should be connected to the same secondary line and X2’s to the remaining secondary line.

Figure 2: Two transformers connected for parallel operation

If the transformer terminals are arranged as shown in fig 3a, the transformer is said to have additive polarity and if arranged as shown in fig 3b, the transformer is said to have subtractive polarity.

Figure 3: Standard polarity markings of transformers (a) additive polarity (b) subtractive polarity
If the polarity of the transformer is not known, it may be determined by the test connections shown in figure 4. Here low voltage side terminals may be temporary marked as $X_A$ and $X_B$ as shown in figure. Adjacent terminals are then connected and a voltmeter is connected across the other two terminals $H_1$ and $X_B$. Any convenient voltage is then applied to the high voltage winding of the transformer. If the voltmeter reads less than the value of the applied voltage, the polarity is subtractive and the terminals $X_A$ & $X_B$ may be marked as the $X_2$ and $X_1$ terminals, respectively.

![Figure 4: Connection for checking the polarity of a transformer](image)

**PROCEDURE**

**Finding out Turns Ratio:**
1. Apply 220V AC to the primary of transformer $T_1$ through autotransformer
2. Now measure $V_s$ using voltmeter.
3. Now calculate turns ratio “$a$” and tabulate in observation column.
4. Repeat for transformer $T_2$.

**Finding out Turns Ratio:**
1. Make connections according to the given circuit fig 4 for $T_1$ and find out the polarity.
2. Make connections according to the given circuit fig 4 for $T_2$ and find out the polarity.
3. Now connect the two transformers according to the figure 2.

**OBSERVATION**
The turns ratio for transformer $T_1$ is found to be $a =$ ____________
The turns ratio for transformer $T_2$ is found to be $a =$ ____________
Mark the dot (•) on the given two transformers, also connects the two with the buses using pencil.

**RESULT:**
The transformers ratio & polarity of the two transformers found out and parallel operation of single phase transformer fully understood.
EXERCISE:

You are given the different types of transformers used in a typical power system; distinguish among the following types of transformers.

a. Generator transformer  
b. Unit transformer  
c. Auxiliary transformer  
d. Station transformer  
e. Interconnecting transformer  
f. Distribution transformer
LAB SESSION 02

TITLE:
Study the types of Standard Explosion Protection Enclosures for Electrical Equipment.

THEORY

Various types of enclosures for electrical machines and other electrical equipment are used to prevent electrical apparatus from igniting the surrounding atmosphere when energized.

TYPES OF EXPLOSION PROTECTION:

Define the following terms as per Standards:

1. Flameproof Enclosures – Ex protection type ‘d’

2. Increased Safety – Ex protection type ‘e’

3. Intrinsic Safety – Ex protection type ‘i’
4. Pressurized or Purged – Ex protection type ‘p’

5. Oil Immersion – Ex protection type ‘o’

6. Powder Filled – Ex protection type ‘q’

7. Non-Sparking and Restricted Breathing – Ex protection type ‘n’
8. **Special Protection – Ex protection type ‘S’**

9. **Moulded /Encapsulated – Ex protection type ‘m’**

**EXERCISE:**
A) Electric motors can also be classified according to environment and cooling methods. Following classifications are made;

- g. **Drip-proof motors**
- h. **Splash-proof motors**
- i. **Totally enclosed**
  - i. *Totally enclosed, non ventilated motors (TENV)*
  - ii. *Totally enclosed, fan cooled motors (TEFC)*
  - iii. *Totally enclosed, Air over (TEAO)*
  - iv. *Totally enclosed, Blower Cool (TEBC)*
- j. **Explosion-proof motors**

Explain the above classifications.

B) Distinguish among the following terms:

- a. **Ignition Temperature**
- b. **Flash point**
- c. **Explosive limits**
LAB SESSION 03(a)

TITILE

THEORY
Hazardous areas are locations where the potential for fire or explosion exists because of gases, dust or easily ignitable fibers in the atmosphere. In North America, Hazardous Areas are separated by classes, divisions and groups to define the levels of safety required for equipment installed in these locations.

*Classes* define the general form of materials in the atmosphere.

*Divisions* define the possibility of the presence of flammable materials.

*Groups* classify the exact flammable nature of the material.

CLASSIFICATIONS

<table>
<thead>
<tr>
<th>The type of flammable material is classified as follows :</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASSES</strong></td>
</tr>
<tr>
<td>Class I</td>
</tr>
<tr>
<td>Class II</td>
</tr>
<tr>
<td>Class III</td>
</tr>
</tbody>
</table>

In the petroleum industry, we are mainly concerned with Class 1.

<table>
<thead>
<tr>
<th><strong>DIVISIONS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Division 1, Division 1:</td>
</tr>
<tr>
<td>Division 2, Division 2:</td>
</tr>
</tbody>
</table>
## GROUPS

<table>
<thead>
<tr>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups A</td>
</tr>
<tr>
<td>Groups B</td>
</tr>
<tr>
<td>Groups C</td>
</tr>
<tr>
<td>Groups D</td>
</tr>
<tr>
<td>Groups E</td>
</tr>
<tr>
<td>Groups F</td>
</tr>
<tr>
<td>Groups G</td>
</tr>
</tbody>
</table>
LAB SESSION 03 (b)

TITLE

THEORY

Hazardous areas are locations where the potential for fire or explosion exists because of gases, dust or easily ignitable fibers in the atmosphere. In Europe and countries outside North America, classification of hazardous area is different and is as follows;

- **Zones** are used to define the probability of presence of flammable materials.
- **Protection types** denote the level of safety for the device. (Ref. Experiment No. 3).
- **Groups** classify the exact flammable nature of the material. These groups are different than American Groups.
- **Temperature Identifications** convey the maximum surface of the apparatus based on 40º C ambient.

CLASSIFICATIONS

Study and complete the following tables

<table>
<thead>
<tr>
<th>ZONES (Degree of “Risk”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 0</td>
</tr>
<tr>
<td>Zone 1</td>
</tr>
<tr>
<td>Zone 2</td>
</tr>
<tr>
<td>Zone 21</td>
</tr>
<tr>
<td>Zone 22</td>
</tr>
<tr>
<td>NON-HAZARDOUS AREA</td>
</tr>
</tbody>
</table>
Gas Grouping
The gas and vapor mixtures are classified as shown in below.

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>Representative Gas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
</tr>
<tr>
<td>Group IIA</td>
<td></td>
</tr>
<tr>
<td>Group IIB</td>
<td></td>
</tr>
<tr>
<td>Group IIC</td>
<td></td>
</tr>
</tbody>
</table>

In addition to the zones (defining probability of occurrence of flammable mixture) and Gas Groups (defining type of flammable gas), the European Standard also has a Temperature Classification.

- The external surfaces of explosion proof equipment must not exceed the temperature whereby they may be liable to become source of ignition for the surrounding atmosphere.
- According to ignition temperature gases and vapours are divided into six temperature classes as follows:

<table>
<thead>
<tr>
<th>TEMPERATURE CODES</th>
</tr>
</thead>
<tbody>
<tr>
<td>T 1</td>
</tr>
<tr>
<td>T 2</td>
</tr>
<tr>
<td>T 3</td>
</tr>
<tr>
<td>T 4</td>
</tr>
<tr>
<td>T 5</td>
</tr>
<tr>
<td>T 6</td>
</tr>
</tbody>
</table>

The surface temperature classification and gas grouping are the primary safety considerations. A major secondary parameter is protection against the ingress of solid bodies and liquid. In some cases the degree of IP protection forms part of the standard requirement of the explosion protection method. Where apparatus is used in dirty or wet conditions the resistance to ingress contributes to the reliability of explosion protection in that electrical faults within the apparatus are often the result of water ingress.
EXERCISE:
  
  A) What are the different insulation classes? Also give their temperature ranges.

  B) Define the following terms:
     
     a. Ambient temperature  
     b. Hot spot temperature  
     c. Temperature rise  
     d. Surface temperature (defined in above standards)

A 75kW motor, insulated class F operates at full load in an ambient temperature of 32 °C. If the hottest spot temperature is 125 °C, does the motor meet the temperature standards?
**LAB SESSION 04**

**TITLE**  
Design of Electrical Equipment – Level of Ingress Protection ("IP Rating")

**THEORY**  
Three digits are used to denote the level of ingress protection that a piece of electrical equipment meets. (Third digit is commonly omitted). It is denoted as IP followed by two digits e.g. **IP 55**. Here the first digit specifies protection against ingress of solids whereas the second digit specifies protection against ingress of liquids.

Complete the following tables.

<table>
<thead>
<tr>
<th>IP</th>
<th>First Number – Protection against Solid Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IP</th>
<th>Second Number – Protection against Liquid Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
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<td>3</td>
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<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
IP | Third Number – Protection against Mechanical Impacts
--- | ---
1
2
3
4
5
6

For example: **IP 23 denotes:**

<table>
<thead>
<tr>
<th>If 1st IP number is...</th>
<th>and the 2nd IP number is...</th>
<th>Then the IP rating is...</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (protection against solid objects)</td>
<td>3 (protection against liquids)</td>
<td><strong>IP 2 3</strong></td>
</tr>
</tbody>
</table>

(An enclosure with this designation is protected against penetration of solid objects greater than 12mm and against spraying water.)

**EXERCISE**

- **What is the dictionary meaning of word “Ingress”?**
  
  ____________________________________________________________
  ____________________________________________________________
  ____________________________________________________________

- **IP 123 denotes?**
  
  ____________________________________________________________
  ____________________________________________________________
  ____________________________________________________________
  ____________________________________________________________
  ____________________________________________________________
LAB SESSION 05

OBJECTIVE
To investigate the three phase transformer connections and characteristics.

APPARATUS
- Three Phase Transformer
- Three Phase Supply
- Scope Meter
- Multi-meter

THEORY

![Diagram of Three Phase Transformer Connections](image)
Most electrical energy is generated and transmitted using three phase systems. The three phase power may be transformed either by use of poly-phase transformers or with a bank of single-phase transformers connected in three phase arrangements. The primary and secondary windings can be connected in either wye (Y) or delta (Δ) configurations, which result in four possible combinations of connections: Y-Y, Δ-Δ, Y-Δ and Δ-Y. Three arrangements are shown in Figure 2.

**Y-Y Connection**
The wye connection offers advantages of decreased insulation costs and the availability of the neutral for grounding purposes. One drawback of the Y-Y connections is that third harmonic problems exist. If the neutrals are ungrounded, there is no path for the third harmonic current to flow and the magnetizing currents are sinusoidal; however, the typical saturating magnetization curve of the transformer core causes the flux variation to be flat topped. In turn, this flat flux wave contains a large third harmonic component, which induces an appreciable third harmonic in phase voltages. The third harmonic components will cancel in the line-to-line voltages and the line voltages are essentially sinusoidal. For example with phase voltages containing third harmonics, the line-to-line voltage \( v_{ab} \) is given by

\[
\begin{align*}
    v_{an} &= V_{m1} \sin \omega t + V_{m3} \sin 3\omega t \\
    v_{bn} &= V_{m1} \sin(\omega t - 120^\circ) + V_{m3} \sin(3\omega t - 120^\circ) \\
    v_{ab} &= v_{an} - v_{bn} = \sqrt{3}V_{m1} \sin(\omega t + 30^\circ) + 0
\end{align*}
\]

To eliminate the harmonics in phase voltages a third set of windings, called a tertiary winding, connected in \( \Delta \) is normally fitted on the core so that the required third harmonic component of the exciting current can be supplied. This tertiary winding can also supply an auxiliary load if necessary.

If the source and both transformer neutrals are grounded, third harmonic currents can flow, thereby restoring a sinusoidal flux variation. In this case, all voltages are approximately sinusoidal (at fundamental frequency), but the third harmonic currents flow back to the source through the neutral ground. This can cause telephone or other related interference. This connection is rarely used because of harmonic magnetizing currents in the ground circuit. The relationships between the line and the phase voltages for the Y-Y connections are:

\[
V_{HL} = \sqrt{3}V_{HP}, \quad V_{XL} = \sqrt{3}V_{XP} \quad \implies \quad \frac{V_{HL}}{V_{XL}} = \frac{V_{HP}}{V_{XP}} = \frac{N_1}{N_2} = a
\]

The letters \( H \) and \( X \) represent high and low voltages, respectively, and the subscript \( L \) stands for line, and \( P \) stands for phase quantities.

**Δ-Δ Connection**
The \( \Delta \) connection provides no neutral connection and each transformer must withstand full line-to-line voltage. The \( \Delta \) connection does, however, provide a path for third harmonic currents to flow. This results in a sinusoidal flux waveform producing sinusoidal phase voltages. This connection
has the advantage that one transformer can be removed for repair and the remaining two can continue to deliver three-phase power at a reduced rating of 58% of that of the original bank. This is known as the V connection. The relationships between the line and the phase voltages for the Δ-Δ connections are:

\[
\begin{align*}
V_{HL} &= V_{HP}, \\
V_{XL} &= V_{XP} \\
\Rightarrow \quad \frac{V_{HL}}{V_{XL}} &= \frac{V_{HP}}{V_{XP}} \Rightarrow \frac{N_1}{N_2} = a
\end{align*}
\]

(3)

Y-Δ Connection

The Y connection has no problem with third harmonic components in its voltages because the closed path provided by the secondary Δ connection permits the third harmonic magnetizing current to exist. In turn, this currents act to virtually eliminate the third harmonic component in the flux wave, thus ensuring a sinusoidal flux wave producing sinusoidal phase voltages. The Y neutral is grounded to reduce the undesirable effects with unbalanced loads. This connection is commonly used to step down a high voltage to a lower voltage.

\[
\begin{align*}
V_{HL} &= \sqrt{3}V_{HP}, \\
V_{XL} &= V_{XP} \\
\Rightarrow \quad \frac{V_{HL}}{V_{XL}} &= \sqrt{3} \frac{V_{HP}}{V_{XP}} \Rightarrow \sqrt{3} \frac{N_1}{N_2} = \sqrt{3}a
\end{align*}
\]

(4)

Δ-Y Connection

The Δ-Y connection is the same as Y-Δ, except that the primary and secondary are reversed. If the Y connection is used on Δ the high voltage side, insulation costs are reduced. This connection is commonly used for stepping up to a high voltage.

The Y-Δ and the Δ-Y connections will result in a phase shift between the primary and secondary line-to-line voltages, with the low voltage lagging the high voltage by 30° as shown in Figure 1. Because of the phase shift inherent in Y-Δ and Δ-Y banks, they must not be paralleled with Y-Y, Δ-Δ, or V-V banks.

![Figure 1 Phase shift in line-to-line voltages in a Y-Δ connection](image)


**PROCEDURE**

1. **Y-Y Connection:**
   (a) **Line and phase RMS voltage Measurements:** Connect the single-phase transformers Y-Y as shown in Figure 2 (a). Connect the high voltage winding to the three-phase 208 V power supply. Turn the power on and using a Digital Multi-meter measure the voltages and record in Table I.

   (b) Connect the secondary neutral to the primary neutral and ground the neutrals. (You can find a ground terminal, a green plug on the right side of the AC supply box located behind your bench). Connect Input A and COM to measure the secondary line-to-neutral voltage. Turn on the Scope Meter and click on the Display Waveforms icon to open its dialog box and check mark Acquisition Memory A to display the secondary line-to-neutral voltage. Obtain the voltage spectrum. Is there any appreciable harmonics in the line-to-neutral voltage? Save these waveforms. Connect Input A and COM to measure the secondary line-to-line voltage and observe
the harmonics content if any.

TURN OFF THE POWER SUPPLY EACH TIME BEFORE YOU RECONNECT THE LEADS

2. Y-Δ Connection

(a) Line and phase RMS voltage Measurements – Reconnect the single-phase transformers Y-Δ as shown in Figure 4.2(b). Connect the high voltage winding to the three-phase 208 V power supply. Turn the power on and using a DMM measure the voltages and record in Table I.

(b) Connect the Scope-Meter input A and COM to measure the phase voltage of one phase of the Δ connected secondary. Examine the voltage spectrum for its harmonic contents. There should be negligible third harmonic component in the phase voltages whether the primary neutral is grounded or isolated. Ground the primary neutral and investigate.

(c) Ground the Y neutral. Open one side of Δ (i.e., connection between two secondary windings) and insert the Scope-Meter input A and COM to measure the open loop voltage. Turn on the Scope-Meter. Measure the secondary open-loop voltage

\[ V_{\text{LOOP}} = \ldots \]

With the primary neutral grounded, third harmonic magnetization current can flow in the primary resulting in sinusoidal secondary voltages, thus the secondary open-loop voltage measured should be approximately zero.

(d) Isolate the primary neutral. With Y-neutral not grounded and Scope-Meter connected as in part (c) in the open delta turn the power on and record the open loop voltage.

\[ V_{\text{LOOP}(\text{con})} = \ldots \quad f = \ldots \]

Click on the Display Waveforms icon \[\text{[icon]}\] to open its dialog box and check mark Acquisition Memory A to display the secondary open-loop voltage Obtain the waveforms spectrum. Record the value in volts and percent and the frequency of the fundamental and up to the 7th harmonics. Save these waveforms.

When the primary neutral is not grounded the primary currents are essentially sinusoidal (No path for the third-harmonics current to flow). However, the flux because of the nonlinear B-H characteristics of the magnetic core is non-sinusoidal and contains odd harmonics, in particular third harmonics. The phase voltages are therefore non-sinusoidal, containing fundamental and third harmonic voltages, with instantaneous values given by

\[ v_{an} = V_{m1} \sin \omega t + V_{m3} \sin 3\omega t \]
\[ v_{bn} = V_{m1} \sin(\omega t - 120^\circ) + V_{m3} \sin(3\omega t - 120^\circ) \]
\[ v_{cn} = V_{m1} \sin(\omega t - 240^\circ) + V_{m3} \sin(3\omega t - 240^\circ) \]

Note that fundamental phase voltages are phase shifted by 120°, from each other, whereas third harmonic voltages are all in phase.
The open loop voltage around delta is the sum of phase voltages. The sum of fundamental components is zero, whereas the third harmonics will add up. The result is

\[ V_{\text{LOOP}} = V_{an} + V_{bn} + V_{cn} = 3V_m \sin 3\omega t \] (6)

Note that when the secondary delta is closed, it permits the third harmonic current to flow in the secondary delta restoring sinusoidal flux and sinusoidal phase voltages as seen in part 2(b).

3. Δ - Δ Connection
(a) Line and phase RMS voltage Measurements: Reconnect the single-phase transformers Δ - Δ as shown in Figure 2(c). Connect the high voltage winding to the three-phase 208 V power supply. Turn the power on and using a DMM measure the voltages and record in Table I.

(b) Connect the Scope-Meter input A and COM to measure the phase voltage of one phase of the Δ connected secondary. Examine the voltage spectrum for its harmonic contents.

(c) Open one side of the secondary Δ (i.e., connection between two secondary windings) and insert the Scope-Meter input A and COM to measure the open loop voltage. Turn on the Scope-Meter. Measure the secondary open-loop voltage

\[ V_{\text{LOOP}} = \text{________________________} \]

The Δ - Δ connection provide a path for third harmonic currents to flow and therefore the phase voltages will not contain third harmonics. Thus, with identical transformers, the phase voltages are balanced and \( V_{\text{LOOP}} \) should be zero or small.

**OBSERVATIONS**

<table>
<thead>
<tr>
<th>Transformer connections</th>
<th>High voltage Measurements</th>
<th>Low-voltage Measurements</th>
<th>Line to phase ratio</th>
<th>Prim. to sec. ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(L-L) ( V_{HL} )</td>
<td>(L-L) ( V_{XL} )</td>
<td>( \frac{V_{HL}}{V_{HP}} )</td>
<td>( \frac{V_{HL}}{V_{XP}} )</td>
</tr>
<tr>
<td></td>
<td>(L-N) ( V_{HP} )</td>
<td>(L-n) ( V_{XP} )</td>
<td>( \frac{V_{XL}}{V_{HP}} )</td>
<td>( \frac{V_{XL}}{V_{XP}} )</td>
</tr>
<tr>
<td>Wye-Wye</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Wye-Delta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta-Delta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table I

Using the measured voltages determine the above ratios in Table I.
4. Improper Y connections

Connect the single-phase transformers Y-Y with connection to one phase of secondary (say phase a) reversed as shown in Figure 4.3.

Turn the power on and record all three secondary line-to-line and line-to-neutral voltages.

\[ V_{an} = \quad V_{bn} = \quad V_{cn} = \]
\[ V_{ab} = \quad V_{bc} = \quad V_{ca} = \]

For the above connections from Kirchhoff’s voltage law the secondary line-to-line voltages are given by

\[ V_{ab} = V_{an} - V_{bn} = V_{XP} \angle 180^\circ - V_{XP} \angle -120^\circ = V_{XP} \angle 120^\circ \]
\[ V_{bc} = V_{bn} - V_{cn} = V_{XP} \angle -120^\circ - V_{XP} \angle 120^\circ = \sqrt{3}V_{XP} \angle -90^\circ \]
\[ V_{ca} = V_{cn} - V_{an} = V_{XP} \angle 120^\circ - V_{XP} \angle 180^\circ = V_{XP} \angle 60^\circ \]

(7)
5. Improper delta connection
In the $\Delta$-$\Delta$ arrangement, reverse the connection of one phase of the secondary winding (say phase $a$). Open the secondary delta (connection between two secondary windings) and insert a voltmeter to read the open loop voltage as shown in Figure 4.5.

![Diagram of improper delta connection](image)

**Figure 5** The improper $\Delta$ connection.

**CAUTION:** COMPLETE THE CIRCUIT FOR IMPROPER $\Delta$ THROUGH A VOLTMETER DO NOT ENERGIZE THE IMPROPER $\Delta$ UNLESS YOU HAVE INSERTED A VOLTMETER IN THE LOOP.

Turn the power on and record the open loop voltage.

$$V_{\text{LOOP}} = \phantom{12345}$$

Neglecting harmonics, voltage around the open delta is given by

$$V_{\text{LOOP}} = V_{an} + V_{bn} + V_{cn} = V_{XP} \angle 180^\circ + V_{XP} \angle -120^\circ + V_{XP} \angle -240^\circ = 2V_{XP} \angle 180^\circ$$ (8)
EXERCISE:
1. What are the problems associated with the Y-Y three-phase transformer connection? Discuss the harmonics in the Y-Y connection and the observation made in parts 1(b) and 1(c). With isolated neutrals does the phase voltage contain third harmonics? Are there third harmonic in the line-to-line voltages (see equation 1).

2. Draw a phasor diagram showing the primary and secondary line-to-line and line-to neutral voltages for the Y-Y, Δ-Δ, and Y-Δ connections. For the Y-Δ connections determine the phase shift between the primary and secondary line-to-line voltages. Enumerate the necessary conditions for parallel operation of two three-phase transformers.

3. In a Δ-Δ connections can one of the transformers be removed with the remaining ones operating satisfactorily why? What is the name of this connection?

4. For V-V connections, find out the three phase transformer rating to the open Δ nameplate rating. Also find out the three phase transformer rating to the close Δ nameplate rating.

5. For the improper Y-Y connection of part 4, use (7) to compute the line voltages and compare with the measured values. Are the line voltages symmetrical?

6. For the improper Δ connection of part 5, use (8) to compute the open loop voltage and compare with the measured value. Is this an appropriate Δ connection? Why?
LAB SESSION 06

OBJECTIVE
Paralleling Alternators

APPARATUS
- Two Motor Generator sets
- Generator control Boards
- Paralleling Board

THEORY
Parallel Conditions of the Alternators
Some conditions are necessary to connect the alternators in parallel. As an example, let’s take the case of two alternators, one of which is already connected to the bars. The second one is to be connected to support the total load, by dividing the active and the reactive load between the alternators.

![Diagram](image)

Suppose G1 connected to the bars with INT1, the conditions that G2 must fulfill to close INT2 with safety are:

1- **Equal sequence of phases**: if the three voltages of G1 make ABC turn, the three of G2 must also make ABC turn. The rotation direction can be checked with different instruments: the first one is an instrument including a three-phase asynchronous motor, that must turn in the same direction powered by the bars and by G2. Another method is with 3-lamp synchronoscope, as the one mounted in the system. If the 2 triads do not turn in the same direction, the 3 lamps never light off simultaneously. *To make the triad turn to the other direction, just change the connection of the 2 phases of G2.*

2- **Equal frequency**: if both generators have the same number of poles, this means that they must turn with the same number of revolutions. This can be seen in the frequency meters
of G1 and G2, that must indicate the same value. Actually, G2 is set at a little higher speed than G1 (this because when “taking load”, the prime mover will naturally drop the rpm). 

*To change the rpm act on the control device (accelerator) of the prime mover of G2.*

3- **Equal effective voltages:** this occurs with the voltmeters installed on G1 and G2. *To change the voltage of G2, you must act on the excitation of G2.*

4- **Equal phases:** it means that both triads, G1 and G2, must coincide to close INT2. This occurs with synchronoscope, when the 3 lamps switch off simultaneously. *To change the phase of G2, you must act on the speed of the prime mover of G2, lightly accelerating it* (it is obvious that if the rotation speeds of both machines are exactly equal, the phases will be never be equal.

**PROCEDURE & OBSERVATION:**

**OBJECTIVE #1**

**ACTIVATION OF THE FIRST GENERATOR**

1. Activate the prime mover of the set 1 and adjust the synchronous generator to the frequency and nominal voltage. The voltage and frequency values can be immediately found on the analog voltmeter and the frequency-meter of the control board 1.

2. With the potentiometer RPM set to DC MOTOR DRIVE, adjust the speed to obtain 50.0 Hz. And adjust the excitation of the synchronous generator to obtain a voltage equal to 400 V.

3. The triad of voltages (with the neutral) produced by the generator 1 is now present in the parallel board and the frequency and voltage values are displayed again on the instruments connected to 3PH-GEN 1. Even the 3 lamps of the synchroscope will light on but with fixed permanent light.

4. Act on the START pushbutton of the contactor K1 to connect the triad of voltages provided by the generator 1 on the main bars. **Note: do not absolutely activate the contactor K2 in this phase.**

5. Check that the protection switches (thermo-magnetic E.L.C.B. OVER CURRENT PROTECTION and E.L.C.B.) are ON or set them ON.

**ACTIVATION OF THE SECOND GENERATOR**

1. Activate the prime mover of the set 2 and adjust the synchronous generator to the frequency and nominal voltage. The voltage and frequency values can be immediately found on the analog voltmeter and on the frequency meter of the control board 2.

2. As for the generator board 1, adjust the speed of the prime mover and the excitation of the generator 2, to get 50.0 Hz and the nominal voltage (400 V).

3. The triad of voltages (with the neutral) produced by the generator 2 is now present, too, in the parallel board and the frequency and voltage values are displayed again on the instruments connected to 3PH-GEN 1. Now the 3 lamps of the synchroscope will light on and off with light modulation depending on the shift between the terms of voltages 3PH-GEN 1 and 3PH-GEN 2.
IDEAL MOMENT TO CARRY OUT THE PARALLEL

1. At this point the 3 lamps of the synchroscope must light on and off *simultaneously with the frequency equal to the difference of the two alternators*. If this does not occur, it means that a triad of voltages “runs” in a reverse way than the other; invert one of the two to make them conform. Check that changing the speed of any of the two alternators a little, the lamps switching on frequency changes consequently.

2. Refer to the frequency of the generator 1, e.g., and adjust the frequency of the generator 2 so that the 3 lamps of the synchroscope light on and off for a long period. Check that the two terms of voltage are about 400 V and are almost equal between them.

3. In the right moment in which the *3 lamps are actually off*, activate the contactor K2. With this procedure the generators are connected in parallel between then.

4. The perfect parallel and the stability of the interconnected generators can be seen on the ammeters (in this case the analog ones give immediate responses). Remember that we are in no-load condition and so there should not be currents crossing the generators.
OBJECTIVE #2

INCLUDE THE PROTECTION RELAYS IN THE POWER GENERATION

1. Let’s start again the experiments and include the overload and short circuit relays in the outputs of each generator.
2. Take off the jumpers on the ENABLE 1 and ENABLE 2 contacts of the parallel board mod. PCB-1/EV and carry out such continuity with the consents of the respective protection relays against overload. In this mode, the power contactors, automatically disable when overcurrents lasts over the given delay time. (for enabling use 4 2-m red cables)
3. E.g. adjust the current relays with the following values:
   - overload threshold = 1 A;
   - intervention delay = 5 s;
   - short-circuit threshold = 5 A.
4. Activate the prime mover of the set 1 and adjust the synchronous generator to the frequency and nominal voltage.
5. Act on the START pushbutton of the contactor K1 to connect the triad of voltages supplied by the generator 1 to the main bars. **Note: do no absolutely activate the contactor K2 in this phase.**
6. Check that the OVER CURRENT PROTECTION and ELCB are ON or turn them ON.
7. Set the generator 1 under load with the insertion of the first step of the resistive module (carry out a balanced load), the appearing drop must be compensated adjusting the relative Uexc.
8. In the sudden load variations, to reset the dynamic balance and prevent the polar wheel to slow down due to the increased braking electromagnetic torque that is caused by the armature reaction on the synchronous machine, the mechanical torque of the prime mover must be increased.
9. Use the digital power analyzer in the parallel board to display the power values that will be distributed to the user.
10. Insert one or two steps of the inductive module (carry out always a balanced load) and take back the supplied voltage to nominal value.
11. Activate the prime mover of the set 2 and adjust the synchronous generator to the frequency and nominal voltage
12. Make the proper adjustments to find the “condition for the parallel” and carry it out.
13. Check the analog ammeters, see the load division on the two generators.
14. The adjustments for each generator are two (remember that the system is adjusted manually); provided voltage adjustment, prime movers speed adjustment.
15. To balance the active powers supplied by the two generators in parallel, you must increment the rotation speed of the prime mover (in jargon accelerate) that carries the generator with less supplied power and/or decelerate the other.
16. To balance the reactive powers provided by the two generators in parallel (to be made always after balancing the active ones), you must act on the excitations. Increment the excitation of the one with less reactive power and drop the other.
17. Even with load (constant load), the possible system instability is immediately seen on the analog ammeters by the progressive increase of the current in a generator and the drop on the other in oscillatory mode (more or less slow oscillations) or it can be produced by accelerating a prime mover, it is sufficient a little.

18. If the system is not self-regulated (as in this case), there is an increase of power on a generator and a drop on the other (keeping the load constant) i.e. the load “moves” toward a generator with consequent increase of the current in transit.

Note: in the quick passages from load to no load, e.g. when the generators disconnect from the parallel by effect of the protection relays, the provided voltages rise over the “nominal” limits (±10 %) and must be quickly taken back to nominal values acting on the respective excitations.

19. The increase of the generator current, if it lasts over the time fixed in the overload relay, causes the automatic tripping of the protection relay with consequent separation of the generator from the parallel.

20. If, as it often occurs, when there is power request from the load, this is fulfilled only by the generator that is still connected, this is another reason why the overload condition is reached and the relay, after the fixed time, controls the opening of the connection conductor. The automatic exclusion of a generator if not contrasted by proper countermeasures, in the time fixed by the protection relays, creates the “dominoes” effect with consequent black-out of the whole electrical system interconnected.

21. To demonstrate the effect, when the parallel is reached, increase the load up to obtain currents over the threshold set by the overload relays (overload threshold = 1 A) and wait for the delay time (intervention delay = 5 s) as from the made regulation.

**EXERCISE:**
Give the complete working of Synchroscope

**Quick Quiz**

a) The speed of the prime mover determines:
   (a) Frequency (b) Phase Rotation (c) Phase relationship

b) The field excitation of the
   (a) Frequency (b) Voltage (c) Phase Rotation

c) The synchronizing (phasing) lamps operate from the difference between two voltages. When they remain dark it means:
   (a) Voltages are equal and 180° out of phase.
   (b) Voltages are equal and in-phase.
   (c) Voltages are unequal and out of phase.

d) The device which can also be used for paralleling instead of bulbs is known as
   (a) Multimeter (b) Synchroscope (c) Energy Analyzer

e) When an alternator is paralleled with the infinite bus, you cannot change:
   (a) The load current it supplies.
   (b) The power it supplies.
   (c) The frequency of its output.
LAB SESSION 07

OBJECTIVE
Home Appliances Machines

APPARATUS
- Fan Motor (Ceiling & Exhaust)
- Washing Machine Motor
- Pump Motor
- Juicer Motor
- Toys Motor
- Transformers

THEORY

Transformer
A transformer is a device that transfers electrical energy from one circuit to another by electromagnetic induction (transformer action). The electrical energy is always transferred without a change in frequency, but may involve changes in magnitudes of voltage and currents. The total VA at primary and secondary is always constant.

There are two types of transformers.
1. Core Type
2. Shell Type

Universal Motor
The universal motor is a rotating electrical machine similar to DC series motor, designed to operate either from AD or DC source. The stator & rotor windings of the motor are connected in
series through the rotor commutator. The series motor is designed to move large loads with high torque in applications such as crane motor or lift hoist.

**Figure:** Universal Motor

**Figure:** Closer View of Universal Motor

**Figure:** Universal Motor Assembly

**Split Phase Induction Motor**
An Induction motor is a motor without rotor windings, the rotor receives electric power by induction rather than by conduction, exactly the same way the secondary of a 2 windings transformer receive its power from the primary.

The single-phase induction motor has no intrinsic starting torque. Starting torque can be achieved by either one of the method.

1. Split phase windings
2. Capacitor type windings
3. Shaded pole stator
PMDC motor
A permanent magnet DC motor is the simple motor that converts electrical energy into mechanical energy through the interactions of the two fields. One field is produced by a permanent magnet poles, the other field is produces by electrical current flowing in the amature windings. These two fields result in a torque which tends to rotate the rotor.

Hystersis Motor
A Hystersis motor is a type of shaded pole motor, operate on the principle of Hystersis.
PROCEDURE
Practical Demonstration.

RESULT
The working of household motors has fully understood.

EXERCISE
1. Why do we use skewed bars in squirrel cage rotor?
2. Why do we use carbon brushes in a machine?
3. What are the different types of bearings exists? How do we select?
4. Why do we not use centrifugal switch in ceiling fan?
5. In ceiling fan and pump motor which one are capacitor start and which one is capacitor run?
6. Why do we use split rings and slip rings in a machine?
7. When do we use Split rings and Slip rings?
8. Give the working of hysteresis motor?
9. What will happen if I will apply 3V AC to PMDC motor instead of 3V DC?
10. What will happen if I will apply 220V DC to the universal motor instead of 220V AC?
EXERCISE
Suppose you are given the name plate of a typical induction motor.

<table>
<thead>
<tr>
<th></th>
<th>Frame</th>
<th>326T</th>
<th>8</th>
<th>Volts</th>
<th>460</th>
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<tr>
<td>2</td>
<td>Hp</td>
<td>50</td>
<td>9</td>
<td>Amps</td>
<td>61</td>
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<tr>
<td>3</td>
<td>Hertz</td>
<td>50</td>
<td>10</td>
<td>Phase</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Insulation Class</td>
<td>F</td>
<td>11</td>
<td>Duty</td>
<td>Cont</td>
</tr>
<tr>
<td>5</td>
<td>Max Ambient Temp</td>
<td>40 °C</td>
<td>12</td>
<td>Temp Rise</td>
<td>70 °C</td>
</tr>
<tr>
<td>6</td>
<td>RPM</td>
<td>1765</td>
<td>13</td>
<td>NEMA Code</td>
<td>G (5.6-6.29)</td>
</tr>
<tr>
<td>7</td>
<td>Service Factor</td>
<td>1.1</td>
<td>14</td>
<td>NEMA Design</td>
<td>B</td>
</tr>
</tbody>
</table>

From above name plate calculate the following data:

a) The Three Phase Apparent Power ____________________________

b) Torque Deliver (in N.m and lb.ft) ____________________________

c) Starting KVA ____________________________

d) Starting (Locked Rotor) Current ____________________________

e) Maximum Allowable Continuous Load ____________________________

f) Slip ____________________________

1. What is the importance of mentioning frame size on name plate?
2. What do you understand by insulation class?
3. How many other insulation classes also exist? Give temperature ranges.
4. What do you understand by service factor?
5. What do you understand by NEMA Design? How will you distinguish between NEMA code & NEMA design?

Give the application of following AC/DC motors.
LAB SESSION 08

OBJECTIVE
Carry out the connections and the sequence of controls to activate the synchronous compensator.

APPARATUS
- Generators parallel board mod. PCB-1/EV.
- Control board for generation set mod. GCB-1/EV.
- Synchronous generator-motor set mod. MSG-1/EV.
- Fixed three-phase power supply source mod. UAT/EV or variable one mod. AMT-3/EV.
- Digital power analyzer mod. AZ-VIP/EV.
- Variable resistive load mod. RL-2/EV.
- Variable inductive load mod. IL-2/EV.
- Set of cables-jumpers for electrical connections

THEORY
The ratio of the actual power consumed by equipment (P) to the power supplied to equipment (S) is called the power factor.

\[ \text{Power Factor} = \cos \Phi = \frac{\text{Real Power}}{\text{Apparent Power}} = \frac{P}{S} \]

Where:

\[ S = \sqrt{P^2 + Q^2} \]

The power factor correction of electrical loads is a problem common to all industrial companies. Every user which utilizes electrical power to obtain work in various forms continuously asks the mains to supply a certain quantity of active power, together with reactive power. This reactive power is not transformed or used by the user, but the electricity supply company is forced to produce it, using generators, wires to carry and distribute it, through transformers and switching gears. There are two methods for power factor improvement.

1. Using Static condensers
2. Using Synchronous Motor

Here in this lab we will use Synchronous motor for power factor improvement. The synchronous motor receives excitation in the rotor from an external d.c. adjustable source. The excitation voltage determines the kind of power the motor absorbs from the network:

- reactive inductive power in under-excitation conditions;
- capacitive reactive power in over-excitation conditions.

- The synchronous motor is often used not only to move a mechanical load at constant speed, but simultaneously as power factor phase advancer of the networks, (it operates in underexcitation conditions).
- This is the typical method of power factor compensation used mainly in the electrical control stations, exploiting also the motor’s capacities to move pumps, fans and other auxiliary services of the power plant.
When used as synchronous phase advancer, its action can be controlled with closed feedback cycle (see drawing hereunder).

**PREPARING THE EXERCISE**

- Start the parallel board mod. PCB-1/EV and the control one of the generator set mod. GCB-1/EV as indicated in part 3 of this manual.
- If not already done, in the control board mod. GCB-1/EV take off all jumpers for protection relays enabling, do not connect the 3-PHASE OVERLOAD and SHORT-CIRCUIT relay, but with 3 cables (50-cm and black) add power to the digital instrument, ELECTRICAL PARAMETERS METER (Neutral included with a jumper)
- In this way, a part the analog instruments, Voltmeter, Ammeter and Frequency meter (not removable), the parameters of the power provided or absorbed by the generator/synchronous compensator can be displayed with a digital instrument (numerical reading).
- Connect the outputs L1-L2-L3-N of the board mod. GCB-1/EB to the lower input of the parallel board mod. PCB-1/EV. (3 black cables and 1 2-mm one). It is good rule to connect also the protection conductor (yellow-green terminal) that in the board mod. GCB-1/EV is on the left side panel.
- Make a connection on the ENABLE 1 terminals of the parallel board mod. PCB-1/EV to enable the power contactor (in this case without the protection relays consents). **Note: Do not absolutely press the START pushbutton to activate the parallel contactor without respecting the parallel procedures.**
- Include the instruments and the protection devices into the control board mod. PCB-1/EV. Using some jumpers, connect the analog frequency meter, the analog voltmeter and a terminal of the 3 signaling lamps of the synchroscope to the line 3PH-GEN 1 (left side). Connect the second analog frequencymeter, the second analog voltmeter and another terminal of the 3 signaling lamps of the synchroscope instead of the line 3PH-GEN 2 (right
part) to the horizontal main bars with some cables. Complete the circuit connecting the thermo-magnetic E.L.C.B. OVER CURRENT PROTECTION, the E.L.C.B. and the digital instrument ELECTRICAL PARAMETERS METER. See the figures 4.9.1, 4.9.2.

- Connect the resistive and inductive step loads mod. RL-2/EV, IL-2/EV to the terminals USER, on the right bottom. The loads are star connected and the star centers must be connected to the neutral. Be sure that all the step switches of the loads are in load excluded position (OFF).
- Connect a three-phase power supply source with the Neutral to the PUBLIC POWER MAINS terminals of the main bars (Public power mains).
- To measure the power absorbed by the public power mains, insert a digital power analyzer or another equivalent instrument.

**ACTIVATION OF THE PUBLIC POWER MAINS**

- Activate the public power mains with the fixed three-phase power supply line mod. UAT/EV or the variable power supply mod. AMT-3/EV adjusting the voltage to about 3 x 400 V.
- The tern of voltage (with the neutral) of the public power mains is now present in the parallel board at the main bars and the frequency and voltage values are displayed on the analog voltmeter and on the frequency meter. The 3 lamps of the synchroscope will light on, too, but with fixed permanent light.
- Check that the protection switches (thermo-magnetic E.L.C.B. OVER CURRENT PROTECTION and E.L.C.B.) are ON or turn them ON.
- Insert one or two steps of load (carry out balanced loads) into the resistive or inductive load. It is important in this exercise, that the load has inductive reactive power to demonstrate that the synchronous compensator can produce capacitive reactive power to reset or at least reduce the inductive component absorbed by the public power mains.
- To make balances on the involved reactive powers, besides the digital power analyzer of the parallel board (set to display the three-phase power absorbed by the load), and the one on the control board of the synchronous machine (set to display the three-phase reactive power in transit) a further instrument is necessary to measure the reactive power coming from the public power mains.

**SYNCHRONOUS MACHINE ACTIVATION TO BE USED AS SYNCHRONOUS COMPENSATOR**

- Activate the prime mover of the set to take the synchronous compensator into rotation, adjust the synchronous generator to the frequency and nominal voltage as to make the parallel of a generator with the network.
- Carry out the proper adjustments to find the “condition for the parallel” and carry it out.
  - Without changing the excitation parameters (variac Uexc 3PH-GEN) of the synchronous compensator) set the switch RUN / STAND-BY to STAND-BY position. This operation makes the DC motor “freewheel”; it does not carry the synchronous machine anymore which becomes synchronous motor.
  - Now increase the synchronous compensator excitation (variac Uexc 3PH-GEN) until the inductive reactive power coming from the public power mains is almost set to zero. This is the effect of the power factor improvement found with the digital power analyzers.
Then change the inductive part of the load and make again the power factor compensation changing the synchronous compensator excitation.

Figure 1 Electrical reference diagram to use the synchronous machine as synchronous compensator.
Figure 2 Activation of the synchronous compensator
LAB SESSION 09

TITLE
Operation and Characteristics of:
1. Reluctance Motor
2. Repulsion Motor
3. Dahlander Motor

APPARATUS:
- EME Module
- Reluctance Motor (Model: EMT 21)
- Repulsion Motor (Model: EMT 14)
- Dahlander Motor (Model EMT 9)

THEORY AND OBSERVATION:
Construction, Working and Characteristics **Reluctance Motor**:
_______________________________________________________________________________
________________________________Answer in Lab Copy______________________________
_______________________________________________________________________________

Construction, Working and Characteristics **Reluctance Motor**:
_______________________________________________________________________________
________________________________Answer in Lab Copy______________________________
_______________________________________________________________________________

Construction, Working and Characteristics **Dahlander Motor**:
_______________________________________________________________________________
________________________________Answer in Lab Copy______________________________
_______________________________________________________________________________

RESULT
The above motors operation has fully understood.
LAB SESSION 10

TITLE
Operation and Characteristics of:
1. Single Phase Asynchronous Shaded Pole
2. Asynchronous Single-Phase Motor With Split Phase
3. Asynchronous Single-Phase Motor With Starting Capacitor
4. Async. Single-Phase Motor With Starting And Running Capacitor
5. Universal Motor

APPARATUS:
- EME Module
- Single Phase Asynchronous Shaded Pole (Model EMT 22)
- Asynchronous Single-Phase Motor With Split Phase (Model EMT 20)
- Asynchronous Single-Phase Motor With Starting Capacitor (Model: EMT 11)
- Async. Single-Phase Motor With Starting And Running Capacitor (Model: EMT 16)
- Universal Motor (Model: EMT 12)

THEORY AND OBSERVATION:

✓ Construction, Working and Characteristics Single Phase Asynchronous Shaded Pole:
  ________________________________________________________________

  Answer in Lab Copy_____________________________________________

  ________________________________________________________________

✓ Construction, Working and Characteristics Asynchronous Single-Phase Motor With Split Phase:
  ________________________________________________________________

  Answer in Lab Copy_____________________________________________

  ________________________________________________________________

✓ Construction, Working and Characteristics Asynchronous Single-Phase Motor With Starting Capacitor:
  ________________________________________________________________

  Answer in Lab Copy_____________________________________________

  ________________________________________________________________
✓ Construction, Working and Characteristics **Asynchronous Single-Phase Motor With Starting And Running Capacitor:**

_______________________________________________________________________________

_______________________________________________________________________________

Answer in Lab Copy

_______________________________________________________________________________

✓ Construction, Working and Characteristics **Universal Motor:**

_______________________________________________________________________________

Answer in Lab Copy

RESULT

The above motors operation has fully understood.
LAB SESSION 11

TITLE
Operation and Characteristics of:
1. Squirrel cage rotor Motor
2. Wound Rotor Motor

APPARATUS:
- EME Module
- Squirrel cage rotor Motor
- Wound Rotor Motor

THEORY AND OBSERVATION:

- Construction, Working and Characteristics **Squirrel cage rotor Motor:**

  Answer in Lab Copy

- Construction, Working and Characteristics **Wound Motor:**

  Answer in Lab Copy

RESULT

The above motor operation has fully understood.
LAB SESSION 12

TITLE
Operation and Characteristics of:
1. Synchronous Three-Phase Machine
2. Permanent Magnet Synchronous Three Phase Generator (24V ac).

APPARATUS:
- EME Module
- Synchronous Three-Phase Machine (Model: EMT6)
- Permanent Magnet Synchronous Three Phase Generator (24vac). (Model: EMT6/E)

THEORY AND OBSERVATION:
✓ Construction, Working and Characteristics Synchronous Three-Phase Machine:

_______________________________________________________________________________
________________________________Answer in Lab Copy______________________________
_______________________________________________________________________________

✓ Construction, Working and Characteristics Permanent Magnet Synchronous Three Phase Generator:

_______________________________________________________________________________
________________________________Answer in Lab Copy______________________________
_______________________________________________________________________________

RESULT
The above motor operation has fully understood.