UEE11 Electrotechnology

Training Package

UEENEEJ153A
Find and rectify faults in motors and associated controls in refrigeration and air conditioning systems

Learner Workbook

Version 1

Training and Education Support
Industry Skills Unit
Meadowbank

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Table of Contents

Introduction 5

1. General introduction 5
2. Using this learner guide 5
3. Prior knowledge and experience 7
4. Unit of competency overview 7
5. Assessment 9
6. References 9
7. Risk Assessment Terminology 10

Topic 1 11

Alternating current supply 11

Topic 2 31

Three phase induction motors 31

Topic 3 69

Three phase direct on line (D.O.L) Motor starters 69

Topic 4 89

Speed control and motor protection of three phase motors 89

Topic 5 123

Split phase, single phase motors and starters 123

Topic 6 141

Capacitor and shaded pole, single phase motors and starters 141

Topic 7 171

Series universal, single phase motors; electronically commutated motors and synchronous motors 171

Topic 8 193

Speed control and protection of single phase motors 193

Review Questions - Answers 211

Sample Tests **227**
Sample theory test 1 228
Sample practical test 1 234
Sample theory test 2 240
Sample practical test 2 251
Sample theory test 3 256
Sample theory test 1 - Answers 269
Sample theory test 2 - Answers 271
Sample theory test 3 - Answers 275
Resource Evaluation Form **281**

Topic 1: Alternating Current Supply

Purpose

In this topic you will revise test equipment and single phase a.c. supply and learn about three phase a.c. supplies.

Objectives

At the end of this section you should be able to:

- safely test and isolate both single and three phase circuits
- draw sine waves to show the nature of EMF and current in single and three phase supplies
- identify Star and Delta connections of a three phase a.c. supply
- explain the need for, and the correct method to test earthing.

Content

- Revision of single phase alternating current
- Impedance and Ohm's Law in an a.c. circuit
- Voltage an current in resistive, inductive and capacitive circuit
  - Resistive circuits
  - Inductive circuits
  - Capacitive circuits
  - Power in a single phase a.c. circuit
  - Apparent power
  - True power
  - Power factor and phase angle
- Generation of three phase alternating current
- Three phase connections
  - Star connection
  - Delta connection
- Revision of electrical safety
- Revision of earthing systems
- Revision of circuit protection and isolation
- Revision of electrical test instruments.

References for this topic

You will find the information to undertake this topic in the following references. At least one reference text should be used.

- ARAC Volume 1, Chapters 11, 13 and 15.

  Discusses single phase alternators; generation of three-phase electricity; circuit protection and isolation; electrical safety; supply voltages and test instruments.

- Jenneson, JR., *Electrical Principles for Electrical Trades*, Chapter 9.

  Discusses three phase:

  - systems
  - supply production
  - wave construction
  - star and delta connections
  - sequence

- AS/NZS 3000, Wiring Rules.

  Discusses Earthing Systems and insulaton resistance measurements.

Revision of single phase alternating current
(ARAC Volume 1, Chapter 11)

Alternating Current (a.c.) is produced by an alternator. It works on the principle that if a conductor is cut by magnetic lines of force, an electromotive force (emf) is produced in the conductor.

The greater the lines of force or the quicker they are cut, the greater the output of the voltage and current.

See Simple Alternators (ARAC Volume 1, Chapter 11) for further details.

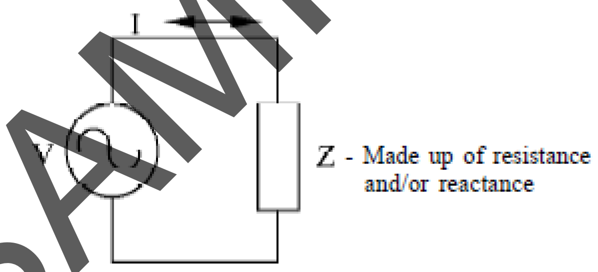
Impedance and Ohm's Law in an a.c. circuit

Impedance (Z) is the name given to the total opposition in an a.c. circuit and is expressed in Ohms. Impedance can be made up of:

- Resistance (R) - measured in Ohms
- Inductive reactance (X_L) – which is the effect of inductance and opposes current flow in an a.c. circuit and is measured in Ohms.
- Capacitive reactance (X_C) – which is the effect of capacitance and opposes current flow in an a.c. circuit and is measured in Ohms.

Impedance is determined from the equation:

$$Z = \frac{V}{I}$$



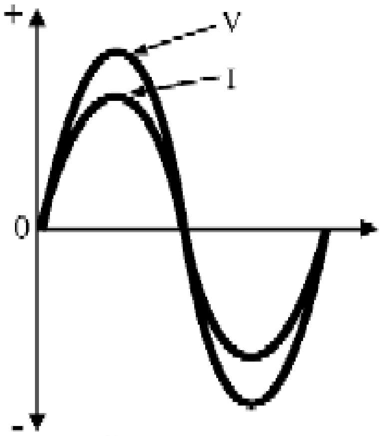
The following formulas show the relationship between impedance, resistance and reactance (either inductive or capacitive):

$$Z = \sqrt{R^2 + X^2}$$
$$X = \sqrt{Z^2 - R^2}$$
$$R = \sqrt{Z^2 - X^2}$$

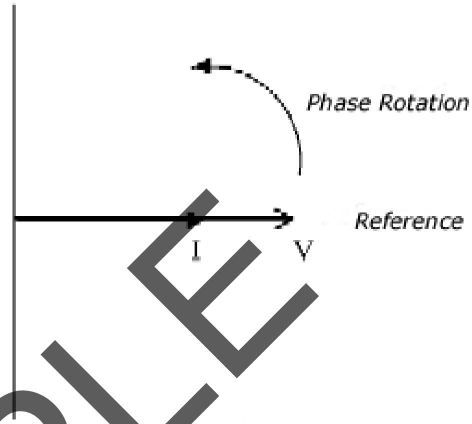
Voltage and current in resistive, inductive and capacitive circuits

Resistive circuits

- In a purely resistive a.c. circuit the impedance (Z) is equal to the resistance.
- Voltage and current is 'in phase' – meaning they reach their peaks and troughs at the same time.



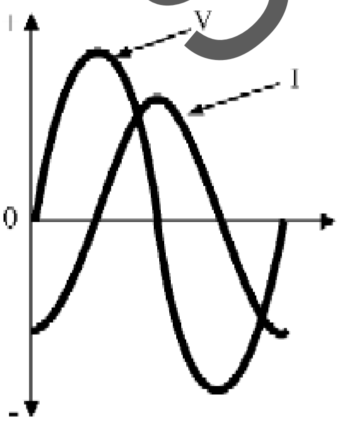
Resistive a.c. waveform



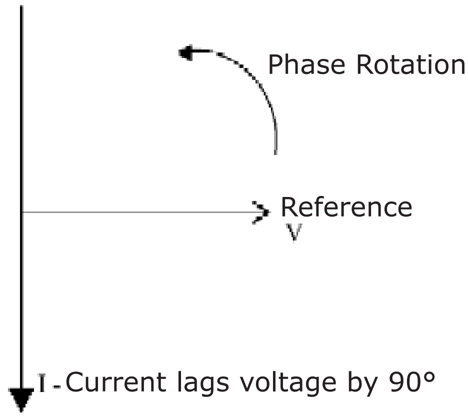
Phasor diagram

Inductive circuits

- In a purely inductive a.c. circuit the inductive reactance (X_L) is equal to the impedance (Z).
- In a purely inductive circuit the voltage leads the current by 90°.
- Voltage and current is 'out of phase'.



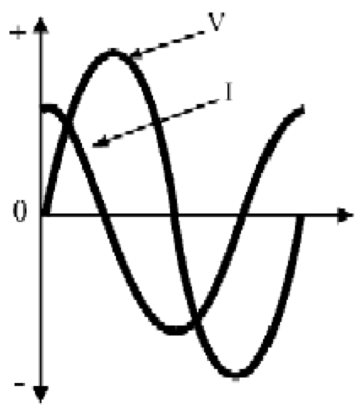
Inductive a.c waveform
At 90° out of phase



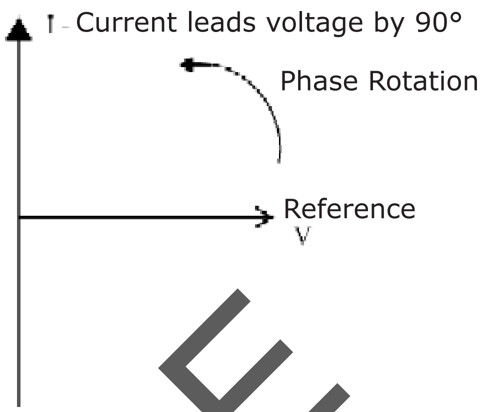
Phasor diagram

Capacitive circuits

- In a purely capacitive a.c. circuit the capacitive reactance (X_C) is equal to the impedance (Z).
- The current also leads the voltage by 90° (out of phase).



Capacitive a.c. waveform
At 90° out of phase



Phasor diagram

Power in a single phase a.c. circuit

Apparent power (S)

Apparent power only takes into account the voltage and current from the supply and is measured in volt-amperes. Many a.c. machines are rated in volt-amperes (i.e. transformers).

S = V x I (Volt-Amps)

True power (P)

True power takes into account how far out of phase the voltage and current is, in a circuit that has both resistance and reactance.

P = V x I x pf (Watts)

The power factor (pf) is a number that can vary between 0 and 1. The more resistive the circuit, the closer this value to 1.

Power factor and phase angle

The phase angle f is the angle between the supply voltage and the circuit current. The power factor is the cosine of the phase angle, that is:

$$\text{Power factor (pf)} = \cos\phi = \frac{\text{True Power (P)}}{\text{Apparent Power (S)}}$$

Generation of three phase alternating current
(ARAC Volume 1, Chapter 11)

Three phase a.c is produced using the same principles as a single phase alternator, except there are three sets of coils in the stator, spaced 120° apart.

See ARAC for further details.

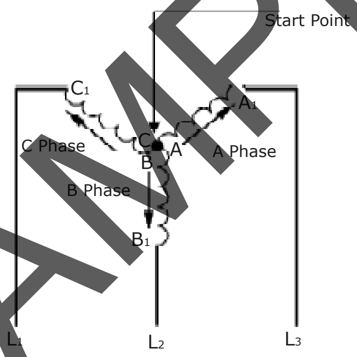
Three phase connections
(Electrical Principle for Electrical Trade, Chapter 9)

Three phase voltages are produced by three sets of windings, mechanically fixed to each other.

Because there are three separate voltages, each can be used as single phase source, but in practice the three winding are interconnected to form a three phase a.c. source.

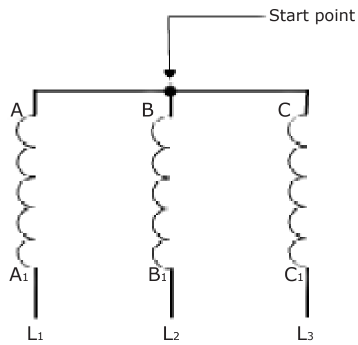
Star connecton (Y)

One method of forming a three phase system is to connect the three similar ends of the windings together as shown in the diagram opposite. Either the start or finish ends of the windings can be used. The common connecting point is called the Star Point.



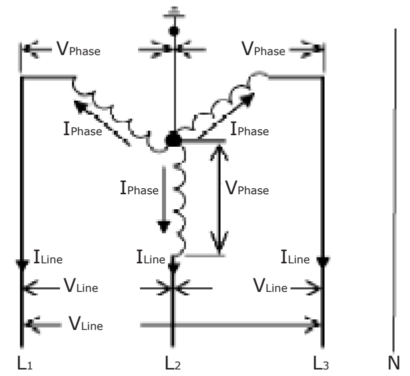
Star connected windings

An alternative method of drawing the windings is shown below.



Star connected windings

The three actives or lines are connected to the phase windings, as shown. The voltage between these lines is called the Line Voltage (V_{Line} or V_L) and the current flowing through the lines is called the Line Current (I_L). The neutral, which is connected to the star point and earthed, is not considered to be a line.



Line/Phase voltages and currents in Star connected windings

The Line Voltage is not equal to the Phase Voltage because two phase windings are connected across each pair of lines. The voltage across a single phase winding is therefore called the Phase Voltage (V_{Phase} or V_P) to distinguish it from the Line Voltage. Similarly, the current flowing through the phase winding is called the Phase Current (I_{Phase} or I_P).

The current in the three phases do not reach their maximum values at the same time but at regular intervals, 120° apart.

In a Star connected system, the Line Current equals the Phase Current. That is:

$$I_{Line} = I_P$$

V_{Line} is equal to the phasor difference between the phase voltages. Therefore:

$$\mathbf{V_{Line} = 415\ V}$$

$$\mathbf{V_P = \frac{V_{Line}}{\sqrt{3}}}$$

$$\mathbf{V_P = 240\ V}$$