Government of Western Australia
North Metropolitan TAFE

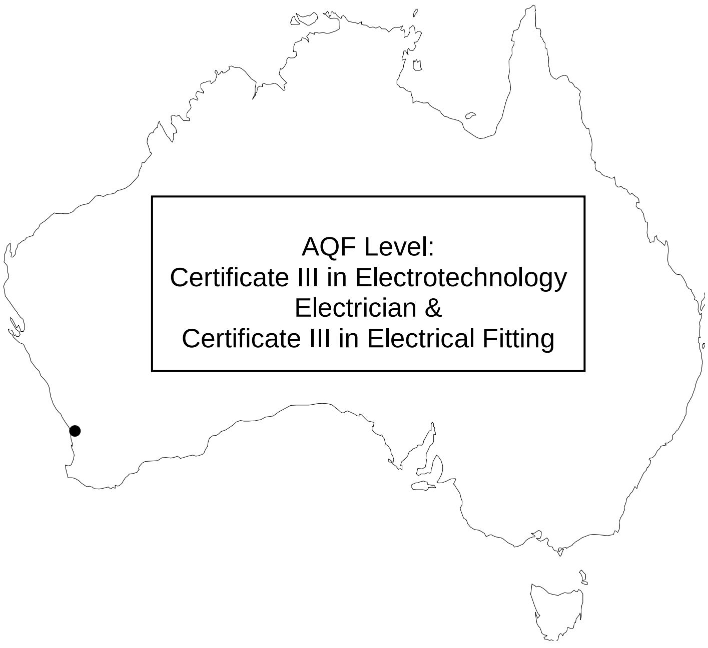
UEE 11 Training Package Support Material
(Non-Endorsed Component)

Based on:
National Electrotechnology Industry Standards

Resource Book

UEENEEG063A

Arrange Circuits, Control and Protection for General Electrical Installations



AQF Level:
Certificate III in Electrotechnology Electrician &
Certificate III in Electrical Fitting

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Edited by J. Waswo - August 2018-V3
North Metropolitan TAFE

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Acknowledgements

This Unit Guide has been prepared by North Metropolitan TAFE Lecturers.

It is intended for North Metropolitan TAFE students only.

UEENEEG063A Arrange circuits, control and protection for general electrical installations

C O N T E N T S

Work Completed:

Section	**Topic**	Completed
1	Risks Associated with Electric Current Flow - Worksheet	
2	Protective Earthing Systems - Worksheet	
2	Protective Earthing Systems – Laboratory Project	
3	Protection Device Principles - Worksheet	
4	Operation and Selection of Protective Devices - Worksheet	
5	RCD Earth Leakage Protection - Worksheet	
6	Electrical Fault Protection - Worksheet	
7	Switchboards - Worksheet	
7	Switchboards - Project	
	Assessments	

References

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (Current edition)
- Electrical Wiring Practice (7th ed.) Pethebridge, K. & Neeson, I.

Competency Standard Units

UEENEEG063A Arrange circuits, control and protection for general electrical installations

Prerequisite Units
Granting competency in this unit shall be made only after competency in the following units have been confirmed.

UEENEEE101A	Apply Occupational Health and Safety regulations, codes and practices in the workplace
UEENEEE102A	Fabricate, dismantle, assemble of electrotechnology components
UEENEEE104A	Solve problems in d.c circuits
UEENEEE105A	Fix and secure electrotechnology equipment
UEENEEE107A	Use drawings, diagrams, schedules, standards, codes and specifications
UEENEEG101A	Solve problems in electromagnetic devices and related circuits
UEENEEG102A	Solve problems in low voltage a.c. circuit
UEENEEG106A	Terminate cables, cords and accessories for low voltage circuits

ELEMENT		PERFORMANCE CRITERIA	
1	Prepare to arrange electrical installations circuits, control and protection	1.1	The extent and nature of the electrical installation is determined from job specifications.
		1.2	Safety and other regulatory requirements to which the electrical installation shall comply are identified, obtained and understood.
		1.3	Load requirements for individual current-using equipment is determined from job specifications or from consultation with appropriate persons.
2	Arrange electrical installations circuits, control and protection	2.1	Circuits, control and protective devices are arranged to ensure safe and functional operation of the installation and to comply with technical standards and job specifications and requirements.
		2.2	Earthing is arranged and terminated to comply with the MEN system requirements.
		2.3	Protective devices are selected to meet the required switching and tripping currents, co-ordination and discrimination for overload and short-circuit protection.
		2.4	Residual current devices are selected to meet the required circuit, switching and tripping currents required.
		2.5	Switchgear/control gear is selected to meet current, voltage and IP ratings and functional requirements.

ELEMENT		PERFORMANCE CRITERIA	
		2.6	Switchboards are arranged to accommodate control and protective devices, links, safety services, and other distributor equipment in accordance with requirements.
3	Document electrical installation circuits, control and protection arrangements	3.1	Evidence is obtained from manufacturers/suppliers that electrical equipment selected complies with safety requirements.
		3.2	Reasons for selections made, including calculations, are documented in accordance with established procedures.
		3.3	Electrical installation arrangement and specifications for all selected items are documented in accordance with established procedures and forwarded to appropriate person(s).

Required Skills and Knowledge

KS01-EG063A **Electrical installations — arrangement, control and protection**

Evidence shall show an understanding of circuit arrangements, control and protection of electrical installations that comply with the Wiring Rules and Service Rules to an extent indicated by the following aspects:

T1 Safety principles to which electrical systems in building and premises shall comply.

- Safety principles are given in Part1 (Section 1) of the Wiring Rules AS/NZS 3000 with deemed-to-comply requirements given in Sections 2 to 8.
- Compliant methods for providing protection - include those for providing protection against direct and indirect contact; thermal effects; unwanted voltages; overcurrent; fault currents; overload; overvoltage; injury from mechanical movement.
- Requirements for installation design and selection of equipment - includes compliant protection arrangements; correct functioning; compatibility with supply; estimation of maximum demands; voltage drop considerations; arrangement of circuits and the like

T2 Circuit and control arrangements encompassing:

- reason for dividing electrical installations into circuits
- factors that shall be considered in determining the number and type of circuits required for an installation.
- daily and seasonal demand for lighting power, heating and other loads in a given installation.
- number and types of circuits required for a particular installation.
- diagrams/schedules of circuits for given installations.
- application and arrangements of SELV and PELV circuits
- application and arrangement of an isolated supply

T3 Hazards and risks in an electrical installation encompassing:

- effects on the human body of various levels of a.c. and d.c. current and duration of current flow for various current paths.
- risk of ignition of flammable materials due the thermal effects of current or electric arcs in normal service of an electrical installation.
- risk of injury from mechanical movement of electrically actuated equipment.
- Protection against direct contact (basic protection)
- acceptable methods
- use of extra-low voltage

T4 Protection against indirect contact encompassing:

- indirect contact with live parts of an electrical installation may occur.
- methods and devices that comply with the Wiring Rules for providing protection against indirect contact.
- components of the 'automatic disconnection of supply' method of protection against indirect contact.
- the terms ‘touch voltage’ and ‘touch current’.
- the current path when a short circuit fault to exposed conductive parts of an appliance occurs.
- protection against indirect contact is by the use of Class II equipment and by electrical separation.
- additional protection by use of Residual Current Devices (RCDs)
- protection against indirect contact by use of extra-low voltage and electrical separation.

- Protection requirements for damp situations.

T5 Earthing encompassing:

- the terms: earthed, earthed situation, earth electrode, equipotential bonding, multiple earthed neutral (MEN) system, protective earth-neutral (PEN) conductor, main earthing conductor, protective earthing (PE) conductor, functional earthing, MEN link.
- selection of minimum size-earthing conductor for a range of active conductor sizes and materials.
- parts of an earthing system and the purpose of each.
- typical arrangement for a MEN earthing system.
- arrangements of protective earthing conductors that comply with the Wiring Rules.
- requirements for equipotential bonding in a range of installation situations.
- Installation of a MEN earthing system for a single phase installation

T6 Protection against overload and short circuit current encompassing:

- overload current or fault currents in an electrical installation.
- equivalent circuit of an earth fault-loop
- level of fault current possible at a given point in an installation from the fault-loop impedance and data from the electricity distributor.
- methods and devices that comply with the Wiring Rules AS/NZS 3000 for providing protection against the damaging effects of overload and fault current
- requirements for co-ordination between protective devices and conductors
- requirements for co-ordination of protection devices for discrimination and back-up protection.

T7 Devices for automatic disconnection of supply encompassing:

- operating principles of thermal/magnet circuit breakers.
- operating principles of common types of fuses.
- operating principles of residual current devices (RCD).
- time/current curves tripping characteristics of various types of circuit breakers that comply with the requirements of the Wiring Rules.
- time/current curves fusing characteristics of various types of fuses that comply with the requirements of the Wiring Rules.
- time/current curves tripping characteristics of various types of RCDs that comply with the requirements of the Wiring Rules.
- factors in a fault loop that will affect the impedance of the circuit.
- maximum impedance of an earth fault-loop to ensure operating of a protection device.
- selecting a fuse for fault current limiting protection.
- drawing switchboard wiring arrangements of 2-pole RCDs, 4-pole RCDs, combination RCD/MCBs.

T8 Protection against over voltage and under voltage encompassing:

- causes of over voltage and how this may affect the electrical system.
- methods for protection against over voltage.
- causes of under voltage and how this may affect the electrical system.
- methods for protection against under voltage.

T9 Control of an electrical installation and circuits encompassing:

- switch types, current and voltage ratings and IP rating and where these apply.
- switching requirements for isolation, emergency, mechanical maintenance and functional control.
- control arrangement for complete installations with and without safety services and an alternative supply.

T10 Switchboards / distribution boards encompassing:

- Purpose, types and applications.
- Physical and circuit arrangements for whole current and CT metering.
- Physical and circuit arrangements of main switches, circuit protection devices, fault-current limiters and metering equipment and other distributor equipment.
- compliance requirements (includes location and access, arc fault protection, identification, construction suitability, equipment marking, wiring, fire protection and arc-fault protection).

G063A Work Performance Tasks:

UEENEEG063A Arrange circuits, control and protection for general electrical installations
1. Performance requirements: 1a. Related to the following elements: 1. Prepare to arrange electrical installations circuits, control and protection. 2. Arrange electrical installations circuits, control and protection. 3. Document electrical installation circuits control and protection arrangements. 1b. For each element demonstrate performance: − across a representative body of performance criteria, − on at least 2 occasions, − autonomously and to requirements, − within the timeframes typically expected of the discipline, work function and industrial environment. 2. Representative range This unit shall be demonstrated in relation to selecting wiring systems and cables for at least two general electrical installations comprising a main switchboard, supplying more than one circuit for; lighting, socket outlets and fixed appliances. One of the installations shall include a distribution board separate from the main switchboard and at least one circuit supplying a three phase load and a fire pump. All listed tasks related to performance across a representative range of contexts from the prescribed items below: The minimum number of items on which skill is to be demonstrated Group No Item List A. All of the following: Arranging circuits for electrical installations • Selecting protection methods • Selecting protection devices including RCD's • Selecting switchgear and control gear • Selecting earthing components • Documentation of electrical installation

Workplace Rules:

Rule 1	Follow the instructions
Rule 2	Tolerate ambiguity
Rule 3	Meet your obligations

Note: This information and current details of critical aspects for each competency standard unit (CSU) in this qualification can be found at the Australian Training Standards website www.training.gov.au.

UEENEEG063A Arrange circuits, control and protection for general electrical installations

Learning and Assessment Plan

Name of Lecturer: ____

Contact Details: ____

Delivery Mode/s: □ Face to Face □ On-Line □ Blended Delivery □ Other

Using:

- AS/NZS 3000 (Current edition) – Wiring Rule (Standards Australia)
- H B 301 – 2001 Electrical Installations: Designing to the Wiring Rules
- AS/NZS 3008.1.1 (Current edition) – Electrical Installations- Selection of Cables
- WA Electrical Requirements (Current edition)
- Electrical Wiring Practice (7^{th} ed.) Pethebridge, K. & Neeson, I.

Session	Nominal Duration	Program of Work (Topics to be covered)	Primary Reference
1A	1 hr	Introduction to CSU, assessment methods, duration, resources, RPL Applications	Lecturer
1B	3hrs	Section 1 Risks Associated with Electric Current Flow	Resource Book
2	4hrs	Section 2 Protective Earthing Systems	Resource Book
3	4hrs	Section 3 Protection Device Principles	Resource Book
4	4hrs	Section 4 - Operation and Selection of Protective Devices	Resource Book
5	4hrs	Section 5 RCD Earth Leakage Protection	Resource Book
6	4hrs	Section 6 Electrical Fault Protection	Resource Book
7	8hrs	Section 7 - Design and Layout of Switchboards and Distribution boards	Resource Book
8	2 hrs	**Written Assessment**	RSAK – KS01 – EG063A
9	2 hrs	**Observed Practical Assessment** Switchboard Layout	G063A Elements and Performance Criteria

I acknowledge that I have received and read this Delivery and Assessment Plan Student Name:______________________ Signature: ____________________ Date: __________		
Lecturer Name	Lecturer Signature	Date

Assessment Strategy

Conditions of Assessment:

Normally learning and assessment will take place in an integrated classroom/ laboratory environment.

It is essential to work through the worksheets and activities in this workbook and follow the guidance of your lecturer. The worksheets and practical activities will provide the required skills and knowledge outlined in this Unit and assist you in achieving competency.

Assessment Methods:

Written Assessment – based on the Require Skills and Knowledge (RSAK). You must achieve a mark of 75% or more in this assessment.

Observed Practical Assessment – based on the Elements and Performance Criteria of this Competency Unit UEENEEG063A. You must achieve a mark of 100% in this assessment.

On-Job-Training:

It is expected that the off-job component of this competency unit will be complemented by appropriate on-job development involving exposure to re-occurring workplace events and supervised experiences. (See Work Performance Tasks.) You are required to log your on-the-job training in your ‘Q-Tracker’account.

Sufficiency of Evidence:

In all instances competency is to be attributed on evidence sufficient to show that a person has the necessary skills required for the scope of work. These include:

- Task skills - performing individual tasks
- Task management skills - managing a number of different tasks
- Contingency management skills - responding to irregularities and breakdowns in routines
- Job/role environment skills - dealing with the responsibilities and expectations of the work environment including working with others.

Evidence must demonstrate that an individual can perform competently across the specified range of activities and has the required skills and knowledge underpinning the competency.

LABORATORY SAFETY INSTRUCTIONS

Students working in Laboratories at this campus do so, on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. No circuit is to be plugged in or switched on without specific permission of the lecturer in charge of the class. A circuit must be switched off and tested for zero volts before any connection leads are removed. The DANGER TAG PROCEDURE must be used at all times.

2. Do not leave any circuit switched on any longer than necessary for testing. Do not walk away and leave the circuit switched on.

3. Report any broken, damaged or unserviceable equipment to your lecturer.

4. All of your wiring must be disconnected at the end of each practical class or as each project is completed.

5. Make all connections in a safe manner with an appropriate connecting device. Unshielded 4 mm banana plugs are not to be used for wiring.

6. Switch off, remove the plug from the socket and attach your danger tag to the plug top before working on the project. It is not sufficient to simply turn the supply switch off.

7. When disconnecting your wiring from a connection made under a screw, undo the screw- do not cut the wires off.

8. Observe the correct colour code for all wiring projects.

9. Check your circuit for short circuits with your multimeter before asking your lecturer to switch on. Check the checker before and after EACH check.

10. Skylarking is not permitted at any time.

11. Proper clothing and footwear must be worn at all times when you attend this campus. Thongs, sandals and singles alone are not permitted. **Safety boots or safety shoes must be worn in workshops, laboratories and installation skills areas**.

12. Where a project sheet is issued for a practical project, complete each step in the Procedure before moving on to the next step.

13. Draw all diagrams in pencil so that they can be easily changed or corrected. Mark off each connection on your circuit or wiring diagram as it is made.

14. Check the function and range before taking a reading with a multimeter.

15. Make sure that it is YOUR plug before you insert it into a socket outlet.

16. Always switch a multimeter OFF or to the highest possible AC volts range when you have finished using it.

Student's Signature ___________________________ Date: __________________

WORKSHOP SAFETY INSTRUCTIONS

Students working in workshops and installation skills areas at this college do so on condition that they agree to abide by the following safety instructions. Failure to observe the safety instructions may result in immediate suspension.

1. Personally owned eye protection must be worn AT ALL TIMES. Other safety equipment including hearing protection must be worn when applicable to a particular task.

2. Loose clothing must not be worn when working on fixed or portable machines. Hairnets must be worn where applicable. Clothing must cover the upper arms and body.

3. Enclosed footwear must be worn at all times on this campus. Thongs or sandals are not permitted. **Safety boots or safety shoes must be worn in workshop and installation skills areas**.

4. Tools and safety equipment are issued from the tool store on request. It is your responsibility to ask for the correct item (Size, Type and Tool). Check to see that you have been given the correct item before using it. If in doubt ask your LECTURER, not the storeperson.

5. Report any broken, damaged or unserviceable equipment to your Lecturer. Do not use damaged tools or machines.

6. Clean down the machines immediately after use. All tools must be cleaned before returning them to the store.

7. Skylarking is not permitted at any time.

8. Always use protective vice jaws when cutting off material in a bench vice.

9. Accidents resulting in cuts, abrasions or other personal injury must be reported to your Lecturer immediately - no matter how minor they may seem. A first-aid kit is available in the tool store.

10. Never leave a machine unattended when it is running. Do not allow yourself to be distracted when operating a machine.

11. Read all safety signs and notices and follow the instructions.

12. Do not use a fixed or portable machine unless you have been instructed in its proper use.

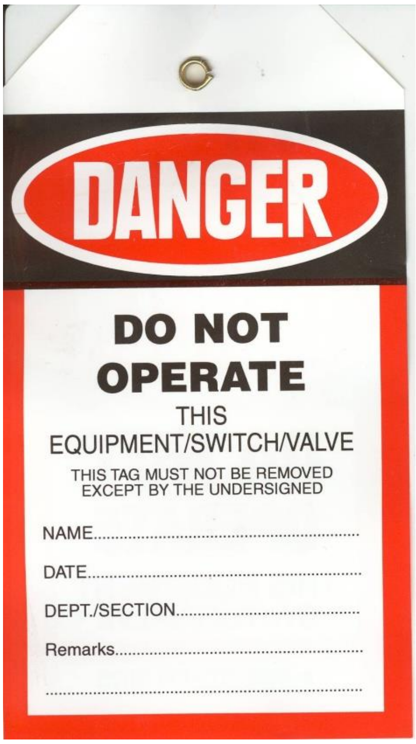
13. Read all risk assessment documentation provided (JSAs) and conduct a relevant risk assessment process before performing any task.

Student's Signature ___________________________ Date: __________________

Danger Tag Procedure

Use of Danger Tags

If you have a practical task to do and there is a possibility that you could be injured if someone turns on the electricity, then you **MUST** fasten a red danger tag to the machine main isolation switch, circuit-breaker or the equipment plug top.



Each danger tag you use must clearly show; your name, your section (class) and the date.

Nobody must operate the danger tagged switch or control point until the job is made safe and the danger tag has been removed.

Your lecturer will check your task before you are allowed to remove your danger tag.

Only the person who is named on the tag and attached the tag, is allowed to remove it.

Points to Watch

Make absolutely sure the switch/circuit-breaker/plug top is the correct one to tag. If you have any doubts, ask your lecturer.

Make sure that you have switched the isolator to **OFF** position before you attach your danger tag.

Fasten the danger tag securely.

The purpose of using Danger Tags is to prevent electrical accidents from happening.

Failure to follow Danger Tag Procedures when working on practical activities and practical assessments will result in a **Not yet competent** comment recorded for this Unit of Competency – UEENEEG063A

Student's Signature ___________________________ Date: __________________

Government of Western Australia North Metropolitan TAFE	**Arrange circuits, control and protection for general electrical installations**	Section 1 Introduction	G063A SGB 01/2014

Risks Associated with Electric Current Flow

Task:

Demonstrate an understanding of risks associated with electrical current flow and the methods of protecting people and livestock against dangers that may arise from contact with exposed metal parts which may become alive under fault conditions.

Why:

It is essential for an electrician to have an understanding of the methods and devices to protect persons, livestock and property against dangers and damage that may arise in the reasonable use of electrical installations and under fault conditions so that hazards associated with electrical current flow can be avoided.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in an observed practical assessment.

Equipment

Simulated electrical installation panels.

References
Current editions of the following publications
* AS/NZS 3000 Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* WA Electrical Requirements.
* Electrical Wiring Practice (7th ed.) – Pethebridge, K & Neeson, I.
* Code of Practice. Safe electrical work on low voltage electrical installations WA Office of Energy.

Government of Western Australia North Metropolitan TAFE	**Arrange circuits, control and protection for general electrical installations**	Section 1 Study Guide	G063A SGB 01/2014

Risks Associated with Electric Current Flow

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000:2007 Wiring Rules

Section 1.5 Protection against dangers and damage
Section 7.7 Hazardous Areas
Clause 1.5.5.3 Earthing system impedance (fault-loop impedance)
Section 5 Earthing arrangements and earthing conductors

Electrical Wiring Practice (7th ed.) Pethebridge, K & Neeson, I.
Volume 1 Section 3.6 Fundamental Requirements (Wiring Rules Part 1)

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Arrange circuits, control and protection for general electrical installations**	Section 1 Summary	G063A SGB 01/2014

Risks Associated with Electric Current Flow

Electric Shock

1. Electric shock can be, and often is, fatal. Electrical workers have a direct responsibility to protect persons, livestock and property against dangers that may arise in the reasonable use of electrical installations under fault conditions. Work should not begin on any electrical device or circuit until a suitable measuring device has been used to confirm that the circuit is dead. Although voltages less than about 30 volts are usually considered to be harmless, unintended contact between parts can result in short circuits, electrical flashes, burns, or damage to the equipment.

2. A small a.c. or d.c. electric shock can cause a mild tingling sensation in the muscles of the arm, but a severe shock causes a sudden contraction of the heart muscles which can stun the victim and may have one or more of the following effects:

   a. The victim stops breathing.

   b. The victim's heart stops, or quivers rapidly without pumping blood - a condition known as ventricular fibrillation.

   c. The victim suffers severe burns.

   d. The victim suffers traumatic shock to the nervous system.

   e. The victim suffers muscular paralysis and may be unable to release his/her grip on a live machine.

Factors

3. The factors which affect the seriousness of electrical shock are:

   a. The amount of current passing through the body.

   b. The path of the current through the body.

   c. The voltage of the circuit.

   d. The duration of contact with the live part.

   e. The resistance of the body at the time of contact.

   f. The surface area of the skin in contact with the live component.

   g. The period of the cardiac cycle during which the shock occurs.

   h. The individual - some people are affected more than others.

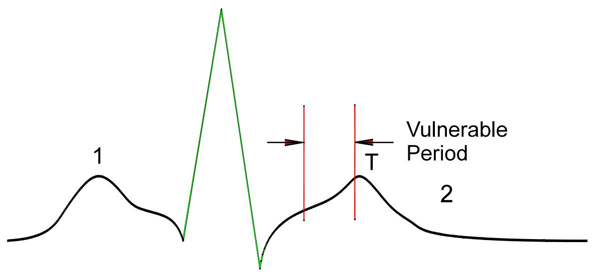
4. It is not possible to define precisely the effects of a given current on the body, but the general effects of alternating current are shown in Figure 1.

```
Current in
  Amperes
           |
    0.5    |--   Severe burns
           |
           |
           |
           |     Breathing stops
    0.2    |--   Death usually occurs
           |
    0.1    | - - - - - - - - - - - - - - - - - -
(100 mA)   |     Extreme breathing difficulties
           |     Breathing upset and laboured
           |
           |     Severe shock
   0.05    |--   Muscular paralysis
 (50 mA)   |     Can not let go
           |
           |
           |     Painful
   0.01    | - - - - - - - - - - - - - - - - - -
 (10 mA)   |
           |     Mild tingling sensation
           |
           |     Threshold of sensation
  0.001    |__________________________________
  (1 mA)
```

Figure 1 - General effects of electric shock

The Cardiac Cycle

5. The small electrical impulses which stimulate normal muscular contraction of the heart follow a regular pattern which can be represented on a graph known as the 'Cardiac Cycle', as shown in Figure 2.



T - The vulnerable period
1 - 2 - One normal cardiac period (heart beat)

Figure 2 - The cardiac cycle

6. It is thought that there is a specific period during the cardiac cycle when the heart is most likely to be affected by an electric shock. This period is known as the 'vulnerable period', as indicated in Figure 2. If a person receives an electric shock during the vulnerable period, the probability that the heart will go into ventricular fibrillation is increased.

7. The existence of a period of higher vulnerability may explain why some people may suffer no long term effects from an electric shock, while others receive a shock under similar conditions and fail to recover.

Burns

8. The passage of electric current through the human body can result in severe burning of body tissue. The effects of electrical burns often contribute more to the cause of death than the electric shock itself.

Test Before You Touch

9. Electrical accidents can be prevented by adopting safe working practices. Two of the guiding principles which must be adopted by any electrical worker are TEST BEFORE YOU TOUCH and ALWAYS CHECK THE CHECKER.

Thermal Effects of Current Flow

10. When electric current flows in any material heat is generated. A correctly designed and installed installation must allow the heat to be dissipated safely under normal operating conditions, and it must provide for reasonable protection of persons, livestock and property under predictable fault conditions. Cabling must be designed and installed so that it does not exceed relevant temperature ratings in normal service, and a circuit protection device must be selected and installed so that the components in the circuit are not damaged under fault conditions.

11. Typical non-electronic devices which open and close electrical circuits cause arcing at the contacts. This arcing can be an ignition source if it is allowed to occur in the presence of flammable gas, vapours, or combustible dust, fibres or flyings - such situations are referred to as 'hazardous areas' and are the subject of special requirements (see AS/NZS 3000 Clause 7.7, AS 2430 and AS 2381). Manufacturers of switching devices such as circuit breakers and a.c. and d.c. contactors provide for arc suppression in the design of the equipment under both normal and fault conditions.

Mechanical Movement

12. Electrical installations must also be designed so that mechanical movement of components under normal or fault conditions can not constitute a hazard. See AS/NZS 3000 Clause 1.5.13.
A common method of reducing hazards associated with moving equipment is to provide electrical or mechanical interlocks so that equipment can only operate if the relevant components are in the correct relative position. Consideration must be given to any hazard which may be created if a device is automatically re-energised after a fault. See AS/NZS 3000 Clause 4.13.1.4.

Direct and Indirect Contact

13. AS/NZS 3000 defines two conditions under which a person could come in contact with a live part - direct contact and indirect contact (see Clause 1.4.38 and 1.4.39).

14. Direct contact is when contact is made with a part which is live in normal service. This can occur if a person touches a live part in, for example, a switch room to which only authorised persons have access, or if the protective insulation around a live terminal block is damaged, exposing the live terminals. Clause 1.5.4.2 of AS/NZS 3000 specifies methods of providing protection against direct contact (basic protection), i.e.:

    a. Insulation.
    b. Barriers or enclosures.
    c. Obstacles.
    d. Placing out of reach.

15. Indirect contact is when contact is made with a conductive part which is not normally live but has become live under fault conditions. This can occur, for example, when an insulation breakdown occurs inside a single insulated electrical device and causes a live part to come in contact with the exposed outer metal casing. If protection against indirect contact was not provided, and a person came in contact with the live metal casing in a 240 volt device while in electrical contact with the general mass of earth, he or she would suffer an electric shock.

16. 'Touch current' and 'touch voltage' are defined in Clauses 1.4.124 and 1.4.125 of AS/NZS 3000. For the purposes of protection against indirect contact the touch voltage limit is defined as 50 V a.c. or 120 V ripple free d.c. (see Clause 1.5.5.3(b).

17. The requirements for protection against indirect contact are specified in AS/NZS 3000 Clause 1.5.5. Clause 1.5.5.2 specifies the methods of providing protection against indirect contact (fault protection), i.e.:

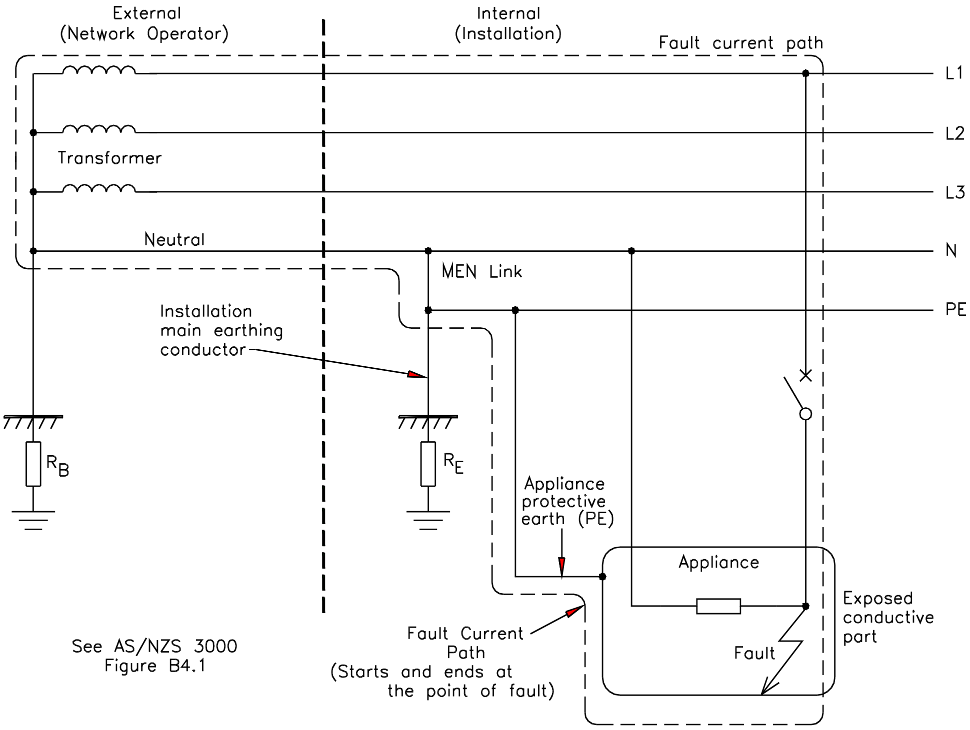
    a. Automatic disconnection of the supply.
    b. The use of Class II (double insulated) equipment.
    c. Electrical separation.
    d. Limit to a safe level the fault current than can pass through a body.

Automatic Disconnection of Supply

18. Protection against indirect contact by automatic disconnection of the supply is typically achieved by providing a system of earthing in which exposed conductive parts are connected to the general mass of earth via a protective earthing conductor, or by providing a residual current device (RCD) (see AS/NZS 3000 Clause 1.5.5.3 and 1.5.6).

Fault Current Path

19. The earth fault current path in a simplified MEN installation in which the exposed conductive parts are connected to the general mass of earth via a protective earthing conductor is shown below.



Class II Equipment

20. Protection against indirect contact can be provided by using Class II (e.g. double insulated) equipment - see AS/NZS 3000 Clause 1.5.5.4. Double insulated equipment has supplementary insulation as well as the functional insulation, and no provision is made for protective earthing. The design of the electrical device is such that the insulation arrangements prevent a live contact from coming in contact with exposed metal so the exposed metal cannot become alive.

Protection by Electrical Separation

21. Protection against indirect contact can be achieved in an individual circuit by preventing shock current through contact with exposed conductive parts which might be energised by a fault in the basic insulation of the circuit wiring. This is known as electrical separation (see AS/NZS 3000 Clause 1.5.5.5).

22. The simplest form of electrical separation is the use of an isolating transformer in the supply. An isolating transformer is a double-wound transformer in which the secondary output voltage is the same as the primary input voltage, and the VA rating is large enough to supply the intended load. When the load is connected to the secondary terminals it operates as it would if connected to the normal supply, but the neutral is no longer connected to the general mass of earth through the MEN link. If an insulation fault develops in the load side circuit wiring, and it results in an internal live part coming in contact with exposed metal, there is no difference of potential between the exposed metal and earth, eliminating/reducing the possibility of a fault to earth.

23. Clause 7.4 contains specific requirements relating to electrical separation.

Summary Table

24. A general summary of the AS/NZS 3000 requirements for protection for safety is given in the table on the following page.

Fundamental Protection Principles - General Outline
(Refer to AS/NZS 3000:2007 Clause 1.5)

Risks			
Electric shock current		Excessive temperatures	Explosive atmospheres
Direct contact	Indirect contact		

Type of Protection	Principles	Methods
Direct contact (Basic protection) 1.5.4	Prevent current flowing. Limit current to low value. Use ELV supply	Insulation. Barriers or enclosures (e.g. IP 2X). Obstacles. Placing out of reach. Use ELV
Indirect contact (Fault protection) 1.5.5	Automatically disconnect supply. Prevent current flowing. Limit current to low value.	Automatic disconnection of supply. Use of double insulation (Class II). Electrical separation. Limit fault current Install RCD Use ELV
Thermal effects 1.5.8	Proper design. Adequate ventilation.	Proper selection and installation. Provide adequate ventilation..
Overcurrent 1.5.9	Prevent or limit overcurrent.	Automatic disconnection. Limiting current to a safe value and duration.
Earth fault current	Prevent shock current flowing.	Install RCD. Prevent direct or indirect contact.
Abnormal voltages	Segregation Reduce electromagnetic induction.	Protect unused conductors. Segregate circuits. Install overvoltage protection
Spread of fire	Proper design.	Proper selection and installation.
Mechanical movement	Restrict or control movement.	Devices to disconnect or isolate.
External influences	Proper design	Adequate design for normal operation. Consider all external influences.

General Design Principles (Clause 1.6)		
a. Protect persons, livestock and property from harmful effects.	b. Ensure correct functioning of installation – as intended.	c. Ensure compatibility with electricity distribution system.
d. Minimise inconvenience under fault conditions.	e. Facilitate safe operation, inspection, testing and maintenance.	f. Consider supply characteristics, maximum demand, utilization voltage and circuit arrangements.

Selection and Installation (Clause 1.7)		
a. Safe operation under normal conditions.	b. Not cause danger from shock or fire under reasonably expected conditions.	c. Be installed according to manufacturer's instructions.
d. Use safe and sound work practices.	e. Select equipment to comply with all requirements.	f. Verification of compliance with all requirements.

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Risks Associated with Electric Current Flow

1. What are the two main undesirable effects of high current passing through the human body?

2. How can the risk of injury from unexpected mechanical movement of electrically actuated equipment be reduced?
Give the AS/NZS 3000 clause number.

3. What are the general requirements where insulation is the method for protecting against direct contact with live parts?
Give the AS/NZS 3000 clause number.

4. What degree of protection is needed where barriers provide the method for protecting against direct contact with live parts?
Give the AS/NZS 3000 clause number.

5. What are the constructional requirements where barriers provide the method for protecting against direct contact with live parts?
Give the Wiring Rules clause number.

6. What are the requirements where the method for protecting against direct contact with live parts is the provision of obstacles?
Give the AS/NZS 3000 clause number.

7. What are the requirements where placing out of reach provides the method for protecting against direct contact with live parts?
Give the Wiring Rules clause number.

8. What is the intention of measures for protecting against indirect contact with live parts?
Give the AS/NZS 3000 clause number.

9. What is the purpose of automatic disconnection of supply when protecting against indirect contact with live parts?
Give the AS/NZS 3000 clause number.

10. If a fault exists between a live part and exposed conductive part, the protective device must automatically disconnect the supply where the touch voltage exceeds what limits?
Give the AS/NZS 3000 clause number.

11. For fault loop impedance, the product of what two values must not exceed the nominal AC rms voltage to earth?
Give the Wiring Rules clause number.

12. For a 240 volt final subcircuit comprising socket outlets, hand-held Class I equipment or other portable equipment, what is the maximum disconnection time for automatic disconnection devices?
Give the AS/NZS 3000 clause number.

13. For a 240-volt final subcircuit supplying fixed equipment or submain, what is the maximum disconnection time for automatic disconnection devices?
    Give the AS/NZS 3000 clause number.

14. It is possible to reduce the fault-loop impedance by bonding extraneous conductive parts to the protective earthing system. What is the name given to this?
    Give the Wiring Rules clause number.

15. What means are suitable for providing protection against dangerous voltages occurring on accessible conductive parts of electrical equipment in the event of a fault in the basic insulation?
    Give the AS/NZS 3000 clause number.

16. What measures are not considered to provide a suitable insulation covering?
    Give the AS/NZS 3000 clause number.

17. Briefly outline the measures for providing electrical separation.
    Give the AS/NZS 3000 clause number.

18. What means are suitable for providing protection from the risk of ignition of flammable materials in normal service?
    Give the AS/NZS 3000 clause number.

19. What means are suitable for providing protection from the risk of burns in normal service?
    Give the AS/NZS 3000 clause number.

20. What means are suitable for protecting an installation from the effect of unwanted voltages?
    Give the AS/NZS 3000 clause number.

21. What means are suitable for protecting an installation from the effect of over-current?
    Give the AS/NZS 3000 clause number.

22. What means are suitable for protecting an installation from the effect of fault currents?
    Give the Wiring Rules clause number.

23. What means are suitable for protecting an installation from the effect of over voltage?
    Give the AS/NZS 3000 clause number.

24. Under what conditions may a person come in 'indirect contact' with a live part.

25. What is an electrical 'interlock'?

26. What are three methods of providing protection against indirect contact with live parts in a 240 volt installation?

Notes:

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Protective Earthing Systems

Task:

To demonstrate an understanding of the purpose of earthing systems, their function under fault conditions and the AS/NZS 3000 requirements for earthing and equipotential bonding.

Why:

A detailed knowledge of earthing and earthing systems is essential for an electrician because earthing is the basic method of protecting people, livestock and property from the hazards associated with indirect contact with live parts.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in an observed practical assessment.

Equipment

Simulated electrical installation panels.

References

* AS/NZS 3000 Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* Electrical Wiring Practice (7th ed.) Pethebridge, K & Neeson, I.
* WA Electrical Requirements (2015).
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

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Protective Earthing Systems

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000 Wiring Rules

Section 1.5.1	Protection against dangers and damage
Clause 1.5.5.3(c)	Earthing system impedance (fault-loop impedance)
Section 5	Earthing arrangements and earthing conductors
Section 7.7	Hazardous areas

Electrical Wiring Practice (7th ed.) Volume 1

Chapter 8 Protection – earthing and protection methods

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.
3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.
4. Complete the projects in this workbook.
5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

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Protective Earthing Systems

1. The purpose of a protective earthing system is to automatically disconnect the supply if a live conductor comes in direct contact with the exposed metal frame of an electrical appliance or device.

2. There are three general systems of earthing used in different countries, only the MEN system is covered by AS/NZS 3000. These are: -

    a. The multiple earthed neutral (MEN) system (see Wiring Rules Clause 5.1.3).
    b. The direct earthing system (see Wiring Rules Clause 5.1.4)
    c. The voltage operated ELCB system (see Wiring Rules Clause 5.1.4).

The MEN System

3. In the multiple earthed neutral (MEN) system the parts of the installation which are required to be earthed are connected to the general mass of earth within the installation and, in addition, are connected within the installation to the neutral conductor of the supply system or the PEN conductor (see Wiring Rules, Clause 1.4.83). The neutral is also earthed at the supply authority's distribution transformers and sub-stations. Internationally, the MEN system of earthing is known as TN-C-S earthing system. A general outline of this arrangement is shown in Figure 1.

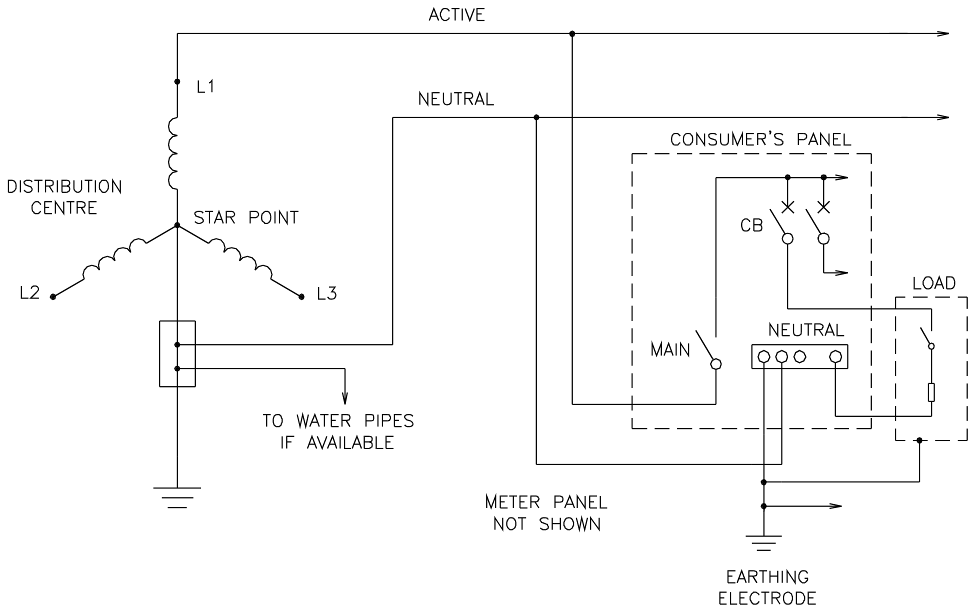

Figure 1 - Outline of the MEN system of earthing

4. The main advantage of the MEN system is that the Supply neutral is connected to the earth at every distribution centre and installation in the supply system, thus providing many parallel paths for any fault currents. The main disadvantage is that the resistance of the earthing conductors and earthing circuits must always be low enough to ensure that sufficient current can flow under fault conditions to allow the protection device to operate within a specified time (see AS/NZS 3000 Clause 5.7.2) The Wiring Rules require that the resistance of a main earthing conductor must not exceed 0.5 ohms (see Clause 5.5.1.4).

5. The MEN system is the system used in most installations in W.A.

The Direct Earthing System

6. In the direct earthing system the parts of a circuit which are required to be earthed are earthed by connecting them to an earthing medium such as metallic water pipes, but the earth is not connected to the neutral at each installation - the neutral is connected to earth at the supply authority's distribution centres. Internationally, the direct earthing system is known as either TT or a TN-S earthing system depending on whether the supply authority uses a separate PE conductor or not. An outline of this arrangement is shown in Figure 2. The direct earthing system is covered in AS/NZS 3000 Clause 5.1.4.

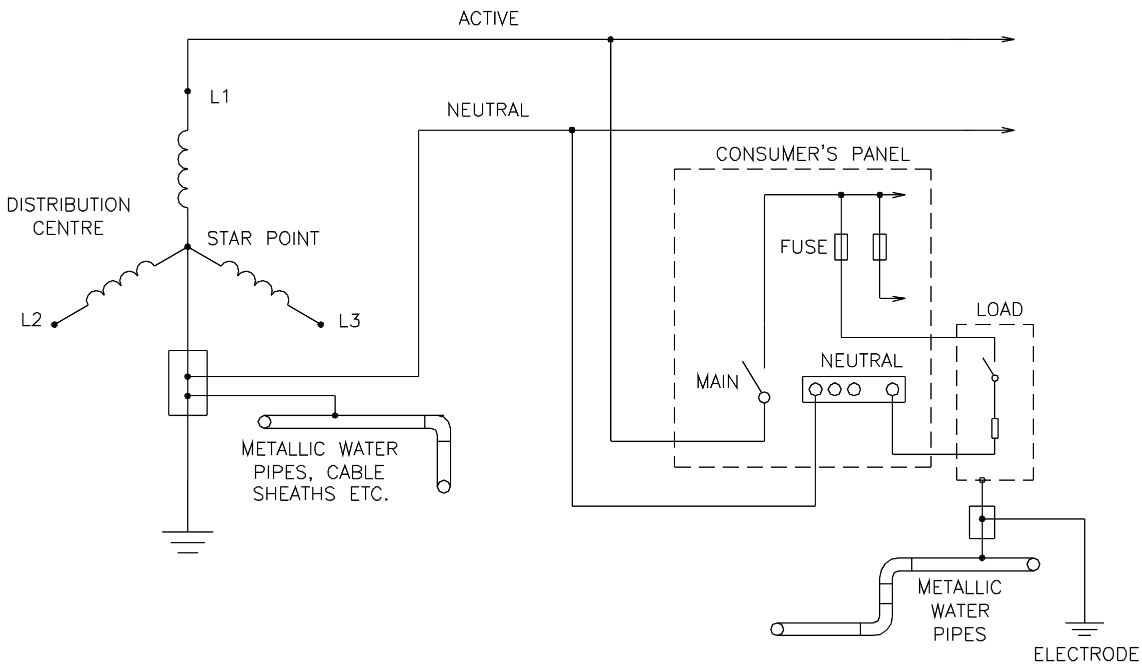

Figure 2 - Outline of the direct system of earthing

7. A disadvantage of the direct earthing system is that it relies heavily on metallic water pipes or separate supply authority earth (PE) conductor to form part of the earthing circuit, so it is not suitable for use in installations where PVC water pipes are used.

The Voltage Operated ELCB System

8. In the voltage operated earth leakage circuit breaker system the parts of the installation required to be earthed are connected through one or more voltage operated ELCB's. An outline of this arrangement is shown in Figure 3. The voltage operated ELCB system is not covered in AS/NZS 3000.

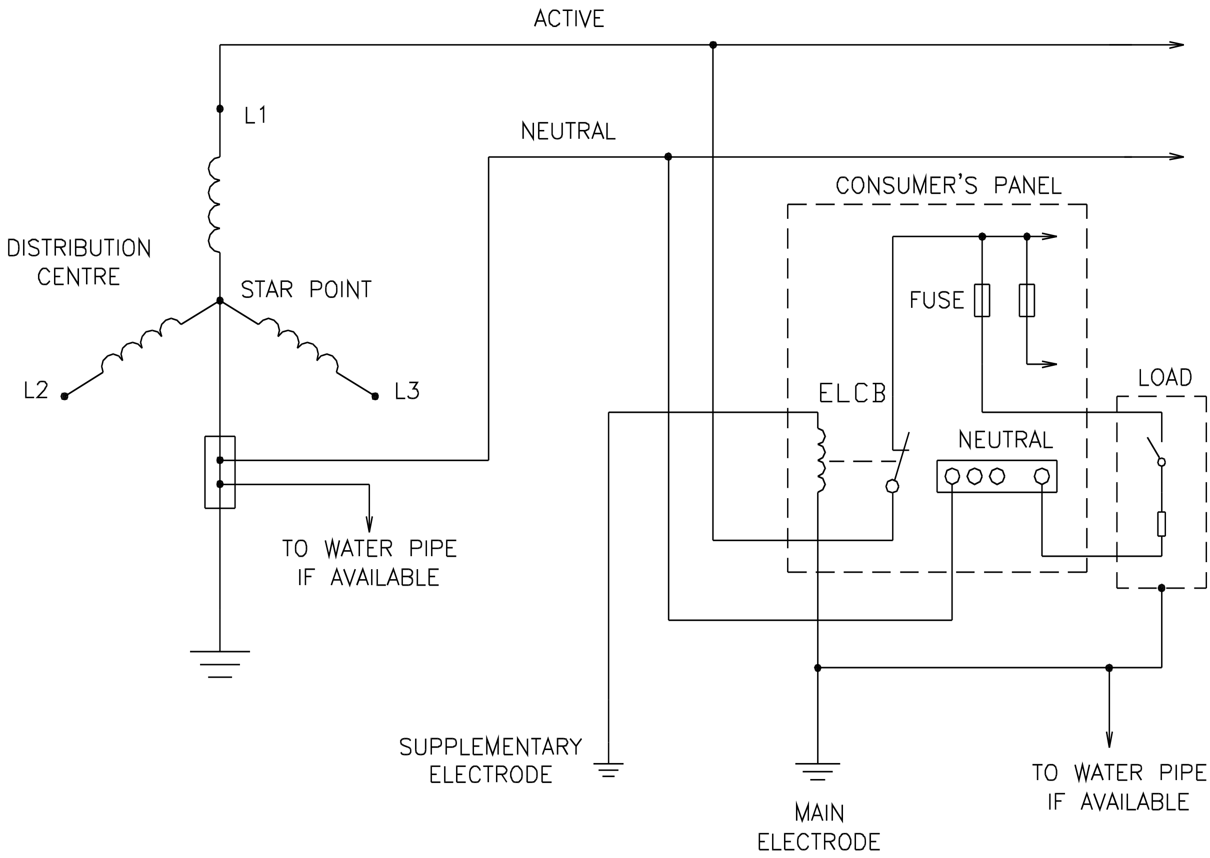

Figure 3 - Outline of the voltage operated ELCB system of earthing

9. The main advantage of the voltage operated ELCB system is that it does not rely on a low resistance earthing circuit. If an earth fault occurs in the installation, and the voltage between the metallic frame of the device and the supplementary earthing electrode exceeds the setting on the ELCB, the ELCB operates and disconnects the supply. This system is not widely used in W.A. because it requires more maintenance and checking, and it is prone to nuisance tripping. The voltage operated ELCB is not the same as a residual current device (RCD) - an RCD is a CURRENT operated ELCB.

Operation of the MEN System

10. The operation of an MEN earthing system depends mainly on there being an adequate conducting path between the neutral conductor and the general mass of earth. The supply is automatically disconnected when sufficient current flows in the circuit to operate the circuit protection device such as a fuse or circuit breaker, thus providing protection against electric shock in case of a fault. The remainder of the discussion in this section relates to the MEN system of earthing.

11. Figure 4 shows an outline of a typical single insulated appliance in an installation.

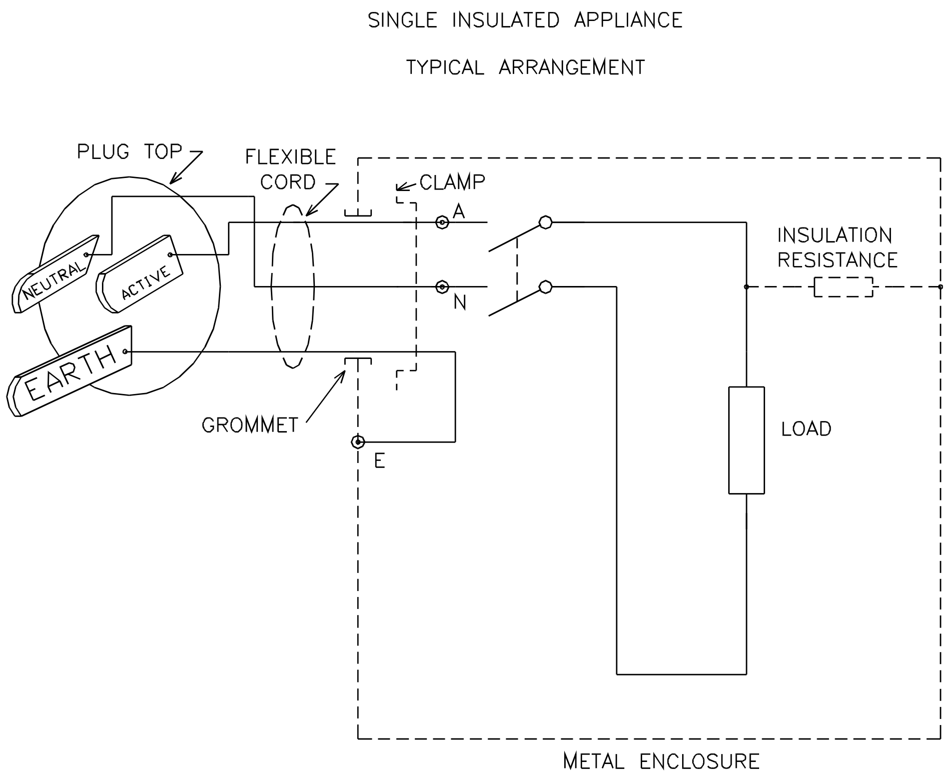

Figure 4 - Outline circuit of a single insulated appliance

12. If the component labelled 'insulation resistance' in Figure 4 had a resistance approaching zero ohms (i.e. it was a short circuit), and the operating switch was turned on, the active from the three pin plug top would be connected direct to the outer metal casing so the full supply voltage would be present between the outer casing and earth. If the earthing conductor was correctly connected a high current would flow from the outer casing to earth via the earth in the socket outlet and the circuit protection device (fuse or circuit breaker) protecting the circuit would operate and automatically isolate the circuit from the supply.

13. If the earthing conductor was not connected, or if it was not able to carry the current required to operate the circuit protection device, or the resistance of the earthing circuit was too high, the outer metal casing would remain alive; any person touching the frame while in contact with any earth would suffer an electric shock.

Limitation

14. Earthing an appliance does not provide protection against electric shock if a person touches the active and neutral or active and earth simultaneously. Earthing an appliance does not prevent faults from occurring, nor does it correct any faults; it limits the touch voltage and removes the supply from the faulty section of the circuit (see AS/NZS 3000 Clause 1.5.5.3(b).

Disconnection Times

15. Clause 1.5.5.3(d) of AS/NZS 3000 specifies the disconnection times for a 230/240 volt supply voltage - e.g. 0.4 seconds for socket outlets and 5 seconds for other circuits including submains and final subcircuits supplying fixed or stationary equipment.

Wiring Rules Requirements

16. The main requirements for earthing are contained in Section 5 of the Wiring Rules. The minimum copper and aluminium conductor size for associated active conductors is given in Table 5.1.

17. The only permissible colour for an insulated earthing conductor is green/yellow.

18. The condition in which the resistance between any part of circuit and the exposed metal frame of an appliance (i.e. the insulation resistance) is below specified limits is known as an 'earth fault' or low insulation resistance to earth. The same term is applied to complete installations. The insulation resistance between all live conductors connected together and earth must not be less than 1 megohm, measured with a high voltage insulation tester (Megger), and with all protective devices in circuit and all switches on (individual consuming devices may be disconnected).

19. Where a portable single insulated appliance is supplied by a flexible cord, and is connected to the supply via a plug and socket-outlet, provision must be made for the earthing pin to automatically make contact first and break contact last. This is achieved by making the earth pin in the plug-top longer that the other pins.

20. If a portable single insulated appliance is supplied by a flexible cord the earthing conductor must be incorporated in the same outer sheath as the associated live conductors (see Clause 5.5.3.3). It is not permissible to supply a single insulated appliance using two core flexible cord, and tape an additional conductor to the outside of the sheath of the flexible cord and use it as an earthing conductor.

21. The conditions under which a protective earthing conductor may be connected to exposed conductive parts such as a constructional bolt are contained in Clause 5.5.6.2.

22. It is not permissible to connect an earthing conductor to structural or ornamental metallic framework which does not form an integral part of an appliance.

23. Joints in earthing conductors must comply with Clause 3.7 of AS/NZS 3000.

24. An 'earthed situation' is a situation wherein there is a reasonable chance of a person touching the exposed metal of an appliance and, at the same time, coming in contact with an earth (see Clause 1.4.48).

25. Joints in copper main earthing conductors up to 16 mm^2 are usually soldered. Soldered joints must be made so that the earthing conductors are retained in position independent of the solder (See Clause 3.7.2.11)

Equipotential Bonding

26. Equipotential bonding is the process of connecting metallic water piping, waste pipes and other extraneous metal in contact with the ground and accessible to personal contact, with the earthing system of the building (See AS/NZS 3000 Clause 1.4.60). They are intended to minimise unwanted voltages between accessible metallic parts of electrical equipment and accessible metallic parts which are not part of the electrical installation. Equipotential bonding conductors are treated in the same way as earthing conductors.

Appliance Insulation Classifications

27. Most low voltage electrical appliances are manufactured to one of three general insulation specifications, namely:

   a. Single Insulated. In a single insulated appliance there is one layer of insulation between the internal live components and the outer metal enclosure. See AS/NZS 3000 Clause 1.4.31 (Class I equipment).

   b. Double Insulated. In a double insulated appliance there are two layers of insulation between the internal live components and the outer metal enclosure; the layers of insulation are called the functional layer and the protective layer. The international symbol to indicate double insulation is one square inside another. Double insulated appliances must NOT have exposed metal connected to earth, and they have a warning label such as 'DO NOT EARTH - DOUBLE INSULATED'. See AS/NZS 3000 Clause 1.4.32 (Class II equipment)

   c. All Insulated. All insulated appliances have no exposed metal parts so they do not have an earth.

28. Many electrical appliances which operate at voltages exceeding 50 volts a.c. are of the single insulated type. Single insulated devices must never be connected to the supply unless the exposed metal is connected to the general mass of earth via the earthing conductor in the flexible cord and the earthed pin in the socket-outlet. Live terminals or parts must not be accessible to users of electrical equipment.

Size of Earthing Conductors

29. Protective earthing conductors must be large enough to carry the current which will enable the associated circuit protection device to operate before the cables in the circuit are damaged under fault current.
The requirements for determining the minimum permissible size of earthing conductors are contained in AS/NZS 3000 Clause 5.3.3. Table 5.1 gives the minimum permissible earthing conductor size for a range of copper and aluminium cables.

Functional Earthing

30. Functional earthing is an earthing arrangement provided to ensure correct operation of electrical equipment or to permit reliable and proper functioning of electrical installations. See AS/NZS 3000 Clause 1.4.66

31. Functional earthing is required in the internal circuitry of some types of electronic equipment such as that used in entertainment, communications and instrumentation applications, to prevent unwanted potential differences in the equipment.

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Protective Earthing Systems

Note: The AS/NZS 3000 clause or Table number must be given for all relevant questions.

1. What is the meaning of the term ‘earthed’? Give the AS/NZS 3000 clause number.

2. What is the meaning of the term ‘earthed situation’? Give the AS/NZS 3000 clause number.

3. What is the meaning of the term ‘equipotential bonding’? Give the AS/NZS 3000 clause number.

4. What is the meaning of the term 'Multiple earthed neutral (MEN) system'? Give the AS/NZS 3000 clause number.

5. What is the meaning of the term 'Main earthing conductor'? Give the AS/NZS 3000 clause number.

6. What is the meaning of the term ‘Protective earth’? Give the AS/NZS 3000 clause number.

7. What is the meaning of the term 'Functional earthing'? Give the AS/NZS 3000 clause number.

8. What is the main reason why single insulated 240 volt equipment must be earthed?

9. What is the only permissible colour for an insulated earthing conductor? (Give the Wiring Rules Clause or Table Number)

10. Name the three recognised types of earthing system referred to and indicate which one is covered in the Wiring Rules.

11. What is the MAXIMUM permissible resistance of a main earthing conductor or any equipotential bonding conductor?

12. What is the MINIMUM permissible size of a copper main earthing conductor (Give the Wiring Rules Clause or Table Number)

13. An EARTHED SITUATION is where there is a reasonable chance of a person touching .....?..... and at the same time coming in contact with an earth. (Give the Wiring Rules clause number)

14. Any situation within .....?..... metres of a concrete floor or metal pipe is deemed to be an earthed situation. (Give the Wiring Rules Clause or Table Number)

15. All parts of a .....?..... are deemed to be an earthed situation. (Give the Wiring Rules Clause or Table Number)

16. Any situation which is external to a building and within .....?..... of exposed earthed metal is deemed to be an earthed situation. (Give the Wiring Rules Clause or Table Number)

17. Is it necessary to provide an earthing conductor to a lighting point consisting of a ceiling mounted batten holder installed inside a domestic building?

18. Is it permissible to install a general purpose 10 amp socket-outlet without earthing the earthing contact?

19. Is it necessary to earth accessible metal parts of low or medium voltage equipment if the accessible metal is separated from live parts by double insulation? (Give the Wiring Rules Clause or Table Number)

20. What type of earthing system is used in most electrical installations in W.A.?

21. Where is the protective earth connected to the neutral in a typical domestic installation?

22. Is it necessary to earth metallic boxes which form part of a wiring system if they are isolated from all other conductive material (other than metal which is earthed), and in no part accessible to personal contact?

23. Is it permissible to install bare MIMS cable without earthing the copper sheathing?

24. An aluminium luminaire is to be installed outdoors on a wooden pole, 3 metres from the nearest earthed metal. Does the Wiring Rules require the exposed metal casing of the luminaire to be earthed?

25. Is it necessary to earth accessible metal parts of low voltage equipment if the accessible metal is separated from live parts by double insulation?

26. What is the internationally recognised symbol which means 'Double insulated - Do not earth'?

27. What precaution must be taken to prevent an internal conductor from coming into contact with accessible metal if it becomes detached from its terminal in a double insulated appliance?

28. Is it necessary to earth exposed metal in a 32 volt portable hand-lamp?

29. Is it permissible to loop a MAIN earthing conductor into a luminaire to avoid having to run another earthing conductor to the luminaire?

30. Is it permissible to connect a subsidiary earthing conductor to a main earthing conductor using a soldered tee joint?

31. Is it permissible to earth equipment by connecting exposed metal to an earthing conductor which is being used to earth equipment supplied from another distribution board?

32. A steel wire armoured (SWA) cable is installed in such a way that the armouring is required to be earthed. At which point in the installation must the armouring be earthed?

33. What limitation is placed on the use of metal conduit as the protective earthing conductor for cables which are contained in the conduit?

34. A metal conduit is installed in such a way that it is required to be earthed. At which point in the installation must it be earthed?

35. How must a hinged door of a metallic electrical cubicle be earthed?

36. The exposed metal of electrical equipment on a wheeled overhead gantry crane is required to be earthed. Can metal-to-metal contact between the wheels and the rail be regarded as an effective connection for the purposes of earthing?

37. A particular electric motor is to be fixed in position using four bolts with nuts. Is it permissible to use one of the fixing bolts as the earthing terminal?

38. What is the minimum permissible size of copper MAIN earthing conductor if the active conductor in the associated consumer's mains is $16mm^2$?

39. What is the minimum permissible size of single core TPI cable (building wire) which can be used an earthing conductor?

40. In general, how must a clamped joints be made in copper earthing conductors up to 4 square mm?

41. What is the minimum permissible diameter of a copper-coated mild steel driven earthing electrode?

42. Is it permissible to use rigid metallic conduit as a driven earth electrode?

43. In general, where must a driven earth electrode be located?

44. To what minimum depth must a driven earth electrode be driven?

45. What action must be taken if exposed metal of wiring enclosures is in unavoidable contact with metallic piping of other systems such as fire sprinklers, gas or hot water?

46. What is the purpose of an equipotential bond in an installation?

47. What are two requirements for an effective earth joint?

48. Is it necessary to earth the metal frame of a domestic installation?

49. What are two general types of earthing conductor which need not be insulated.

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Earthing Connections

Objective

To terminate earthing conductors using various methods.

Equipment

Insulated earthing conductors
Propane gas burner with flint gun
Soft solder (50/50)
Non-corrosive soft soldering flux
Crimp lug for 4 mm^2 stranded TPI cable
12 mm diameter main earthing electrode with earth clip
11 hole neutral link
Hand tools as required

Procedure

1. Make off a soldered tee joint in a 1 metre length of 4 mm^2 earthing conductor using a propane gas burner.

2. Terminate a 500 mm length of 4 mm^2 earthing conductor with a suitable crimp lug.

3. Terminate a 500 mm length of 4 mm^2 earthing conductor at the main earthing electrode using an earth clip.

4. Connect a 10 mm^2 MEN conductor to the appropriate terminal in a typical neutral link.

5. Submit your terminations to your Lecturer for assessment and comment.

6. Return all of the equipment to its proper place.

Questions

1. Is it allowable to use 'Baker's Soldering Fluid' (a corrosive flux) to solder joints in electrical cables?

____

2. What is the minimum permissible size of main earthing conductor according to AS/NZS 3000?

____

AS/NZS 3000 Reference: ____

3. Is it permissible to make a join in a main earthing conductor using a standard two terminal blue-point connector?

____

AS/NZS 3000 Reference: ____

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Protection Device Principles

Task:

To select suitable devices for the protection and control of circuits in accordance with the Wiring Rules and manufacturers' recommendations.

Why:

Electrical circuit protection devices are essential to protect circuits and components from the damaging effects of excess current or voltage. You need to be able to select an appropriate protective device and install and correctly test it to avoid damage to circuit components or injury to operators.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in an observed practical assessment.

Equipment:

Samples of commonly used electrical protective devices.
Manufacturers' data relating to electrical protective devices.

References:

* Manufacturers' catalogues of electrical protective devices.
* AS/NZS 3000 - Wiring Rules.
* AS/NZS 3008.1.1 - Electrical installations - Selection of cables.
* Electrical Wiring Practice (7th ed.). Volume 2. Pethebridge, K & Neeson, I.
* Video: HRC Fuse Links

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Protection Device Principles

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

Manufacturers' Catalogues

Illustrated catalogues of electrical protection devices.
Protective device data sheets.

Electrical Wiring Practice (7th ed.). Pethebridge, K & Neeson, I.

Volume 2 Chapter 1

Section 1.1	Protection against overcurrent
Section 1.2	Overcurrent protection devices
Section 1.3	Protection against indirect contact with live
Section 1.4	Protection against overvoltage and under-voltage
Section 1.5	Protection arrangement and discrimination

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

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Protection Device Principles

1. In any circuit there are four main type of electrical fault which can occur, although there are varying degrees of each. The four types of fault are:

    a. Short circuits.

    b. Open circuits.

    c. Earth faults.

    d. Under or over voltage faults.

Short Circuits

2. A short circuit is said to have occurred when the impedance between two points is reduced to a lower than normal value due to a fault condition - often resulting from the failure of the insulation between the points, but it could also be due to faulty wiring or workmanship. The degree of the short circuit is often described using the terms 'dead short' and 'partial short', where a dead short (also known as a ‘bolted fault’) is virtually no resistance between the two points.

3. The result of a short circuit is excessive current flow in the circuit, which, in turn, results in a higher than normal temperature in the effected components; this condition is known as an overcurrent, overload or over-temperature condition. The heating effect of an electric current is proportional to the SQUARE of the current ($P = I^2.R$), so doubling the current increases the heating effect by four times. A short circuit can result in severe magnetic stress on circuit components.

4. The most common types of short circuits are:

    a. Between two different phases (phase to phase).
    b. Between any phase and neutral (phase to neutral).
    c. Between any phase and earth (phase to earth).

Fuses

5. A fuse is essentially a device which has a short length of wire of known current carrying capacity (called the fusible element), enclosed in a suitable insulated carrier mechanism. - See Wiring Rules Clause 1.4.68. The fuse is connected in series with the supply line, so that if the current flow in the circuit exceeds a critical value for a pre-determined time the fusible element will melt, thus interrupting the supply of current to the circuit.

6. The most common types of fuses are:

   a. High rupturing capacity (HRC) fuses.
   b. Glass cartridge fuses.
   c. Semi-enclosed rewirable fuses.

7. Fuses are rated according to the maximum current which they can carry continuously under normal conditions (not the current at which they will interrupt the supply). A 10 amp fuse does not 'blow' at 10 amps.

8. The fusing current depends on the type of fuse and the magnitude and duration of the fault current. A 10 amp semi-enclosed rewirable fuse element may not melt until the current reaches about 18 amps if the fault current is increased gradually; an HRC fuse element (or link) would melt at more than 10 amps but less than 18 amps. Thus fuses provide protection against high short circuit currents, but not against relatively small excess currents which would occur if a motor was slightly overloaded. In the latter case additional motor protection would need to be provided in the form of motor 'overloads' or direct temperature sensing devices such as Thermistors, Microtherms or Klixons.

9. If a fuse operates it indicates a fault condition in the relevant circuit. The fault must be located and corrected before the fuse element is replaced. When the fault has been corrected the procedure for replacing the fuse element(s) is as follows:

   a. Turn the main isolating switch off.

   b. Carefully withdraw the fuse carrier from the fuse base.

   c. Replace the fuse with the same size and type as the original (after checking to see that the size of fuse matches the fuse rating marked on the fuse base).

   d. Turn the main isolating switch on.

10. The approximate current rating for fuse elements composed of tinned copper wire for superseded semi-enclosed rewirable fuses are:

    8 amps - 0.315 mm diameter
    10 amps - 0.355 mm diameter
    16 amps - 0.500 mm diameter
    20 amps - 0.560 mm diameter

11. HRC fuse links are not repairable and must be replaced with the same size and type as the original. It would be highly dangerous to replace an HRC fuse link with a length of fuse wire of the same current rating, because the HRC fuse carrier is not designed to contain the arc which would result if the fuse blew. The time taken for an HRC fuse to interrupt a circuit under fault conditions is much more predictable than semi-enclosed rewirable fuses, so rewirable fuses are no longer used in new installations.

12. The amount of current flowing in a circuit is determined from the applied voltage and the impedance of the circuit. The following general equations can be used to determine the approximate current in the circuit:

Single Phase $I = \frac{V}{Z}$ Three Phase $I = \frac{V}{\sqrt{3} \times Z}$

13. Under fault conditions the impedance of a circuit could be very low, in which case the 'prospective short circuit current' would be very high. In large three phase circuits it is not uncommon for the prospective short circuit currents to be of the order of thousands of amps. If, for example, a short circuit occurred on the load side of a 22 000/415 volt three phase transformer which had an impedance of 0.1 ohms per phase, the prospective short circuit current would be:

$$I = \frac{V}{\sqrt{3} \times Z}$$

$$I = \frac{415}{\sqrt{3} \times 0.1}$$

= 2396 amps

14. The time taken to clear a short circuit must be such that the stresses due to heavy currents are kept within acceptable limits. Most fuses have an 'inverse time characteristic' - meaning that as the magnitude of the fault current increases, so the time required to clear the fault decreases. A graph of the general operation of an HRC fuse under short circuit conditions is given in Figure 1.

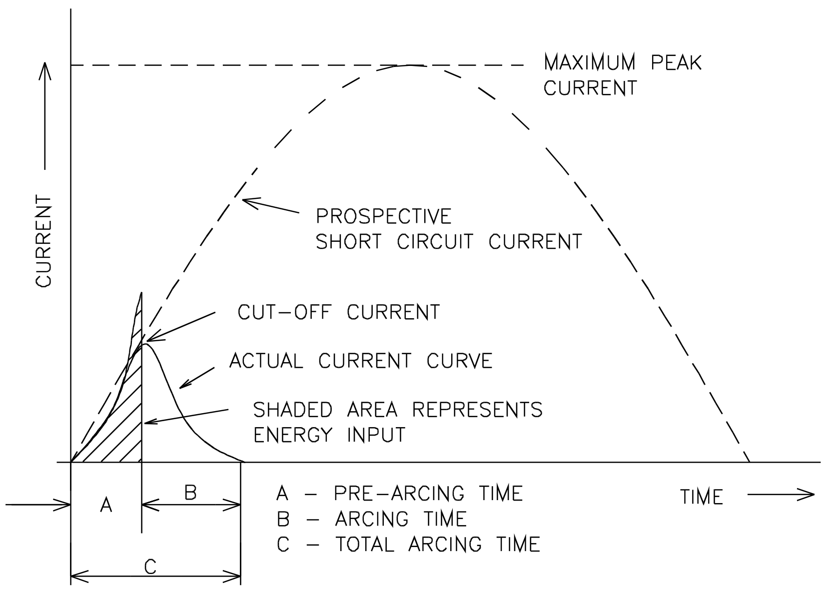

Figure 1 - HRC fuse characteristics

15. **Discrimination** When two or more circuit protection devices are connected in series (one on a main switchboard and another on a sub-board), the protective devices need to be selected so that the device closest to the fault operates first - that is, the sub board fuse operates before the main board fuse. Providing this characteristic in a circuit is known as discrimination.

16. **Categories of Duty.** Fuses are classified as having categories of duty according to the value of prospective short circuit current which they are able to safely interrupt. These categories are:

A1 - 1.0 kA

A2 - 4.0 kA

AC3 - 16.5 kA

AC4 - 33 kA

AC5 - 46/50 kA

AC6 - 80 kA

17. The fusing requirements for a motor circuit are different to those of, say, a circuit involving resistive components because motors have a high short-time starting current. Most HRC fuse manufacturers provide different fuse links for each purpose and they are generally known as either motor fuse links or general fuse links. Information on the characteristics and ratings of each type is available from fuse manufacturers.

18. **Wiring Rules** Clause 2.5.1 of the Wiring Rules contains the requirements relating to the types of protective device for protection against overcurrent. Clause 2.10.5.2 states the requirements for fuses and circuit breakers mounted on switchboards.

Circuit Breakers

19. A circuit breaker is a switch which automatically opens a circuit under pre-determined fault conditions (See Wiring Rules Clause 1.4.30). The operating mechanism can be thermal, magnetic or a combination of both, but in all cases the circuit breaker must be capable of interrupting any current up to and including the prospective short circuit current at the point where the device is installed (See Clause 2.5.2). Small moulded case circuit breakers (MCCB's) are sealed and are not usually repairable.

20. Air circuit breakers (ACB's) have similar operating characteristics to HRC fuses, but they have the advantage that power can be restored to the circuit by simply turning them back on (after the fault has been corrected). Another advantage is that multi-phase circuit breakers disconnect all phases if a fault occurs on one phase.

21. Care must be taken when examining the status of air circuit breakers because they are usually ON in the fully UP position; this is the reverse of the usual convention used for switches in W.A., where the UP position is OFF.

22. When a typical air circuit breaker trips due to overcurrent in the circuit the operating toggle usually remains in a position slightly less than fully up. To reset the circuit breaker (after the fault has been located and cleared) it is necessary to push the operating toggle down to the OFF position, then back up to the ON position.

23. Circuit breakers have contacts which must open under specified high current fault conditions. The interruption of the current results in potentially dangerous arcing which must be controlled (or extinguished). In typical small moulded case air circuit breakers the arc is usually extinguished by a mechanism known as a 'De-ion grid' in which the arc is extinguished by cutting it into a series of smaller sections within the body of the circuit breaker. In larger circuit breakers the arc can be extinguished by a blast of compressed air (an 'air-blast' circuit breaker) or by using a mechanism based on the insulating properties of a vacuum (a vacuum circuit breaker).

Under-Voltage Protection

25. An under-voltage fault is said to have occurred when the supply voltage falls below a pre-determined value. Under-voltage and no-volt protection can be provided by incorporating magnetically operated relays or contactors in the circuit, so that if the voltage falls below the hold-in value the relays or contactors drop out and disconnect the supply.

26. Under-voltage faults can cause lamps to dim or fail, and they can cause electric motors to draw excessive currents, resulting in the operation of the associated overcurrent protection device.

Over-Voltage Protection

27. In any supply system the switching or control of various types of load give rise to short-duration increases in the supply voltage - these are known as voltage surges, spikes, voltage transients, electronic noise and similar terms. Increases in the voltage in installations can also result from lightning strikes. These voltages may cause a breakdown of the insulation in particular devices or, in the case of sensitive electronic devices such as computers, permanent damage to internal electronic components.

28. High induced voltages always occur when the supply is interrupted to electromagnets such as the field coils in d.c. motors.

29. The most common method of protecting individual devices against over-voltage is by connecting voltage dependent resistors (VDR's) in parallel with the device; they are usually incorporated in the design of the equipment. A VDR (also known as Varistor or Metrosil) is a special resistor in which the resistance decreases as the applied voltage increases. The symbol for a VDR is shown in Figure 2.

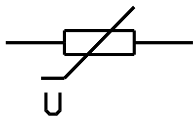

Figure 2 - Symbol for a voltage dependent resistor

30. Under normal voltage conditions the current flow through the VDR is insignificant, but when the voltage rises above designed limits the resistance falls rapidly, providing a path for the induced current thus limiting the induced voltage. A VDR connected across the shunt field of the field coil of a d.c. motor is shown in Figure 3.

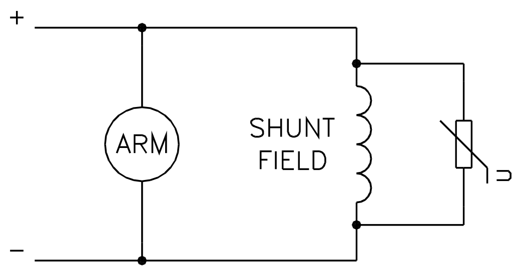

Figure 3 - A VDR across a d.c. motor shunt field coil.

31. A similar form of protection against high induced voltage can be provided in a d.c. circuit by connecting a reverse biased diode across the electromagnetic coil as shown in Figure 4. Under normal voltage conditions the current flow through the diode is insignificant because it is reverse biased, but when the supply voltage is removed the high induced voltage (which is of the opposite polarity) forward biases the diode and it conducts, providing a path for the induced current thus limiting the induced voltage.

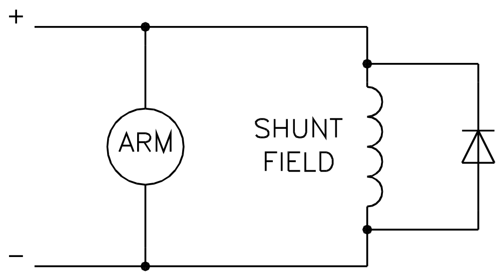

Figure 4 - A diode providing induced voltage protection

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Protection Device Principles

1. What part of a motor circuit are fuses designed to protect?

2. What diameter fuse wire has a current rating of 16 amps?

3. What does the abbreviation HRC stand for when applied to fuses?

4. What are two advantages of an HRC fuse compared to semi-enclosed rewireable fuses?

5. Why is it dangerous to temporarily replace an HRC fuse element with a length of fuse wire of the same current rating?

6. What is the most important action to take before replacing any blown fuse element (assuming that the power has been switched off)?

7. What voltage would be indicated if a voltmeter was connected in parallel with a blown fuse immediately after the fuse had blown due to a temporary severe overload (if all switches are still in the ON position)?

8. At what approximate current would a 10 amp semi-enclosed rewireable fuse ‘blow’ if the load current was increased gradually?

9. List two possible sources of overvoltage in a 3 phase electrical installation.

10. What effect does it have on the rupturing time of an HRC fuse as the fault current INCREASES?

11. At what approximate current would a 100 amp HRC fuse interrupt the circuit if the load current was increased gradually?

12. The operating lever of a small air circuit breaker is in the 'tripped' position. What action is necessary to return the operating lever to the ON position (assuming that the fault had been cleared)?

13. What is the essential difference between the performance of a semi-enclosed rewireable fuse and an HRC fuse of the same current rating?

14. What value would you expect to read if the resistance of an 100 amp HRC fuse element was measured with a multimeter set on the OHMS x 1 range?

15. List two possible reasons for an ‘under-voltage’ fault in a typical 3 phase electrical installation. What effect could it have on the operation of the installation?

16. What does the abbreviation ACB stand for when applied to an electrical component?

17. What is a typical 'clearing time' for an HRC fuse under extreme short circuit conditions?

18. What is the usual position of the operating lever in a typical moulded case circuit breaker when it is in the ON position?

19. What is the basic operational difference between a switch and a circuit breaker?

20. List three common types of fuse.

21. What is the meaning of the term 'inverse time' when applied to circuit protection devices?

22. What effect causes the most damage when high, short duration fault currents occur in circuit conductors?

23. What is a typical clearing time for a small moulded case air circuit breaker under extreme short circuit conditions?

24. List four common measuring devices which can be used to check an HRC fuse element for continuity.

25. What is the common name of each of the components which make up what the Wiring Rules define as a 'fuse'?

26. What effect does it have on the rupturing time of an HRC fuse as the fault current increases?

27. Why is a semi-enclosed rewireable fuse not recommended as adequate circuit protection in new installations?

28. What is the main purpose of a circuit protection device?

29. What is the main potentially hazardous effect of a short duration voltage surge or 'spike' in an installation?

30. What is a voltage dependent resistor (VDR)?

31. What type of protection does a VDR provide?

32. How is 'no-volt' protection usually provided in an electric motor contactor circuit?

33. A particular fuse has a Category of Duty rating of A1. What is the maximum current the fuse is permitted to interrupt?

34. What additional type of protection must be provided in d.c. circuits in which large electromagnetic coils with many turns are to be switched on and off?

35. List four types of circuit protection which apply to the selection and installation of control gear according to AS/NZS 3000.

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Operation and Selection of Protective Devices

Task:

To describe the principle of operation of devices for the protection and control of circuits in accordance with the Wiring Rules and manufacturers' recommendations.

Why:

You need to be able to describe the general principle of operation of various circuit protection and control devices so that you can select the most appropriate device for a given situation.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in an observed practical assessment.

Equipment

Samples of commonly used electrical protective devices.
Manufacturers' data relating to electrical protective devices.

References

* Electrical Wiring Practice (7th ed.). Volume 2. Pethebridge, K & Neeson, I.
* Manufacturers' catalogues of electrical protective devices.
* AS/NZS 3000 - Wiring Rules.
* AS/NZS 3008.1.1 - Electrical installations - Selection of cables.

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Operation and Selection of Protective Devices

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

Electrical Wiring Practice (7th ed.). Pethebridge, K. & Neeson, I.

Volume 2 Chapter 1

Section 1.1	Protection against overcurrent
Section 1.2	Overcurrent protection devices
Section 1.3	Protection against indirect contact with live
Section 1.4	Protection against overvoltage and under-voltage
Section 1.5	Protection arrangement and discrimination

Manufacturers' Data

Illustrated catalogues of electrical protection devices.
Protective device data sheets.

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	Arrange circuits, control and protection for general electrical installations	Section 4 Summary	G063A SGB 01/2014

Operation and Selection of Protective Devices

1. Fuses and circuit breakers are used to protect conductors, transformers and measuring equipment from excessive heat caused by over current. Over current may be very high due to either a short circuit or to overload due to misuse or poor design.

2. Fuses and circuit breakers have the following ratings:

   a. Maximum operating voltage

   b. Full load or continuous current rating

   c. Rupturing capacity.

   Rupturing capacity is the maximum fault condition the device is able to safely interrupt, typically expressed as current (kA) or MVA.

3. If a fault occurs between any two phases, any one phase and neutral, or any one phase and earth, the protective device should operate to disconnect the faulty circuit from the supply.

4. Common protective devices are:

   a. Circuit Breakers
   b. High Rupturing Capacity (HRC) fuses
   c. Cartridge or totally enclosed fuses
   d. Semi-enclosed rewirable fuses (not for new installations)
   e. Combination switch fuse units (CSF)
   f. Residual current devices (RCDs)

Fuses

5. The current rating of a fuse is the maximum current that the fuse will carry continuously without undue deterioration. This rating should be marked on the fuse carrier and links.

6. The time taken for the fuse to operate is called the OPERATING TIME, and the greater the excess current, the shorter the operating time.

7. Semi-enclosed rewirable fuses are often found in older installations, but they are no longer recommended. The advantages of semi-enclosed rewirable fuses are:

   a. They can be rewired by replacing the fusible element.
   b. An indication of type of fault is indicated by the appearance of the fused element.

8. The main disadvantages of semi-enclosed rewirable fuses:

   a. Can be rewired with oversize fuse wire
   b. Fusing time is unpredictable.
   c. Whilst once cheap in cost, now could be more expensive than circuit breakers and HRC fuses.
   d. Not permitted for new installations by AS/NZS 3000.

Cartridge or Totally Enclosed Fuses

9. A cartridge or totally enclosed fuse has a link that consists of a fuse element totally enclosed in a cartridge. The cartridge is made of a non combustible insulating material such as glass, porcelain or ceramic.

10. Cartridge fuses are manufactured in standard sizes varying in current ratings from milliamps to thousands of amps.

High Rupturing Capacity (HRC) Fuses.

11. A high rupturing capacity fuse is a special cartridge fuse having a category of duty not less than AC3 (not less than 16.5 kA).

12. The fusible element typically consists of several pure silver fusible elements surrounded by a compact filling of fine silica sand.

13. Normal HRC fuses are fast acting to protect circuitry, cutting off the supply within one third of a cycle. Special slower acting motor rated HRC fuses are used to accommodate high starting currents of motors.

14. Fault Current Limiters are especially fast acting HRC fuses operating at approximately five milliseconds and designed to clear short circuits and not overloads. This high speed operation reduces the large thermal and magnetic stresses caused by the very high short circuit current.

15. The main advantages of HRC fuses compared with semi enclosed fuses are:

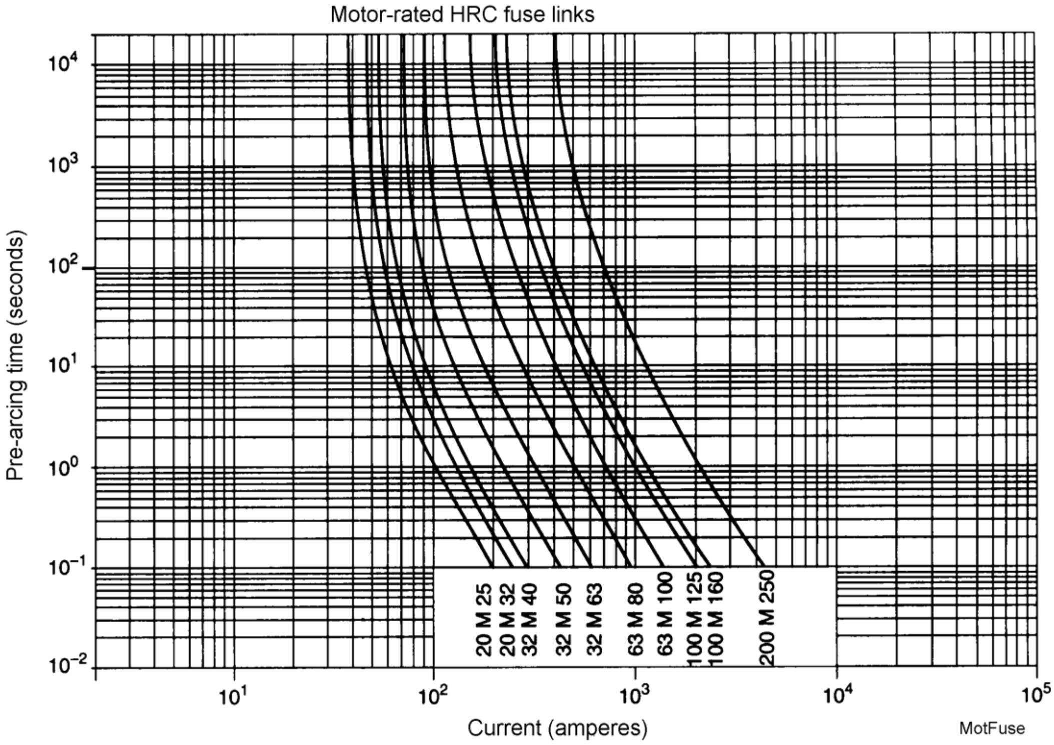
   a. **Accurate Calibration**. The time/current characteristics are constant and predictable.

   b. **Rapid Rupture**. The largest rating HRC fuse made will interrupt a full capacity short circuit fault in less than half a cycle.

Time/Current Characteristics for HRC Fuses

16. The time characteristic for various fuses is a graph supplied by manufacturers showing the relationship between the fusing current and the time taken to interrupt the supply.

17. The graph below shows a typical example of a time/current characteristic curves for motor-rated HRC fuses. The spacing between each curve indicates the discrimination between fuse ratings. The label 20 M 25 means a 20 amp fuse, type M25.



Typical Motor-rated HRC Time/Current Characteristic Curves

Circuit Breakers (ACBs, CBs and MCBs)

18. A circuit breaker is a device containing a compact electro-mechanical device for making and breaking a circuit both under normal conditions as well as fault conditions.

19. Circuit breakers have a time-delay tripping characteristic similar to HRC fuses and are not usually affected by transient by transient overloads such as motor starting conditions and switching surges.

20. Circuit breakers are usually installed on distribution boards in preference to fuses for the following reasons:

   a. Easily re-setable after fault has been removed.

   b. Usually give visual indication when tripped.

   c. Current carrying capacity of cable used is increased.

   d. They do not age in service.

   e. Their settings, once set are unalterable.

21. The main disadvantages of miniature circuit breakers are:

    a. Size.

    b. Mechanical complexity.

    c. Relatively low rupturing capacity

22. The tripping operation of circuit breakers is either:

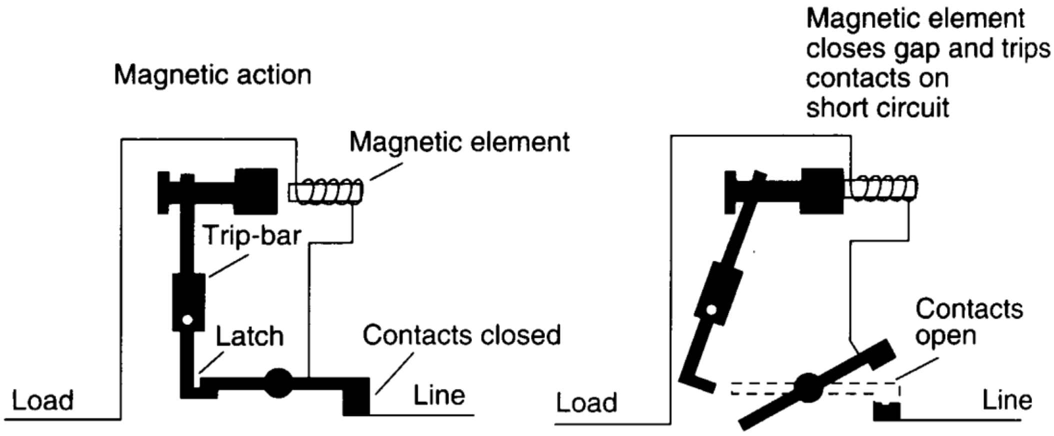
    a. Magnetic,

    b. Thermal, or

    c. Combination of magnetic and thermal.

Magnetic Tripping

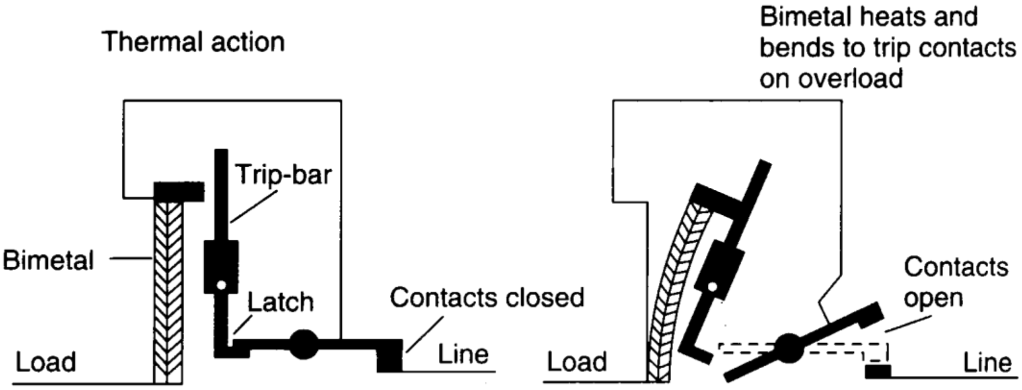
23. A typical magnetic circuit breaker action is shown below. The current flowing in the breaker passes though the coil of an electromagnet that has a pivoted metal arm at a set distance from one end. When an overload occurs, the magnetic pull is increased and the arm is attracted to the magnet and trips the circuit breaker.



24. Under heavy overload or short circuit conditions the magnetic pull on the armature is large enough to trip the circuit breaker instantaneously.

Thermal Tripping

25. The principle of operation is a bimetal strip which bends when heated. The time delay characteristic being provided by the time taken to heat the element.



26. Thermal operated circuit breakers have three disadvantages compared with magnetic type circuit breakers which are:

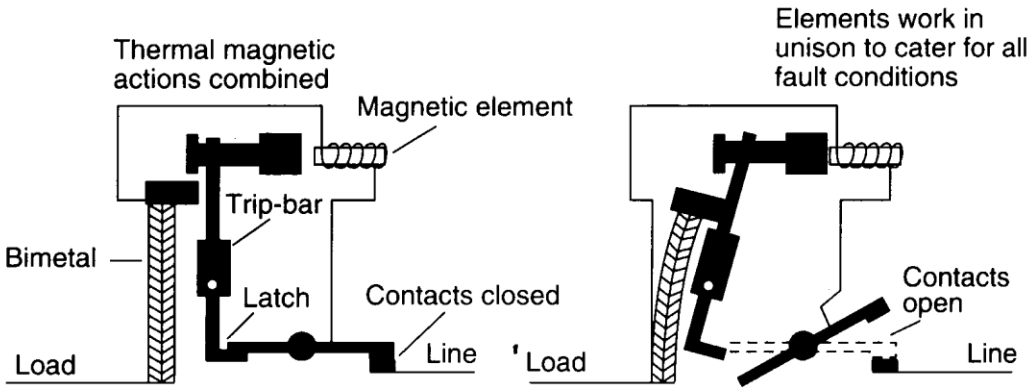
    a. They are affected by ambient temperature.

    b. They require a short time after tripping to enable the bimetal strip and heater to cool down before being able to be reset.

    c. Thermal tripping is ideal for overload protection but unsatisfactory against short circuits.

Thermal Magnetic Combination

27. Because of the characteristics of both thermal and magnetic operations, the development of the third type of circuit breaker included their combined characteristics as illustrated below:

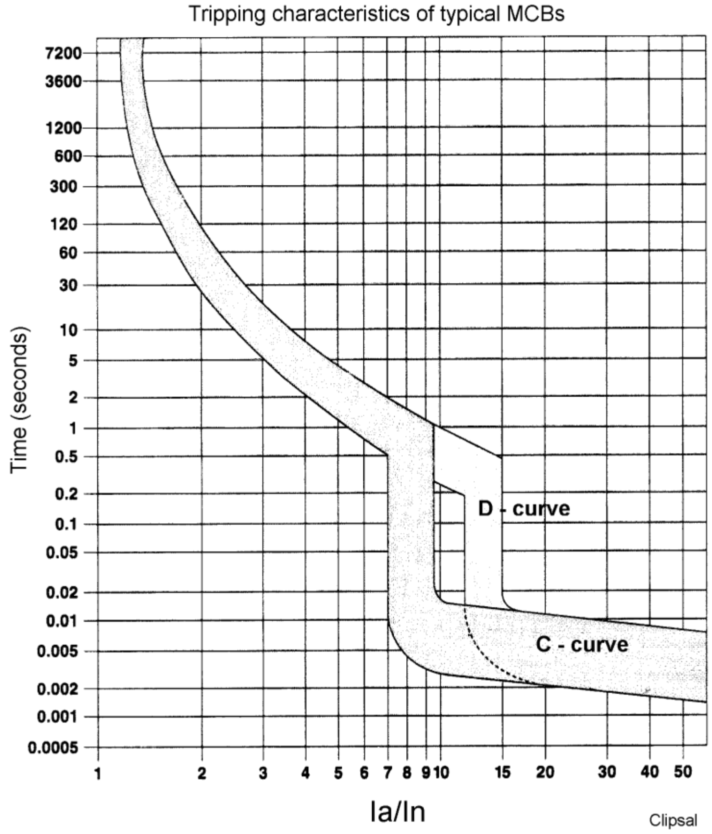


28. When overload occurs, time delay is provided by the time taken to heat the bimetal element. With massive overload or short circuit, the magnetic element influences the tripping time and is adjusted so that with approximately ten times the rated current occurs it takes over completely to provide almost instantaneous tripping with a typical interrupting time of 0.01 seconds.

Time/Current Curves

29. Manufacturers of circuit breakers provide Time/Current curves that show response times in seconds for applied overloads expressed as a percentage of rated current. A typical example is shown below:

Tripping characteristics of typical MCBs



Ia = tripping current   In = rated current

30. Time/current characteristics are presented not as a single curve but as a band defined by maximum and minimum curves. The characteristic for any particular breaker will lie within this band. 'Type C' circuit breakers for general purpose applications have a magnetic trip setting about 7.5 times the rated current and 'Type D' circuit breakers for high inductive loads such as motors have a magnetic trip setting about 12.5 times the rated current (see AS/NZS 3000 Appendix B).

31. On the set of time/current curves shown above the smoother upper portions of the curve is for thermal action alone.

32. The 'knees' in the curves represent the tripping of the breaker under co-operative thermal-magnetic action. The vertical portions represent the current at and above which the magnetic trip instantly opens the breaker.

33. When large fault currents (e.g 1000% of rated current or short circuit) occur, HRC fuses may blow before the circuit breaker has a chance to operate. This is where factor of 'discrimination' of the circuit protection device selection becomes important.

34. The time taken to clear a short circuit must be such that the stresses due to heavy currents are kept within safe bounds. These stresses are due to magnetic forces between current carrying components, rapid heating of components and arcing at the fault. It follows that if large values of prospective fault current are possible, then the fault must be cleared BEFORE the current can attain its first maximum or peak value of fault current.

35. AS/NZS 3000 stipulates in Clause 2.5.2 that the interrupting capacity of the protection devices must be adequate to enable interruption of the highest value of current available at the point of installation of the protection device.

Fault Discrimination

36. Discrimination between two or more circuit interrupting devices in series is said to occur when, on the incidence of a short circuit or overcurrent, the fuse or other overload device nearest the fault operates before any other protective device even begins to clear the fault.

37. If, for example, several distribution boards are each fed through fuses on a main switchboard, then the smaller fuses on any one distribution board (minor fuses) are in series with the larger fuses on the main switchboard (major fuses). If a fault occurs on a circuit fed by the distribution board, then, with adequate discrimination, the minor fuse should operate to isolate the faulty circuit.

Inverse Definite Time Tripping

38. Where discrimination in the order of tripping is required, a time delay device is built in. For a given fault current, the order of tripping time could be:

    a. high voltage protection in the sub station - 0.1 second

    b. low voltage protection in sub station - 0.06 seconds

    c. protection in consumers board - 0.02 seconds.

39. Because of differing operational time for the protective devices at each point an inverse definite time tripping arrangement has been set up. As a general rule, a ratio of 2:1 between the major and minor protection devices will give adequate discrimination.

Methods of Arc Quenching

40. **De-ion Arc Quenching**. De-ion is a trade name for an arc chute arranged to stretch and break up the arc that may occur on switching. The operation of the grid depends on the fact that the arc established between the contacts is a current carrying conductor surrounded by a magnetic field. The U-plates distort the circular field thereby pushing the arc into the plates which cut the arc into a number of small segments.

41. **Magnetic Blow Out**. Most small and medium range circuit breakers on a.c. well as d.c. cause the contact or arc current to produce a magnetic field across the contacts. The polarity of this field is arranged so that the arc bends outwards and stretches until it is broken.

42. **Oil Quenching**. In oil circuit breakers (OCB) the contacts are submerged in a non-conducting oil and the arc is quenched very quickly by the oil due to rapid cooling.

43. **Air Blast Quenching**. Very large air circuit breakers (ACB), as used by the supply authority mostly in the high tension switchgear, use a blast of air across the contact gap to stretch and quench the arc.

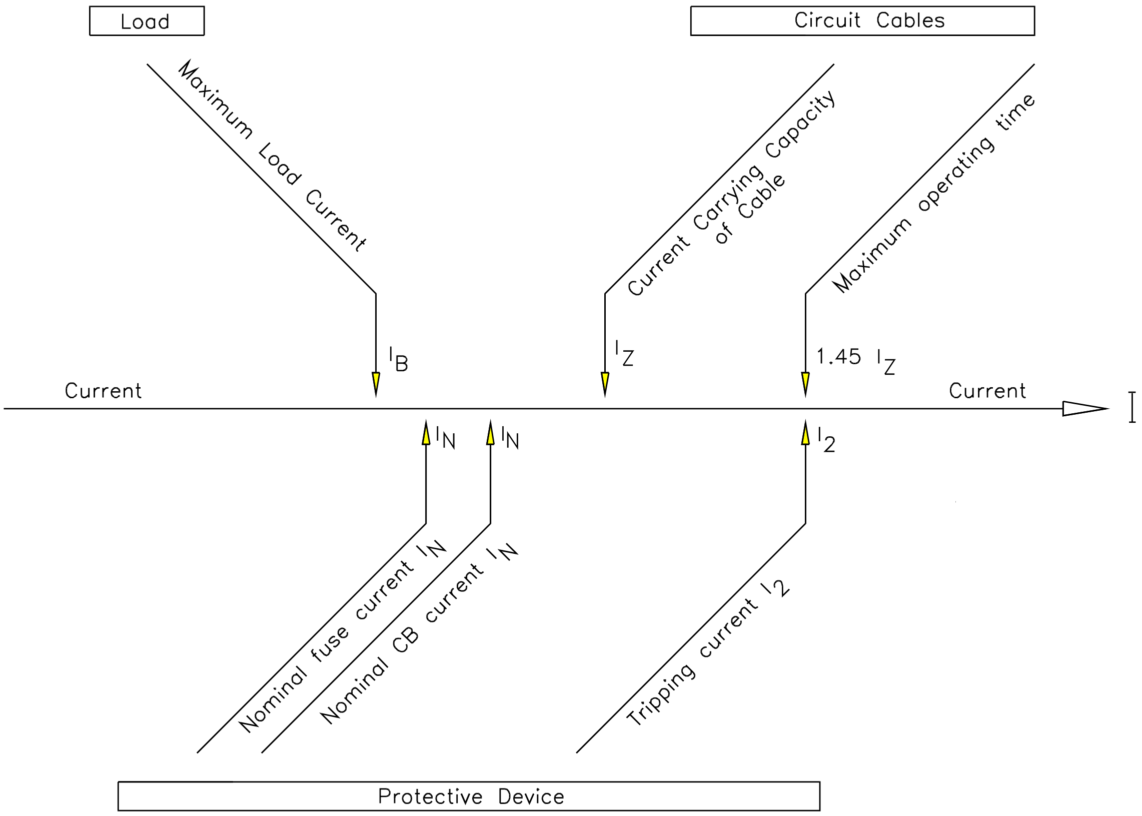
Coordination

44. AS/NZS 3000 requires coordination between circuit conductors and the associated protective device - i.e. the protective device must operate under overload or short circuit conditions before the cable is damaged by overheating (see Clauses 2.5.3 and 2.5.4, and Appendix B).

45. Clause 2.5.3 requires that the maximum demand of the circuit must be less than or equal to the nominal current rating of the protective device and less than or equal to the continuous current rating of the cable. It also requires that the current required to operate the protective device must be less than or equal to 1.45 times the current carrying capacity of the cable for a circuit breaker (or 1.6 times for an HRC fuse).

46. The 'conventional time' referred to in Clause 2.5.3.1 (a) and (b) is 1 hour up to 63 amps and 2 hours over 63 amps for circuit breakers. Conventional time may be determined from AS/NZS 60898.1:2004. Its meaning is basically that a circuit breaker can carry a specified value of current (1.13 times its nominal rating) without tripping, or a different specified value (1.45 times its nominal rating) which causes the circuit breaker to operate. Conventional time for fuses is provided in IEC 60269 series.

47. The equations given in AS/NZS 3000 Clause 2.5.3.1 can be shown diagrammatically as follows (see AS/NZS 3000 page 442):



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Operation and Selection of Protective Devices

1. What are the three main ratings applied to circuit breakers?

2. State two advantages of HRC fuses compared to rewirable fuses of the same current rating.

3. What type of load requires a special slower-acting HRC fuse cartridge?

4. Which type of protective device operates fastest, a thermal type circuit breaker or a fault current limiter fuse?

5. What is meant by the term 'discrimination' in a circuit protection system?

6. List the various methods used to quench arcs within circuit breakers. Give an application for each type.

7. If the maximum safe working current for wiring is exceeded and the protection is inadequate or does not operate, how will the wiring be affected.

8. Explain the term inverse time characteristic as applied to fuses and circuit breakers.

9. What limits the value of short circuit current when a short occurs in a final sub-circuit.

10. What is the most common type of tripping mechanism in small air circuit breakers?

11. What is the common name given to the method of arc quenching which involves magnetic attraction and compartmentalisation of the arc?

12. Which type of fuse will let through the most electrical energy before it interrupts the supply under short circuit conditions?

13. A particular final sub circuit is protected by a 16 amp Type C circuit breaker. Use the tripping characteristics curve in this Section to determine how much time it would take for the circuit breaker to trip if the circuit current increased to 48 amps as a result of a circuit fault.

14. A particular final sub circuit is protected by a 20 amp motor-rated HRC fuse link. Use the characteristic curves in this Section to determine how much time it would take for the fuse to interrupt the circuit if the current increased to 45 amps as a result of a circuit fault.

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RCD Earth Leakage Protection

Task:

To describe the principles of operation of residual current devices for protection against earth leakage in circuits in accordance with the Wiring Rules and manufacturers' recommendations.

Why:

Residual current devices are essential to protect people and livestock from electric shock resulting from direct contact with a live part. You need to be able to select an appropriate RCD and install and correctly test it to reduce the possibility of electrocution.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.

2. You must satisfactorily complete the set laboratory tasks.

3. You must achieve 100% in a final observed practical assessment.

Equipment

Samples of commonly used RCDs
Manufacturers' data relating to RCDs

References

* Electrical Wiring Practice (7th ed.). Volume 2. Pethebridge, K & Neeson, I.
* Manufacturers' data
* AS/NZS 3000 - Wiring Rules.
* WA Electrical Requirements (Current edition)

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RCD Earth Leakage Protection

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000 - Wiring Rules:

Clause 2.6 Additional Protection by Residual Current Devices

Electrical Wiring Practice (7th ed.). Volume 2

Chapter 1 Protection by residual current devices (RCDs) pp 25 - 32

Manufacturers' Data

Illustrated catalogues of electrical protection devices.
Protective device data sheets.

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

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RCD Earth Leakage Protection

Protection Systems

1. An earthing system which requires exposed metal of electrical devices to be connected to the general mass of earth provides protection against electric shock and fire by automatically isolating the supply if a live part comes in direct contact with the exposed metal of the device. No protection is provided if a person inadvertently touches a live component while in contact with earth.

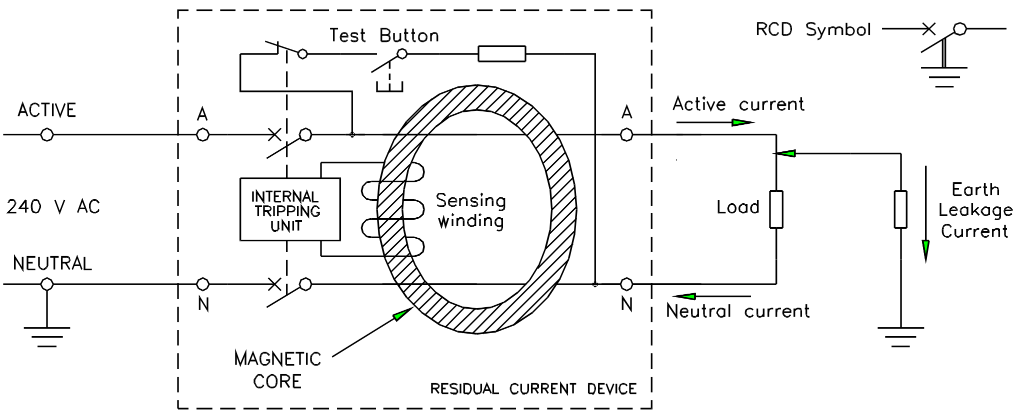
2. A residual current device (RCD) is a supplementary type of protection which provides for the supply to automatically be disconnected if a person touches a live component in such circumstances as will result in a current of more than a pre- set value (typically 10-30 milliamps) flowing through him or her to earth. RCD protection is in addition to the earthing system - it does not replace it.

3. RCDs are also known as 'safety switches', 'core balance earth leakage circuit breakers' or core balance ELCBs. There is another type of ELCB system known as the 'voltage operated ELCB system' - this is a system of earthing and is not the same as the RCD system, so the use of the term ELCB to describe the RCD system is not recommended.

RCD Operating Principle

4. The current which flows into an electrical circuit via the active conductor should be equal to the current flowing out of the circuit via the neutral. An RCD is a device which automatically disconnects the supply if the active and neutral currents are not equal and opposite, within about 10-300 milliseconds (depending on the particular RCD).

5. The general arrangement for a typical single phase RCD is shown below:



Drawings © NMTAFE

6. The diagram above shows that the active and neutral conductors pass through a toroidal ring of magnetic material. The magnetic flux resulting from the current in the active should be equal and opposite to the current in the neutral, so the resulting flux in the core should be zero. If the active and neutral currents are not balanced, a flux will be present in the toroidal magnetic core.

7. The toroidal core inside the RCD has a sensing winding wound on it. This sensing winding acts as the secondary of a transformer, so a voltage will be induced in it if the magnetic flux in the core is greater than zero. A mechanism is provided inside the RCD so that if the voltage in the sensing winding causes a current to flow because of an imbalance between the active and neutral currents, internal contacts will operate and disconnect the supply to the device connected to the circuit.

8. An imbalance in the active and neutral currents would occur if, for example, a person touched the active while in contact with earth. The current flowing through the person to earth (known as earth leakage current or residual current) would cause the RCD contacts to open if the leakage current exceeded the designed value for the particular RCD. The value of leakage or residual current for RCDs in domestic installations must not exceed 30 milliamps (see AS/NZS 3000 Clause 2.6.3.2.2).

9. It is important to note that the RCD does not provide protection if a person touches active and neutral at the same time, nor does it provide protection if a person touches a live component 'upstream' of the RCD. Medical research indicates that currents below about 30 milliamps for short durations are not likely to be lethal.

10. An RCD should trip whenever the leakage current exceeds the designed value, regardless of the path of the leakage current. This means that an RCD will operate if the insulation resistance to earth is too low because of the presence of moisture or conductive dust. Unintended operation of an RCD is known as 'nuisance tripping'.

11. All RCDs are provided with a means of testing them for correct operation - usually a test button. It is a good practice to test an RCD for correct operation about once per month.

Types of RCD

12. There are four different types of RCD in common use - they are classified according to the leakage or residual current at which tripping will occur (also known as their 'sensitivity'). The classifications are:

Type I	Residual current rating not exceeding 10 mA.
Type II	Residual current rating exceeding 10 mA but not exceeding 30 mA.
Type III	Residual current rating exceeding 30 mA but not exceeding 300 mA (without selective tripping time delay).
Type IV	Residual current rating exceeding 30 mA but not exceeding 300 mA (with selective tripping time delay). Type IV is also known as an 'S type' RCD.

13. Single phase general purpose socket outlets are available which incorporate 10 mA or 30 mA residual current protection - they have the same general physical shape as other socket outlets. If a residual current type socket outlet is installed as the first point in a power circuit, it will provide earth leakage protection for all outlets 'downstream' of the protected unit.

Applications of RCDs

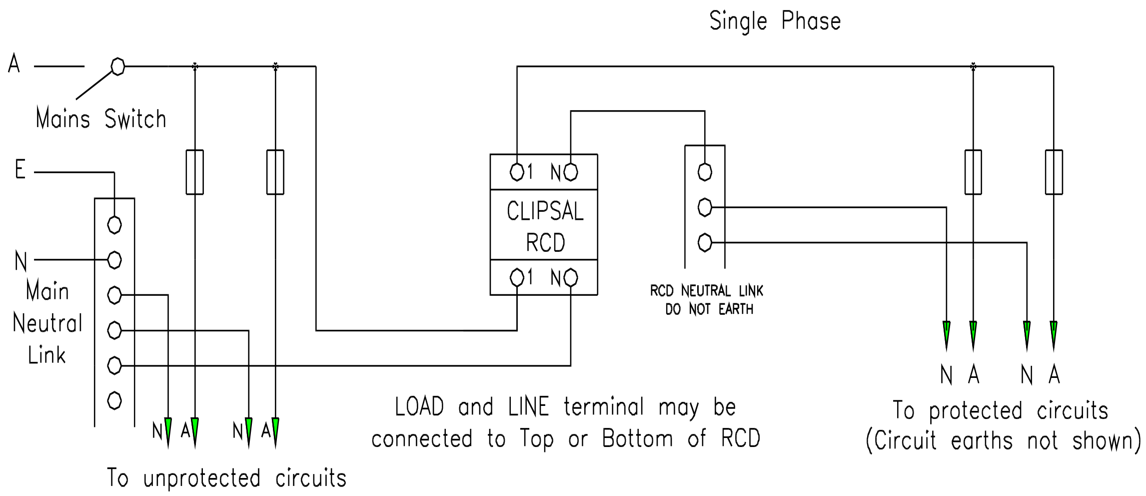
14. Typical applications for RCDs are residential installations, mine sites, construction sites, hospitals, boiler systems and school laboratories.

Domestic and residential installations

15. The Wiring Rules require that RCDs be installed to protect all final subcircuits in domestic and residential electrical installations (see Clause 2.6.3.2.2).
The Wiring Rules requires at least two RCDs in domestic and residential installations (see Clause 2.6.2.4) so as to provide the user with protection against total loss of power and lighting in the installation should an RCD operate. Ideally, the installation should be designed so that some lighting and some socket-outlet (power) circuits are protected by one RCD and the remainder by the other RCD - i.e. mixed circuits.

RCD Arrangements

16. There are many different methods of arranging circuits to provide earth leakage protection with RCDs. One general arrangement for one RCD is shown below.



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RCD Earth Leakage Protection

1. What is the main type of protection provided by a 'residual current device' or RCD?

2. To what value of tripping current are small domestic RCDs commonly set?

3. What is another name for a current operated 'earth leakage circuit breaker'?

4. At what earth leakage current is a Type I RCD designed to trip?

5. At what earth leakage current is a Type II RCD designed to trip?

6. Does an RCD provide protection against electric shock if a person comes in contact with the active and neutral at the same time?

7. All lighting and power final sub-circuits in a domestic installation must be protected by an RCD. What is the exception?

8. What is the minimum number of RCDs which must be installed in a domestic or residential type electrical installation?

9. Is it compulsory for electric Hot-water systems in residential installations to be protected with residual current devices? Give the AS/NZS 3000 Clause number.

10. Draw the consumer's switchboard layout for a single phase domestic installation consisting of the following circuits, with RCD protection as required by AS/NZS 3000.

    2 Lighting circuits – use 10 amp circuit breakers
    1 Power circuit for a 4 kW 240 V fixed cooking appliance – use Table C5 to determine the circuit breaker size
    2 Power circuits for 10 A 240 volt outlets – use 16 amp circuit breakers
    1 3.4 kW storage hot water system – calculate circuit breaker size.

As a guide, there is a diagram of a consumers switchboard in Section 7

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Electrical Fault Protection

Task:

To determine the fault current levels and related characteristics in typical electrical circuits.

Why:

The determination of fault current levels is a critical factor in the design of an electrical installation. If the equipment in an installation is unable to perform satisfactorily under fault conditions, catastrophic damage to circuits and equipment may result.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in an observed practical assessment.

Equipment

Samples of commonly used electrical protective devices.
Manufacturers' data relating to electrical protective devices.

References

* Electrical Wiring Practice (7th ed.). Pethebridge, K. & Neeson, I.
* AS/NZS 3000 - Wiring Rules.
* AS/NZS 3008.1.1 Electrical installations – Selection of cables.
* Manufacturers' data for electrical protective devices.
* WA Electrical Requirements

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Electrical Fault Protection

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

AS/NZS 3000 - Wiring Rules

Section 1 Scope and fundamental safety principles
Section 2 Selection and installation of switchgear and control-gear
Appendix B Circuit arrangements

AS/NZS 3008.1.1 Electrical installations – Selection of cables.

Section 5 Short circuit performance

Australian Electrical Wiring - Volume 1

Chapter 8 Page 224 Figure 8.1b – Limiting the rise in touch voltage

Australian Electrical Wiring - Volume 2

Chapter 1 Electrical Protection and protective devices

Manufacturers' Catalogues

Illustrated catalogues of electrical protection devices.
Protective device data sheets.

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

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Electrical Fault Protection

Wiring Systems

1. Electrical wiring systems must be installed in such a way that safe working limits are not exceeded. One of the main considerations is the maximum safe current. In a typical installation such as the one outlined below, all components selected must be such that a short circuit from active to earth (i.e. a 'bolted fault') will not cause permanent damage to the installation

2. If the maximum safe current in a circuit is exceeded it can result in damage to the cable and/or associated parts of the installation

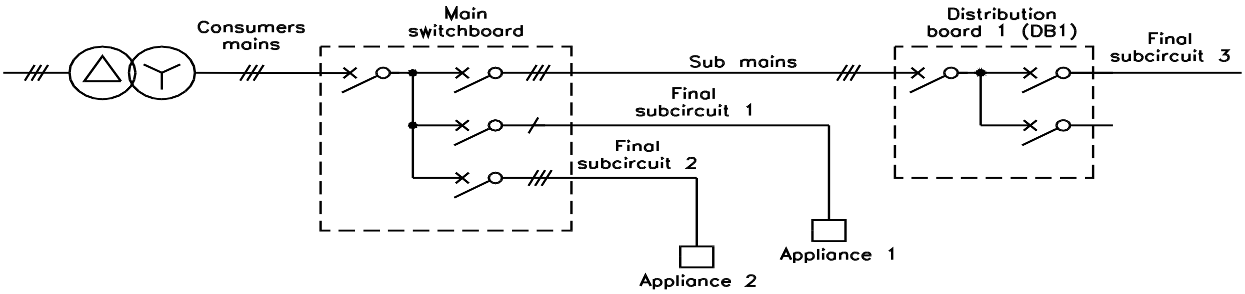
3. AS/NZS 3000 provides the following definitions relating to current:

   Overcurrent – A current exceeding the rated value. (Clause 1.4.90).

   Fault current – A current resulting from an insulation failure or from bridging of insulation. (Clause 1.4.41).

   Overload current – An overcurrent occurring in a circuit which is electrically sound. (Clause 1.4.42).

   Short-circuit current - A fault current resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions. (Clause 1.4.43)



Protection of Wiring

4. The general requirements for the protection of wiring are:

   a. Small overloads of short duration should not cause the protection to operate.

   b. The protection must operate, even on a small overload, and if the overload persists long enough to cause overheating of the circuit conductors.

   c. The protection must open the circuit before damage caused by fault currents can occur.

   d. Protection must be 'discriminative' in that only the faulty circuit is isolated and other circuits remain operative and unaffected.

Overload Protection

5. Overload protection is achieved by opening the circuit before overheating or deterioration of the protected wiring can occur.

Coordination

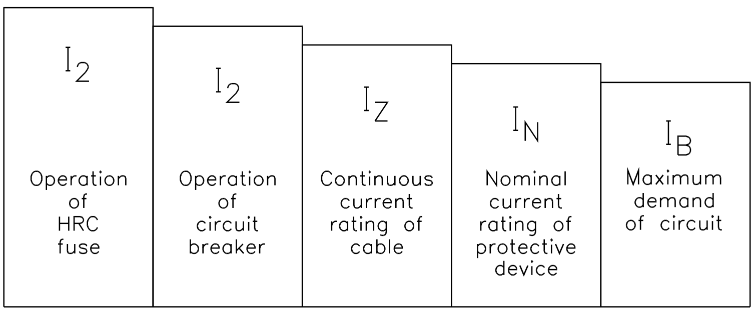
6. AS/NZS 3000 Clause 2.5.3.1 requires coordination between conductors and protective devices. The operating characteristics of a device protecting a cable against overload shall satisfy the following two conditions:

   $I_B \leq I_N \leq I_Z$ (The symbol $\leq$ means 'is less than or equal to'.)

   $I_2 \leq (1.45 \times I_Z)$

Where:

I_B = Circuit maximum demand.
I_N = Nominal current of protective device.
I_Z = Current carrying capacity of cable.
I_2 = Current to operate protective device:
 1.4 x I_N for circuit breakers or
 1.6 x I_N for HRC fuses.



Short-circuit Protection

7. Short-circuit fault protection is achieved by

   a. The action of the fuse or circuit breaker being fast enough to open the circuit before the let-through energy can attain a value that would cause damage by overheating, arcing or mechanical stress; and

   b. The protective device being capable of opening the circuit, under these high fault current conditions, without damage to itself.

Short Circuit Current

8. In the case of a short circuit the only limit to the value of current in the circuit is the impedance of the faulty circuit, and the available short circuit energy. This includes the impedance of the supply source, usually a distribution transformer provided by the network operator.

Transformer Impedance

9. The impedance of a transformer is usually stated as the percentage of the primary-rated voltage that is necessary to cause full-load current in the secondary if the load terminals have a short across them.

10. A common transformer impedance value is 5 per cent. If 5% of the supply voltage will produce full load current, then, with a secondary short circuit and normal supply voltage of 100%, twenty times the rated full load current will be present.

$$Short\ circuit\ current \quad = \quad Full\ load\ current \quad \times \quad \frac{100}{Impedance\%}$$

    The short hand form of this formula is:

$$I_{SC} \quad = \quad I_{FL} \quad \times \quad \frac{100}{Z\%}$$

11. A distribution transformer having a full load current rating of 500 amps and an impedance of 5% would have a theoretical short circuit current of 20 x 500 or 10 000 amps. Since the heating effect of current is proportional to the square of the current, doubling the current results in four times the heating effect. Currents of thousands of amps can result in explosions and catastrophic damage to the cables and related equipment.

Prospective Fault-current Levels

12. The rated full load output current of a typical three-phase distribution transformer is given by the equation:

$$I_{FL} = \frac{kVA \times 1000}{\sqrt{3} \times V_L}$$

13. So the rated full load current of a 500 kVA, 415/240 volt three phase distribution transformer with an impedance of 5% is:

$$I_{FL} = \frac{500 \times 1000}{\sqrt{3} \times 415}$$

= 695.6 A

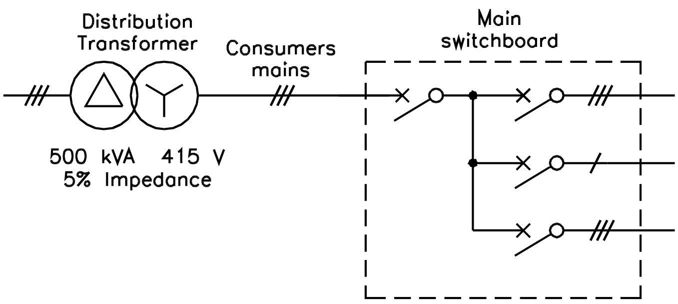
Prospective Fault Current

14. The available short circuit current (I_{SC}) if the 415 volt 500 kVA transformer had an impedance of 5% would be:

$$I_{SC} = I_{FL} \times \frac{100}{Z\%}$$

$$I_{SC} = 695.6 \times \frac{100}{5}$$

= 13 912 amps



Impedance/Phase of Supply

15. If the available short circuit current of the 415 volt 500 kVA transformer was 13 912 amps, the supply impedance per phase (Z_1) would be:

$$Z_{Phase} = \frac{E_{Phase}}{I_{SC}} \quad Z_1$$

$$= \frac{240}{13912}$$

= 0.01725 ohms

16. The prospective fault current (I_F) per phase at the main switchboard is limited by the impedance of the supply plus the impedance of the cables from the source to the switchboard (the consumers mains)(Z_2):

$$I_F = \frac{E_{Phase}}{Z_1 + Z_2}$$

17. The impedance of the consumers mains can be found from relevant tables if the cable size, type and length are known.

Cable impedance (ohms) - copper

Cutler Hammer

Nominal area of conductor (mm^2)	Nominal resistance of conductor at 20 °C	Length of cable - metres							
		5	10	15	20	25	30	40	50
1	0.01770	0.0885	0.1770						
1.5	0.01190	0.0595	0.1190	0.1785					
2.5	0.00720	0.0360	0.0710	0.1080	0.1443	0.1785			
4	4.52×10^{-3}	0.0226	0.0452	0.0678	0.0904	0.1130	0.1356	0.1808	
6	3.02×10^{-3}	0.0151	0.0302	0.0453	0.0604	0.0755	0.0906	0.1208	0.1510
10	1.79×10^{-3}	0.0090	0.0179	0.0269	0.0358	0.0448	0.0537	0.0716	0.0895
16	1.13×10^{-3}	0.0057	0.0113	0.0170	0.0226	0.0283	0.0339	0.0452	0.0565
25	6.60×10^{-4}	0.0033	0.0065	0.0099	0.0132	0.0165	0.0198	0.0264	0.0330
35	5.14×10^{-4}	0.0026	0.0051	0.0077	0.0103	0.0129	0.0154	0.0206	0.0257
50	3.79×10^{-4}	0.0019	0.0038	0.0057	0.0076	0.0095	0.0114	0.0152	0.0190
70	2.62×10^{-4}	0.0013	0.0026	0.0039	0.0052	0.0066	0.0079	0.0105	0.0131
95	1.95×10^{-4}	0.0010	0.0020	0.0029	0.0039	0.0049	0.0059	0.0078	0.0098
120	1.50×10^{-4}	0.0008	0.0015	0.0023	0.0030	0.0038	0.0045	0.0060	0.0075
150	1.22×10^{-4}	0.0006	0.0012	0.0018	0.0024	0.0031	0.0037	0.0050	0.0061
185	9.72×10^{-5}	0.0005	0.0010	0.0015	0.0019	0.0024	0.0029	0.0039	0.0049
240	7.40×10^{-5}	0.0004	0.0007	0.0011	0.0015	0.0019	0.0022	0.0030	0.0037
300	5.90×10^{-5}	0.0003	0.0006	0.0009	0.0012	0.0015	0.0018	0.0024	0.0030
400	4.61×10^{-5}	0.0002	0.0005	0.0007	0.0009	0.0012	0.0014	0.0018	0.0023
500	3.66×10^{-5}	0.00018	0.00037	0.0005	0.0007	0.0009	0.0011	0.0015	0.0018
630	2.83×10^{5}	0.00014	0.00028	0.0004	0.0006	0.0007	0.0008	0.0011	0.0014

Values above line reduce fault currents to less than 2 kA

Aluminium conductors have resistance values approx. 1.65 × copper.
Parallel cables – divide values by number of cables.

Ohms

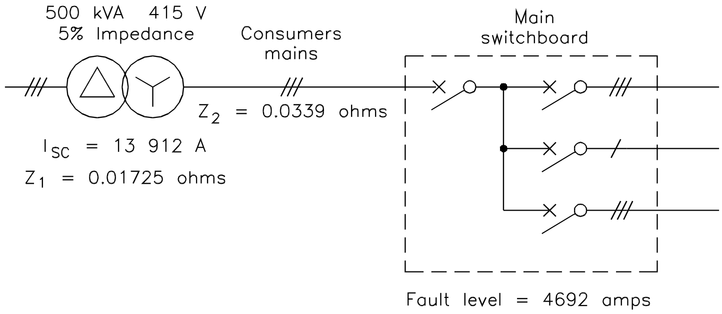
Fault Level at Main Switchboard

17. If the consumers mains consisted of 30 metres of 16 mm^2 copper TPS cable the impedance of the active conductor (Z_2) would be approximately 0.0339 ohms per phase (from a Table). The prospective fault current level at the main switchboard would be:

$$I_{Fault} = \frac{E_{Phase}}{Z_1 + Z_2}$$

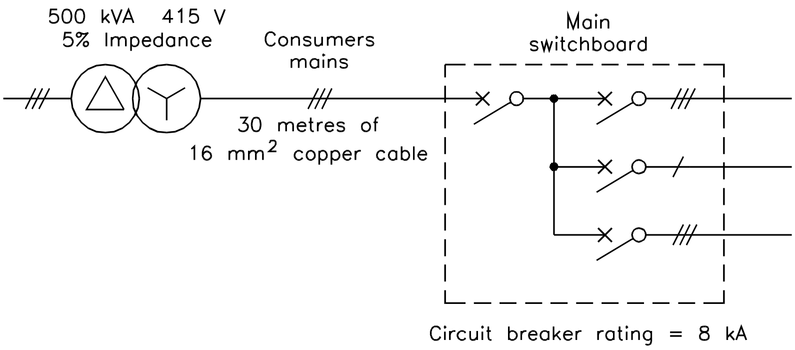
$$= \frac{240}{0.01725 + 0.0339}$$

= 4692 amps



Circuit Breaker Rating

18. Since the prospective fault current at the main switchboard is 4692 amps, the circuit breakers on the main switchboard need to rated at a short circuit current at or above this value. A rating of 6kA would be suitable.



Equation Summary

$$I_{FL} = \frac{kVA \times 1000}{\sqrt{3} \times V_L}$$ (Transformer full load current)

$$I_{SC} = I_{FL} \times \frac{100}{Z\%}$$ (Transformer short circuit current)

$$Z_{Phase} = \frac{E_{Phase}}{I_{SC}} \quad Z_1$$ (Supply impedance per phase (Z_1))

$$I_F = \frac{E_{Phase}}{Z_1 + Z_2}$$ (Prospective fault current at switchboard)

Fault Loop Impedance

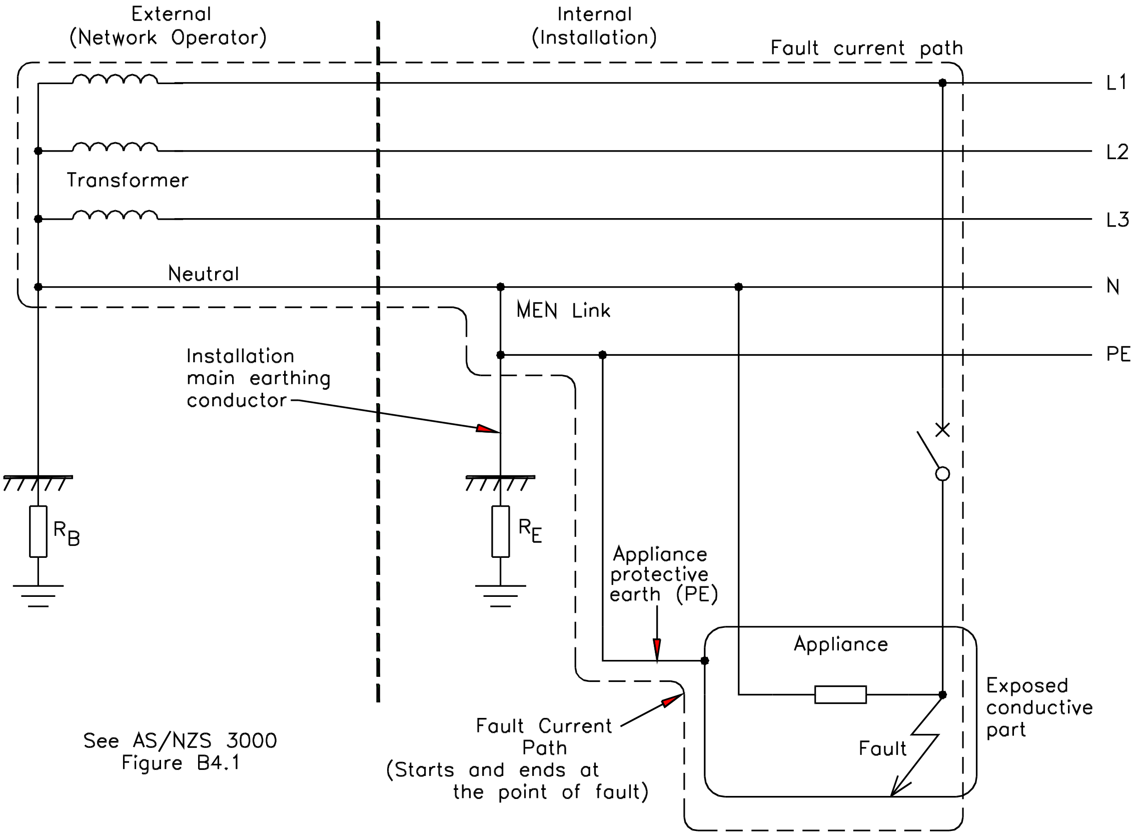
19. Fault-loop impedance is the impedance of the conductors in the series path taken by the current in the event of a fault between an active conductor and an earth fault, starting and ending at the point of the earth fault.

20. AS/NZS 3000 requires that each circuit is protected such that automatic disconnection of supply occurs within a specified disconnection time when a fault of negligible impedance occurs between an active conductor and a protective earthing conductor or an exposed conductive part anywhere in an electrical installation. See Clause 1.5.5.3(d).

21. This condition is satisfied when the fault-loop impedance is sufficiently low to allow enough current to flow in the fault-loop to cause the circuit protection device to operate within the specified time, thus limiting the touch voltage as required by Clause 5.7.4.

Fault Current Path (MEN)

22. The fault current path (or fault loop) in an MEN system starts and ends at the point of the fault. At the instant of the fault, current will flow through the fault loop and its magnitude is only limited by the total system impedance which is obtained from all of the individual impedances in the fault loop (see AS/NZS 3000 Clause B4.4).



Disconnection Times

23. The maximum disconnection time for 230/240 V supply voltage shall not exceed the following (See AS/NZS 3000 Clause 1.5.5.3(d):

a. 0.4 seconds for final subcircuits that supply:

(i) socket-outlets having rated currents not exceeding 63 A; or

(ii) hand-held Class I equipment; or

(iii) portable equipment intended for manual movement during use.

b. 5 seconds for other circuits including submains and final subcircuits supplying fixed or stationary equipment.

Circuit Breaker Mean Tripping Time

24. The maximum value of fault loop impedance (Z_S) can be calculated for circuits protected by circuit breaker using manufacturers' information relating to the approximate mean tripping current for the circuit breaker. The mean tripping current for typical circuit breakers can be taken as:

Type B = 4 times rated current
Type C = 7.5 times rated current (e.g. general purpose loads)
Type D = 12.5 times rated current (e.g. high inductive loads)

See AS/NZS 3000 Clause B4.5 and Table 8.1 – note the 230 V.

Fault Loop Impedance Equation

25. The earth fault loop impedance (Z_S) for a circuit breaker can be determined using AS/NZS 3000 Clause 4.5 and Table 8.1:

$$Z_S = \frac{U_O \quad (The\ norminal\ voltage)}{I_a \quad (The\ mean\ tripping\ time)}$$

The maximum permissible values of measured resistance are given in AS/NZS 3000 Table 8.2 (see notes).

Fault Loop Impedance Calculation

26. A 240 volt final sub-circuit supplies a load consisting of a 10 A socket outlet protected by a 16 A, Type C, 8 kA circuit breaker. Determine the maximum internal resistance (R_{phe}) of the circuit, if the supply is not available.

$$Z_S = \frac{U_O}{I_a} = \frac{240}{16 \times 7.5} = 2 \text{ ohms (Clause B4.5)}$$

$R_{phe} = Z_s \times 0.64 \quad = 2 \times 0.64 \quad = 1.28$ ohms (T8.2 Note 1)

Note: Table 8.2 is calculated using 230 V.
For 240 V multiply by a factor of 1.04.

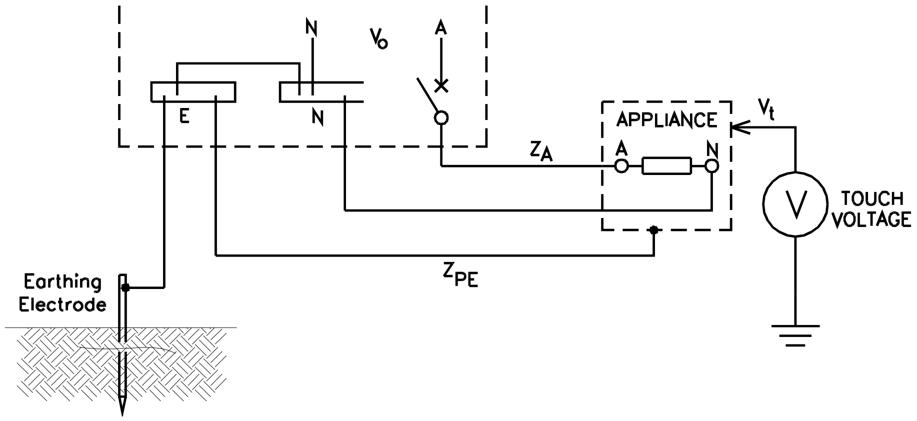
Maximum Circuit Lengths - Table B1

27. Table B1 of AS/NZS 3000 contains maximum circuit lengths, above which the impedance of the conductors will limit the magnitude of the short-circuit current to a level below that required to operate the protective device protecting the circuit in sufficient time (within 0.4 seconds socket outlets) to ensure safety against indirect contact.

28. The maximum circuit lengths in Table B1 are based on a nominal phase voltage of 230 volts. For 240 volt circuits the maximum length can be determined by multiplying the value in the table by 1.04.

Touch Voltage

29. AS/NZS 3000 Clause 1.5.5.3(b) specifies that in the event of a fault between a live part and an exposed conductive part which could give rise to a prospective touch voltage exceeding 50 V a.c. or 120 V ripple-free d.c., a protective device shall automatically disconnect the supply to the circuit or electrical equipment concerned. A typical circuit outline is shown below.



Touch Voltage Equation

30. If the details of the circuit are known the touch voltage (V_t) can be calculated using the equation:

$$V_t = \frac{V_O \times Z_{PE}}{Z_A + Z_{PE}}$$

Where:

V_O = Voltage at protective device – Usually supply voltage
Z_{PE} = Impedance of the protective earth conductor
Z_A = Impedance of the active conductor

Touch Voltage Calculation

31. An appliance is installed with a 4 mm^2 copper active conductor (0.0452 ohms) and has a 2.5 mm^2 earthing conductor (0.071 ohms). Calculate the touch voltage if the supply voltage is 240 volts a.c.

$$V_t = \frac{V_O \times Z_{PE}}{Z_A + Z_{PE}}$$

$$V_t = \frac{240 \times 0.071}{0.0452 + 0.071}$$

Touch voltage = 147 V

Touch Voltage Limit

32. The circuit protection device must automatically disconnect the supply if a fault occurs which could result in a touch voltage greater than 50 V a.c. or 120 V d.c. (AS/NZS 3000 Clause 1.5.5.3(b).

Short Circuit Current

33. AS/NZS 3000 Clause 2.5.4 requires that general protective devices shall be provided to interrupt any over current flowing in the conductors before such a current can cause danger due to thermal and electro-mechanical affects produced in conductors and connections. For short circuits of duration up to 5 seconds, the time in which a given short-circuit current will raise the conductors from the highest admissible temperature in normal duty to the limit temperature may, as an approximation, be calculated from the following equation:

$t = \frac{K^2 \times S^2}{I^2}$ See AS/NZS 3000 Clause 2.5.4.2(b)

Where:

t = duration in seconds

K = a factor dependent on the material of the conductor, the insulation and the initial and the final temperatures. See AS/NZS 3008.1.1 Table 51. A typical value of K is 111.

S = cross-sectional area of the conductor in mm^2

I = effective short-circuit current (A r.m.s)

34. An equation to calculate the current required to disconnect the circuit in a given time can be determined by transposition:

$$t = \frac{K^2.S^2}{I^2} \qquad\qquad I = \sqrt{\frac{K^2.S^2}{t}}$$

Where:

t = duration in seconds

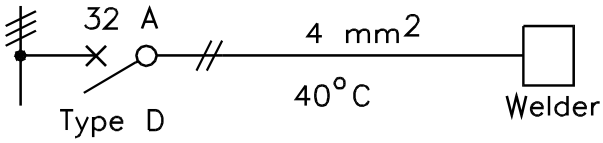
K = a factor dependent on the material of the conductor, the insulation and the initial and the final temperatures. See AS/NZS 3008.1.1 Table 51. A typical value of K is 111.

S = cross-sectional area of the conductor in mm^2

I = effective short-circuit current (A r.m.s)

Short-Circuit Current Calculation

35. A single phase final subcircuit supplies a 415 volt welding transformer from a 4 mm^2 V75 TPI copper active conductor with a 2.5 mm^2 copper protective earthing conductor. Determine the maximum short-circuit current that could flow in the circuit if the associated 32 A, Type D, 8 kA circuit breaker is to operate within 4.5 seconds. The ambient temperature is 40 degrees C.



$$I = \sqrt{\frac{K^2.S^2}{t}}$$

$$= \sqrt{\frac{111^2 x 4^2}{4.5}}$$

= 209.3 amps

Reference Summary

36. The following is a list of the main references for this Section:

AS/NZS 3000 Clause 1.5 Fundamental Principles – Protection against dangers and damage

AS/NZS 3000 Clause 1.4.41 Fault current

AS/NZS 3000 Clause 1.4.42 Overload current.

AS/NZS 3000 Clause 1.4.43 Short circuit current

AS/NZS 3000 Clause 1.4.125 Touch voltage.

AS/NZS 3000 Clause 2.5.3.1 Coordination between conductors and protective devices.

AS/NZS 3000 Clause 2.5.1 General (Protection devices)

AS/NZS 3000 Clause B4.5 Calculation of fault loop impedance.

AS/NZS 3000 Clause Table B1 Maximum circuit lengths.

AS/NZS 3008.1.1 Table 51 Values of constant K

Australian Electrical Wiring (7th ed.), Vol 2, Pethebridge, K and Neeson, I. : McGraw-Hill

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Electrical Fault Protection

1. What effects can it have on an electrical circuit if the maximum safe working current is exceeded?

2. List three of the general requirements for the protection of electrical wiring.

3. Which clause in AS/NZS 3000 specified the requirements for coordination between conductors and protective devices?

4. What two factors govern the value of current which can flow in a circuit if a ‘short circuit’ or ‘bolted fault’ occurs?

5. If a distribution transformer had an impedance of 5%, what value of short circuit current would flow if the full load secondary current was 100 amps per phase?

6. Calculate the rated full load current of a 350 kVA, 415/240 volt three phase distribution transformer with an impedance of 5%.

7. Calculate the prospective short circuit current of a 350 kVA, 415/240 volt three phase distribution transformer that has an impedance of 5%.

8. The network operator advises that the prospective short circuit current at the point of supply to a particular 415 volt three phase installation is 10 000 amps. What is the supply impedance per phase?

9. Calculate the prospective fault current (fault level) per phase at the 3 phase 415 volt main switchboard if the impedance of the consumers mains is 0.028 ohms and the specified impedance at the point of supply is 0.02 ohms.

10. When providing protection against indirect contact in a 240 volt installation, what is the maximum permissible disconnection time for final subcircuits that supply 10 amp socket outlets?

11. When providing protection against indirect contact in a 240 volt installation, what is the maximum permissible disconnection time for a final subcircuit supplying a fixed-wired air conditioning unit?

12. A 240 volt final subcircuit supplies 10 amp socket outlets and is protected by a 16 amp Type C circuit breaker. Calculate the maximum internal fault-loop impedance of the final subcircuit if the supply is unavailable.

13. List the internal and external parts of an MEN system which comprise the ‘fault-loop’ according to AS/NZS 3000. State the Clause number.

14. Determine the prospective short circuit fault current per phase at the main switchboard of an installation if the network operator gives the three phase distribution transformer details as 415 V, 500 kVA, with an impedance of 4.9%. The impedance of the 16 mm^2 copper consumers mains is 0.4 ohms.

Notes:

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Design and Layout of Switchboards and Distribution Boards

Task:

To design the layout for switchboards and Distribution boards to comply with the requirements of the Wiring Rules' and local electricity distributor's service rules.

Why:

All switchboards and distribution boards must be designed to operate safely under normal operating conditions and anticipated fault conditions. Switchboard design must comply with the wiring rules, other relevant standards and local service rules.

To Pass:

1. You must correctly answer the questions on the Work Sheets provided and achieve a mark of 75% or more in a written assessment.
2. You must satisfactorily complete the set laboratory tasks.
3. You must achieve 100% in an observed practical assessment.

Equipment

Simulated electrical installation panels.

References

* Electrical Wiring Practice (7th ed.). Pethebridge, K & Neeson, I.
* AS/NZS 3000:2018 - Wiring Rules. Standards Australia
* AS/NZS 3008.1.1 - Electrical installations. Selection of cables.
* WA Electrical Requirements:2015.
* AS/NZS 4836:2011 - Safe working on or near low-voltage electrical installations and equipment
* Code of Practice. Safe electrical work on low voltage electrical installations. WA Office of Energy.

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Design and Layout of Switchboards and Distribution Boards

Suggested Self-Study Guide

1. Study the following sections in the recommended references:

Wiring Rules

Section 2	General Arrangement, Control and Protection
Clause 2.9	Switchboards

AS/NZS 3008.1.1

Relevant Tables

Electrical Wiring Practice (7th ed.). Volume 2; Pethebridge, K. & Neeson, I.

Chapter 4	Switchboards, control panels and metering

WA Electrical Requirements

Section 6	Metering and Service Equipment

2. Read the Summaries and practise answering the questions provided on the Work Sheets. Refer to other relevant texts if you feel it is necessary.

3. Answer the questions given on the Work Sheets. Use a separate answer sheet or sheets for each Work Sheet. Note that you are required to answer ALL questions correctly, although not necessarily at the same time.

4. Complete the projects in this workbook.

5. Submit your answers to the Work Sheets to your Lecturer for discussion and assessment.

Government of Western Australia North Metropolitan TAFE	**Arrange circuits, control and protection for general electrical installations**	Section 7 Summary	G063A SGB 01/2014

Design and Layout of Switchboards and Distribution Boards

1. The main requirements relating to the selection of switchboards and protection equipment are contained in AS/NZS 3000 Clause 2.10 and the WA Electrical Requirements. It is important to consult both publications when determining the location and accessibility of switchboards, meter panels, sub-boards and any protection requirements. The Standard AS/NZS 3439.1:2002 Low Voltage Switch Gear and Control Gear Assemblies is also available and should also be consulted if necessary.

2. The type of switchboard to be installed depends on several factors, including:

   a. The number of circuits to be controlled
   b. The size and type of load to be controlled.
   c. The type of circuit protection to be provided.
   d. The location of the switchboard.
   e. The amount and type of metering required.
   f. The level and type of fault protection required.
   g. The amount and type of segregation required between components.
   h. Accessibility.

Location and Accessibility of Switchboards

3. **Location** When selecting the position of a switchboard, AS/NZS 3000 and the WA Electrical Requirements provide a set of guidelines/clauses to be followed. Some requirements to be considered are the amount clearance required around the board, the height of the panel, and environment aspects such as the positioning of the switchboard in relation to automatic fire sprinkler systems, fire hoses or any other services.

4. AS/NZS 3000 Clause 2.10.2.1 specifies that the switchboard should be installed in a suitable place dry and well ventilated area unless the switchboard is protected against moisture, and that the access to the switchboard is not obstructed.

5. **Accessibility** Accessibility relates to both the access to the switchboard itself and to exiting an switchboard area in an emergency. AS/NZS 3000 specifies that switchboards with exposed live parts should only be accessed by authorised persons (Clause 2.10.2.2).

6. AS/NZS 3000 Clause 2.9.10.2 specifies that there must be adequate space to allow access to all sides for a person to pass to enable all equipment to be effectively operated and adjusted and to enable a person to readily escape under emergency conditions.

7. The above requirements can be achieved by providing horizontal and vertical clearances that take door opening angle into consideration. AS/NZS 3000 Clause 2.10.2.2 provides further information on the exit requirements that must be provided in relation to switchrooms.

Switchboard Terminology

8. The following terminology is commonly used in relation to large switchboards:

Incomers	Incoming supply to switchboard
Cable Zones	Compartments where conductors are run
Busbar Zones	Areas containing busbars
Gland Plates	The plates which house the cable glands.
Module	A section of a switchboard that is dedicated to a particular task
Isolators	Isolating switches
MCB's	Miniature circuit breakers
Pan	Blank metal assembly with cutouts to allow for electrical equipment to be mounted
MDB	Main Distribution Board
DB	Distribution Board
CFS Unit	Combination fuse-switch unit
MCC	Motor Control Centre
ACB	Air circuit breaker
CTs	Current Transformers
Segregation	Separating parts of a switchboard with barriers
Escutcheon	The removable front-cover plates

Installation of Metering and Service Equipment

9. The WA Electrical Requirements provides the information that will determine the installation of the kilowatt hour meters used to monitor the amount of energy used by the consumer. Because there are several tariffs it is possible that there will be more than one meter to provide mounting for. The positions of the meter panel need not necessarily be adjacent to the main switchboard. Remote meters can be installed not more than 30 metres inside the property – see WAER Section 6.4.

10. The WA Electrical Requirements Section 3 provides information on metering that will meet with the Office of Energy requirements. An example of this is Section 3 which recommends that the metering position should be along the front of the building. When addressing metering another consideration is the use of current transformers (CT's) when the load is will exceed 100 amps – see WAER Section 6.2.1.

11. Information on typical tariffs (charges for the supply of electrical energy) are available from Synergy in WA. The tariffs change from time to time. Web site: synergy.net.au

Purpose and Location of Fault Current Limiters

12. The purpose of fault current limiting devices is to interrupt the supply should a short circuit occur within the switchboard. The fault current limiters must have the capability to interrupt very high fault currents, which can reach values of thousands of amps. HRC fuses are often used to limit fault current on switchboards. They are normally connecting in the incoming mains cable before the main switch. See Electrical Wiring Practice : Vol 2, Figure 1.5a pp 39.

13. Clause 1.4.64 of AS/NZS 3000 defines fault-current limiters as a circuit opening device designed or selected to limit the instantaneous fault current. HRC fuses are often used as an economical fault current limiter because in most cases circuit breakers do not provide sufficient protection for this purpose. Some types of circuit breakers include HRC fuses as an integral part of the assembly to provide fault current limiting and circuit protection in one unit. Clause 2.5.5- Protection against internal arcing faults for switchboards rated at 800 amp or over.

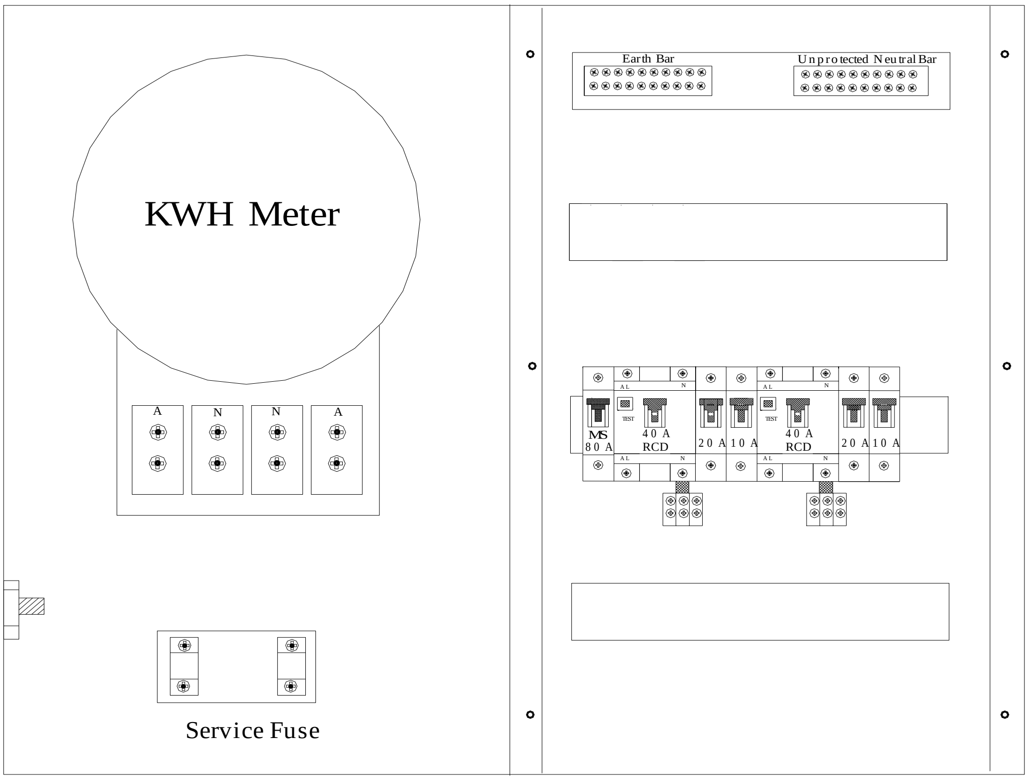
Types of Switchboard

14. The types of switchboards used in non-domestic installations vary widely according to the type of installation, but the main general classifications are:

    a. Dead front assembly. No live parts are accessible from the front, but they may be accessible to authorised persons from other directions.
    b. Cubicle type. Components are contained in one or more enclosed metal cubicles - usually free standing.
    c. Desk type. Components are enclosed in a desk so that an operator can control process from a seated position if required.
    d. Box type assembly. Components are contained in adjoining boxes which can be sealed for use in hazardous areas.

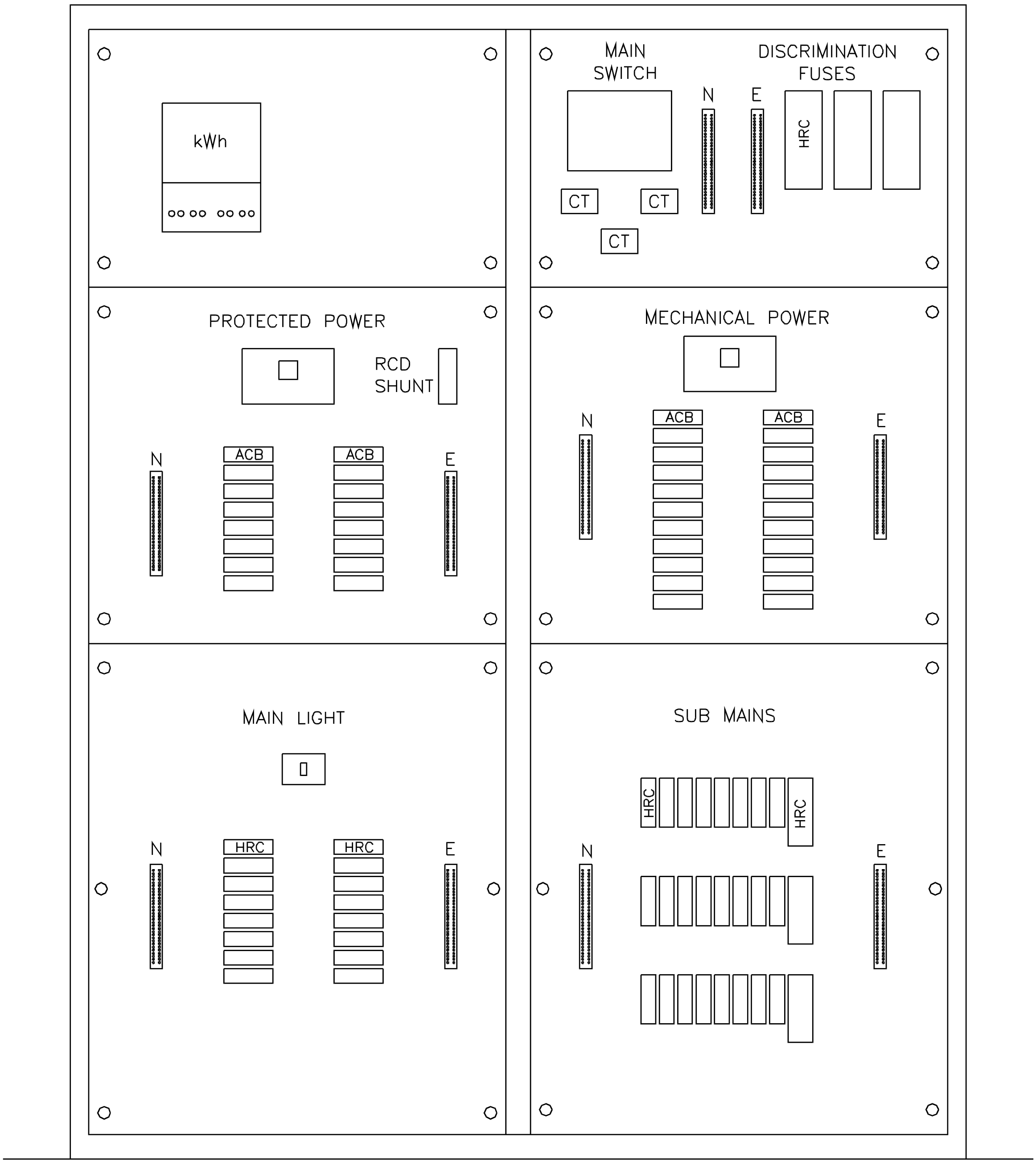
15. The general arrangement for switchboards are shown on the following pages.

Domestic Switchboard



Commercial

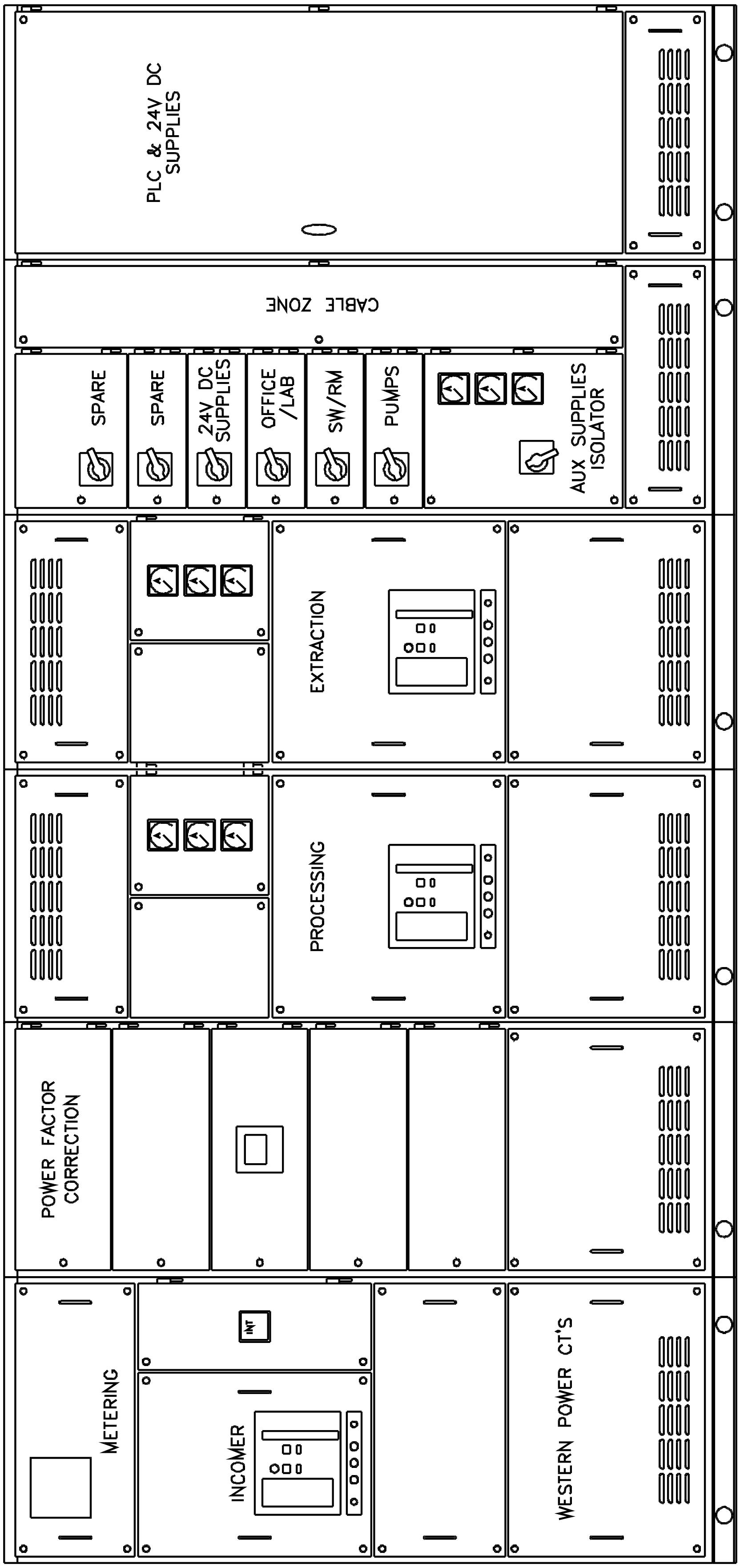
COMMERCIAL SWITCHBOARD – GENERAL ARRANGEMENT



Escutcheon plates removed

Major components only – detail not shown

Industrial



Sample Industrial Switchboard – General Arrangement

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Design and Layout of Switchboards and Distribution Boards

1. Which two publications determine the position of an electrical switchboard?

2. What W.A. publication and in which section is the physical location of switchboards location determined?

3. State the three main considerations when choosing a suitable position for a main switchboard? Give the AS/NZS 3000 Clause number(s)

4. When determining the requirements for marking an enclosure or door of an electrical switchboard, when would it NOT be necessary to mark the door in a commercial establishment?

5. Is it permissible to install a switchboard in a fire isolated stair well? Give the AS/NZS 3000 Clause number.

6. What is the general requirement of AS/NZS 3000 in relation to the accessibility of switch boards? Give the Clause number.

7. What are the three requirements to assist in providing sufficient clearance around a switchboard? Give the AS/NZS 3000 Clause number.

8. Under emergency evacuation conditions, what is the minimum number of exits that must be provided for a switchboard that is 3.5 metres long? Give the AS/NZS 3000 Clause number.

9. Sketch the front view of a main switchboard for a typical single phase domestic installation. Label all electrical components.

10. Sketch the front view of a typical industrial three phase main switchboard connected for a 300 amp maximum demand with the following loads:

    4 X Lighting circuits (general purpose)
    7 X 10 amp 240 volt socket outlet circuits
    3 X 15 amps 1 phase socket outlet circuits
    6 X 20 amp 3 phase socket outlet circuits
    8 X 20 amp 3 phase fixed equipment circuits

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Switchboard Layout Project

Objective

To design and wire a domestic switchboard.

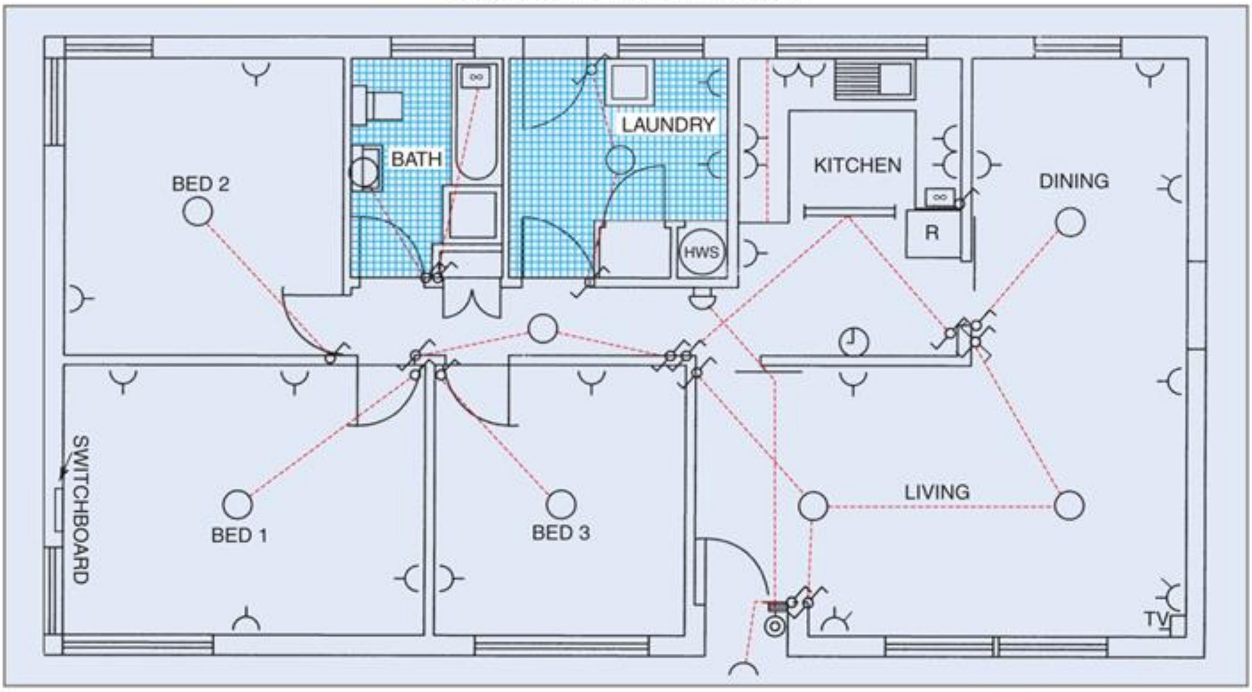
Equipment

AS/NZS 3000 Wiring Rules.
WA Electrical Requirements
Switchboard template
Switchboard project
Cable and wiring accessories
Wiring tools
Manufacturers' catalogues as required.

Procedure

1. Examine the floor plan and specifications provided. Make valid assumptions for detail not given.
2. Specify final subcircuits, cables and protective devices using ASNZS 3000 Table C9.
3. Using the Template of the main switchboard. Show the layout of all equipment (approximately to scale) on the switchboard. Use manufacturer's catalogues or actual components to determine their size. Show identification of circuit relationship to protection devices according to ASNZS3000 and WAER.
4. Submit your switchboard drawing to your Lecturer for comment and assessment
5. Using your drawing, wire the project switchboard.
6. When you have completed wiring the switchboard, ask your lecturer to assess your project.

Domestic Installation Floor plan



Specifications:

1. House construction – double brick
2. 240 volt single phase underground consumer's mains are 15 metres long.
3. HWS in laundry is rated at 4.5 kW
4. The electric range in the kitchen is rated at 5.5 kW
5. Exhaust fan above the electric range to be connected in lighting circuit.
6. Two smoke detectors, one in the living/dining room and the other in the passage way adjacent to bathroom door way, connected in lighting circuit.

Notes:

Assessment (Switchboard Layout):

Satisfactory:		Not Satisfactory:	

Lecturer: ___________________________ Date: _______________

Reference:

- *National Curriculum* - EE-Oz Training Standards Australia

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