UEE30811 – Certificate III Electrotechnology Electrician

October 2018

UNIT UEENEEG107A SELECT WIRING SYSTEMS AND CABLES FOR LOW VOLTAGE REQUIREMENTS

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Please note that within this competency and all others there are required non supervised learning times in this competency there is allocated 63 hours supervised (at TAFE) and 36 in the students time.

Performance requirements - design and safety

Topics

- Protection against harmful effects
- Correct functioning
- Supply characteristics
- Determining maximum demand
- Voltage drop limitations
- Arrangement into circuits
- External factors
- Protection against
  - Direct contact
  - Indirect contact
  - Thermal effects
  - Over current
  - Earth fault current
  - Abnormal voltages
  - Mechanical movement
- Integrity of fire rated construction

Aim

Learners will be introduced to basic electrical design considerations when selecting electrical equipment to meet safety and performance standards.

References:- AS 3000:2018

Learning objectives:

Learners should be able to meet the following learning objectives:

- Outline the harmful effects against which the design of an electrical installation must provide protection.
- Outline the acceptable performance standards of a correctly functioning electrical installation.
- Explain each of the supply characteristics that shall be considered when designing an electrical installation.
- Describe the acceptable methods for determining the maximum demand in consumer's mains and sub-mains.
- State the AS/NZS 3000 requirements limiting voltage drop in an installation.
- State the reason for dividing electrical installations into circuits and the factors that shall determine their number and type.
- List typical external factors that may damage an electrical installation and that shall be considered in the installation design.
- Describe the methods for protecting persons and livestock against direct contact with conductive parts.
- Describe the methods for protecting persons and livestock against indirect contact and the typical application of each.
- Describe acceptable methods of protection against the risks of ignition of flammable materials and injury by burns from the thermal effects of current, in normal service.
- Describe the acceptable methods for protecting persons and livestock against injury and property against damage from the effects of over current.
- Outline the requirement for protection against earth fault current.
- Describe the likely sources of abnormal voltages and the methods for dealing with this potential hazard.
- Outline the requirement for protection against the harmful effects of faults between live parts of circuits supplied at different voltages.
- Explain the need for protection against injury from mechanical movement and how this may be achieved.
- Describe the features of 'fire rated construction' and how the integrity of the fire rating can be maintained in relation to electrical installations.

Introduction.

As an electrical tradesman, especially in the contracting industry, you are required to make design decisions about various parts of an installation. This may be as simple as selecting the correct current rating of a circuit breaker to protect the circuit for a piece of equipment, or as complex as the complete design of an installation.

Topic 1 - Protection against harmful effects

Risk management has three parts.

- Identification, what is the risk?
- Assessment, what danger and how often the risk will occur?
- Mitigation, what actions and processes can be used to eliminate or control the risk?

Activity - 1 - Protection against dangers and damage

Read AS 3000 clause 1.5.1  	
1. What 3 items require protection?	a) ____________________ b) ____________________ c) ____________________
2. What are the 3 major risks?	a) ____________________ b) ____________________ c) ____________________

Now the risks have been identified, it is obvious that assessment will show the dangers are catastrophic and frequent. Designing an electrical installation to the appropriate Australian standards will mitigate the risks to an acceptable level.

Topic 2 - A correctly functioning electrical installation.

So how do we select the correct equipment so that we **do not** cause electric shock and or potentially burn the installation to the ground? Section 1.6 of AS3000 (2018) gives guidance.

Activity - 2 - Design of an Electrical Installation.

Read AS 3000 clause 1.6.1

1. List 5 functions that a electrical installation must be able to do.

a) ______________________________

____

b) ______________________________

____

c) ______________________________

____

d) ______________________________

____

e) ______________________________

____

Topic 3 - Supply characteristics

The electrical equipment and the wiring systems installed must be compatible with the characteristics of the supply. Most installations are supplied by large electrical distributors such as Energy Australia, Integral Energy and Country Energy. However it is not uncommon for private supply sources to be in use. In remote areas solar, wind and small internal combustion generators are common. Larger factories may have there own steam turbines as a source of supply.

Overseas countries such as the United States use a 110 V 60 Hz system, equipment to suit the American supply will not be compatible with Australia's 230 V 50 Hz system.

Activity - 3 - Design of an Electrical Installation.

Read AS 3000 clause 1.6.2 Read the suggested text or resource	Write a response
1. List 9 characteristics of the supply system that must be compatible with the electrical installation connected to it. Group discussion	a) ____________________ b) ____________________ c) ____________________ d) ____________________ e) ____________________ f) ____________________ g) ____________________ h) ____________________ i) ____________________

(a) Generally the supply in Australia is A.C.

(b) If an installations maximum demand is greater than that of the supply available it is normal for the supply distributor to ask for a financial contribution to any upgrades in infrastructure.

The number of supply phases will depend on the maximum demand and load types. Small installations up to 100 A will be connected only to 1 phase and a neutral. If the load exceeds 100 A or a 3 phase motor is installed 3 phases and a neutral will be connected. Known as a 4 wire 3 phase supply it is show in figure 1.

Service and Installation Rules of New South Wales October 2009 rule 1.5.3.3 gives guidance on the number of phases connected to an installation.

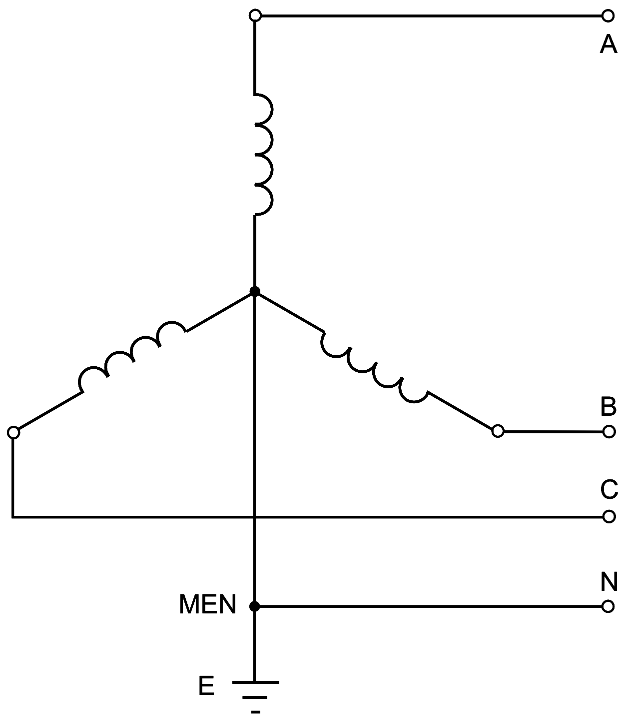


figure 1.

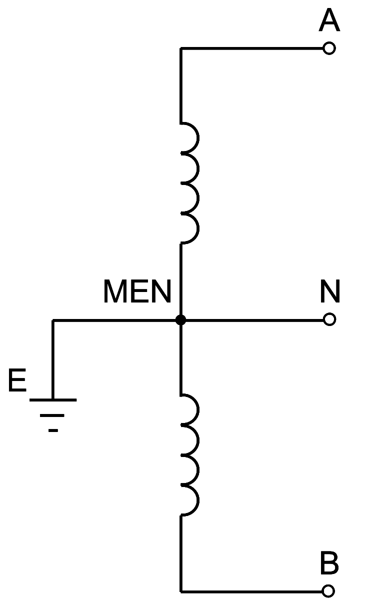


figure 2.

Outside metropolitan areas 3 phase supply is not always available. Many rural distributors use a 3 wire 2 phase supply as shown in figure 2. Heavy loads are wired across A and B phases but are connect to 480 volts single phase, not 415 volts. A 3 phase 415 V motor would not be compatible with the 2 phase 480 volt supply

(c) The nominal supply voltage is 230 volts for single phase supply and 400 volts for three phase supply, not 240/415 Volts. All calculations for this subject are to be performed at 230/400 V.

It is important to ensure the supply voltage is within tolerance. If the voltage is ether too high or low damage to electrical wiring and equipment will occur.

Activity - 4 - Supply characteristics

Write a response	Use AS 3000 2018 rule 1.6.2 (C) to Complete the following activities:
1. Calculate the **maximum** permissible **supply** voltage for a single phase 230 V installation.	
2. Calculate the **minimum** permissible **supply** voltage for a single phase 230 V installation.	
3. Calculate the **maximum** permissible **supply** voltage for a three phase 400 V installation.	
4. Calculate the **minimum** permissible **supply** voltage for a three phase 400 V installation.	

(d) The standard frequency in Australia is 50 Hz. Operation at any other frequency will cause three phase induction motors to run at speeds different to rated values and cause changes in characteristics of other inductive devices.

(e) The maximum current that is supplied to the installation can be set to limit at the electricity distributors discretion. Maximum demand will be covered in the next objective.

(f) The prospective short circuit current is the maximum possible current that could flow under short circuit conditions. Protection devices must be capable of interrupting this current without damage.

Alert

Service and Installation Rules of New South Wales October 2009 Section 1.10.4 gives guidance on prospective short circuit current values at various locations.

(g) The MEN system is used. Many countries in Europe and Asia do not ground the neutral conductor, this is not compatible with our Multiple Earthed Neutral (M.E.N.) system

(h) Limits on the use of equipment. Devices such as motors can draw large currents when starting, this in turn will cause disruptions such as low voltage and distortion to the supply it self.

Service and Installation Rules of New South Wales October 2009 Section 1.10.2 gives guidance on Limits on the Connection and Operation of Equipment.

(i) Harmonic current or other limitations. Modern electronic equipment such as computers, inverters, electronic ballasts and variable speed drives cause harmonics. Harmonics can cause transformers and neutral conductors to over heat.

Topic 4 - Methods of determining maximum demand

Activity - 5 - Maximum demand consumers and sub mains

Read AS 3000 clause 2.2.2 	
1. List 4 methods for determining the maximum demand of consumer's mains and sub-mains. 	a) ______ b) ______ c) ______ d) ______

Service and Installation Rules of New South Wales October 2009 Section 1.5 gives guidance on minimum size of **consumers mains**.

Maximum demand is the highest current expected to flow in a conductor at any given time. It is not necessarily the total of the connected load on the conductor. "Diversity" is the term used to describe the difference between the actual connected load and the current assigned for maximum demand described in activity 5. Take an example of a power circuit with say 8 x 10A outlets. The maximum expected current to be drawn by this circuit will not be 80 amperes. It is very unlikely that all 8 socket outlets will operate at the 10 A maximum current all of the time, some will be lightly loaded or have no load.

The most commonly used methods of determining maximum demand are, for;

- Consumers mains ______________________________
- Sub mains ______________________________
- Final sub-circuits ______________________________

Topic 5 - Voltage drop limitations.

Activity - 6 - Limiting Voltage Drop

Read AS 3000 clause 3.6.2 Read the suggested text or resource	Write a response
1. What permissible percentage of the nominal supply voltage is permitted as voltage drop between the point of supply and electrical equipment in a 230 volt installation?	
2. What permissible percentage of the nominal supply voltage is permitted as voltage drop between the point of supply and electrical equipment in a 400 volt installation?	
3. What is the maximum value of voltage drop is permitted for a single phase 230 volt installation?	
4. What is the maximum value of voltage drop is permitted for a three phase 400 volt installation?	

This percentage of voltage drop is spread across the whole installation, from the point of supply to the load. Not applied separately to consumer's main, sub-main and final sub-circuit. It is a general rule of thumb that approximately a 3% / 2% split is made between the consumer mains and the final sub-circuit.

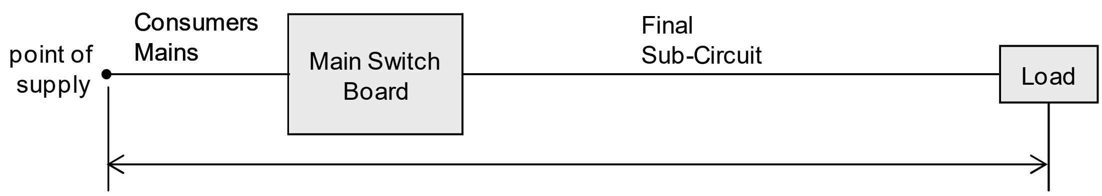


figure 3.

If an installation contains both consumers and sub-mains, the consumers and sub-mains are combined together. The 3% / 2% split is then made between the combination of consumer / sub-main and the final sub-circuit.

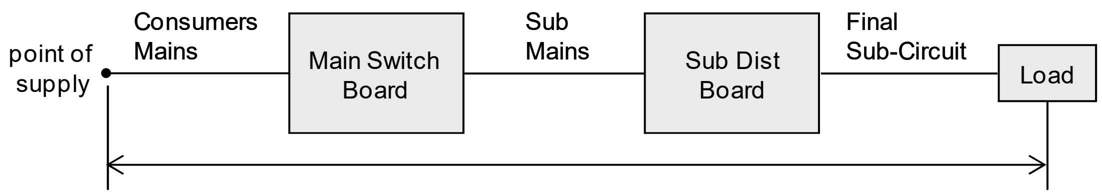


figure 4.

Long runs of cable any where in the installation will cause the voltage drop to increase about the permissible amount. This will cause electric motors to over heat and fail. A simple solution to the problem is to increase cable size.

The voltage drops on each section of cable are series connected; therefore the total voltage drop is the sum of each individual cable.

Activity - 7 - Permissible Voltage Drop

Task	Write a response
1. Figure 5 is a 230 V single phase installation. Determine the total conductor voltage drop.	
2. Does the circuit of figure 5 comply with Australian standards (yes/No) why?	

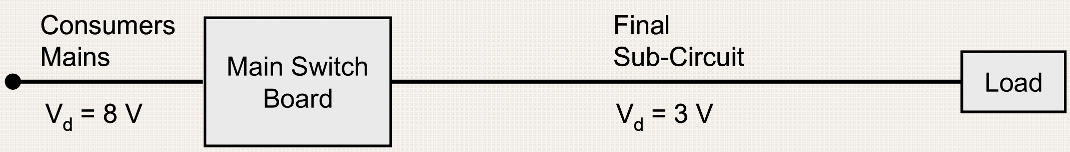


figure 5.

Choose an item.

Activity - 8 - Permissible Voltage Drop

Task	Write a response
1. Figure 6 is a 400 V three phase installation. Determine the total conductor voltage drop.	
2. Does the circuit of figure 6 comply with Australian standards (yes/No) why?	

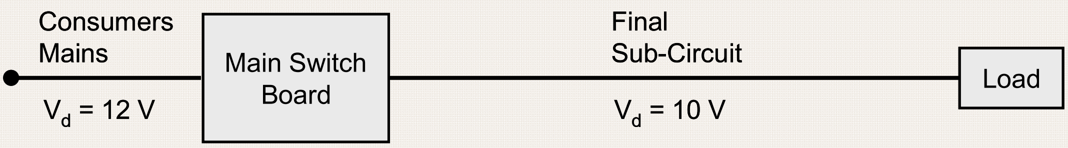


figure 6.

Activity - 9 - Permissible Voltage Drop

Task	Write a response
1. Figure 7 is a 400 V three phase installation. What is the permissible voltage drop on the f.s.c.?	

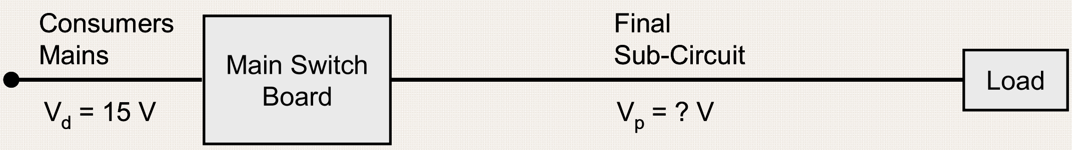


figure 7.

Activity - 10 - Permissible Voltage Drop

Task	Write a response
1. Figure 8 is a 400 V three phase installation. What is the permissible voltage drop on the f.s.c.?	

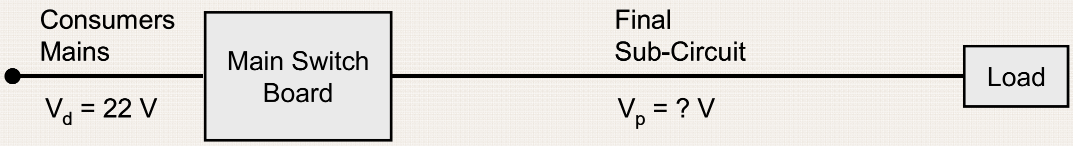


figure 8.

Activity - 11 - Permissible Voltage Drop

Task	Write a response
1. Figure 9 is a 230 V single phase installation. Determine the total conductor voltage drop.	
2. Does the circuit of figure 9 comply with Australian standards (yes/No) why?	

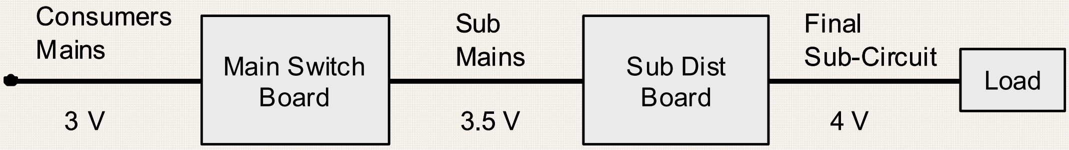


figure 9.

Activity - 12 - Permissible Voltage Drop

Task	Write a response
1. Figure 10 is a 400 V three phase installation. Determine the total conductor voltage drop.	
2. Does the circuit of figure 10 comply with Australian standards (yes/No) why?	

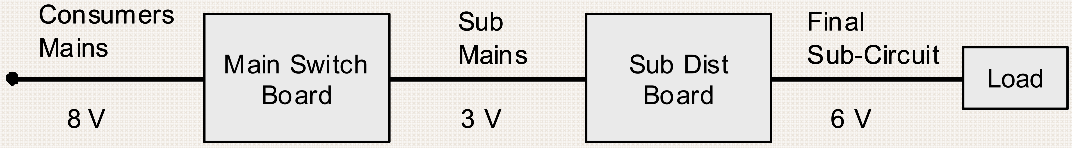


figure 10.

Activity - 13 - Permissible Voltage Drop

Task	Write a response
1. Figure 11 is a 400 V three phase installation. What is the permissible voltage drop on the f.s.c.?	

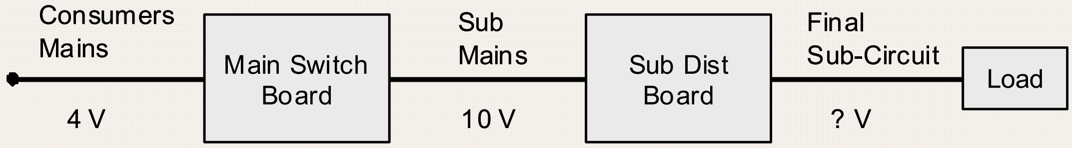


figure 11.

Topic 6 - Arrangement into circuits.

It is simply not practical place all of the electrical load on just one circuit. Consider topic 2 of the lesson, Design of an installation, to satisfy all of these requirements it is necessary to split the installations load into a number of circuits.

Consumers mains - are used to connect the entire installation to the street supply at only one point for ease of isolation.

Sub-mains - connect between switchboards, no load is connected directly to a sub-main.

Final Sub-Circuits - connect the load to the switch board, figure 12 shows an example.

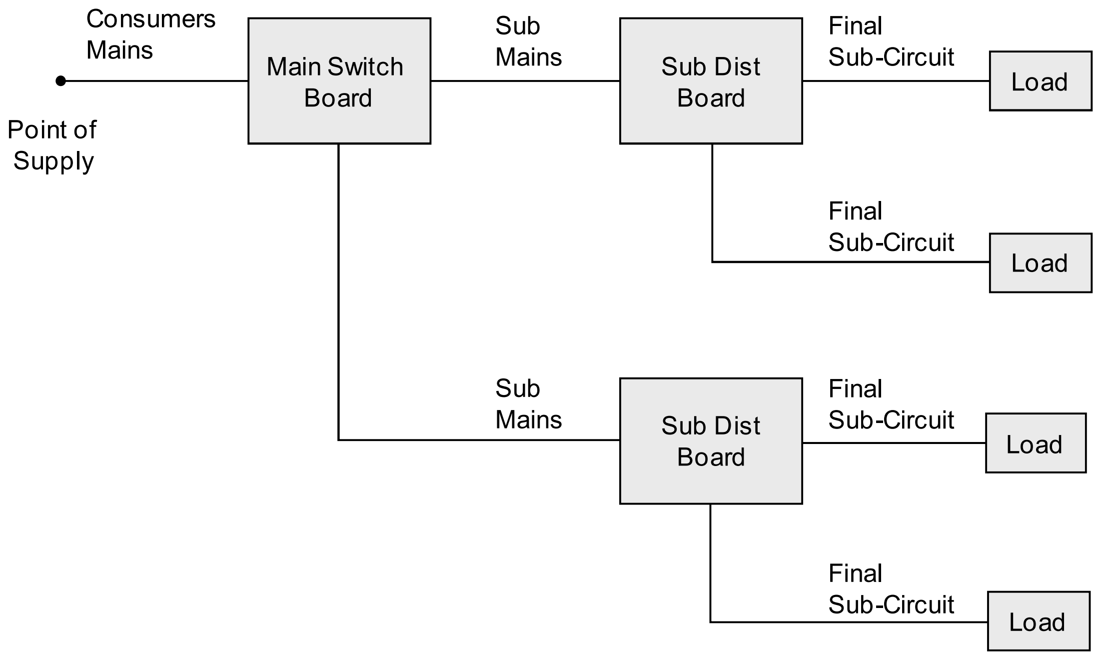


figure 12.

Activity - 14 - Separate Circuits.

Read AS 3000 clause 1.6.5

Choose an item.

Activity - 15 - Separate Circuits.

Read AS 3000 clause 2.2.1.1 	
1. List 6 Typical groups of load that are divided in to separate final sub-circuits. 	a) __________ b) __________ c) __________ d) __________ e) __________ f) __________

Once separated into appropriate circuits a suitable circuit protection device and cable can be selected for each circuit. The protection device (H.R.C. fuse or C.B.) is selected to supply the load and protect the cable.

The cable size is to have a current rating lager than or equal to the circuit protect device selected. The type of cable used should suit the environment in which to which is to be installed and be cost effective. In most cases the Thermo Plastic Sheathed (T.P.S.) cables are commonly used. More detailed selection of cable types will be discussed in following lessons.

The number of points per final sub-circuit ranges from one single point to many. In industrial and commercial installations the number of points is restricted to ensure correct operation of the circuit.

Australian Standard AS3000 gives guidance to number of points per final sub-circuit in table C8.

In domestic installations "diversity" is applied to the circuits to allow the number of points to be increased to reduce costs. Diversity simply means that not all load will be on at the same time.

Topic 7 - External Factors

Activity - 16 - External Factors.

Read AS 3000 rule 1.5.14

1. List 16 External factors that need to be considered in the design of an electrical installation.

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

e) ______________________________

f) ______________________________

g) ______________________________

h) ______________________________

i) ______________________________

j) ______________________________

k) ______________________________

l) ______________________________

i) ______________________________

j) ______________________________

k) ______________________________

l) ______________________________

Choose an item.

Topic 8 - Protection against direct contact (basic protection).

Direct contact is when persons and or livestock come in contact with electrical conductors which are "live" under normal use.

Activity - 17 - Direct Contact.

Read AS 3000 clause 1.4.34 Read the suggested text or resource	Group discussion

Activity - 18 - Protection against direct contact.

Read AS 3000 clause 1.5.4 Read the suggested text or resource	Write a response
1. List 4 methods of protect against direct contact.	a) ____________________ b) ____________________ c) ____________________ d) ____________________

Activity - 19 - Arms reach

Read AS 3000 clause 1.4.12  	
1. What distance is considered arms reach above a surface?	
2. What distance is considered arms reach below a surface?	

Topic 9 - Protection against indirect contact (Fault protection).

Activity - 20 - Indirect Contact.

Read AS 3000 clause 1.4.35  	

In direct contact is a very important concept to understand. When a fault to earth occurs large currents will flow back to the supply via the protective earthing conductor. As the protective earthing conductor is made from copper it will have resistance. Ohms law tells us that when we have both current flow and resistance in a circuit the result is a voltage drop or difference. This voltage drop know as "touch voltage" is now present between the exposed metal of the equipment under fault and the rest of the earthing system as shown in figure 13. A risk now occurs of a person touching the exposed metal of the equipment under fault and another healthy part of the earthing system simultaneously (at the same time). A current called a shock current will flow through that person. The degree of risk of electric shock that person receives depends on three factors;

- the value of touch current.
- the time the person is exposed to the touch current.
- and the path the touch takes through the persons body.

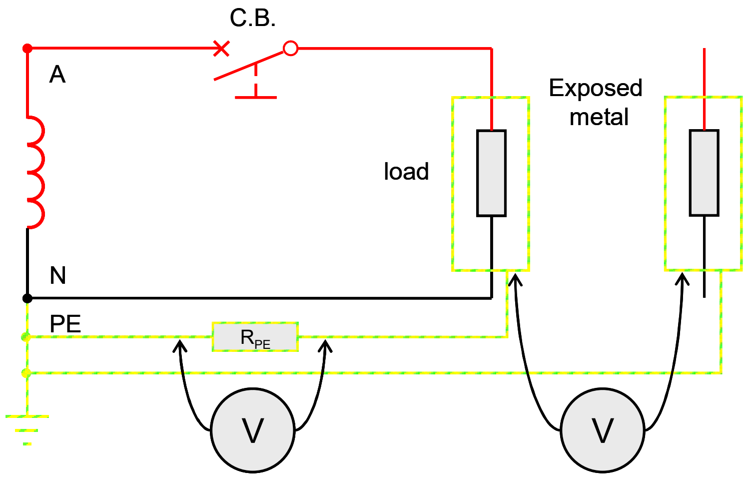


figure 13.

Methods used to protect against indirect contact are called **fault protection**. They reduce the risk of electric shock to an acceptable level by reducing the value and time of that touch current. **DONOT CONFUSE WITH DIRECT CONTACT!**

Activity - 21 - Protection against indirect contact (fault protection).

Read AS 3000 clause 1.5.5.2 	
1. List 4 methods of protect against indirect contact.	a) __________ b) __________ c) __________ d) __________

Please note the most commonly used method is automatic disconnection of supply.

Activity - 22 - Protection by automatic disconnection of supply.

Read AS 3000 clause 1.5.5.3 Read the suggested text or resource	Write a response
1. At what maximum values of touch voltage must automatic disconnection occur?	A.C. ___________ D.C. ____________
2. What is the maximum disconnection time for circuits that supply socket outlets not exceeding 63A, hand held class I equipment, or portable equipment.	
3. What is the maximum disconnection time for circuits that supply other circuits including sub-mains and final sub-circuits supplying fixed or stationary equipment.	
4. Does a R.C.D. satisfy the requires of automatic disconnection of supply (Yes / No).	

Activity - 23 - Disconnection times.

Examine AS 3000 figure B4 (appendix B) Read the suggested text or resource	Write a response
1. What is the maximum duration of touch voltage under normal conditions at 100 Volts.	
2. What is the maximum duration of touch voltage under normal conditions at 50 Volts.	

When the circuit under fault is examined, it effectively becomes a series circuit as shown in figure 14. The active and the protective earthing conductors form a voltage divider. Typically approximately 80% (0.8) of the supply voltage is available at the circuit protection device in the active.

Circuits wired in 1.0, 1.5 and 2.5 mm^2 have the same size active and protective earthing conductors. This means there resistance will be similar; in turn they will share the total voltage across them equally. Under active to earth fault conditions the touch voltage can be high as 230 x 0.8 x 0.5 = 92 volts. As these size conductors are used in final sub-circuits which supply socket outlets or other equipment which may be hand held, the user will be in very good contact with the exposed metal of the equipment under fault. Disconnection times are required to be short (0.4 seconds) to decrease the risk of electric shock

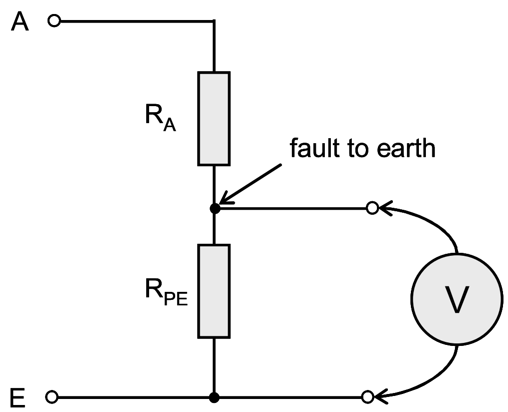


figure 14.

Circuits wired in conductors larger than 2.5 mm^2, 4.0 mm^2 and above have smaller protective earthing conductors than the active. The protective earthing conductor's resistance will be higher than the active conductor. Under active to earth fault conditions the same current passes though both active and protective earthing conductors, because the protective earth's resistance is higher, so the touch voltage across the protective earthing will be larger than the voltage drop in the active. Fortunately these larger conductors are generally used to connect fixed or stationary appliances. By nature of their use, the user will not make as good a contact with the appliance as if it were hand held. A longer disconnection time of 5 seconds is allowed.

Topic 10 - Protection against thermal effects.

Activity - 24 - Protection against thermal effects

Read AS 3000 clause 1.5.8 	

Activity - 25 - Protection against thermal effects

Read AS 3000 Rule 4.2.2.3 	
1. List 3 methods of protecting adjacent materials against high temperatures.	a) ______________________ b) ______________________ c) ______________________

Activity - 26 - Protection against burns

Read AS 3000 rule 4.2.3 Read the suggested text or resource	Write a response
List the maximum temperature limits in normal service for parts of electrical equipment with in arms reach for metallic and non-metallic surfaces for;	
1. Hand held operation	
2. Parts intended to be touched but not hand-held	
3. Parts that need not be touched for normal operation	

Topic 11- Protection against over current

Activity - 27 - Protection against over currents.

Read AS 3000 clause 1.4.37 - 39

There are three over currents;

Fault current – current flowing due to insulation failure/damage from Active to Earth. This current is the cause of touch voltage.

Overload – current flowing due to additional connection of load in an undamaged circuit. The conductors will eventually over heat and be damaged without operation of the circuit protection device.

Short Circuit – this is the largest possible current flow due to a fault of almost zero impedance. The circuit protection must operate very quickly as cable damage and fire is certain.

Activity - 28 - Protection against the effects of over current

Read AS 3000 Rule 1.5.9

1. List 2 methods of protecting against over current.	a) ______________________________ b) ______________________________

Activity - 29 - Devices for protection against the effects of over current

Read AS 3000 Rule 2.5.2 Read the suggested text or resource	Write a response
1. List 4 devices suitable as protection against both short circuit and overload currents	a) ____________________ b) ____________________ c) ____________________ d) ____________________
2. What device is not suitable as protection against both short circuit and overload currents?	
3. Is a RCD a suitable device to protect against over current?	

Topic 12 - Protection against earth fault current.

Activity - 30 - Protection against earth fault current.

Read AS 3000 Rule 1.5.10 Read the suggested text or resource	Group discussion

Topic 13- Protection against sources of abnormal voltages.

Activity - 31 - Protection against abnormal voltages.

Read AS 3000 Rule 1.5.11 Read the suggested text or resource	Write a response
1. List 3 sources of abnormal voltages.	a) ____________________ b) ____________________ c) ____________________

Activity - 32 - Protection against abnormal voltages.

Read AS 3000 Rule 1.5.11.4 Read the suggested	Write a response
1. What precautions must be taken with **unused** conductors to protect against abnormal voltages?	______________________________ ______________________________ ______________________________

Activity - 33 - Protection against the harmful effects of circuits operating at different voltages.

Read AS 3000 Rule 1.4.98 Read the suggested	Write a response
1. List the voltage range of extra-low voltage	
2. List the voltage range of low voltage	
3. List the voltage range of high voltage	

Activity - 34 - Protection against the harmful effects of circuits operating at different voltages.

Read AS 3000 Rule 1.5.11.2 Read the suggested text or resource	Write a response
1. List two methods of protection against the harmful effects of circuits operating at different voltages.	a) ______________________________ b) ______________________________

Topic 14 - Protection against injury from mechanical movement.

Activity - 35 - Protection against injury from mechanical movement.

Read AS 3000 Rule 1.5.13 Read the suggested text or resource	Write a response
1. List two situations where protection against mechanical injury would be required.	a) ______________________________ b) ______________________________

Activity - 36 - Emergency Switching.

Read AS 3000 Rule 2.3.5.1

Read the suggested text or resource

Write a response

1. List 3 situations where an emergency stop would be required.

a) ______________________________________

b) ______________________________________

b) ______________________________________

Activity - 37 - Shutting down for mechanical maintenance.

Read AS 3000 Rule 2.3.6.1

Read the suggested text or resource

Write a response

1. List 3 types of electrical equipment that require a means of shutting down for mechanical maintenance.

a) ______________________________________

b) ______________________________________

c) ______________________________________

Activity - 38 - Shutting down for mechanical maintenance.

Read AS 3000 Rule 2.3.6.3 Read the suggested text or resource	Write a response
1. List three devices that may be used as a means of shutting down for mechanical maintenance.	a) ______________________________ b) ______________________________ c) ______________________________

Topic 15 - Integrity of fire rated construction.

Activity - 39 - Fire rated construction and integrity.

Read AS 3000 Rule 1.5.12 Read the suggested text or resource	Write a response
1. Electrical equipment shall be selected, installed and protected such that the equipment will not—.	a) ______________________________ b) ______________________________ c) ______________________________ d) ______________________________

Activity - 40 - Fire protective measures

Read AS 3000 Rule 2.9.7 Read the suggested text or resource	Write a response
1. What should be done with openings greater than 5 mm of free space in switch boards?	

Activity - 41 - Penetration of fire barriers.

Read AS 3000 Rule 3.9.9.3 Read the suggested text or resource	Write a response
1. Where a wiring system passes through elements of building construction, that is required to be fire-rated, what is the maximum permitted size of the opening for a circular cable?	
2. What must be done internally to conduits that pass through elements of building construction?	

Activity - 42 - Building Code Australia

Read AS 3000 clause E2.1 Read the suggested text or resource	Group discussion

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. What maximum disconnection time does AS/NZS 3000 specify for a final sub-circuit supplying a fixed cooking appliance (free-standing range)?

   (a) 30 milliseconds.

   (b) 40 milliseconds.

   (c) 0.4 second.

   (d) 5 seconds.

2. Which of the following methods provides protection against indirect contact?

   (a) Obstacles.

   (b) Secure barriers.

   (c) Placing out of reach.

   (d) Automatic disconnection of the supply.

3. Arms reach is what vertical distance (↕) above a surface that a person may stand on:

   (a) 0.5m

   (b) 0.75.

   (c) 1.25m

   (d) 2.5m

4. Arms reach is what horizontal distance (↔) from a surface that a person may stand on:

   (a) 0.5m

   (b) 0.75.

   (c) 1.25m

   (d) 2.5m

5. The minimum permissible voltage measured at the load terminals of a 230V appliance is:

   (a) 218.5V

   (b) 230V

   (c) 11.5V

   (d) 225V

6. A method of protecting against direct contact is:

   (a) using Class 1 equipment
   (b) installing an RCD
   (c) automatic disconnection of supply
   (d) placing equipment out of arms reach

7. The maximum disconnection time specified for protection against indirect contact for a final sub circuit supplying socket outlets is:

   (a) unspecified.
   (b) 100ms.
   (c) 400ms.
   (d) 5s.

8. What is the maximum allowable prospective touch voltage before a protective device must automatically disconnect the supply for circuits supplying hand held equipment?

   (a) 32Vac.
   (b) 50Vac.
   (c) l00Vac.
   (d) 240V ac.

9. It is normal to divide an electrical installation into a number of circuits. One reason for this is to:

   (a) Maximise the number of cables used.
   (b) Minimise the number of cables used.
   (c) Allow for the use of a single cable size.
   (d) Minimise the inconvenience in the event of a fault.

10. One method for determining the size of consumer's mains and sub-mains of an electrical installation is:

   (a) Location of points.
   (b) Safe design and construction.
   (c) Demand of devices for isolation.
   (d) Measuring the highest rate of electricity in any 15 minute period.

11. The two points in an electrical installation from where the maximum permissible voltage drop is considered:

(a) Is between any two points in the installation.

(b) Is between the point of supply and the main switchboard.

(c) Is between the point of supply and any other point in the installation.

(d) Is between the main switchboard and the furthermost final sub-circuit.

12. The term *'direct contact'* refers to:

(a) touching a live uninsulated conductor or busbar.

(b) contact with an exposed conductive part which is not normally live, but is live due to a fault.

(c) touching another person who is in contact with the supply.

(d) contact with exposed metal which is earthed.

13. The limit to circuit lengths, as set down in AS 3000, is required:

(a) to keep the cost of electrical installations as low as possible.

(b) to limit the voltage drop in the circuit.

(c) because shorter cable runs are the easier to install

(d) for protection against the danger of indirect contact

14. Which of the following methods does not provide protection against direct contact?

(a) obstacles.

(b) secure barriers.

(c) placing out of reach.

(d) circuit breakers and fuses.

15. An example of a situation where a emergency stop is required is a:

(a) Lathe

(b) Hot Water System

(c) Sub main

(d) Lighting circuit

16. Specify the four (4) acceptable methods of protection against indirect contact.

(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

AS 3000 Reference (Clause number ________________)

17. List three factors to consider when designing an electrical installation.

(a) ____

(b) ____

(c) ____

AS 3000 Reference (Clause number _______________)

18. Live parts are to be protected against direct contact by enclosures or barriers.

(a) What is the minimum degree of protection that must be provided by the enclosures or barrier?

____

AS 3000 Reference (Clause number _______________)

(b) What is the maximum size of an object that is allowed to enter the enclosure or barrier?

____

AS 3000 Reference (Clause number _______________)

19. List three factors that aid in determining the number and type of circuits needed in an electrical installation.

(a) ____

(b) ____

(c) ____

AS 3000 Reference (Clause number _______________)

20. List four methods of determining the maximum demand of a consumer main.

(a) ____

(b) ____

(c) ____

(d) ____

AS 3000 Reference (Clause number _______________)

21. List two of the essential requirements for the selection and installation of electrical equipment.

(a) ____

(b) ____

AS 3000 Reference Clause number ______________)

22. What are the requirements regarding protecting a redundant cable against induced voltages?

____

____

____

AS 3000 Reference (Clause number ______________)

23. List two of methods of protecting against the harmful effects of abnormal voltages for electrical equipment of different rated voltages.

(a) ____

(b) ____

AS/NZS 3000 Reference (Clause number ______________)

24. When protecting electrical actuated equipment against injury from mechanical movement, what is the protection device required to do?

____

____

____

AS 3000 Reference (Clause number ______________)

25. What is the maximum size hole aloud to be made if a single cable is required to penetrate a fire rated wall?

____

AS 3000 Reference (Clause number ______________

Tutorial 1

Section 2

Final sub-circuit arrangements

Topics

- **Daily and seasonal dem**

and

- **Factors determining number and type of circuits**
- **Circuit layouts/schedules**

Aim

Learners will plan the cable arrangements for final sub-circuits in a variety of installations.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Determine the daily and seasonal demand for lighting, power, heating and other loads in a given installation.
- Determine the number and types of circuits required for a particular installation.
- Determine the current requirements for given final sub-circuits.
- Prepare a layout/schedule of circuits for given installations.

Topic 1 - Maximum demand of final sub-circuits

Maximum demand is the maximum expected current that may be drawn by a particular circuit at any given time. For single items of equipment it is set by **assessment** of the connected load. In light and power circuits, or other circuits with more than one point per final sub-circuit, the maximum demand of a final sub-circuit is set by **limitation** (clause C2.5.1). The purpose of the final sub-circuit will determine the number of points that may be connected to that final sub-circuit.

In section 1 we learned that load in an installation is divided into a number of circuits logically arranged to group loads of a similar type onto the same circuit. The more load connected to a single circuit the higher the demand will be, light and power circuits tend to have a large number of points connected to a single circuit. This reduces the cost of the installation. If too much load is connected at the same time the circuit protection device will operate, automatically disconnecting the circuit. Circuits for appliances such air conditioning, hotplates and hot water systems are arranged so that each appliance is on its own separate final sub-circuit for maintenance and testing purposes.

The key to circuit design is to limit the number of lights or socket outlets on the one circuit so the circuit protection device does not trip, while still using the minimum number of circuits to keep installation cost to a minimum. Table C8 gives guidance to the recommended number of points per final sub-circuit.

Daily Demand - different types of installations will use power in different ways. For example socket outlets installed in a domestic installation may rarely ever be used, but in a non domestic installation such as a factory, the socket outlet is probably installed for a purpose and will most likely be in use frequently. For the circuit to function correctly as intended the number of points per final sub-circuit will be less in the factory.

Seasonal Demand - the demand of circuits that supply appliances such as air conditioner will very throughout the year. Most A/C units use more current to heat than to cool. The higher current must be taken as the maximum demand.

Connected load - is the actual current drawn by the circuit with no "diversity" applied. It can be found on the compliance plate of an appliance or calculated using the power equation transposed to find current;

Single phase appliances use

Three phase appliances use

where

I = Current in Amperes

V = Voltage in Volts

λ = power factor

I_L = Line current in Amperes

V_L = Line voltage in Volts

λ = power factor

In circuits with only one point per circuit this current becomes the maximum demand of the circuit.

Activity - 1 – Calculating current from power

Determine the current drawn by a 230 Volt, 2.0 kW single HID luminare operating at a rated power factor of 0.85.

Activity - 2 – Calculating current from power

Determine the line current drawn by a 400 Volt, 40 kW three phase kiln.(resistive load)

Topic 2 - Number and type of final sub-circuits

Activity - 3 - Number of points per f.s.c.

Read the suggested text or resource	Read AS3000 2018 • Rule C.5.1 • Table C8 • footnotes to Table C8
Write a response	1. A **House** wired using T.P.S. cable has the following load installed 32 lights (10A C.B.) 24 Double 10A Socket Outlets (20A C.B.) 1 25A A/C (25A C.B.) 1 4.4 kW Hot Water System (20A C.B.) Complete the table below

Circuit number	Purpose	Protection Device / Rating (A)	Number of points per circuit
1			
2			
3			
4			
5			
6			
7			

Activity - 4 - Number of points per f.s.c.

Write a response

1. A **shop** is wired using T.P.S. cable has the following load installed

   44 lights (20A C.B.)

   21 10A Socket Outlets (20A C.B.)

   Complete the table below

Circuit number	Purpose	Protection Device / Rating (A)	Number of points per circuit
1			
2			
3			
4			
5			
6			
7			

Activity - 5 - Number of points per f.s.c.

Write a response

1. A 3 phase **factory unit** is wired using T.P.S. cable has the following load installed

   10 Hi-bay MV lights rated at 1.85 A each (16A C.B.)

   12 10A Socket Outlets (20A C.B.)

   3 three phase 32 A Socket Outlets (32A C.B.)

   Complete the table below

Circuit number	Purpose	Protection Device / Rating (A)	Number of points per circuit
1			
2			
3			
4			
5			
6			
7			
8			

Domestic Cooking Appliances

Cook tops, stoves ovens and hotplates in domestic installations are allowed some diversity in calculation of their maximum demand. When the elements of are energised they heat up, within a couple of minutes the temperature controllers operate and begin to cycle the elements on and off. Not all of the elements will be on or off at the same time the current drawn by the appliance will be less than the rating on the name plate. A lower current is given for the maximum demand to reduce installation cost. Even if all elements are switched on at the same time the circuit protection device will take time to operate. The current flowing is only a small overload in relation to the nominal rating of the protection device and the cable it protects. In other words by the time the circuit breaker is about to trip the temperature controllers start to cycle the elements and current drops to a value that will not operate the protection or damage the conductors.

Activity - 6 - Maximum demand of cooking appliances

Using Table C4 of AS 3000 		
List the assessed maximum demand from table C4 and calculate the current from the connected load for each load below.		
1. Not greater than 5000W.		
2. 5000W to 8000W		
3. 8000W to 10000W		

Note Table C4 does not apply to cooking appliances in non domestic installations.

Topic 3 - Current requirements of final sub-circuits

To protect conductors from overload and short circuit faults protection devices such as circuit breakers or H.R.C. fuses are used. They must be able to carry the maximum demand continuously without operation, and still be able to detect an overload or short circuit and disconnect the circuit before the circuit conductors are damaged.

Activity - 7 - Devices for protection against both overload and short circuit.

Read AS 3000 Rule 2.5.2 	
List 4 circuit protection devices suitable to protect against both overload and short circuit conditions	a) ______ b) ______ c) ______ d) ______
Can a rewireable fuse to protect against overload and short circuit conditions? Yes/No	

When selecting the circuit protection device (C.B.) it is important to remember the protection device protects the cable not the load. Clause 2.5.3.1 provides the statement;

where

I_B = the maximum demand current in Amperes

I_N = the nominal current of the protective device

I_z = the current capacity of the conductor.

Activity - 8 - Coordination between conductors and protective devices

Read AS 3000 Rule 2.5.3.1 Read the suggested text or resource	Write a response

Below are a number of load, circuit breaker and cable rating combinations. Do the following circuits comply with clause 2.5.3.1?

Maximum demand I_B	Protective device rating I_N	Conductor current carrying capacity I_Z	Complies **Yes/No**
10A	10A	10A	
18A	10A	13A	
32A	25A	33A	
40A	63A	40A	

If the circuit satisfies the equation $I_B \leq I_N \leq I_Z$ it will not operate the circuit protection under normal load. (Will it work?) See figure 1.

To ensure the circuit protection will operate in the case of an over current we use the equation;

where

I_2 = the current ensuring effective operation of the protective device (operates in 1 hour) as shown in figure 1. C.B.'s 1.45 x I_Z, fuses 1.6 x I_Z

I_z = the current capacity of the conductor.

Where the protection is a circuit breaker, if the equation $I_B \le I_N \le I_Z$ is true, so will this equation and the circuit will trip under over current conditions.

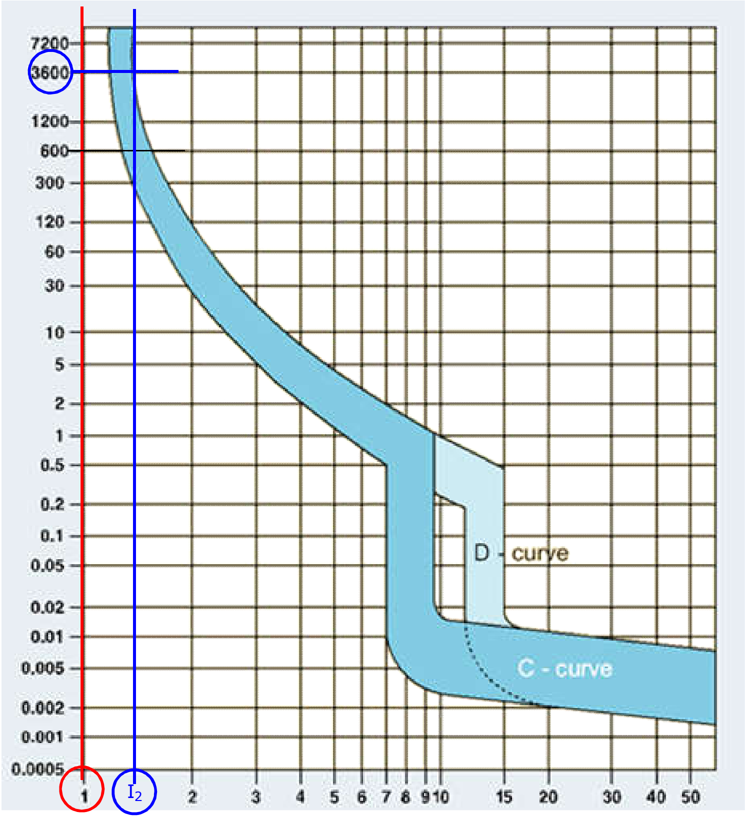


figure 1.- source www.clipsal.com

If a H.R.C. fuse is the protection device the cable rating (I_Z) must be de-rated to 90% of its original capacity eg. if the cable was originally rated at 20 Amperes the cable would only have a current caring a capacity of 18 Amperes (I_Z x 0.9) after it had been de-rated. Once de-rated I_N **is not less than** I_Z.

To ensure the fuse will operate in the case of an over current we use the equation;

where

I_B = the maximum demand current in Amperes

I_N = the nominal current of the protective device

I_z = the current capacity of the conductor.

Activity - 9 - Coordination between conductors and protective devices (fuse)

Below are a number of load, fuse and cable rating combinations. Do the following circuits comply with clause 2.5.3.1?

Maximum demand I_B	Protective device rating I_N	Conductor current carrying capacity I_Z	Complies **Yes/No**
10A	10A	10A	
18A	20A	21A	
32A	32A	36A	
16A	12A	16A	

To determine the minimum current carrying capacity of a conductor protected by a H.R.C. fuse use the equation;

where

I_z = the current capacity of the conductor.

I_N = the nominal current of the protective device.

D.R = the de-rating factor that applies to fuse protection (0.9)

Note: the de-rating factor for a C.B. is

1

Activity - 10 - De-rating factors

Write a response

List the required current carrying capacity of conductors protected by the following protection devices

Protection **(I_N)**	De-rating	Current carrying capacity **(I_Z)**
1. 20A C.B.		
2. 20A H.R.C. fuse		
3. 32A C.B.		
4. 32A H.R.C. fuse		
5. 40A H.R.C. fuse		

Cable Selection

When a conductor carries an electric current work is done to overcome the resistance of the conductor, as a result heat is produced. If the temperature rise in the cable exceeds safe limits the insulation of the cable will be permanently damaged.

Activity - 11 - Current Carrying Capacity

Read AS 3000 clause 3.4.1

Read the suggested text or resource

Group discussion

Activity - 12 - Operating temperature limits

Read AS 3000 Rule 3.4.2 and Table 3.2 Read the suggested text or resource	Normal	Write a response Maximum
1. What is the normal and maximum use temperature for V75 cable?		
2. What is the normal and maximum use temperature for V90 cable?		
3. What is the normal and maximum use temperature for X90 cable?		

A simplified cable and protection device selection process is shown in tables C5 and C6 of AS 3000. These tables show how to select cables and circuit breakers to suit a number of installation conditions, for cables ranging from 1.00 mm^2 to 25.0 mm^2. In later sections we will examine AS 3008.1 (2009) which provides more detailed current ratings for a large range of cables and cross sectional areas.

Installation Conditions - the environment into which a cable is installed will affect the current carry capacity of that cable. Cables installed in thermal insulation will be unable to transfer heat into the air, as a result the cable will retain heat and have a much lower current rating that that of cable installed in air or a underground situations.

Activity - 13 - Circuit protection and cable selection

Using Table C5 AS 3000 	
1. What is the maximum rating of a C.B. protecting a 2.5mm^2 cable installed in air.	
2. What is the maximum rating of a C.B. protecting a 2.5mm^2 cable installed partially surrounded by thermal insulation.	
3. What is the maximum rating of a C.B. protecting a 2.5mm^2 cable installed enclosed in an underground conduit.	
4. What is the maximum rating of a C.B. protecting a 4.0 mm^2 cable installed enclosed in air.	
5. What is the maximum rating of a C.B. protecting a 6.0 mm^2 cable installed completely surrounded by thermal insulation.	

Activity - 14 - Circuit protection and cable selection

Using Table C6 AS 3000 Read the suggested text or resource	Write a response
1. What is the maximum rating of a C.B. protecting a 2.5mm^2 four core and earth, circular cable installed enclosed in air.	
2. What is the maximum rating of a C.B. protecting a 4.0 mm^2 four core and earth, circular cable installed in air.	
3. What is the maximum rating of a C.B. protecting a 6.0 mm^2 four core and earth, circular cable installed enclosed in the ground.	
4. What is the maximum rating of a C.B. protecting a 4.0 mm^2 cable installed enclosed in air.	
5. What is the maximum rating of a C.B. protecting a 10.0 mm^2 cable installed completely surrounded by thermal insulation.	

When selecting cable cross sectional areas (c.s.a) the size must be both cost effective and practical. A power circuit wired in 6.0 mm^2 will be impossible to terminate. Table C5 is used to select the cable c.s.a. and circuit protection. Table C8 is then used to determine the number of points per final sub-circuit.

For 3 phase circuits table C6 is used to select circuit protection ratings for given cable cross sectional areas.

Activity - 15 - Final sub-circuit design

A single phase house is wired using T.P.S. cable has the following load installed

- Complete the table below

22 - Light points wiring installed clipped to timbers in the roof

24 - Double 10A Socket Outlets wiring installed clipped to timbers in the roof

1 - 15A socket outlet for a split system A/C wiring installed clipped to timbers in the roof.

1 - 6.0 kW cook top wiring installed clipped to timbers under the floor

1 - 3.9 kW wall oven wiring installed clipped to timbers under the floor

1 - 4.4 kW storage H.W.S. wiring installed enclosed in conduit in air.

Circuit number	Purpose	Cable C.S.A.	Protection Device / Rating (A)	Number of points per circuit
1				
2				
3				
4				
5				
6				
7				

Activity - 16 - Final sub-circuit design

A three phase house is wired using T.P.S. cable and orange circular has the following load installed

- Complete the table below

Write a response

48 - Light points wiring installed clipped to timbers in the roof.

30 - Double 10A Socket Outlets wiring installed clipped to timbers in the roof.

2 - 3 in one Fan/heat lamps (4 x 275 W) clipped to timbers in the roof.

1 - 18A 3 Φ ducted A/C wiring installed enclosed in conduit in air.

1 - 7.8 kW 1 Φ range wiring installed clipped to timbers under the floor

1 - 22.0 kW 3 Φ spa heater, wiring installed enclosed in conduit in air.

1 - 3.6 kW Sauna wiring installed clipped to timbers in the roof

1 - 4.4 kW storage H.W.S. wiring installed enclosed in conduit in air.

Circuit number	Purpose	Cable C.S.A.	Protection Device / Rating (A)	Number of points per circuit
1				
2				
3				
4				
5				
6				

Activity - 16 - Final sub-circuit design (cont'd)

Circuit number	Purpose	Cable C.S.A.	Protection Device / Rating (A)	Number of points per circuit
7				
8				
9				
10				

Activity - 17 - Final sub-circuit design

A three phase factory unit is wired using T.P.S. and orange circular cable, has the following load installed

- Complete the table below

Write a response

16 - MH Hi-bay Lights (1.25A each) split over two circuits unenclosed in air.

24 - Twin 36W Fluorescent lights (0.333 A each) unenclosed in air.

15 - 10A double socket outlets wiring installed enclosed in conduit in air.

3 - 32A 3 Φ socket outlets wiring installed enclosed in conduit in air.

1 - Hard wired machine 54A / phase installed enclosed in conduit in air.

2 - Hard wired machines 34A / phase enclosed in conduit in air.

1 - 4.4 kW H.W.S. wiring installed enclosed in conduit in air.

Circuit number	Purpose	Cable C.S.A.	Protection Device / Rating (A)	Number of points per circuit
1				
2				
3				
4				
5				
6				

Activity - 17 - Final sub-circuit design (cont'd)

Circuit number	Purpose	Cable C.S.A.	Protection Device / Rating (A)	Number of points per circuit
7				
8				
9				
10				

Topic 4 - Final sub-circuit schedules and layouts.

Circuit schedules are used to detail which protection device controls which circuit. An example is shown in figure 2.

Installation By: Electric Electricians
Phone: 0414 123 456
Sub Board No.: **DB-Garage (60 pole)**
Fed From: **Main Switchboard C.B.20**
Cable Size: **25mm 4 x 1c XLPE/PVC + E**

Pos.	Amps	Designation	Pos.	Amps	Designation
1	32	Lighting Distribution Board No. 01 (Kitchen Pantry)	2	20	Spare
3	32	Lighting Distribution Board No. 01(Kitchen Pantry)	4	20	Spare
5	32	Lighting Distribution Board No. 01 (Kitchen Pantry)	6	20	Spare
7	32	Lighting Distribution Board No. 02 (First Floor Study)	8	20	Kitchen – Dishwasher GPO (RCD)
9	32	Lighting Distribution Board No. 02(First Floor Study)	10	20	Kitchen – Steam Oven GPO (RCD)
11	32	Lighting Distribution Board No. 02 (First Floor Study)	12	20	Kitchen – Microwave GPO (RCD)
13	25	10 HP Daikin Air Conditioning Unit No. 01	14	20	Kitchen – Bench GPO's (RCD)
15	25	10 HP Daikin Air Conditioning Unit No. 01	16	20	Spare
17	25	10 HP Daikin Air Conditioning Unit No. 01	18	20	Ground Floor – General GPO's (RCD)
19	25	10 HP Daikin Air Conditioning Unit No. 02	20	20	Ground Floor – General GPO's (RCD)
21	25	10 HP Daikin Air Conditioning Unit No. 02	22	20	Ground Floor – Home Theatre GPO's (RCD)
23	25	10 HP Daikin Air Conditioning Unit No. 02	24	20	Ground Floor – Garage GPO's (RCD)
25	20	Sauna Heater – Squash Area	26	20	Ground Floor – Squash GPO's (RCD)
27	20	Sauna Heater – Squash Area	28	20	Spare
29	20	Sauna Heater – Squash Area	30	20	First Floor – General GPO's (RCD)
31	20	Spare TP MCB	32	20	First Floor – General GPO's (RCD)
33	20	Spare TP MCB	34	20	Spare
35	20	Spare TP MCB	36	20	Front Gate – GPO (RCD)
37	20	1 x 3.6kW Heat Pump Hot Water Unit (Squash)	38	20	Pool – GPO's (RCD)
39	32	Kitchen – Electric Induction Cook-top	40	20	First Floor – Spa GPO (RCD)
41	25	Kitchen – Electric Wall Oven	42	20	Tennis Court Future – GPO's (RCD)
43			44	20	Spare
45	10	Dimmer 1 (RCD)	46	20	Spare
47	10	Dimmer 2 (RCD)	48	20	Spare
49	10	Dimmer's 3 & 4. (RCD)	50		
51	10	Dimmer's 5 & 15. (RCD)	52		
53	10	Relay 1 (RCD)	54		
55	10	Relay 2 (RCD)	56		
57	10	Relay 3 (RCD)	58		
59	10	Relay's 7, 8 & 9. (RCD)	59		

figure 2.

Activity - 18 - Final sub-circuit schedule

Complete a schedule of circuits for the house used in activity 15.

Write a response

Pos.	Amps	Designation	Pos.	Amps	Designation
1			2		
3			4		
5			6		
7			8		
9			10		
11			12		
13			14		
15			16		
17			18		
19			20		
21			22		
23			24		
24			26		
25			28		

Activity - 19 - Final sub-circuit schedule

Complete a schedule of circuits for the house used in activity 16.

Write a response

Pos.	Amps	Designation	Pos.	Amps	Designation
1			2		
3			4		
5			6		
7			8		
9			10		
11			12		
13			14		
15			16		
17			18		
19			20		
21			22		
23			24		
25			26		
27			28		

Tutorial 2

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. Which of the following considerations is not necessary in determining the number and type of circuits within an electrical installation?

   (a) Load on the various circuits.

   (b) Location of the points or load.

   (c) Exposure to external influences.

   (d) Seasonal and daily variations of demand

2. A final sub-circuit of 230 volt 10 ampere socket outlets is wired in 2.5mm^2 two core and earth TPS cable installed laid flat on the ceiling of a domestic installation covered by thermal insulation batts. The maximum current rating of the type C circuit breaker protecting the circuit would be:

   (a) 10A.

   (b) 16A.

   (c) 20A.

   (d) 25A.

3. When selecting a circuit breaker for a water heater final sub-circuit, its current rating should be:

   (a) equal to or less than the demand of the final sub-circuit and equal to or less than the cable rating

   (b) equal to or greater than the demand of the final sub-circuit and equal to or less than the cable rating

   (c) equal to or less than the demand of the final sub-circuit and equal to or greater than the cable rating

   (d) equal to or greater than the demand of the final sub-circuit and equal to or greater than the cable rating.

4. A separate final sub-circuit is recommended for any single point of load exceeding;

   (a) 16A.

   (b) 20A.

   (c) 25A.

   (d) 32A.

5. What is the term used in AS/NZS 3000 to describe the maximum demand current for which a circuit is designed?

   (a) I_N

   (b) I_Z

   (c) I_{SC}

   (d) I_B

6. Under **normal** operating conditions, what is the maximum permissible temperature of a **V75** insulated, 2.5mm^2, TPS cable?

   (a) 90° C

   (b) 160° C

   (c) 75° C

   (d) 250° C

7. Under **normal** operating conditions, what is the maximum permissible temperature of a **V90** insulated, 2.5mm^2, TPS cable?

   (a) 90° C

   (b) 160° C

   (c) 75° C

   (d) 250° C

8. What de-rating factor is applied to a cable protected by a HRC fuse?

   (a) 0.707.

   (b) 0.8.

   (c) 0.9.

   (d) No de-rating required.

9. The recommended number of lighting points that can be connected to a circuit wired in 1.0 mm^2 TPS cable and protected by a 6A type C circuit breaker in a domestic installation is:

   (a) 10

   (b) 12

   (c) 20

   (d) unlimited

10. The recommended number of double 10A socket outlets that can be connected to a circuit wired in 2.5 mm^2 TPS cable and protected by a 20A type C circuit breaker in a factory without air conditioning is:

(a) 5

(b) 10

(c) 20

(d) unlimited

11. A house contains

- 22 x lighting points protected by a 10 A C.B
- 16 x double 10 A S/O’s protected by a 20 A C.B.
- 1 x 15 A S/O for a clothes drier protected by a 20 C.B.
- 1 x 13 A A/C unit protected by a 20 C.B
- 1 x 800 W heat pump HWS. protected by a 20 C.B

Determine the number of circuits and the number of point per final sub-circuit required.

Circuit number	Purpose / load	Protection Device / Rating (A)	Number of points per circuit
1			
2			
3			
4			
5			
6			
7			

12. For the house in tutorial question 11 complete a circuit schedule;

Pos.	Amps	Designation	Pos.	Amps	Designation
1			2		
3			4		
5			6		
7			8		
9			10		
11			12		
13			14		
15			16		
17			18		

13. A factory unit contains

- 10 x 400 W hi-bay lights rated at 2.08 A each protected by 16 A C.B.'s

- 12 x single 10A S/O's protected by a 20 A C.B.
- 4 x 15A 3 phase S/O protected by a 20 A C.B.'s.
- 4 x 20A 3 phase S/O protected by a 20 A C.B.'s.
- 2 x 32A 3 phase S/O protected by a 40 A C.B.'s.

Determine the number of circuits and the number of point per final sub-circuit required.

Circuit number	Purpose / load	Protection Device / Rating (A)	Number of points per circuit

14. For the factory in tutorial question 13 complete a circuit schedule;

Pos.	Amps	Designation	Pos.	Amps	Designation

1			**2**		
3			**4**		
5			**6**		
7			**8**		
9			**10**		
11			**12**		
13			**14**		
15			**16**		
17			**18**		
19			**20**		
21			**22**		
23			**24**		
25			**26**		
27			**28**		
29			**30**		
31			**32**		
33			**34**		
35			**36**		

Section 3

Factors affecting the suitability of wiring systems

Topics

- **Construction methods**
- **Installation conditions**
- **External influences**
- **Selecting wiring systems**

Aim

Learners will plan the cable arrangements for final sub-circuits in a variety of installations.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Identify wiring systems typically used with various construction methods and particular environments.
- Describe the installation conditions that may affect the current-carrying capacity of cables.
- Explain the external influences that may affect the current-carrying capacity and/or may cause damage to the wiring system.
- Apply the AS/NZS 3000 requirements for selecting wiring systems for a range of circuits, installation conditions and construction methods into which the wiring system is to be installed.

  Note: Wiring systems include cable enclosures, underground wiring, aerial wiring, catenary support, safety services, busbar, trunking and earth sheath return.

Introduction

When selecting a wiring system (which includes cabling and enclosures or supports) consideration must be given to:-

- the degree of support present or required in the building;
- fire protective measures, in lift or fire fighting equipment;
- reliability of connections, or ease of changing connections or position of equipment;
- mutual detrimental influences, ie the effect of one cable on another cable;
- the protection required against external influences,
- selection of cable sizes to suit
    - current requirements of the circuit,
    - voltage drop considerations,
    - and fault loop impedance;
- cost.

Activity - 1 - Cable selection and installation.

Read AS 3000 clause 3.1.2 Read the suggested text or resource	Group discussion

Topic 1 - Construction Methods

Whether the building is timber, steel, aluminium or concrete, and what its function is, will affect the wiring system chosen. As an example, the type of wiring used in a prefabricated steel structure, such as a temporary field maintenance workshop would differ from that supplying similar equipment permanently installed in a concrete building.

The method of construction used will be set by the purpose and budget of the building under construction. Typical construction methods are;

Domestic

- timber / steel frame
    - brick veneer
    - PVC or aluminium clad
- cavity or double brick
- Steel re-enforced concrete slab.

The cavity between frame and cladding or brickwork offers a suitable a medium for cables such as T.P.S. and orange circular. The cavity provides both a path and mechanical protection for cables, minimising installation cost and improving the finished appearance. In double brick construction it will be necessary to "chase" cables into walls.

Industrial and commercial (non-domestic)

- pre cast - the steel re-enforcing is tensioned prior to pouring concrete into removable formwork. Tensioning gives the structure strength.
- post cast - the steel re-enforcing is tensioned after pouring concrete into removable formwork.
- prefabricated - sections or panels of construction are formed off site and assembled to suit.

Steel re-enforced beams and column support walls and floors. Walls are; concrete, brick or besser block. Floors are typically post cast concrete. This method construction requires careful planning. Conduits must be installed prior to the concrete pour. Provisions for "cable risers" must be included in the buildings initial design. A wiring system should be selected to take advantage of any mechanical protection or concealment the building construction method has to offer.

Topic 2 - Installation conditions

The method used to install wiring must be suitable to the type of wiring selected and the environment in which it is installed. Naturally not all wiring systems are suitable for any environment; reductions in current carrying capacities (de-ratings) may also result of the installation method. If **more than 1 circuit is grouped** with other circuits de-rating of all cables in the group is required.

Activity - 2 - Installation conditions.

Read AS 3000 Table 3.1  	
Give examples of cables installed; Unenclosed • On a surface • On a surface partly surrounded by thermal insulation • On a surface fully surrounded by thermal insulation • Buried direct in the ground	
In an enclosure • On a surface • On a surface and partly surrounded by thermal insulation • Fully surrounded by thermal insulation • Underground,	
Supported on a catenary system	
Supported on insulators	

Topic 3 - External Influences

Activity - 2 - External Factors.

Read AS 3000 section 3.3 Read the suggested text or resource	Write a response
1. List 12 External factors that need to be considered in the design of an electrical installation.	a) _______________________________________ b) _______________________________________ c) _______________________________________ d) _______________________________________ e) _______________________________________ f) _______________________________________ g) _______________________________________ h) _______________________________________ i) _______________________________________ j) _______________________________________ k) _______________________________________ l) _______________________________________
2. What is the ambient temperature for cables installed in air?	
3. What is the ambient temperature for cables installed underground?	

All equipment including wiring systems, must comply with the requirements of Clause 1.7 of AS/NZS 3000; that is, the equipment itself must be safe in design and construction, including its proper assembly and installation. Equipment must also be able to function properly in the environment in which it is installed and not cause any damaging effect on the electrical installation, or the premises in which it is installed. There is no universal wiring system for all applications, but there is usually one system that is the best, or most suitable for a particular application, after considering all technical and economic aspects.

Topic 4 - Selecting Wiring Systems

Wiring systems are a combination of the cable type, supports and were required the enclosure that protects the cable. Table 3.1 AS3000 shows common combinations. Not all cable types are suitable for use with all enclosures/supports.

Activity - 3 - Wiring system selection

Read AS 3000 table 3.1 Read the suggested text or resource	Write a response
1. List 6 commonly used cable types	a) ____________________ b) ____________________ c) ____________________ d) ____________________ e) ____________________ f) ____________________

Table 3.2 AS 3000 shows a selection of insulation types for commonly used cable types.

Activity - 4 - Wiring system selection

Read AS 3000 section 3.10.1 	

Enclosed Cables

Clause 3.10.1 AS3000 states, "insulated, unsheathed cables shall be enclosed in a wiring enclosure throughout their entire length." TPI cables (building wire) must be enclosed in conduit or similar enclosure, to provide double insulation, mechanical protection, and cable support.

Activity - 5 - Wiring system selection

Read AS 3000 section 3.10.1 	
1. List 5 exceptions where unsheathed (single insulated) cables may be installed without a wiring enclosure	a) ______________________________ b) ______________________________ c) ______________________________ d) ______________________________ e) ______________________________

Applications

- TPI cables enclosed in conduit in cement slabs and walls.
- TPI cables enclosed in conduit or trunking on surfaces.

Activity - 6 - types of wiring enclosures

Read AS 3000 section 3.10.2.1 Read the suggested text or resource	Write a response
1. List 3 wiring enclosures suitable for use with single insulated cable.	a) ____________________ b) ____________________ c) ____________________
2. List 4 types of conduit.	a) ____________________ b) ____________________ c) ____________________ d) ____________________

While TPI cables in most cases always require some form of enclosure T.P.S. cables in most cases do not. However where T.P.S. cables are "likely to be disturbed" mechanical protection is required when they are run on the surface of a wall or on the underside of a ceiling or roof.

Activity - 7 - Wiring systems likely to be disturbed

Read AS 3000 clause 3.9.3.3 Read the suggested text or resource	Group discussion

Activity - 8 - Protection against mechanical damage

Read AS 3000 clause 3.9.4.1 Read the suggested text or resource	Group discussion
Read AS 3000 clause 3.3.2.6 Read the suggested text or resource	Group discussion
Do T.P.S. cables installed in an area likely to be disturbed and where they are subject to mechanical damage, need to be enclosed?	

Cables installed within a ceiling are **not** expected to be subject to mechanical damage and do not require additional mechanical protection (enclosure).

Un-enclosed Cables

Only cables which are double insulated are suitable for un-enclosed installation. Cables such as S.D.I. T+E and multicore are suitable for use. As there is no wiring enclosure to provide support for the cable devices such as clips, cleats, ladders and cable tray are used as support. The type of support will depend on the building construction, where the cables are being installed and the number of cables requiring support.

Activity - 9 - Wiring system support

Read AS 3000 section 3.3.28 Read the suggested	Group discussion

Underground cables

Underground cables may be installed either buried direct or in a enclosure. Smaller conductors are normally enclosed for mechanical protection. The enclosure also allows for repair or upgrades to larger size or additional number of phases. Larger cables such as street distribution mains are direct buried to reduce cost. It is unlikely because of their size that another cable will be "pulled in" as a replacement. Single insulated or unsheathed cables are not permitted to be installed buried direct.

Activity - 10 - Underground wiring systems

Read AS 3000 rule 3.11.1 Read the suggested	Group discussion

Activity - 11 - Underground wiring systems

Read AS 3000 section 3.11.2. Name the category of wiring system described below Read the suggested	Write a response
1. The wiring system is inherently suitable for installation below ground and no further mechanical protection is required.	
2. The wiring system is suitable for installation below ground only with additional mechanical protection provided for the cable or cable enclosure.	
3. The wiring system is laid within a channel chased in the surface of rock.	

Activity - 12 - Underground wiring systems

Read AS 3000 table 3.5

Read the suggested

Group discussion

Activity - 13 - Underground wiring systems

Read AS 3000 table 3.6

Read the suggested

Group discussion

Aerial cables

To cover large distances at minimal cost an aerial wiring system is used. The types of cable which are suitable as aerials are listed in AS300 rule 3.12.1.

Activity - 14 - Aerial wiring systems

Read AS 3000 rule 3.12.1

Read the suggested

Group discussion

Catenary Wiring Systems

Catenarys are used to support the mass of cables not suitable for aerial wiring. A orange circular strung between two supports of any distance will not be able to support its own weight. Depending on the distance it will stretch and possibly even break. The solution is the catenary support. The requirements for cables in catenary system are listed in AS300 rule 3.13.1.

Activity - 15 - Catenary wiring systems

Read AS 3000 rule 3.13.1

Is it permissible to use building wire (TPI) in a Catenary wiring system?

Safety Service Wiring Systems

Formally known as emergency systems electrical safety services supply such apparatus as;

- fire detection
- warning and extinguishing systems
- smoke control systems
- evacuation systems
- lifts.

Any electrical wiring system what could be described as "emergency equipment" or an "essential service" is required to maintain supply when exposed to fire. Normal organic based insulations will fail in a very short period of time in such conditions cutting power to the safety services when they are most needed. Cables such as M.I.M.s or Radox are required.

Activity - 16 - Safety services

Read AS 3000 rule 7.2.1.1

Activity - 17 - Safety service wiring systems

Read AS 3000 rule 7.2.7.2 Read the suggested	Write a response
Do consumers mains, sub-mains and f.s.c.'s that supply safety services need to have a WS classification?	

Activity - 18 - Safety services

Read AS 3000 Tables H1 and H2 Read the suggested	Group discussion

Activity - 19 - Safety service wiring systems

Read AS 3000 section H2 Read the suggested	Write a response
What is the required WS classification for a wiring system that supplies;	
1. residential sprinkler pumpsets.	
2. Smoke venting equipment	
3. Passenger and goods lifts.	

Busbar Trunking (Busway) Systems

Busbar trunking has several key advantages over conventional wiring systems. On-site installation times are reduced compared to hard-wired systems, thus leading to cost savings. It provides increased flexibility in design and versatility with regard to future modifications.

Activity - 20 - Busbar Trunking (Busway) Systems

Read AS 3000 Section 3.15 Read the suggested	Group discussion

Distribution busbar distributes power along its length through tap-off points along the busbar at typically at 0.5 or 1 m centres. Tap-off units are plugged in along the length of the busbar to supply a load; this could be a sub distribution board or, in a factory, to individual machines. Tap-offs can normally be added or removed with busbar live, eliminating production down time.

Installed vertically the same systems can be used for rising-mains applications, with tap-offs feeding individual floors. Certified fire barriers are available at points where the busbar passes through a floor slab. Protection devices such as fuses, combination switch fuses or circuit breakers are located along the busbar run, reducing the need for large distribution boards and the large quantities of distribution cables running to and from installed equipment.

Busbar trunking systems are used in a variety of applications, including production plants, workshops, assembly lines, warehouses, distribution centres, supermarkets, retail outlets etc.

Earth Sheath Return (ESR) Systems

Used with M.I.M.'s cable, a substantial installation cost saving is made by combining the protective earthing (PE) conductor and the neutral (N) conductor into a single protective earth neutral (PEN) conductor.

Activity - 21 - Earth Sheath Return wiring systems

Read AS 3000 section 3.16 	
1. What is a PEN conductor ?	
2. If unserved ESR conductors are not run in a trefoil formation, at what distance must the sheaths of the conductors be bonded together?	
3. Is it permissible once a ESR wiring system has been split into a protective earthing and neutral conductor to recombine the two conductors back to a ESR system again?	
4. Is it possible to protect ESR circuits with a R.C.D.	

Summary of common wiring systems:-

- 'Aerial conductors', either bare or insulated, chosen mainly for low cost reticulation of power over long distances as a cheaper alternative to underground wiring or catenary systems. Aerial cables used outdoors may be subject to lightning strike, damage from motor vehicle collisions, termites etc. and have a poor visual impact on the environment. Section 3.12 and Appendix D relates to aerial conductors.

- 'Catenary systems' use multistranded double insulated cables supported on steel catenary wire. It is commonly used for temporary installations, such as building sites, to distribute power, or in permanent installations, such as large exhibition halls, to support cables and luminaires above the ground, or to support cables in roof spaces above suspended ceilings. Section 3.13 relates to catenary systems.

- 'Cable trays' and ladders are open enclosures, used to support double insulated and MIMS cables, normally in industrial installations, where other support is not available (used extensively behind the scenes in the opera house for example).

- ‘Cable ducts’, which are closed enclosures larger than a conduit which often form hidden cableways in floors or on walls or ceilings. There are several proprietary brands of ducting systems available, though the "miniduct" is really a troughing system (it has a removable lid).

Activity - 22 - Cable ducts

Read AS 3000 clause 1.4.39

- ‘Troughing’, similar to duct but with removable lid.

- ‘Busbar trunking systems’, or ‘busways’, is popular in factories or other installations requiring the flexibility to move equipment around within an installation without rewiring circuits. Plug in busway forms a type of submain, with plug in points fitted with protective devices situated above the equipment they supply. If equipment is moved it is simply unplugged from the old position and plugged back in at the new location.

- ‘Track systems’, like a mini plug in busway, is often used for flexible lighting design (track lighting). Section 3.9.7.5 relates to low voltage track systems.

- ‘Underground wiring systems’ are used for the underground distribution of power in areas where aerial or catenary conductors are not allowed or where they are considered unsightly. Section 3.11 relates to the three categories of underground wiring systems and the cable types and enclosures required.

- Under carpet wiring systems’ (Section 3.9.7.6) is installed between the floor and carpet. It is expensive but requires little disturbance of the building structure.

- ‘Modular wiring systems’ use pre-connected sections of cables which plug together on the job, allowing large commercial jobs to be wired and terminated quickly with minimum use of tools.

- ‘Thermo plastic sheathed’ (TPS) cables are probably **the most used** wiring system as it incorporates conductors, insulation and a protective layer in one convenient, easy to install package. It is used in most domestic installations concealed in wall and ceiling spaces, in industrial and commercial installations on cable tray, catenary support, in ceiling spaces or in troughing systems.

- ‘Conduit systems’, can be either non metallic or metallic, of the rigid, flexible or corrugated types, are used to support and protect single or double insulated cables where the building structure does not provide the support or protection required. Non metallic conduit has a high expansion rate. Expansion joints must be made fitted during installation to allow for for the movement of the conduit with changes in temperature. Steel conduit is more expensive and takes longer to install but gives better mechanical protection and requires less support than non metallic conduit. Steel conduit enclosing single insulated cables must be earthed.

- 'MIMS' (Pyrotenax) and fire rated cables (Radox cable) may be used in higher temperature areas or for the supply of power to fire fighting equipment etc (safety services). MIMS cable is sometimes used as a quality wiring system which is required to have a long life. These cables may be operated at higher temperatures than other cables but must be segregated from cables of a lower temperature rating.

Tutorial 3

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. A cable / wiring system suitable for installation in a concrete slab would be:

   (a) Unenclosed TPI cable

   (b) Bare MIMS cable

   (c) TPI cable enclosed in rigid PVC conduit

   (d) Unenclosed TPS cable

2. A suitable wiring system used as sub-mains to a site shed on a construction site is:

   (a) Thermoplastic sheathed cables with catenary.

   (b) Flexible insulated conductors.

   (c) Polymeric insulated cable

   (d) Annealed copper conductors

3. A suitable wiring system used to supply machinery on a factory production line is;

   (a) Thermoplastic sheathed cables with catenary.

   (b) Busbar trunking (busway)

   (c) MIMS cables on a cable tray

   (d) TPI conductors in medium duty conduit.

4. A suitable wiring system used as aerial cable without further support is:

   (a) Thermoplastic sheathed cables

   (b) Flexible insulated conductors

   (c) Polymeric insulated cable

   (d) Annealed copper conductors

5. A suitable wiring system for supply to a lift is:

   (a) V90 SDI cables on cable tray

   (b) V75 TPI cables in PVC rigid conduct

   (c) MIMS cables on a cable tray

   (d) TPS cables sharing the same conduit as power and light circuits.

6. A suitable wiring system for smoke detectors connected to a fire indicator panel is:

   (a) TPS cable

   (b) TPI in steel conduit

   (c) Radox cable

   (d) XLPE on cable tray

7. A suitable wiring system for sub-main in a factory is:

   (a) TPS cable

   (b) TPI in steel conduit

   (c) Radox cable

   (d) XLPE on cable tray

8. A suitable wiring system for light fitting in suspended ceiling of a shopping centre is:

   (a) TPS cable

   (b) TPI in steel conduit

   (c) Radox cable

   (d) XLPE on cable tray.

9. A suitable wiring system for vandal proof light fitting in bus shelter is:

   (a) TPS cable

   (b) TPS in steel conduit

   (c) Radox cable

   (d) XLPE on cable tray

10. A suitable wiring system for a sub-main to a detached garage in a domestic installation is:

   (a) TPS cable.

   (b) TPI in steel conduit.

   (c) TPI in heavy duty conduit.

   (d) TPI suspended on a Catenary.

11. A suitable and **cost effective** wiring system for irrigation pump on a rural property is:

 (a) Aluminium aerials

 (b) TPI in steel conduit.

 (c) TPI in heavy duty conduit.

 (d) 4 core + earth XLPE orange circular buried direct.

12. What is the minimum depth of cover of a Category A underground wiring system, external to a building, below natural ground:

 (a) 300mm

 (b) 500mm

 (c) 600 mm

 (d) Not permitted

13. A TPS wiring system installed within a PVC conduit in a concrete floor on, or above the ground would be deemed to have the same current carrying capacity as cables installed:

 (a) Enclosed in air

 (b) Buried direct in the ground

 (c) Unenclosed in air

 (d) Enclosed in underground enclosure.

14. Cables enclosed in heavy-duty conduit, and chased into rock to a depth of not less than 50 mm, fall into the underground wiring system category of:

 (a) Category A

 (b) Category B

 (c) Category C

 (d) Not permitted as underground wiring.

15. When single-insulated wire is installed in trunking / toughing that has a removable lid:

 (a) the cables must be taped together and held in position

 (b) the lid must be held in position with cable ties

 (c) building wire is not permitted in a duct which has a lid

 (d) the lid shall not be removed without a special tool if the duct is readily accessible.

16. The minimum height above ground for insulated live aerial conductors over a roadway is:

    (a) 3.0m

    (b) 4.6 m

    (c) 5.5m

    (d) Insulated conductors are not permitted over a roadway

17. Mineral insulated metal sheathed (MIMS) cables, which are buried in the ground without further enclosure, must be:

    (a) protected by a suitable serving

    (b) classed as a category A wiring system

    (c) protected by a type 'D' circuit breaker

    (d) buried at a depth of not less than 0.75 metre.

18. In the expression $I_B \leq I_N \leq I_z$ used when co-ordinating cables with circuit protective devices, the variable I_Z is the:

    (a) calculated maximum demand current.

    (b) continuous current capacity of the cable.

    (c) current which gives a maximum 5% voltage drop in the circuit.

    (d) 1.45 times the rated current of the circuit breaker.

19. The maximum current rating for a HRC fuse protecting a circuit with a maximum demand of 20 A and wired with a cable rated at 28 A would be:

    (a) 18A.

    (b) 20 A.

    (c) 25 A.

    (d) 28 A.

20. The de-rating factor applied a cable protected by a C.B is:

    (a) 1.6

    (b) 1.45

    (c) 1

    (d) 0.9

21. The minimum current (I_2) which would ensure operation of a 20 A single pole circuit breaker:

    (a) 18A.

    (b) 20A.

    (c) 29A.

    (d) 32A.

22. A wiring system for a safety service has a WS classification of WS52. This means the wiring system can maintain its integrity under fire conditions for;

    (a) 52 minutes.

    (b) 60 minutes.

    (c) 5 hours.

    (d) 120 minutes.

23. In Australia the ambient temperature for cables installed in air is;

    (a) 90° C

    (b) 75° C

    (c) 40° C

    (d) 25° C

24. The maximum permitted operating temperature of a V90 insulated conductor in normal use is;

    (a) 90° C

    (b) 75° C

    (c) 40° C

    (d) 25° C

25. Protection against mechanical damage to a wiring system is provided by:

    (a) the location selected.

    (b) an R.C.D.

    (c) a circuit breaker

    (d) a H.R.C. fuse.

Section 4

Maximum demand of consumers mains

Topics

- **Determining maximum demand for domestic consumers mains**

Aim

Learners will determine the maximum demand of the consumer's mains in single and multiple domestic installations.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Describe the acceptable methods for determining the maximum demand on an installation's consumer's mains.
- Calculate the maximum demand for the consumer's mains for given installations up to 400 A per phase.

Introduction

When designing a new electrical installation it is necessary to predict the performance requirements for all parts of the installation. This is especially so for consumers mains and sub-mains in an installation, which will have some diversity as all loads may not be connected at the same time. The methods of determining maximum demand of consumers mains and sub-mains are outlined in AS/NZS 3000. Figure 1 shows an example of a typical installation.

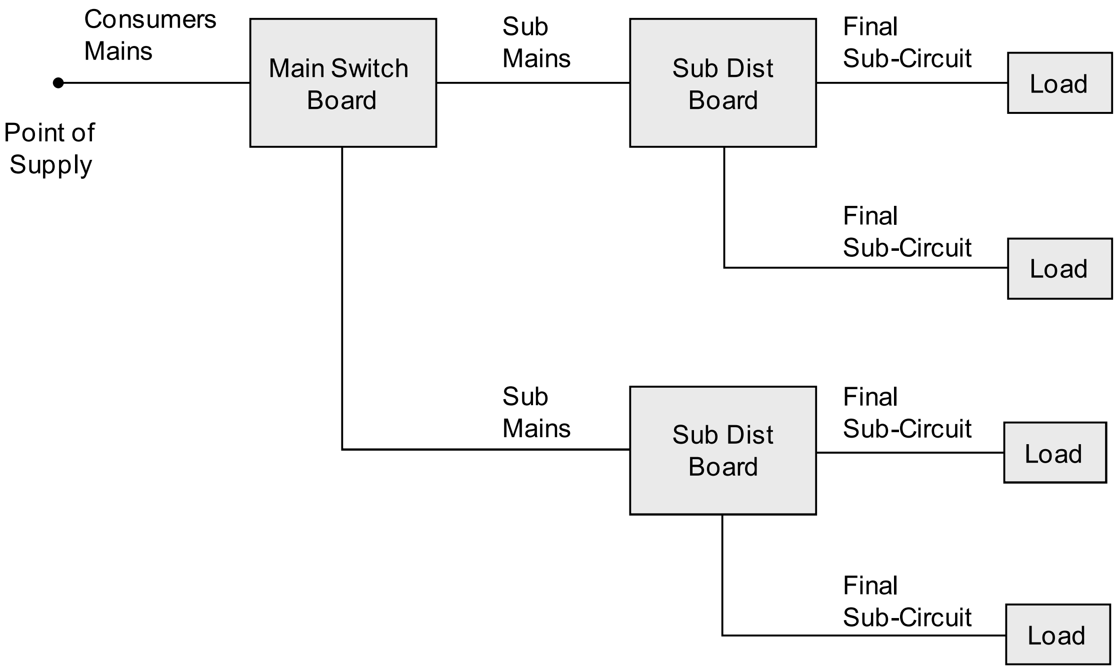


figure 1.

Activity - 1 - Consumers mains definition

Examine N.S.W.S.R Figures 1.1 and 1.2

Figures 1.1 and 1.2 of the NSWSR show various arrangements for over head and underground consumer's mains.

Electrically unprotected consumers mains do not have either a fuse or circuit breaker fitted at the connection point, or point of supply. These are the vast majority of installations. **Electrically protected** consumers mains do have either a fuse or a circuit breaker fitted at the connection point, or point of supply.

Topic 1 - Methods of determining the maximum demand

The maximum demand of consumers mains (from the consumers terminals to the main switchboard in the installation) and sub mains (between the main or other switchboard to distribution boards) is the subject of Clause 2.2.2of AS/NZS 3000 and may be determined by:-

- measurement (only possible in existing installations);
- calculation, using Appendix C of AS/NZS 3000;
- limitation by fixed current circuit breaker (inconvenient if the c/b trips);
- assessment (used for unusual loads, or installations where the number and type of loads is not known) (See Table C3)

The supply authority may set minimum cable sizes and types and installation conditions for consumer's mains.

Activity - 2 - Underground consumer's mains

Read N.S.W.S.R 2.3.1 and 2.6.1 Read the suggested	Write a response
What is the minimum C.S.A. and type of insulation required for unprotected consumer's mains installed U/G?	

Activity - 3 - Over head consumer's mains

Read N.S.W.S.R 3.3.1, 3.3.2 and 3.4 Read the suggested	Write a response
What is the minimum C.S.A. and type of insulation required for unprotected consumer's mains installed O/H?	

Topic 2 - Determining the maximum demand of consumers mains

Calculation of Maximum Demand.

Calculation of maximum demand in consumers mains and sub-mains is the simplest method of ensuring that minimum adequate cable sizes can be used.

NOTE: For installations supplied by two or three phases:-

- The maximum demand must be calculated for each active conductor separately;
- The single phase loads must be arranged so that the loads in each phase are balanced to within specified limits (25 A is the maximum difference allowed by Clause 1.10.3 of NSW Service & Installation Rules).
- The maximum demand in the consumer’s mains (or sub-mains) is the maximum demand of the highest loaded active conductor.

Many loads in an installation are not always turned on at the same time or only for short periods. This means that some 'diversity' can be applied in determining the maximum demand in consumer mains and sub-mains, allowing mains and sub-mains to have a maximum demand much less than the total current of all the individual loads, and cables smaller than that required to carry the total current for all loads.

Load groups and contribution to maximum demand.

When calculating maximum demand in consumers mains and submains:-

- Individual loads are allocated to load groups such as lighting, socket outlets, cooking ranges etc;
- Each load group is assessed as contributing a value of current to the maximum demand, which may be less than the total load ('diversity allowance');
- The assessed contribution to the maximum demand of each load group is given in Table C1 (domestic installations), Table C2 (non-domestic installations) and Clause C2.5.2 (welding machines);
- The maximum demand per phase is the sum of the assessed contributions by all the load groups on that phase supplied by that active conductor.

Note:Determining the maximum demand in consumer’s mains and sub-mains is different from determining it for the final sub-circuit. Be careful not to get the two confused. DO NOT USE TABLES C1 or C2 FOR FINAL SUB CIRCUITS. Use Tables C4 to C6.

The following questions will help you to calculate maximum demand in mains and sub-mains.

- Is installation domestic or non-domestic:-
  - Use Table C1 for domestic installations;
  - Use Table C2 for non-domestic installations.
- What loads are to be supplied?
  - This information is obtained from job specification and or job plans.
- What equipment is in each load group?
  - Equipment in each load group is specified in column 1 of Tables C1 & C2.
  - Footnotes to the tables give additional information on the equipment in the various load groups
- Is the installation to be supplied with single, two or three phase?
  - Local supply authorities stipulate the maximum total load for single and two phase supplies. For example, single phase for total loads up to 100A, two phase for total load greater than 100A and up to 200A (maximum 100A per phase) and three phase for total load over 200 A (split over three phases). An installation is supplied with three phase where individual three phase loads are installed such as a three phase motors (multi phase supply may not be available in some rural areas).

Activity - 4 - Number of phases

Read N.S.W.S.R 1.5.3.3  Read the suggested	 Write a response
What is the minimum kilowatt rating of a motor to require three phase supply?	

- Is the load to be arranged on more than one phase?
  - Distribute the loads evenly across all phases.
  - This is a preliminary arrangement and may need adjusting after calculating the maximum demand in each phase.
- What is the contribution of each load group connected to each active conductor?

- Calculations must be done separately for each conductor and only for the loads connected to it. You do not calculate the contribution for all phases once then divide by three.
- Follow the instructions in column 2 of Table C1 for each load group in single domestic installations, that is individual houses (consumers mains) or individual home units in a block (sub mains).
- Follow the instructions in column 3, 4 or 5 of Table C1 for each load group in multiple domestic installations that is for consumer's mains in blocks of home units.
- Follow the instruction in Column 2 of Table C2 for each load group in non-domestic residential installation such as hospital, hotels etc.
- Follow the instruction in column 3 of Table C2 for each load group in non-domestic installation such as factories, shops, offices.

○ What is the maximum demand in each active conductor?

- Add together the contribution of each load group supplied through the same active conductor.

○ Is the load across all conductors balanced to satisfy the local supply authority?

- If there is a large difference in the maximum demand between any two active conductors of a multiphase supply, rearrange single phase loads to balance the load across all active conductors.

Activity - 5 - Balancing of load

Read N.S.W.S.R 1.10.3 	
What is the maximum difference in current between phases of a multiphase consumer's mains?	

Single Domestic.

The maximum demand of consumers mains in single domestic premises, or of individual units (townhouses or villas) in blocks of home units (townhouses or villas) is calculated using column 2 of Table C1.

Example Calculation 1

Calculate the maximum demand of the single phase consumer’s mains for a single domestic dwelling (house) with the following loads:-

15 - lighting points;

16 - double 10A sockets outlets (doubles count as 2);

4 - single 10A socket outlets;

1 - 4.4 kW storage type hot water system;

1 - 11.4kW cooking range.

Solution 1

Using Table C1 Column 2:-

Load Group	Load	Calculation	Demand
A(i)	15 x lights	3A	3.0A
B(i)	36 x 10A socket outlets	10 + 5 = 15A	15.0A
C	11.4kW range	11,400/230 x 0.5	24.8A
F	4.6kW hot water	4600/230 = 20A	20A
		Maximum Demand	62.8A

Activity - 6 - Calculation of consumer’s mains maximum demand

Calculate the maximum demand for the single domestic installation from section 2

- Complete the table below

22 - Light points

24 - Double 10A Socket Outlets

1 - 15A socket outlet

1 - 6.0 kW cook top

1 - 3.9 kW wall oven

1 - 4.4 kW storage H.W.S.

Load Group	Load	Calculation	Demand
		Maximum Demand	

Activity - 7 - Calculation of consumer's mains maximum demand

Calculate the maximum demand for the single domestic installation

- Complete the table below

16 - lighting points;

15 - double 10A socket outlets;

2 - single 10A socket outlets;

1 - 4.4 kW controlled load water heater;

1 - 6.0kW oven.

Load Group	Load	Calculation	Demand
		Maximum Demand	

Activity - 8 - Calculation of consumer's mains maximum demand

Calculate the maximum demand for the single domestic installation • Complete the table below	Write a response

38 - lighting points;

6 - 200W exterior lights;

20 - double 10A socket outlets;

3 - single 10A socket outlets;

1 - 230V x 4.4kW twin element, 24 hour off peak hot water system;

1 - 15A socket outlet for a room air conditioner;

1 - 13.5kW cooking range;

1 - 1.1kW 240V pool filter pump rated at 10.5A.

Load Group	Load	Calculation	Demand
		Maximum Demand	

Two and three phase installations are calculated in a similar fashion, but the load is 'balanced' over the number of phases not to exceed 25A.

Activity - 9 - Calculation of consumer’s mains maximum demand (3 phase)

Calculate the maximum demand for the single domestic installation from section 2

- Complete the table below

Write a response

48 - Light points (2 circuits)

30 - Double 10A Socket Outlets (3 circuits)

2 - 3 in one Fan/heat lamps 4 x 275 W heat lamps (1 circuit)

1 - 18A 3 Φ ducted A/C

1 - 7.8 kW 1 Φ range

1 - 22.0 kW 3 Φ spa heater

1 - 3.6 kW sauna

1 - 4.4 kW storage H.W.S.

Load Group	Load	Calculation	A	B	C

Multiple Domestic.

The maximum demand of consumers mains in multiple domestic premises (blocks of home units) is calculated using columns 3, 4 or 5 of Table C1. Column 3 is used where there are between 2 and 5 units per phase in the installation. Column 4 is used for between 6 and 20 units per phase and column 5 is used for 21 or more units per phase.

Unit Loads.

Notice in load groups A to C and E to G there is no reference to the number or rating of loads in individual units in columns 3 to 5, the loading being assigned as either a fixed value (e.g. 15A total for ranges in load group C, column 3) or assigned values per unit (e.g. 2.8A/unit for load group C column 4). In load group D (fixed space heating or air conditioning) the full connected load per phase is required to calculate the maximum demand component for this load as 0.75 times connected load per phase (don't forget to multiply by the number of units).

Community Loads.

Loads in common areas (foyers, stairwells, community laundries, garages, common recreational or outdoor areas etc) are covered in load groups H to M. In large blocks the community loads may be connected over three phases (due to lifts, fire pumps, air conditioning in common areas etc) but in smaller blocks, where the common area loads are only single phase the supply authority may allow connection of these loads to **single phase only, to reduce the metering required**. If this is the case the number of units per phase may need to be assigned to allow for community loads.

Example Calculation 2

A block of 24 home units is connected across three phases but each unit is supplied with single phase only. Each unit has the following loads:-

11 - lighting points;

7 - double socket outlets;

3 - single socket outlets;

1 - 15A socket outlet;

1 - 9.2kW range;

1 - 4.4 kW storage water heater.

There is no communal load

Using Table C1 Column 4 (24/3 = 8 units per phase):-

Load Group	Load	Calculation	Demand
A(i)	11 - lights	5 + (0.25 x 8)	7.0A
B(i)	17 - 10A socket outlets	15 + (3.75 x 8)	45.0A
B(ii)	1 - 15A Outlet	10A	10.0A
C	Ranges	2.8 x 8	22.20A
F	Hot Water	6 x 8	48.0A
		Maximum demand	132.2A per phase

As the load is identical on each phase the load is balanced. The c.s.a. of the consumer's mains can now be determined using AS 3008.1. Table C6 of AS 3000 does not specify cable sizes above 25mm^2.

Example.

A block of 24 home units, with 8 units connected per phase, and a community load of 35 amperes would have an out of balance in the maximum demands per phase of 35 amperes, outside the maximum of 25A. If the number of units per phase were reassigned as 9 units per phase on A and B phases, then 6 units plus community loads on C phase the balance would be closer.

Activity - 10 - Calculation of consumer's mains maximum demand (multiple domestic)

Calculate the maximum demand for the multiple domestic installation.

A group of 4 townhouses are to be connected to a 2 phase supply, 2 units per phase. Each contains the following load;

18 - Light points

6m - Track lighting

11 - Double 10A Socket Outlets

1 - 6.0 kW 1 Φ range

1 - 15A socket for a clothes dryer

1 - 4.4 kW storage H.W.S.

Load Group	Load	Calculation	A	B	C

Activity - 11 - Calculation of consumer's mains maximum demand (multiple domestic)

Calculate the maximum demand for the multiple domestic installation.

A block of 22 units are to be connected to a 3 phase supply, the communal load is greater than 25 A. Complete the table below.

Each contains the following load	Community load;
16 - Light points	20 - fluorescent (0.33A each) Car park
16 - Double 10A Socket Outlets	50 - 60W lamps house lights
1 - 6.0 kW cook top	15 - single 10A socket outlets house power
1 - 3.0 kW oven	2 - 15A socket outlets clothes dryers
1 - 4.4 kW storage H.W.S.	

No of Units A phase _________ B phase _________ C phase _________

Load Group	Load	Calculation	A	B	C

Tutorial 4

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. ONE (1) method for determining the size of consumer mains and sub-mains of an electrical installation is:

   (a) location of points

   (b) safe design and construction

   (c) demand of devices for isolation

   (d) calculation

2. The maximum demand of a final sub-circuit supplying 10A socket outlets in a domestic installation is set by

   (a) location of points

   (b) limitation

   (c) demand of devices for isolation

   (d) calculation

3. The maximum permitted difference between the highest and lowest maximum demand current flowing in consumers mains is;

   (a) 10A

   (b) 100A

   (c) 25A

   (d) 50A

4. The minimum conductor permitted for use as an unprotected consumers main is;

   (a) 16mm^2 XLPE insulated Cu

   (b) 16mm^2 PVC insulated Cu

   (c) 10mm^2 XLPE insulated Cu

   (d) 25mm^2 PVC insulated Cu

5. The appropriate load group for “house lights” in a block of home units is;

   (a) A(i)

   (b) A(ii)

   (c) B(i)

   (d) H

6. For the purpose of calculating maximum demand, lighting track is regarded as ______ point/s per meter of track

   (a) 1

   (b) 2

   (c) 3

   (d) 4

7. For the purpose of calculating maximum demand of consumers mains, a 96 W ceiling fan installed 2.3m above the floor is considered as a;

   (a) lighting point

   (b) Socket outlet

   (c) motor

   (d) fixed space heating or air condition equipment.

8. For the purpose of calculating maximum demand of consumers mains, 4 x 275W heat lamps are considered as;

   (a) lighting points

   (b) a socket outlet

   (c) a motor

   (d) fixed space heating or air condition equipment.

9. For the purposes of maximum demand of consumers mains, a double 10A socket outlet is considered as;

   (a) a single point.

   (b) 2 points.

   (c) 3 points.

   (d) 4 points.

10. If an installation contains no three phase load, additional phases are not permitted by the supply authority until the maximum demand exceeds;

   (a) 40A

   (b) 63A

   (c) 80A

   (d) 100A

11. Calculate the maximum demand for the single domestic single phase installation.

32 - lighting points;
3 - 500W flood lights
27 - double 10A socket outlets;
5 - single 10A socket outlets;
1 - 4.4 kW controlled load water heater;
1 - 10.2 kW Range.
1 - 8 A split system Airconditioner

Load Group	Load	Calculation	Demand
		Maximum Demand	

12. 63 town houses are to be connected to a 3 phase supply, Calculate the maximum demand for the multiple domestic installation.

Each contains the following load	Community load;
12 - Light points 11 - Double 10A Socket Outlets 1 - 8.0 kW Range 1 - 4.4 kW storage H.W.S.	48 - Compact fluorescent (0.22A each) for Car park lighting 10 - Bollard lights (0.15A each) 2 - single 10A socket outlets house power

No of Units A phase ________ B phase ________ C phase ________

Load Group	Load	Calculation	A	B	C

Section 5

Maximum demand of consumer’s mains and sub mains

Topics

- **Determining maximum demand for consumers mains in non domestic installations**
- **Determining maximum demand for sub mains in domestic and non domestic installations**

Aim

Learners will be able to determine the maximum demand of the consumer’s mains and sub mains in a range of installations.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Describe the acceptable methods for determining the maximum demand on an installation’s consumer’s mains.
- Calculate the maximum demand for the consumer's mains for given installations up to 400 A per phase.
- Describe the acceptable methods for determining the maximum demand on sub mains.
- Calculate the maximum demand for given sub mains

Topic 1 - Calculation of maximum demand

Non Domestic Maximum Demand

When calculation non domestic installations such as factories, shops and offices, table C2 of AS3000 is used. The load that is installed is more likely to be use more frequently than in a domestic installation, therefore less diversity is applied. The contribution to the maximum demand of each load group will be closer to the connected load.

Example Calculation 1.

Determine the maximum demand of an industrial installation comprising:-

6 - twin x 36W fluorescent lights rated at 0.46A each;

12 - mercury vapour high bay lights rated at 1.8A each;

21 - single phase double 10A socket outlets;

2 - three phase 10A socket outlets;

2 - 15A single phase socket outlets;

2 - three phase 20A socket outlets;

1 - single phase 2.2kW instantaneous water heater;

1 - single phase 3.6kW storage water heater;

1 - three phase 5 kW, 9A compressor;

1 - three phase 4.1 kW, 8A milling machine;

1 - three phase 2.2 kW, 5A lathe;

1 - three phase 370W, 1A pedestal drill;

1 - three phase 560W, 3A grinder;

1 - single phase, 400V electric arc welder rated at 14A.

Solution.

Using Table C2 Column 3 and balancing loads over all phases as much as possible:-

Load Group	Load	Calculation	A Phase	B Phase	C Phase
A	6 x 0.46A Fl Lts (C Φ)	6 x 0.46 = 2.76A (2.8A)			2.8A
A	12 x MV Lts (A & C Φ)	6 x 1.8 = 10.8A	10.8A		10.8A
B(i)	21 x 2 x 1Φ 10A S/Os (14/Φ) + 2 x 3Φ 10A S/Os 16 points per phase	$\frac{1000 + (750 \times 15)}{230}$	53.3A	53.3A	53.3A
B(i)	2 x 3Φ 10A S/Os	add extra 2 points above			
B(iii)	2 x 3Φ 20A S/Os	20 + (0.75 x 20) = 35A	35.0A	35.0A	35.0A
B(iii)	2 x 1Φ 15A S/Os (A & BΦ)	(0.75 x 15) = 11.25A (11.3A)	11.3A	11.3A	
C	1 x 1Φ 2.2kW Inst HW(BΦ)	2,200/230 =		9.6	
D	1 x 9A motor	9 + (0.75 x 8) + 0.5(5 + 3 + 1) = 19.5A	19.5A	19.5A	19.5A
D	1 x 8A motor				
D	1 x 5A motor				
D	1 x 3A motor				
D	1 x 1A motor				
G	1 x 1Φ 3.6kW storage HW	3600/230 = 15.7A			15.7
H	1 x 400V 14A welder		14.0A	14.0A	
		Demand	137.3A	142.7A	137.1A

Activity - 1 - Calculation of consumer's mains maximum demand (non domestic)

Use AS3000 to calculate the maximum demand in the consumer's mains for a factory with the following load;

Write a response

36 - high bay MV luminaries rated at 2.6A each (12/phase)

21 - 10A double single phase socket outlets (7/phase)

4 - 20A three phase socket outlets

2 - lathes with three phase induction motors rated at 28A

3 - 400V single phase spot welders with a rated primary current of 40A and a duty cycle of 40%.

Load Group	Load	Calculation	A	B	C

Activity - 2 - Calculation of consumer's mains maximum demand (non domestic)

Use AS3000 to calculate the maximum demand in the consumer's mains for a factory with the following load;

Write a response

30 - twin 36W fluorescent lights rated at 0.5 amperes each;

12 - single 36W fluorescent lights rated at 0.25 amperes each;

3 - 500W floodlights;

6 - 100W incandescent lamps;

9 - 10 ampere single phase socket outlets

12 - three phase 15 ampere socket outlets;

1 - 2.3kW 230V quick recovery water heater;

1 - 1.102kW 230V food warmer;

2 - three phase motors rated at 42 amperes each;

3 - three phase motors rated at 16.8 amperes each;

4 - three phase motors rated at 2.8 amperes each.

Load Group	Load	Calculation	A	B	C

Activity - 3 - Calculation of consumer's mains maximum demand (non domestic)

Use AS3000 to calculate the maximum demand in the consumer's mains for a factory with the following load;

Write a response

28 - single 36W fluorescent lights rated at 0.25 amperes each (2 circuits);

1 - three phase rectifier rated primary current 72 amperes per phase;

20 - double 10 ampere single phase socket outlets;

7 - three phase 20 ampere socket outlets;

2 - three phase exhaust fan motors rated at 5.2 amperes each;

3 - three phase exhaust fan motors rated at 6.3 amperes each.

Load Group	Load	Calculation	A	B	C

Activity - 4 - Calculation of consumer's mains maximum demand (non domestic)

Use AS3000 to calculate the maximum demand in the consumer's mains for a shop with the following load;

36 - single 36W fluorescent lights rated at 0.25 amperes each;

20 - double 10 ampere single phase socket outlets;

2 - single 10 ampere single phase socket outlets;

1 - 15 ampere single phase socket outlet;

1 - 4.4 kW quick recovery water heater;

1 - 10.5 kW single phase range.

Load Group	Load	Calculation	A	B	C

Non Domestic Energy Demand Method

In some cases the installing electrician will not know the exact load details of equipment being installed in a non domestic installation. Installations such as factory units, shops and offices are mostly rental properties. The electrical demand will vary from tenant to tenant. In these cases an estimate based on experience gained from other similar installations can be made using table C3 of AS3000.

The maximum demand is assessed depending on the area, use and climate control (air conditioning) of the installation. The demand is given in VA and is converted to current using the equation;

where

I_L = the line current /maximum demand current in Amperes

S = the energy demand in VA

V_L = the line voltage of the supply in volts.

Example Calculation 2.

A small retail complex consisting of 3 shops at street level (280m^2 each) and 3 offices (250m^2 each) on the first floor. All shops and offices have reverse cycle air conditioning. Determine the maximum demand of this commercial installation.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
Shops	Light and power	840 m^2	70	58800 VA
	Air conditioning	840 m^2	30	25200 VA
Offices	Light and power	750m^2	50	37500 VA
	Air conditioning	750m^2	25	18750 VA
			Total	140250 VA

Maximum demand $$I_L = \frac{S}{\sqrt{3} \times V_L} = \frac{140250}{\sqrt{3} \times 400} = 203\text{A per phase}$$

Activity - 5 - Assessment of consumer's mains maximum demand (non domestic)

Use AS3000 table C3 to determine the maximum demand in the consumer's mains for a shop with the following load;

A retail complex consisting of 5 shops at street level (330m^2 each) and 3 offices (300m^2 each) on the first floor. All shops and offices have reverse cycle air conditioning. Determine the maximum demand of this commercial installation.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
			Total	

Maximum demand =

Activity - 6 - Assessment of consumer's mains maximum demand (non domestic)

Use AS3000 table C3 to determine the maximum demand in the consumer's mains for a complex with the following load;

A complex consisting of

- 2200m^2 of ventilated warehouse,
- 250 m^2 of reverse cycle air conditioning offices
- 500 m^2 of open air car park.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
			Total	

Maximum demand =

Activity - 7 - Assessment of consumer's mains maximum demand (non domestic)

Use AS3000 table C3 to determine the maximum demand in the consumer's mains for a factory unit complex with the following load;	Write a response

A complex consisting of

- 1200m^2 of ventilated light industrial units,
- 850 m^2 of reverse cycle air conditioning offices
- 500 m^2 of open air car park.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
			Total	

Maximum demand =

Topic 2 - Calculation the maximum demand of sub mains

The methods used to calculate the maximum demand of sub are exactly the same as consumer's main as stated in AS 3000 clause 2.2.2;

- Calculation
- Assessment
- Measurement
- Limitation

The only variation is that only the load connected to the sub-main is included in the calculation of the sub-main.

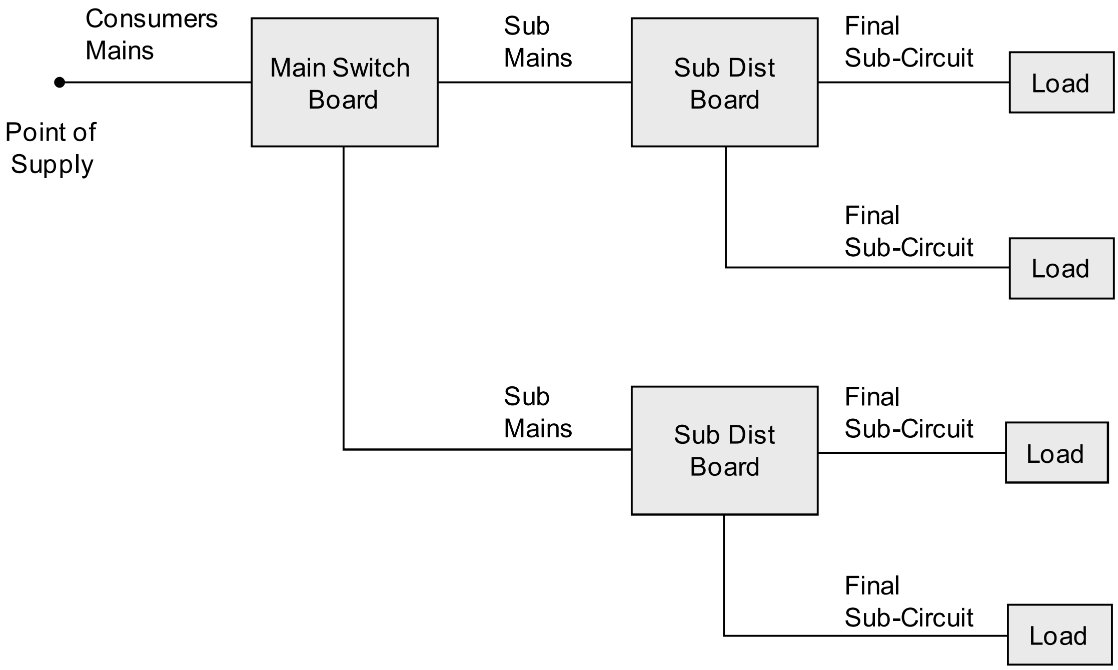


figure 1.

Sub-mains in Single domestic installations

In modern domestic installations the space available on the customer's main switchboards has decreased, supply authorities are requiring larger "foot prints" for metering equipment. There has also been an increase in the number of final sub-circuits and protection devices such as 2 pole combination R.C.D / M.C.B and voltage surge diverters fitted in main switch boards. It now common practice in larger installations, to run a sub-main to a location such as the garage or kitchen. A distribution board placed in the kitchen shortens the runs of a majority of the final sub-circuits, reducing cost and provides the convenience to customer of not having to go outside to reset a tripped circuit breaker. Sub-mains are also used to supply out buildings such as granny flats or garages.

Unlike consumer's mains, sub-mains are **electrically protected** at their origin. The nominal rating of the protection device is set by the sub-mains maximum demand.

Colum 2 of Table C1 AS 3000 is used to calculate the maximum demand.

Activity - 8 - Calculation of sub-main maximum demand

Calculate the maximum demand for a granny flat in a single domestic installation

- Complete the table below

8 - lighting points;

5 - double 10A socket outlets;

1 - single 10A socket outlets;

1 - 3.3 kW heat pump storage H.W.S;

1 - 4.4 kW Range.

1 - 15A socket outlet for a split system air conditioner

Load Group	Load	Calculation	Demand
		Maximum Demand	

Activity - 9 - Calculation of sub-main maximum demand

Calculate the maximum demand for the garage of a single domestic installation

- Complete the table below

12 - lighting points;

1 - 1100W flood light

6 - double 10A socket outlets;

1 - single 10A socket outlet;

Load Group	Load	Calculation	Demand
		Maximum Demand	

In cases such as the one in activity 8 where the demand is low, it is not cost effective to run sub-mains and distribution board. A simpler alternative is to wire the garage as a mixed circuit supplied from a C.B. at the house main switch board.

Note clause 3.5.1 requires a minimum C.S.A. of 2.5mm² in circuits supplying socket outlets.

Sub-mains in Single domestic installations

To determine the maximum demand of the sub-main Colum 2 of table C1 AS3000 is used. Below is the example of 4 town houses from the previous section. In this case the load within the unit not the number of units per phase will set the maximum demand of the sub-main.

Activity - 10 - Calculation of sub-main maximum demand (multiple domestic)

Calculate the maximum demand for the sub-main of a single unit in a multiple domestic installation. A group of 4 townhouses are to be connected to a 2 phase supply, 2 units per phase. Each contains the following load;	Write a response

18 - Light points

6m - Track lighting

11 - Double 10A Socket Outlets

1 - 6.0 kW 1 Φ range

1 - 15A socket for a clothes dryer

1 - 4.4 kW storage H.W.S.

Load Group	Load	Calculation	Demand

Activity - 11 - Calculation of sub-main maximum demand (multiple domestic)

Calculate the maximum demand for the sub-main of a single unit in a multiple domestic installation.

A block of 22 units are to be connected to a 3 phase supply, the communal load is greater than 25 A. Complete the table below.

Write a response

Each contains the following load	Community load;
16 - Light points	20 - fluorescent (0.33A each) Car park
16 - Double 10A Socket Outlets	50 - 60W lamps house lights
1 - 6.0 kW cook top	15 - single 10A socket outlets house power
1 - 3.0 kW oven	2 - 15A socket outlets clothes dryers
1 - 4.4 kW storage H.W.S.	

Load Group	Load	Calculation	Demand

Sub-mains in non domestic installations

Once again the procedure to determine the maximum demand of sub-mains in a non domestic installation is the same as consumer's mains, but only the load in that section of the building is included.

Activity - 12 - Calculation of sub-mains maximum demand (non domestic)

Use AS3000 to calculate the maximum demand in the sub mains for a factory unit with the following load;

Write a response

6 - high bay MV luminaries rated at 2.6A each (1 circuit)

30 - twin 36W fluorescent lights 0.333A each (1 circuit)

20 - 10A double single phase socket outlets (5 circuits 4 points per)

4 - 20A three phase socket outlets

4 - three phase induction motors rated at 32A

1 - 400V single phase arc welding machines with a rated primary current of 40A

1 - 4.4 kW 230V HWS

Load Group	Load	Calculation	A	B	C

Non Domestic Energy Demand Method

Example Calculation.

From the previous section, recall the small retail complex consisting of 3 shops at street level (280m^2 each) and 3 offices (250m^2 each) on the first floor. All shops and offices have reverse cycle air conditioning. In the previous section the maximum demand of the entire complex was calculated at 203A per phase. Determine the maximum demand of the sub-main supplying the individual shops and offices.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
Shops	Light and power	280 m^2	70	19600 VA
	Air conditioning	280 m^2	30	8400 VA
			Total	28000 VA
Offices	Light and power	250m^2	50	12500 VA
	Air conditioning	250m^2	25	6250 VA
			Total	18750 VA

Shop Maximum demand

$$I_L = \frac{S}{\sqrt{3} \times V_L} = \frac{28000}{\sqrt{3} \times 400} = 41A \text{ per phase}$$

- A 50A H.R.C. fuse or circuit breaker would be selected as the protection device.
- A cable size is then selected to that it has a current carrying capacity higher than or equal to 50A after any applicable de-ratings have been applied.

Office Maximum demand

$$I_L = \frac{S}{\sqrt{3} \times V_L} = \frac{18750}{\sqrt{3} \times 400} = 28A \text{ per phase}$$

- A 32A H.R.C. fuse or circuit breaker would be selected as the protection device.
- A cable size is then selected to that it has a current carrying capacity higher than or equal to 32A after any applicable de-ratings have been applied.

Activity - 13 - Assessment of sub-mains maximum demand (non domestic)

Use AS3000 table C3 to determine the maximum demand in the sub mains for the shops and offices with the following load;

Write a response

A retail complex consisting of 5 shops at street level (330m^2 each) and 3 offices (300m^2 each) on the first floor. All shops and offices have reverse cycle air conditioning. Determine the maximum demand of the sub mains for this commercial installation.

Type of Occupancy		Energy Demand		
	Load	Area	Average VA/m^2	Demand
			Total	

Maximum demand =

Tutorial 5

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. ONE method for determining the size of sub-mains of an electrical installation is:
   (a) location of points
   (b) safe design and construction
   (c) demand of devices for isolation
   (d) calculation

2. When selecting a **cable** for a sub-main, its continuous current carrying capacity should be:
   (a) greater than the demand of the sub-main and at least equal to the circuit breaker rating.
   (b) greater than the demand of the sub-main and less than the circuit breaker rating.
   (c) less than the demand of the sub-main and greater than the circuit breaker rating
   (d) less than the demand of the sub-main and less than the circuit breaker rating

3. Sub-mains and final sub-circuits having a rating exceeding 100 A per phase must:
   (a) not able to be isolated in the event of over-current
   (b) have over-voltage protection installed on the originating switchboard
   (c) be controlled by a separate isolating switch on the originating switchboard
   (d) have residual current protection installed on the originating switchboard.

4. What is the contribution of a 230 V, 9.2 kW stove (the highest rated appliance), to the maximum demand on the sub mains of a residential boarding house in which it is installed?
   (a) 20A
   (b) 15A
   (c) 25A
   (d) 40 A.

5. The maximum demand of a large and complex installation is determined by:
   (a) Calculation
   (b) Assessment
   (c) Measurement

(d) Limitation

6. Use AS3000 to calculate the maximum demand in the consumer's mains for a factory with the following load;

18 - high bay MH luminaries rated at 2.6A each (6/phase)
33 - 10A double single phase socket outlets (11/phase)
4 - 32A three phase socket outlets
3 - 20A three phase socket outlets
2 - three phase induction motors rated at 42A
1 - three phase induction motors rated at 28A
2 - 400V single phase arc welders a rated current of 18A.

Load Group	Load	Calculation	A	B	C

7. 33 town houses are to be connected to a 3 phase supply, Calculate the maximum demand for the consumer's mains of the multiple domestic installation.

Each contains the following load	Community load;
22 - Light points 18 - Double 10A Socket Outlets 1 - 8.0 kW Range 1 - 4.4 kW storage H.W.S. 1- 14A Air conditioner	24 - Compact fluorescent (0.22A each) for Car park lighting 10 - Bollard lights (0.15A each) 10 - single 10A socket outlets house power

No of Units A phase _________ B phase _________ C phase _________

Load Group	Load	Calculation	A	B	C

8. Calculate the maximum demand for the single phase sub- main of an individual unit in the multiple domestic installation.

Load Group	Load	Calculation	Demand

Cable selection based on current carrying capacity

Topics

- **Installation conditions**
- **De-rating factors**
- **Current carrying capacity tables in AS/NZS3008.1.1**
- **Cable selection**

Aim

Learners will be able to select the minimum size cable to supply a given maximum demand, and determine the current carrying capacity of conductors up to 400A.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Describe installation conditions for a range of wiring systems and applications.
- Identify external influences that require the use of a de-rating factor.
- Describe the AS/NZS 3000 requirements for coordination of cables and protection devices.
- Use AS/NZS 3008.1.1 to select conductor size based on the maximum current requirement for a given installation condition including any applicable de-rating factors.

Topic 1 - Installation conditions

Current carrying capacity is the maximum continuous current that a particular cable can carry without overheating.

Installation conditions which affect current carrying capacity, and thus the size of cable conductor needed for a circuit, are:-

Installation conditions (AS/NZS 3008. 1.1, Clause 3.4)

- ambient temperature;
- cables installed in:
    - air;
    - thermal insulation;
    - conduits, ducts and trunking
    - underground.

Table 3 of AS3008.1.1 (2009) gives guidance to installation methods

- Table 3(1) ______________________________
- Table 3(2) ______________________________
- Table 3(3) ______________________________
- Table 3(4) ______________________________

In all tables in AS3008.1.1 only the current carrying conductors are generally shown. In other words in single phase circuits only the active and neutral conductors are shown. In three phase circuits the load is assumed to be balanced so the neutral conductor is not shown to keep the diagram simple.

Single core cables can be configured;

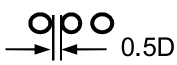
- Trefoil 
- Laid flat touching 
- Laid flat separated 

figure 1

The separation between cables improves the heat dissipation of the conductors and improves current carrying performance. Laying the cables in trefoil reduces magnet effects. It is important not to confuse **separation** between conductors with cable supports systems that **space** the cable from surfaces such as walls and ceilings. If cables are installed so that they are in contact with cables of another circuit they are said to be **grouped** (see table 1 AS3008.1.1.)

Activity - 1 - Installation conditions

From AS 3008.1.1. Table 3.1 (only current carrying conductors are shown)		
Draw a free hand picture of un**grouped** cables installed;	1 phase	3 phase
1. Single core cables **separated** in air and spaced from a vertical surface or supported on cable tray		
2. Single core cables with minimum cable **spacing** in air and spaced from a vertical surface or supported on cable tray.		
3. Single core cables of the one circuit touching and installed clipped direct to a wall floor, ceiling or similar surface;		
4. Multi core cables with minimum spacing's in air **spaced** from a wall or vertical; supported on ladders, racks, perforated or unperforated trays, cleats or hangers:		
5. Multi core cables installed in air touching a surface i.e. clipped direct to a wall, floor, ceiling or similar surface.		

External influences (AS/NZS 3008.1.1, Clause 3.5)

- grouping of cables;
- ambient temperature;
- depth of laying
- different soil types for underground cables;
- varying loads
- thermal insulation
- direct sunlight.
- Harmonic currents
- Parallel cables.
- Electromagnetic interference.

The circuit protection device selected to protect the cable will also affect the cable current carrying capacity.

- Circuit Breaker - 100% of current carrying capacity of cable (x 1).
- H.R.C. fuse - 90% of current carrying capacity of cable (x 0.9).
- Semi-enclosed rewireable fuses **existing installations only** 80% of current carrying capacity of cable (x 0.8).

Activity - 2 - Installation conditions that cause de-rating.

Read AS 3008.1.1. sections 3.4 to 3.5 	
List the "standard" conditions of installation and operation to avoid de-rating;	
1. Ambient **air** temperature	
2. Ambient **soil** temperature	
3. Depth of laying cable underground	
4. Soil thermal resistivity	
5. Cable grouping	
6. Harmonic distortion	
Read AS 3000 clause 2.5.3.1	
7. Circuit protection	

If cables are installed as described in activity 1, the cable will not be "de-rated". If any variation to these installation conditions occurs the cable will have to be de-rated, this means its current carrying capacity will be lower, a larger cable c.s.a. may be required.

Topic 2 - De-rating Factors

Tables 2 and 22 to 29 of AS3008.1.1 show the de-rating factors that must be applied to cables if they have installation conditions that differ from Activity 2. The de-rating factor for grouping of circuits is listed in the final column of each table for tables 3(1) to 3(4) as shown in figures 2 and 3.

TABLE 3(1)

SCHEDULE OF INSTALLATION METHODS FOR CABLES DEEMED TO HAVE THE SAME CURRENT-CARRYING CAPACITY AND CROSS-REFERENCES TO APPLICABLE DERATING TABLES—UNENCLOSED IN AIR

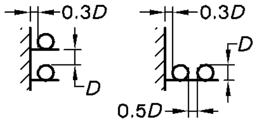
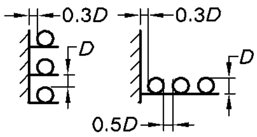
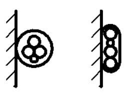
1	2	3	4	5	6
Item No.	**Cable details (see Note 2)**	**Reference drawing (see Note 3)**	**Current-carrying capacity table reference**	**Methods of installation for cables deemed to have the same current-carrying capacity (See Notes 4, 5 and 6)**	**Derating table for more than one circuit**
1	Two single-core cables		Tables 4 and 5 Columns 2 to 4 Table 6 Columns 2 and 3	Cables with minimum cable separation in air as shown for horizontal and vertical mounting and installed— (a) spaced from a wall or vertical surface; (b) supported on ladders, racks, perforated trays, cleats or hanger; or	23
2	Three single-core cables		Tables 7 and 8 Columns 2 to 4 Table 9 Columns 2 and 3		
3				(c) suspended from a catenary wire.	22

figure 2.

Foot notes at the bottom tables 3(1) to 3(4) give guidance to which de-rating table to use for installation conditions other than the grouping of cables. As shown if figure 2.

			Columns 4 and 5	plaster or render on a wall;	22
13	Three-core cables		Tables 13 and 14 (see Note 4) Columns 5 to 7 Table 15 Columns 4 and 5	(c) in a ventilated trench or open trunking; or (d) in a switchboard or similar enclosure	

NOTES:

1 *D* equals the cable outside diameter or in the case of a flat multicore cable the maximum dimension of the cable.

2 Earthing conductors, lightly loaded neutral conductors of three-phase circuits and conductors subject only to momentary loading, such as control wiring, shall not be counted in the number of cable cores.

3 See column headings of Tables 4 to 15.

4 See Table 22 for the derating factor applicable to a single circuit fixed to the underside of a ceiling or similar horizontal surface.

5 See Tables 23 and 24 for the derating factors applicable to a single circuit fixed to perforated or unperforated trays.

6 See AS/NZS 3000 for the restricted installation conditions of certain types of cable, e.g. unarmoured cables in plaster or cement render on walls.

figure 3.

Activity - 3 - De-rating factors

Use AS 3008.1.1.

Read the suggested text or resource

Write a response

Determine the de-rating factor for	De-rating Factor	Table/Column
1. A single phase V75 T+E cable installed on perforated cable tray in a factory with a ambient air temperature of 55°C.		
2. A three phase V75 4 core +E cable installed in an underground conduit with a ambient soil temperature of 35°C.		
3. A three phase V75 4 core +E cable installed in an underground conduit at a depth of 0.6m.		
4. A three phase V75 4 core +E cable installed in an underground conduit with a soil thermal resistivity of 1.5°C.m/W		
5. A single phase V75 T+E cable installed on perforated cable tray in a factory touching 3 other circuits.		
6. A three phase V75 T+E cable installed on perforated cable tray in a factory with a measured third harmonic content of 20%.		

If more than one de-rating factor is to be applied they are multiplied together e.g.

	H.R.C. fuse	= 0.9
	Grouping of circuits	= 0.8

Total de-rating applied to current carrying capacity of conductor

D.R. = 0.9 x 0.8 = 0.72

Installation conditions that avoid de-rating (AS3008.1.1 clause 3.5.2.2)

When cables are secured to supports such as ladder or cable tray it is preferred to space the cables of different circuits from each other to allow the circulation of air around the conductors. If cables must be grouped it is better to group cables in small groups. If say 20 or more circuits are bunched on a surface or enclosed in the same conduit, they must be de-rated to 0.38 of their original current carrying capacity.

Activity - 4 - Installation conditions that avoid de-rating

Read AS3008.1.1 clause 3.5.2.2 (figure 1.) 	
1. Do unserved MIMS cables in the same wiring enclosure need to be de-rated due to grouping of cables? Y/N	
2. What is the maximum length of groups of copper cables that enter a switchboard if they are under 150mm^2?	
3. When installed in **free air**, and fixed to a wall, what horizontal distance is required between single core conductors of different circuits to avoid de-rating?	
4. When installed in **free air**, and fixed to a wall, what horizontal distance is required between multi core conductors of different circuits to avoid de-rating?	

Topic 3 - Current carrying capacity tables in AS/NZS3008.1.1

How AS/NZS 3008.1.1 is organised.

Section	Purpose
Contents	Lists, sections, clause appendices tables and figures.
1	Scope, references and Section definitions.
2	Summary of cable selection procedure.
3	Cable selection based on current carrying capacity; includes Tables I to 29
4	Cable selection based on voltage drop; includes Tables 30 to 51.
5	Cable selection based on short circuit performance; includes Table 52 to 55
Appendices	Additional information to help apply the standard

Selecting Cable Size Based on Current Rating.

Selection of cable size based on current carrying capacity is based on;

$$I_B \leq I_N \leq I_Z$$

Determine the minimum current carrying capacity (I_Z) by:

- determining the current requirements, maximum demand (I_B) for the circuit;
- determine the current rating of the protective device (I_N) to be used. Table 8.1, 8.2 and B1 of AS 3000 shows standard protection device ratings up to 200A;
- decide which cable type and installation method to use;
- apply de-rating/rating factor from tables of AS/NZS 3008.1.1 for the installation environment conditions where applicable;

If a de-rating factor is to be used you will need to calculate a "look up current rating" or if you like a minimum current rating for the required cable to take to the tables as a reference to find cable size:-

$$I_{Z_{min}} = \frac{I_N}{\text{D.R. Factors}}$$

Select a minimum conductor size for the look up current rating (or next largest) from tables of AS/NZS 3008.1.1. The actual current rating of the cable under these conditions will be the current rating from the table times de-rating factor/s. If there is more than one de-rating factor the overall de-rating factor is the product of all de-rating factors that apply.

Activity - 5 - Applying de-rating factors

A load has a maximum demand of 180A. The circuit will be protected by a 200A HRC fuse. Determine the minimum current carrying capacity of the cable.

Write a response

1.

2. Is the statement $I_B \leq I_N \leq I_Z$ true? Y/N

Current Carrying Capacities of Cables

The current carrying capacities for various types of commonly used cables and installation methods are given in Tables 4 to 21.

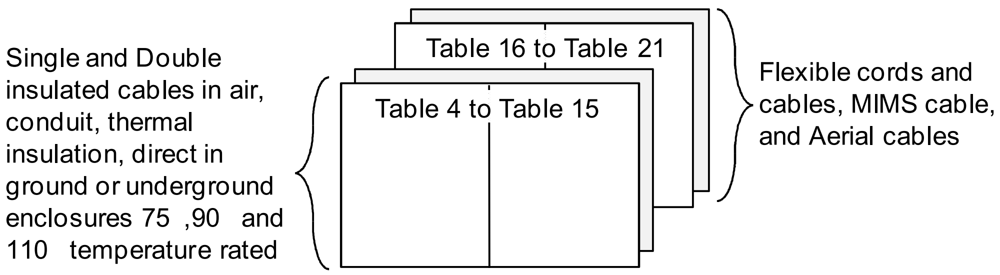


figure 4.

The current carrying capacity of a cable may be reduced or increased when particular external influences are present. In these cases a de-rating factor or rating factor must be applied before the correct minimum size conductor can be determined. Tables 22 to 29 provide de-rating/rating factors for various external influences.

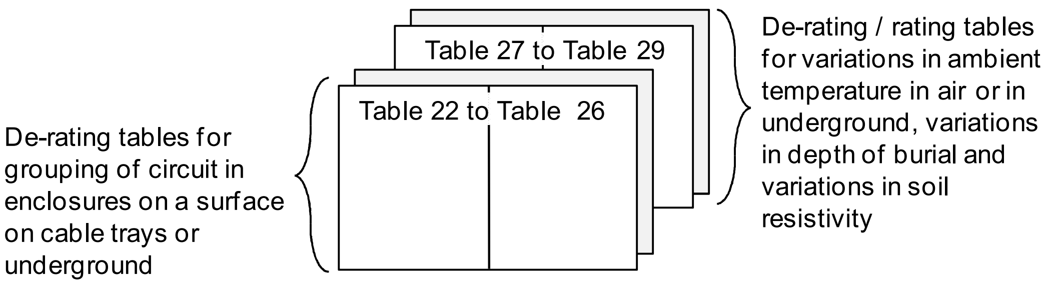


figure 5.

Which table to use.

Tables 4 to 15 are the most frequently used current carrying capacity tables, they cover the most common used cables types and cable grouping arrangements. Tables 16 to 21 cover the more unusual cables such as flexible, MIMS and aerial cables.

Table 3 gives directions to which of these tables to use for various cable configurations and installation methods. Table 3 is arranged in four parts as follows:

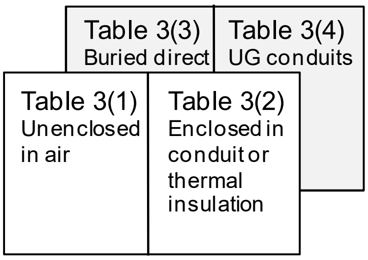


figure 6.

Each Table 3(1) to 3(4) has the same format as shown below.

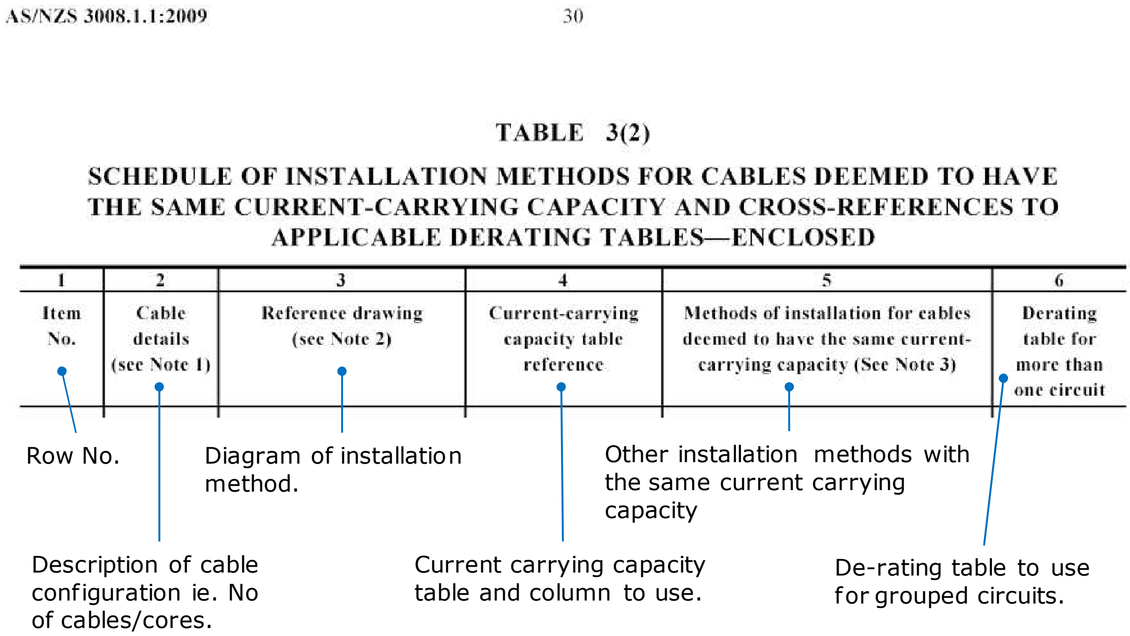


figure 7.

How to use Table 3.

The following is a guide to using Table 3.

- Look up the Table 3 that applies to how the cable is to be installed. For example you would you use Table 3(2) enclosed, for a cable enclosed in conduit.

- Go down column 2 and match a description of the cable configuration you are to use against a reference drawing in column 3 that shows you how the cable is to be installed.

For example three single core cables installed in conduit in air:

TABLE 3(2)

SCHEDULE OF INSTALLATION METHODS FOR CABLES DEEMED TO HAVE THE SAME CURRENT-CARRYING CAPACITY AND CROSS-REFERENCES TO APPLICABLE DERATING TABLES—ENCLOSED

1	2	3	4	5	6
Item No.	**Cable details (see Note 1)**	**Reference drawing (see Note 2)**	**Current-carrying capacity table reference**	**Methods of installation for cables deemed to have the same current-carrying capacity (See Note 3)**	**Derating table for more than one circuit**
1	Two single-core cables		Tables 4 and 5 Columns 15 to 17 Table 6 Columns 11 and 12	Cables in wiring enclosures installed in— (a) air; (b) plaster, cement render, masonry or concrete in a wall or floor; (c) a concrete slab on or above the surface of the ground; or (d) a ventilated trench. Cables installed in— (a) a wiring enclosure on a wall; or (b) an enclosed trench with a removable cover.	22
2	Three single-core cables		Tables 7 and 8 Columns 15 to 17 Table 9 Columns 11 and 12		

figure 8.

- Column 4 on the same row gives the current carrying capacity tables and columns to use to select the minimum conductor size.

1	Two single-core cables		Tables 4 and 5 Columns 15 to 17 Table 6 Columns 11 and 12	Cables in wiring enclosures installed in— (a) air; (b) plaster, cement render, masonry or concrete in a wall or floor; (c) a concrete slab on or above the surface of the ground; or (d) a ventilated trench. Cables installed in— (a) a wiring enclosure on a wall; or (b) an enclosed trench with a removable cover.	22
2	Three single-core cables		Tables 7 and 8 Columns 15 to 17 Table 9 Columns 11 and 12		

figure 9.

- The reference drawing in column 3 may not fully show how you intend to install the cable. In this case check column 5 for a description of installation methods deemed to be the same.

1	Two single-core cables		Tables 4 and 5 Columns 15 to 17 Table 6 Columns 11 and 12	Cables in wiring enclosures installed in— (a) air; (b) plaster, cement render, masonry or concrete in a wall or floor; (c) a concrete slab on or above the surface of the ground; or (d) a ventilated trench. Cables installed in— (a) a wiring enclosure on a wall; or (b) an enclosed trench with a removable cover.	22
2	Three single-core cables		Tables 7 and 8 Columns 15 to 17 Table 9 Columns 11 and 12		

figure 10.

- When cables are to be installed with cables of other circuits, a de-rating factor must be applied. Column 6 gives the table to use to find the correct de-rating factor for groups of cables.

For example a three core cable installed unenclosed in air on cable tray with two other circuits;

TABLE 3(1) *(continued)*

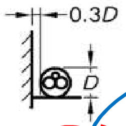
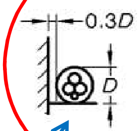
1	2	3	4	5	6
Item No.	**Cable details (see Note 2)**	**Reference drawing (see Note 3)**	**Current-carrying capacity table reference**	**Methods of installation for cables deemed to have the same current-carrying capacity (See Notes 4, 5 and 6)**	**Derating table for more than one circuit**
9	Two-core cables		Tables 10 and 11 (see Note 5) Columns 2 to 4 Table 12 Columns 2 and 3	Cables with minimum spacings in air as shown and installed— (a) spaced from a wall or vertical surface; (b) supported on ladders, racks, perforated or unperforated trays, cleats or hangers; (c) in a switchboard or similar enclosure; or	24
10	Three-core cables		Tables 13 and 14 (see Note 5) Columns 2 to 4		
11			Table 15 Columns 2 and 3	(d) suspended from a catenary or as a self-supported overhead cable.	22

figure 11.

How de-rating (and rating) factors are applied.

The minimum current carrying capacity in a cable (I_Z) when installed with cables of other circuits is **decreased** according to the de-rating factor that applies. The result can mean a larger cable is required for the circuit.

- De-rating factor applied to a particular cable results in a reduction in current carrying capacity for that cable.
- De-rating can be avoided by installing cables with minimum spacing as shown in Figure 1 of AS/NZS 3008.1.1.
- Remember, when using HRC fuses as the circuit protective device, a de-rating factor of 0.9 will automatically apply to the current carrying capacity of the cable.
- Rating factors (Tables 27 to 29) are applied to cables in ambient temperatures (other than 40°C air temperature or 25°C soil temperature) in the same way as de-rating factors. Rating tables are not given in the Table 3 schedule.

I_Z = Current carrying capacity from AS3008.1.1 x De-rating factor for installation conditions

Tables 4 to 21.

Table 3 can be used as an index to find which table from 4 to 14 has the equivalent current carrying capacity for that cable configuration and installation conditions. Tables 15 to 21 are not mentioned in table 3 as they are for different cable types (flexible cords, MIMS cables, aerial conductors etc). When selecting conductor size for these cables consult the appropriate table directly.

De-rating and rating factor from the appropriate Tables 22 to 29 must be applied where necessary.

Topic 4 - Cable selection

Activity - 6 - Cable selection based on current carrying capacity

Read the suggested text or resource	Read AS3000 clause 3.1	Group discussion

Activity - 7 - Limitation of cable temperatures

Read the suggested text or resource	Read AS3000 3.4.2 and Table 3.2	Group discussion

State the maximum **Normal use** operating temperature for;	
1. Twin + E and orange circular V75 cables	
2. Twin + E and orange circular V90 cables	
3. XLPE (X90) insulated cables	
4. MIMS cable	

Activity - 8 - Conductors in parallel

Read the suggested text or resource	Read AS3000 clause 3.4.3	Group discussion

Activity - 9 - Neutral conductor size

Read the suggested text or resource

Read AS3000 3.5.2

Group discussion

State the minimum size of the neutral conductor for the following circuits

1. Single phase consumers mains, sub-mains or final sub circuit	
2. Multi phase consumers mains, sub-mains or final sub circuit not carrying harmonic currents	
3. Multi phase consumers mains, sub-mains or final sub circuit carrying more than 40% harmonic currents	
4. List 3 loads likely to generate harmonic currents.	

Activity - 10 - Protective earthing conductor size

Read the suggested text or resource Read AS3000 5.3.3.1.2	Group discussion
State the minimum size of the protective earthing /main earthing conductor for the following circuits;	
1. 2.5 mm^2 TPI copper active conductors enclosed in L.D. PVC conduit.	
2. 1.0 mm^2 TPI copper active conductors enclosed in L.D. PVC conduit.	
3. 1.0 mm^2 TPI copper active conductors in a V90 T+E cable.	
4. A 10mm^2 copper, 3 phase XLPE single core final sub-circuit installed on cable tray.	
5. A main earthing conductor, if the consumers mains are single phase 16mm^2 copper XLPE cables.	
6. Sub-mains are 3 phase 95mm^2 copper XLPE single core cables installed in underground enclosures.	
7. Sub-mains are 3 phase 95mm^2 Aluminium XLPE single core cables installed in underground enclosures.	
8. A main earthing conductor, if the consumers mains are 3 phase 240mm^2 copper XLPE cables.	
9. A main earthing conductor, if the consumers mains are 3 phase 240mm^2 aluminium XLPE cables.	

Activity - 11 - Cable selection

	Using AS3008.1.1:2009 determine the minimum allowable cable size.

The maximum demand current of a submain cable, has been calculated to be 172 amperes. The type of cable to be used is a 4 core, non armoured, V75 insulated and sheathed circular cable with copper conductors. The cable is to be clipped directly to a vertical surface, open to the air and is to be protected by a circuit breaker with fixed current setting.

Minimum Circuit Breaker Rating that could be used	
Table Number 3(?) / Item Number	
Table Number / Column Number	
Cable Size	
Protective earthing conductor cable size	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective device	
I_Z = Current Carrying Capacity of the selected cable after any de-rating has been considered.	
Is $I_B \leq I_N \leq I_Z$?	
Would the cable need to be upgraded?	
If so, select the new cable size.	

Activity - 12 - Cable selection

Using AS3008.1.1:2009 determine the minimum allowable cable size.

The maximum demand current for the sub-mains of a non-domestic installation has been calculated to be 135 amperes. The type of cable to be used is four single core, non-armoured, XLPE insulated, sheathed copper cables laid touching in open trunking. The cables are to be protected by a circuit breaker.

Minimum Circuit Breaker Rating that could be used	
Table Number 3(?) / Item Number	
Table Number / Column Number	
Cable Size / Current rating from table	
Protective earthing conductor cable size	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective device	
I_Z = Current Carrying Capacity of the selected cable after any de-rating has been considered.	
Is $I_B \le I_N \le I_Z$?	
Would the cable need to be upgraded?	
If so, select the new cable size.	

Activity - 13 - Cable selection

Using AS3008.1.1:2009 determine the minimum allowable cable size.

One circuit, consisting of three single core V75 insulated, unsheathed non-armoured cables with copper conductors is to carry 155 amperes and be enclosed in non-metallic pipe buried in the ground to a depth of 1.25 metres below the ground surface in an ambient soil temperature of 25 degrees Celsius. Protection for the circuit is via circuit breakers. Determine the minimum permissible cable size of the circuit.

Minimum Circuit Breaker Rating	
Table Number 3(?) / Item Number	
Table Number / Column Number	
Cable Size / Current rating from table	
Protective earthing conductor cable size	

Coordination between conductors and protective devices (AS3000 2.5.3.1)

I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective device	
I_Z = Current Carrying Capacity of the selected cable after any de-rating has been considered.	
Is $I_B \leq I_N \leq I_Z$?	
Would the cable need to be upgraded?	
If so, select the new cable size.	

Activity - 14 - Cable selection

Write a response	Using AS3008.1.1:2009 determine the minimum allowable cable size.

Find the minimum size served MIMS single core cable to supply a distribution board for safety services with a maximum demand of 80A per phase. The cables are laid in trefoil on perforated cable tray spaced from other conductors. The serving of the cable is suitable for a copper sheath temperature of 105◦ C. Circuit protection is C.B.

Minimum Circuit Breaker Rating	
Table Number 3(?) / Item Number	
Table Number / Column Number	
Cable Size / Current rating from table	
Protective earthing conductor cable size	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective device	
I_Z = Current Carrying Capacity of the selected cable after any de-rating has been considered.	
Is $I_B \leq I_N \leq I_Z$?	
Would the cable need to be upgraded?	
If so, select the new cable size.	

Activity - 15 - Cable Current Carrying Capacity

Write a response	Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

A C.B. protected 4 core + E, 10 mm^2 V75 orange circular cable laid flat touching two other circuits on perforated cable tray.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Activity - 16 - Cable Current Carrying Capacity

Write a response

Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

A H.R.C. fuse protected 4 core + E, 16 mm^2 Aluminium XLPE circular cable laid flat touching one other circuit on perforated cable tray.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum H.R.C. fuse Rating	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Activity - 17 - Cable Current Carrying Capacity

Write a response	Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

Two single core, 4 mm^2 V75 TPI conductors enclosed in medium duty conduit in a concrete slab above the ground with three other circuits. C.B. protected

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Activity - 18 - Cable Current Carrying Capacity

Write a response	Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

A submain to an out building is installed burried direct in the ground, single core XLPE 120 mm² Aluminium cables laid in trefoil spaced from another circuit by 300 mm at a depth of 0.5m. The cable is C.B. protected.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Activity - 19 - Cable Current Carrying Capacity

Write a response	Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

A single phase submain consisting of two single core 16mm^2 V75 Cu cables installed in an underground enclosure. The enclosure is buried at a depth of 0.5m and touches two other circuits. All circuits are in separate enclosures. The cable is C.B. protected.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Coordination between conductors and protective devices (AS3000 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \le I_N \le I_Z$?	

Adjustable Circuit Breakers (200A - 400A)

When a circuit requires a protection device larger than 200A an adjustable circuit breaker may be used to match the setting of the breaker to the capacity of the cable. This way no capacity between the preset size of the breaker and the cable is lost.

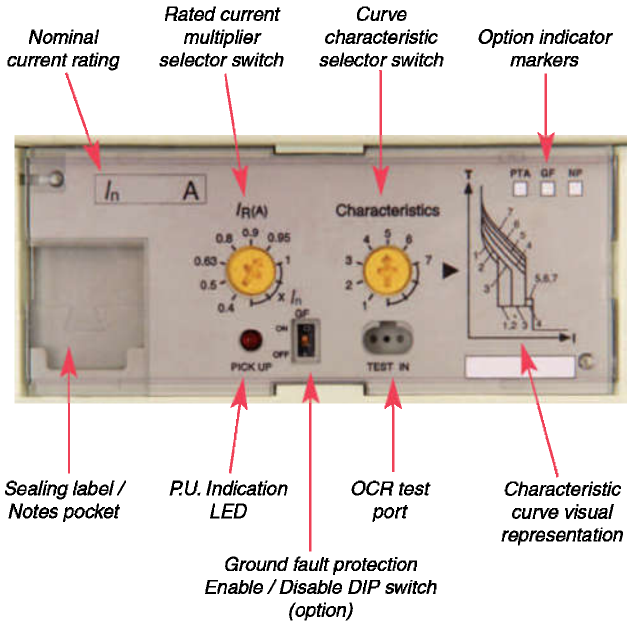


figure 10. - www.nhp.com.au

Figure 10 shows how the current rating of the device can be adjusted between 100 to 40% of its rated value. Nominal ratings of adjustable circuit breakers are typically 250 and 400A.

Setting $\% = \frac{I_Z}{I_N} \times \frac{100}{1}$

Circuit Breaker Increment Settings

1.0	**0.95**	0.9	0.8	0.63	0.5	0.4

Example 1

Four single core 70 mm² XLPE copper cables are installed laid flat touching as a single circuit on cable ladder. What size and current setting of an adjustable C.B. will allow the full optimisation of the cable current carrying capacity.

Table 3(1) Item 5 Tables 8 column 5 to 7 CCC = 240A

Setting $\% = \frac{I_Z}{I_N} \times \frac{100}{1}$ $= \frac{240}{250} \times \frac{100}{1}$ = 96 %

A 250 C.B. is now set to **95%** of its rated value to match the protection device to the cable rating. Had a preset C.B. been used a 95mm² cable would have been required.

Activity - 20 - Adjustable circuit breakers

Write a response	Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

A 150 mm^2 Aluminium XLPE 4 core + E cable is installed burried direct in the ground at depth of 0.5 m, as a single circuit. Select a suitable size and current setting for a C.B to protect the cable.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Circuit Breaker setting	
Coordination between conductors and protective devices (refer to clause 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Activity - 21 - Adjustable circuit breakers

Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

Four 120 mm^2 copper XLPE single core cables are installed in trefoil touching one other circuit on a single tier cable ladder. Select a suitable size and setting for a C.B to protect the cable.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Maximum Circuit Breaker Rating	
Circuit Breaker setting	
Coordination between conductors and protective devices (refer to clause 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_Z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Paralleling Cables

To increase the current carrying capacity of a circuit, the conductors may be run in parallel. Smaller conductors are used allowing a tighter radius when bending, and easier installation, than one single larger conductor. The cables used in parallel must be identical in material, c.s.a. and root length. The current rating of the parallel group is; 2 x the single cable current rating x any de-rating applicable including grouping.

Activity - 22 - Conductors in parallel

Read AS 3000 clause 3.4.3 	
What is the minimum size of a cable that can be connected in a parallel group?	

Example 2

Determine the current carrying capacity of two sets of 70mm^2 copper single core XLPE cables laid in trefoil on cable ladder. Each set is touching the other. Protection is by H.R.C. fuse.

Table 3(1) Item 5	Tables 8	column 5	CCC = 240A
D.R. Gouping	Table 23	column 7	2 circuits = 0.95
D.R. H.R.C. fuse	0.9		

I_Z = 2 x 240 x 0.95 x 0.9 = 410A

Select a 400A H.R.C. fuse as protection device

I_B = 400A

I_N = 400A

I_Z = 410A

Is $I_B \leq I_N \leq I_Z$? Yes

Activity - 23 - Conductors in parallel

Write a response

Using AS3008.1.1:2009 determine the maximum allowable cable current carrying capacity.

Two sets of 4 x 50mm^2 single core XLPE copper cables are parallel connected. They are installed in two seperate 125mm underground ducts spaced 450mm apart. Select a suitable size and setting for a C.B to protect the cable.

Table Number 3(?) / Item Number	
Initial Current Carrying Capacity	
Table Numbers / Column Numbers	
De-rating factors	
Table Numbers / Column Numbers	
Current Carrying Capacity after de-rating	
Protective earthing conductor cable size	
Maximum Circuit Breaker Rating	
Circuit Breaker setting	
Coordination between conductors and protective devices (refer to clause 2.5.3.1)	
I_B = Maximum demand current	
I_N = Nominal current rating of the selected protective	
I_z = Current Carrying Capacity of the selected cable	
Is $I_B \leq I_N \leq I_Z$?	

Tutorial 6

1. The maximum demand current of a sub-main cable, has been calculated to be 172 amperes. The type of cable to be used is a 4 core, non-armoured, V75 insulated and sheathed circular cable with copper conductors. The cable is to be saddled directly to a vertical surface (eg. wall), open to the air and is to be protected by a circuit breaker.

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________ $I_B \leq I_N \leq I_Z$ (Y/N)

2. The maximum demand current of a single phase domestic installation has been calculated to be 80 amperes. To select a size cable for the consumer's mains, consider the following:

Type of Cable to be used - SDI, non-armoured, XLPE cable with copper conductors.

Method of installation - the cable is to be enclosed in heavy duty PVC conduit in ceiling and partially surrounded by thermal insulation.

Circuit protection - Unprotected consumer's main

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________ $I_B \leq I_N \leq I_Z$ (Y/N)

3. The maximum demand current for the sub-mains of a non-domestic installation has been calculated to be 185 ampere. The type of cable to be used is four single core, non-armoured, V75 insulated, unsheathed copper cables laid touching in open troughing. The cables are to be protected by H.R.C. fuses.

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

4. The maximum demand current of a non-domestic installation has been calculated to be 141 amperes. The type of cable selected for the consumer's mains for this installation is to be 4 single core, V75 insulated, sheathed cables with copper conductors which are to be run in non-metallic conduit, which in turn is to be saddled to an external wall. Determine the size of the consumer's mains if they are to be protected by HRC fuses.

Table No _______ Column No ________ Cable Size _________ ME Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

5. A sub-mains cable size is to be selected for a domestic installation from the following information:

Type of Cable - 2 core, V75, flat insulated and sheathed, non-armoured cable with copper conductors including earth conductor.

Method of Installation - Clipped to a ceiling joist in air.

Maximum demand current - 27 ampere

Protection device - Circuit Breaker

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

6. A final sub-circuit is to be run in a non-domestic installation for the purpose of supplying power to a reverse cycle air conditioner. The full load current of the appliance has been calculated to be 35A. The type of cable to be used is two single core, V75 insulated and unsheathed copper cables with earthing conductor and will be protected by circuit breakers. The cable is to be run in a non-metallic conduit and saddled to an external wall.

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________

$I_B \leq I_N \leq I_Z$ (Y/N)

7. Circuit protection and cable size are to be selected from the information given:

   Maximum Demand Current - 188 ampere.

   Cable type - 4 core, X.L.P.E. circular, insulated and sheathed armoured cable with aluminium conductors.

   Method of installation - To be buried directly in the round to a depth of 0.5 metres below the ground surface in an ambient soil temperature of 25 degrees Celsius.

   Circuit Protection - Circuit breaker.

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________

$I_B \leq I_N \leq I_Z$ (Y/N)

8. Four single core, V75 insulated, unsheathed copper cables are to be run in non-metallic PVC conduit installed in the ground to a depth of 0.5 metres below the ground surface in an ambient soil temperature of 25 degrees Celsius. Each single core cable is to be installed in its own conduit, laid touching in the ground and be protected by a circuit breaker. The maximum demand current to be carried by the cable has been calculated to be 400 ampere. Determine the minimum permissible cable size for the above;

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________

$I_B \le I_N \le I_Z$ (Y/N)

9. Two circuits of two core V90, insulated and sheathed flat copper cables are to be installed directly in the ground to a depth of 0.5 metres below the ground surface in an ambient soil temperature of 25 degrees Celsius and be protected by H.R.C. fuses. The cables will be laid flat in the ground and spaced at a distance of 0.15 metres apart. Each cable must be able to safely carry a full load current of 20 amperes. From the above information, determine the minimum permissible cable size.

De-rating Table _____________ Column No_________ D.R. _________

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________ $I_B \le I_N \le I_Z$ (Y/N)

10. Two circuits of two core V90 non-armoured, insulated and sheathed cables with copper conductors are to be clipped to the underside of a ceiling in a single layer formation. The cables are to be touching. Each circuit is to carry a load current of 34 ampere and will be protected by circuit breakers. Determine the minimum permissible cable size for each circuit from the information supplied.

De-rating Table _____________ Column No_________ D.R. _________

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ I_Z = _________

$I_B \le I_N \le I_Z$ (Y/N)

11. Four circuits of three core, V90 TPS circular cables with copper conductors are to be bunched together in closed trunking which in turn is to be fixed to a wall in a horizontal position and open to air. Each circuit is to carry a maximum demand current of 54 amperes and will be protected by circuit breakers. Determine the minimum permissible size of the cables to meet the above requirements.

De-rating Table No_________ _____________ D.R. __________ Column

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

12. Four circuits of four core HFI-90-TP thermoplastic insulated and sheathed non-armoured circular cables with copper conductors are to be buried directly in the ground to depth of 0.5 metres below the ground surface in an ambient soil temperature of 25 degrees Celsius. The cables are to be laid spaced 0.15 metres from each other. The circuits are to be protected by HRC fuses and the full load current of each circuit has been calculated to be 125 ampere. Determine the minimum permissible cable size for each of the above circuits.

De-rating Table No_________ _____________ D.R. __________ Column

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

13. Six circuits, each which consist of three single core XLPE (X-HF-110) unsheathed PVC insulated copper conductors, are to carry a maximum demand current of 32 ampere and be protected by circuit breakers. Each circuit will have its three single core conductors enclosed in a separate PVC conduit. i.e. Three conductors to a conduit. The six conduits will be buried in the ground to a minimum depth as specified by the requirements of AS/NZS3000:2018 (Note: Not under a continuously paved concrete area). The soil temperature is assumed to also meet the AS/NZS3008. 1.1 minimum requirements. Each conduit will be horizontally laid in single layer formation and spaced a distance of 0.3 metres from each other. Determine the minimum permissible cable size for each circuit.

De-rating Table ____________ Column No________ D.R. _________

Table No ______ Column No _______ Cable Size ________ PE Size ________

I_B = ________ I_N =________ I_Z = ________ $I_B \leq I_N \leq I_Z$ (Y/N)

14. Two circuits of three single core V90, single double insulated non-armoured cables with copper conductors, are to be fixed to a single tier horizontally mounted perforated cable tray in a trefoil formation. Each trefoil formation will be touching. Each circuit will carry a maximum demand current of 42.5 ampere and will be protected by circuit breakers.

De-rating Table ____________ Column No_______ D.R. _________

Table No ______ Column No _______ Cable Size ________ PE Size ________

I_B = ________ I_N =________ I_Z = ________ $I_B \leq I_N \leq I_Z$ (Y/N)

15. One circuit, consisting of three single core V90 insulated, unsheathed non-armoured cables with copper conductors is to carry 175 amperes and be enclosed in non-metallic conduit buried in the ground to a depth of 1.25 metres

below the ground surface in an ambient soil temperature of 25 degrees Celsius. Protection for the circuit is via circuit breakers. Determine the minimum permissible cable size of the circuit.

De-rating Table No_____________ _____________ Column

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

16. Two, four core X-HF-90 insulated and sheathed non-armoured circular cables with copper conductors are to be installed and connected in parallel to feed a three-phase load that draws a full load current of 400 ampere when in operation. The two cables form the one circuit that is to be protected by a circuit breaker. Each cable is to be installed in its own non-metallic conduit and buried in the ground to a depth of 0.5metres. The conduits are to be touching. Determine the minimum permissible size for each cable.

De-rating Table No_____________ _____________ Column

Table No _______ Column No ________ Cable Size _________ PE Size _________

I_B = _________ I_N =_________ $I_B \leq I_N \leq I_Z$ I_Z = _________ (Y/N)

17. A four core non-armoured circular cable, with an insulation temperature R-CPE-90 rating, is to be used to supply a high-rise installation which has a calculated maximum demand of 390 amperes. The cable is to be installed in heavy duty approved PVC conduit and buried in the ground to the minimum depth of 0.5m and protected by circuit breakers. The ambient soil temperature has been measured to be 10°C. Show all relevant table and column numbers in determining the:

(a) minimum permissible cable size required if copper conductors, are to be used.

De-rating Table ____________ Column No____________

Table No ______ Column No _______ Cable Size ________ PE Size ________

I_B = ________ I_N =________ I_Z = ________ $I_B \leq I_N \leq I_Z$ (Y/N)

(b) minimum permissible cable size required if aluminium conductors are to be used.

De-rating Table ____________ Column No____________

Table No ______ Column No _______ Cable Size ________ PE Size ________

I_B = ________ I_N =________ I_Z = ________ $I_B \leq I_N \leq I_Z$ (Y/N)

Section 7

Cable selection based on voltage drop

Topics

- **Voltage drop tables in AS/NZS3008.1.1**
- **Voltage drop calculations**
- **Cable selection**
- **Maximum length of cable**

Aim

Learners will be able to determine the voltage drop for a variety of different cable types and select the minimum size cable to satisfy AS3000.2018 voltage drop requirements.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Describe the AS/NZS 3000 requirements for maximum voltage drop in an installation.
- Locate appropriate tables in AS/NZS 3008.1.1 for unit values of voltage drop.
- Calculate the expected voltage drop in a given circuit.
- Select cables to satisfy voltage drop requirements in addition to current carrying capacity requirements.
- Determine the maximum length of a cable to satisfy voltage drop requirements.

Introduction

Electrical cables made from either copper (Cu) or Aluminium (Al) have resistance. When an electric current flows in those conductors a voltage drop across the length of the cable will occur. This voltage drop will reduce the supply voltage available at the terminals of the load supplied by the cables.

Activity - 1 - Limiting Voltage Drop

Read AS 3000 clause 3.6.2 	
1. What percentage of the nominal supply voltage is permitted as voltage drop between the point of supply and electrical equipment in a installation?	
2. What is value of voltage drop is permitted for a single phase 230 volt installation?	
3. What is value of voltage drop is permitted for a three phase 400 volt installation?	

Excessive voltage drop in an installation may cause:

- a reduction in the effective operation of appliances and lighting;
- overloading of cables if a fault occurs by delaying the operating time of circuit protection devices;
- over-heating of motors, noticeable when the voltage reduction is more than 5%.

You must consider the effect of voltage drop when selecting cables, especially for circuits which have long route lengths (ie. length of cable) and circuits with relatively high currents.

Voltage drop (V) in the cables of a circuit is caused by the current in the circuits (I) and the resistance (R) of the circuit

$$V_{DROP} = I \times R_{cable}$$

Factors that determine the voltage drop in a cable are the;

- length of the cable.
- c.s.a. of the cable.
- current flowing in the cable.
- type of material of the cable (copper or aluminium).
- operating temperature of the cable and ability to dissipate heat
- installation method of the cable. (trefoil, laid flat or in a multi-core cable).

The voltage drop on any given combination of the above can be predicted before the cable is selected and installed by using tables 40 t0 51 of Section 4 of AS3008.1.1 (2009).

Section	Purpose
Contents	Lists, sections, clause appendices tables and figures.
1	Scope, references and Section definitions.
2	Summary of cable selection procedure.
3	Cable selection based on current carrying capacity; includes Tables I to 29
4	Cable selection based on voltage drop; includes Tables 30 to 51.
5	Cable selection based on short circuit performance; includes Table 52 to 55
Appendices	Additional information to help apply the standard

table 1

Topic 1 - Voltage drop tables in AS3008.1.1 (2009)

Tables 40 to 51 show values of $\mathbf{V_c}$ in milliVolts per Ampere metre for a number of copper and aluminium cable configurations. The value of $\mathbf{V_c}$ was determined by passing a current of 1 Ampere, through a 1 metre length of conductor, in sizes from $1mm^2$ to $630mm^2$ for both copper and aluminium conductors at operating temperature ranging from 45° to 110° C. as shown in figure 1. The temperature used is the maximum **normal use** operating temperature as shown in table 1 AS3008.1.1. The voltage drop across the 1 metre length of conductor is then recorded as V_c.

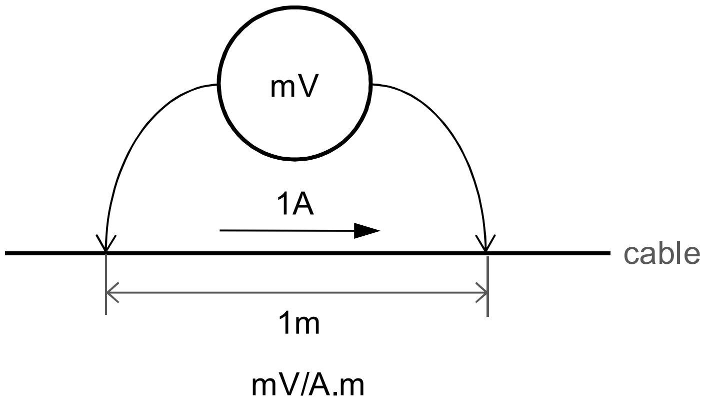


figure 1.

All of the values listed in tables 40 to 51 are 3 phase values of V_c. When performing a voltage drop calculation the value of Vc is obtained directly from the table.

The 3 phase values of V_C were obtained using the **line current** (I_L) of a balanced 3 phase circuit. The 3 phase values of V_C require adjustment when applied to a 1 phase circuit to allow for current flowing in the neutral.

If the voltage drop of a single phase cable needs to be calculated, the 3 phase value of V_c for a given cable size (from tables), must be converted to a single phase value of V_c;

3 phase V_c to 1 phase V_c

When the single phase value of V_c has been calculated, the single phase value of Vc must be converted to a 3 phase value of V_C. The c.s.a. of a suitable cable is then found from a table;

1 phase V_c to 3 phase V_c

All values of V_C in Tables 40 to 51 of AS3008.1.1 are 3 phase values of V_C.

A characteristic of a 3 phase circuit is that it has lower 'losses', than a single phase circuit of the same material, length and c.s.a. Voltage drop is a loss. The 3 phase V_C for an equivalent conductor is always smaller than the V_C of single phase circuit.

Activity - 2 - Values of V_c

Use AS 3008.1.1 **Table 40**

1. For the following copper conductor sizes, operating temperature of 75° C, covert the **3 phase values of Vc to 1 phase**.

a) 1 mm^2	
b) 4 mm^2	
c) 16 mm^2	

2. Convert the following values of **single phase V_c, to 3 phase** values of V_c and determine the copper conductor sizes, at a operating temperature of 75° C.

a) 0.96327 mV/A.m	
b) 0.68295 mV/A.m	
c) 0.255255 mV/A.m	

Topic 2 - Voltage drop calculations using AS3008.1.1

It is possible to predict the voltage drop on a cable using the equations supplied by AS3008.1.1 on page 86.

To determine the **actual voltage drop** for a given cable size, use the equation;

where

V_d = the actual voltage drop, in volts

V_C = the value found from AS3008.1.1 tables in mV/A.m

L = the route length of circuit, in metres

I = the current to be carried by the cable, in amperes.

Activity - 3 - Calculating voltage drop (V_d)

Use AS 3008.1.1

Read the suggested text or resource

Write a response

Calculate the voltage drop on a 6mm^2 V90 3 phase multicore copper cable, if protected by a 32A C.B. with a length of 30m.

To find the total voltage drop for an entire installation the voltage drops of the consumer's mains and final sub-circuits are added together.

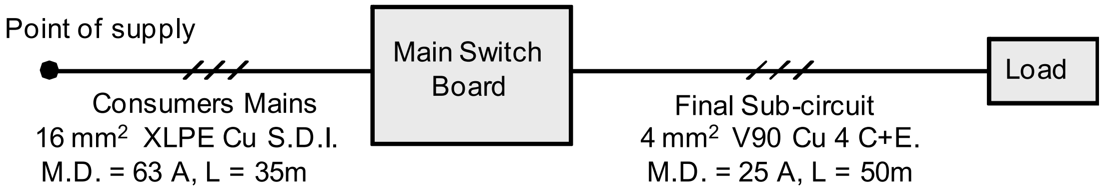
Activity - 4 - Calculating voltage drop (V_d)

Use AS 3008.1.1

Read the suggested text or resource

Write a response

Calculate the voltage drop for the installation.



Does the installation comply with AS3000 clause 3.6.2 (Y / N)

Why ?

Single phase installations

When an installation contains single phase circuits the values of V_C must be converted to single phase values and then used in the voltage drop equation.

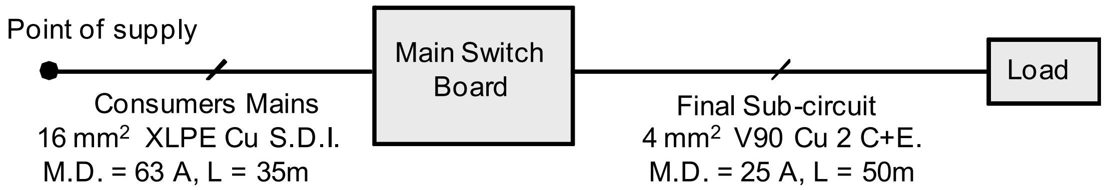
Activity - 5 - Calculating voltage drop (V_d)

Use AS 3008.1.1

Read the suggested text or resource

Write a response

Calculate the voltage drop for the installation.



Does the installation comply with AS3000 clause 3.6.2 (Y / N)

Why ?

Three phase installations with single phase circuits

If an installation is supplied by three phase and has single phase circuits within the installation, both 3 and 1 phase voltage drops must be converted to a common unit value so they can be added together. Both values can be converted to a percentage of their nominal value, or the 3 phase V_d may be converted to a single phase V_d, by dividing it by $\sqrt{3}$, in the same way a line voltage (V_L) of 400V is converted to a phase voltage (V_P) of 230V.

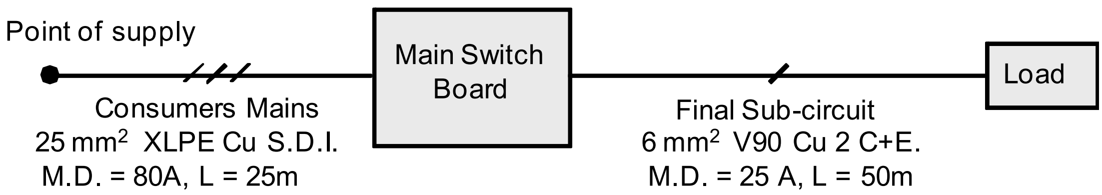
Activity - 6 - Calculating voltage drop (V_d) %

Use AS 3008.1.1

Read the suggested text or resource

Write a response

Calculate the voltage drop for the installation using the percentage method



Does the installation comply with AS3000 clause 3.6.2 (Y / N)

Why ?

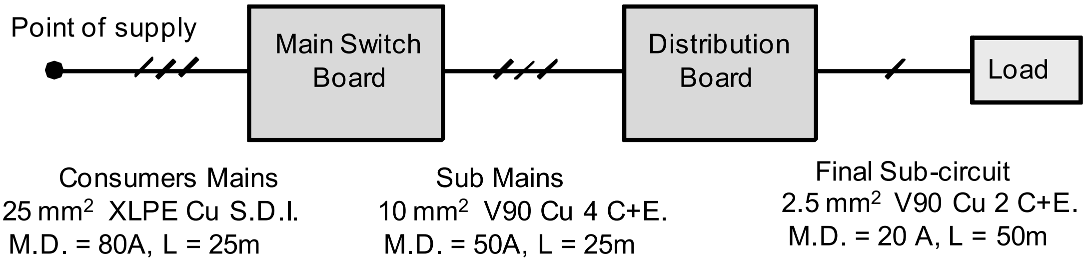
Activity - 7 – Calculating Values of V_d ($\sqrt{3}$)

Use AS 3008.1.1

Read the suggested text or resource

Write a response

Calculate the voltage drop for the installation using the $\sqrt{3}$ method.



Does the installation comply with AS3000 clause 3.6.2 (Y / N)

Why ?

Topic 3 - Cable selection based on voltage drop.

To determine the minimum required **cable size**, use the equation;

where

V_C = the value found from AS3008.1.1 tables in mV/A.m

V_p = the permissible voltage drop on the circuit run, e.g. 5% of supply voltage, in volts

L = the route length of circuit, in metres

I = the current to be carried by the cable, in amperes.

Activity - 8 - Calculating Values of V_c

Use AS 3008.1.1

1. Calculate the maximum permissible value of V_c for a 3 phase V90 copper multi-core cable, if the permissible voltage drop is 14V, the length of the cable run is 45m and the maximum demand is 25A.

2. Determine the minimum cable size

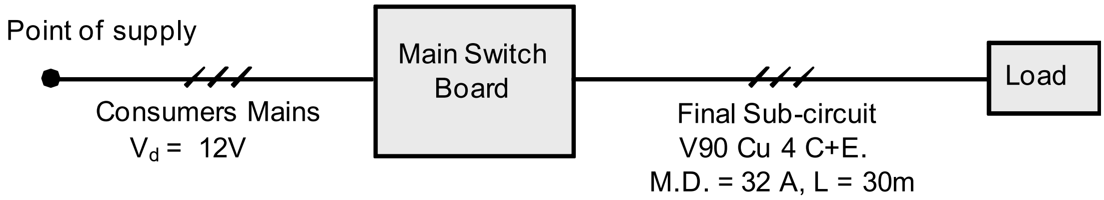
Activity - 9 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

2. Calculate the maximum permissible value of V_c

3. Determine the minimum cable size

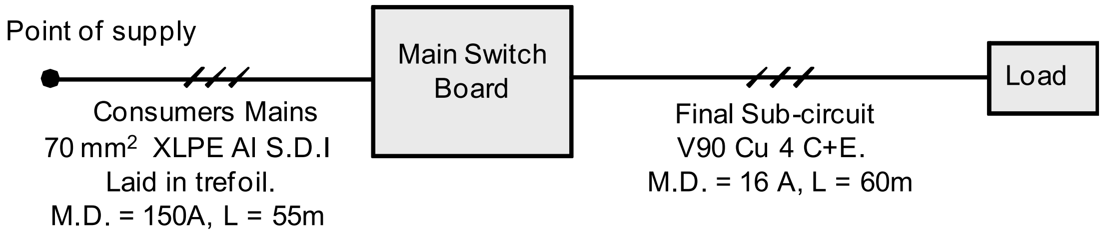
Activity - 10 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Calculate the voltage drop (V_d) on the consumers mains

2. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

3. Calculate the maximum permissible value of V_C for the f.s.c.

4. Determine the minimum cable size for the f.s.c.

Single phase installations

When an installation contains single phase circuits, values of V_C must be calculated using the single phase permissible voltage drop (V_P). The calculated single phase V_C is then converted to a 3 phase value by multiplying it by **0.866**. The cable size can then be selected using the appropriate operating temperature for the cable.

Activity - 11 - Calculating Values of V_c

Use AS 3008.1.1

Read the suggested text or resource

Write a response

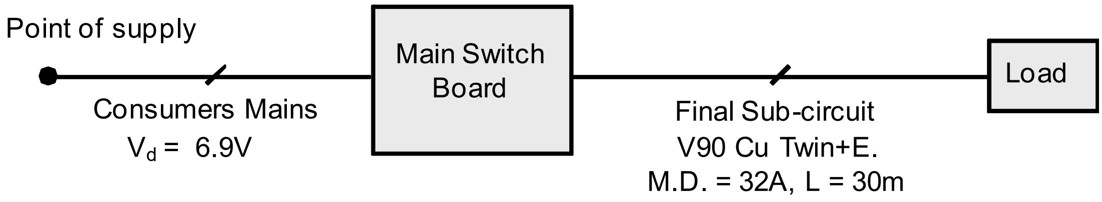
1. Calculate the maximum permissible value of V_C for a 230V 1 phase V90 copper multi-core cable, if the permissible voltage drop is 8V, the length of the cable run is 45m and the maximum demand is 25A.

2. Determine the minimum cable size

Activity - 12 - Cable selection based on voltage drop

Use AS 3008.1.1

For the installation bellow



1. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

2. Calculate the maximum permissible value of V_c

3. Determine the minimum cable size.

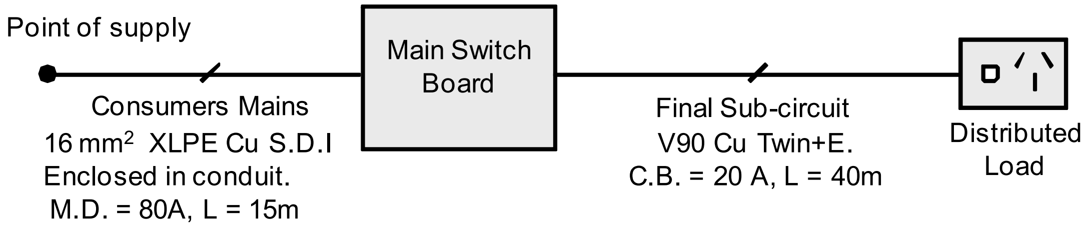
Activity - 13 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation be low (hint refer to clause 3.6.2 distributed load)



1. Calculate the voltage drop (V_d) on the consumer's mains

2. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

3. Calculate the maximum permissible value of V_C for the f.s.c.

4. Determine the minimum cable size for the f.s.c.

Three phase installations with single phase circuits

1. As discussed in topic 2 of this section, the 3 phase V_d is calculated and then must be converted to a single phase V_d. This done either converting both 3 phase and 1 phase voltage drops to a percentage, or by dividing the 3 phase V_d by $\sqrt{3}$. A single phase V_P is then found and used to calculate a single phase V_C This is then converted back to a three phase V_C so that the cable size can be determined by looking up the table.

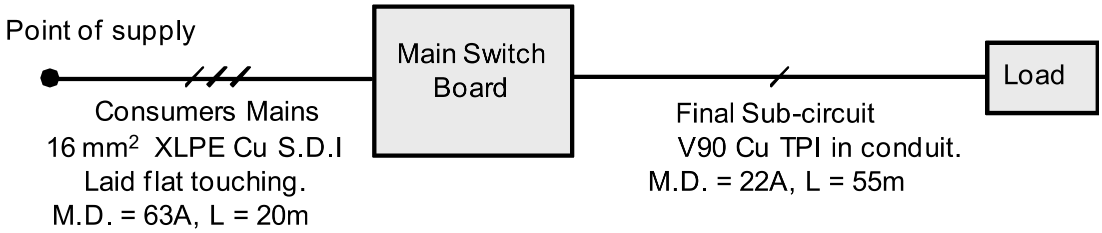
Activity - 14 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Calculate the voltage drop (V_d) on the consumer's mains

2. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

3. Calculate the maximum permissible value of V_C for the f.s.c.

4. Determine the minimum cable size for the f.s.c.

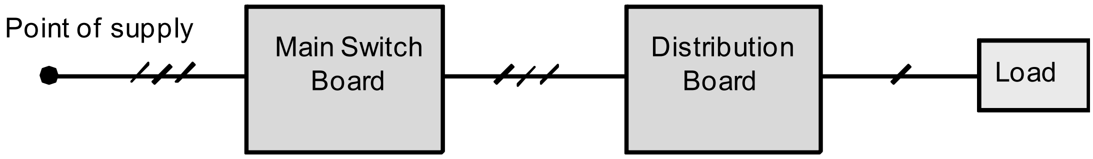
Activity - 15 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



Consumers Mains	Sub Mains	Final Sub-circuit
25 mm^2 XLPE Cu S.D.I.	16 mm^2 V90 Cu 4 C+E.	V90 Cu 2 C+E.
Enclosed in U/G conduit	M.D. = 63A, L = 45m	M.D. = 10 A, L = 50m
M.D. = 100A, L = 25m		

1. Calculate the voltage drop (V_d) on the consumer's mains.

2. Calculate the voltage drop (V_d) on the sub mains.

3. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

3. Calculate the maximum permissible value of V_C for the f.s.c.

4. Determine the minimum cable size for the f.s.c.

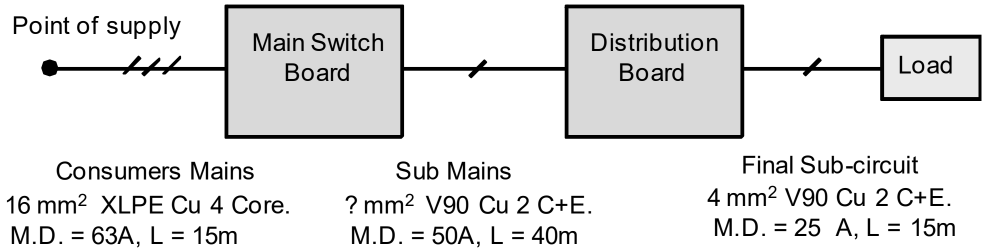
Activity - 16 - Cable selection based on voltage drop

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Calculate the voltage drop (V_d) on the consumer's mains.

2. Calculate the voltage drop (V_d) on the f.s.c.

3. Calculate the maximum permissible voltage drop (V_P) for the sub-main.

3. Calculate the maximum permissible value of V_C for the sub-main.

4. Determine the minimum cable size for the sub-main.

Topic 4 - Maximum length of cable based on voltage drop.

To determine the maximum permissible **Length** for a given cable size, use the equation;

where

V_P = the permissible voltage drop on the circuit run, e.g. 5% of supply voltage, in volts.

V_C = the value found from AS3008.1.1 tables in mV/A.m

L = the route length of circuit, in metres

I = the current to be carried by the cable, in amperes.

Activity - 17 – Calculating maximum length of cable

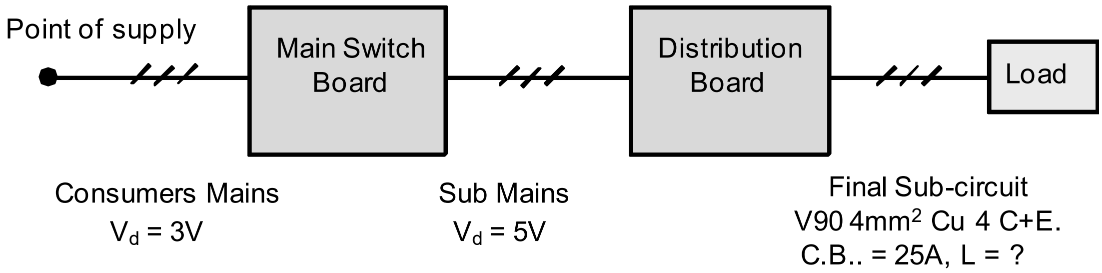
Use AS 3008.1.1

Calculate the maximum length of a 3 phase 2.5mm^2 V75 multicore copper cable protected by a 20A C.B, if the permissible voltage drop is 12V.

Activity - 18 - Calculating maximum length of cable

Use AS 3008.1.1

For the installation bellow



1. Determine the maximum permissible voltage drop (V_P) for the f.s.c.

2. Determine the value of V_C for the f.s.c.

3. Calculate the maximum permissible length for the f.s.c.

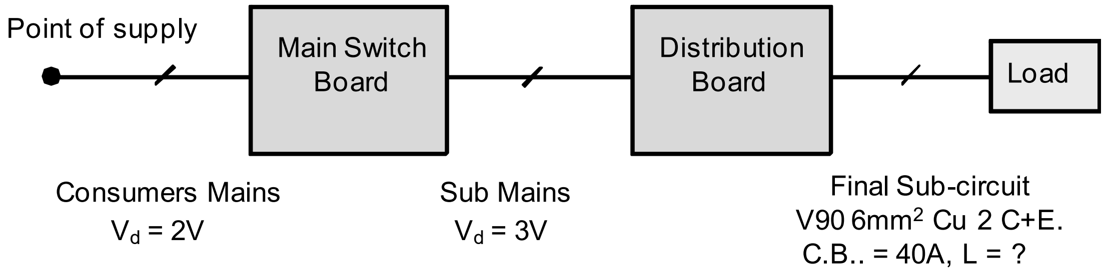
Activity - 19 - Calculating maximum length of cable

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Determine the maximum permissible voltage drop (V_P) for the f.s.c.

2. Determine the value of V_C for the f.s.c.

3. Calculate the maximum permissible length for the f.s.c.

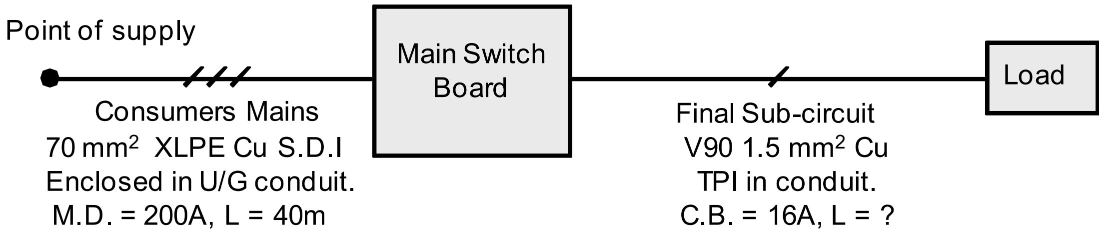
Activity - 20 - Calculating maximum length of cable

Use AS 3008.1.1

Read the suggested text or resource

Write a response

For the installation bellow



1. Calculate the voltage drop (V_d) on the consumer's mains

2. Calculate the maximum permissible voltage drop (V_P) for the f.s.c.

3. Determine the value of V_C for the f.s.c.

4. Calculate the maximum permissible length for the f.s.c.

Section 7

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. A 230V final sub-circuit is considered:

   (a) S.E.L.V.

   (b) P.E.L.V.

   (c) L.V.

   (d) H.V.

2. A 400V sub-main is considered:

   (a) S.E.L.V.

   (b) P.E.L.V.

   (c) L.V.

   (d) H.V.

3. A 11,000 V sub-transmission power line is considered:

   (a) S.E.L.V.

   (b) P.E.L.V.

   (c) L.V.

   (d) H.V.

4. The two points in an electrical installation from where the maximum permissible voltage drop is considered:

   (a) Is between any two points in the installation

   (b) Is between the point of supply and the main switchboard

   (c) Is between the point of supply and any other point in the installation

   (d) Is between the main switchboard and the further most final sub-circuit

5. The voltage drop between the point of supply for the **low voltage** electrical installation and any point in that electrical installation does not exceed ______ of the nominal voltage at the point of supply;

   (a) 2%

   (b) 5%

   (c) 7%

   (d) 10%

6. For final sub circuits, with the load distributed over the whole of the length of the circuit (such as socket-outlets or lighting points), ______ the current rating of the protective device may be used as the value of current.

   (a) 0.9 x

   (b) 1.45 x

   (c) 1.6 x

   (d) 0.5 x

7. An acceptable line voltage drop across an entire 400V installation would be;

   (a) 15V

   (b) 21V

   (c) 30V

   (d) 40V

8. Where the point of supply is the low voltage terminals of a substation located on the premises containing the electrical installation and dedicated to the installation, the permissible voltage drop may be;

   (a) 2%

   (b) 5%

   (c) 7%

   (d) 10%

9. The drop in voltage at any point in an **extra-low voltage** electrical installation shall not exceed ______ of the nominal value when all live conductors are carrying the circuit-operating current.

   (a) 2%

   (b) 5%

   (c) 7%

   (d) 10%

10. To convert values of V_C listed in the Voltage Drop Tables of AS3008.1.1, to a single phase values of V_C, the table value must be multiplied by;

   (a) 1

   (b) 1.155

   (c) √3

   (d) 0.866

11. For the installation in figure 2 determine the;

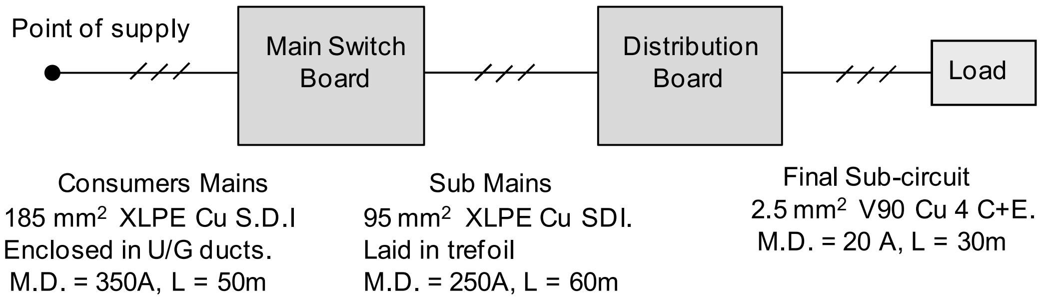


figure 2.

(a) Consumer's Mains V_d

(b) Sub Mains V_d

(c) F.s.c. V_d

(d) Total V_d

12. For the installation in figure 3 determine the;

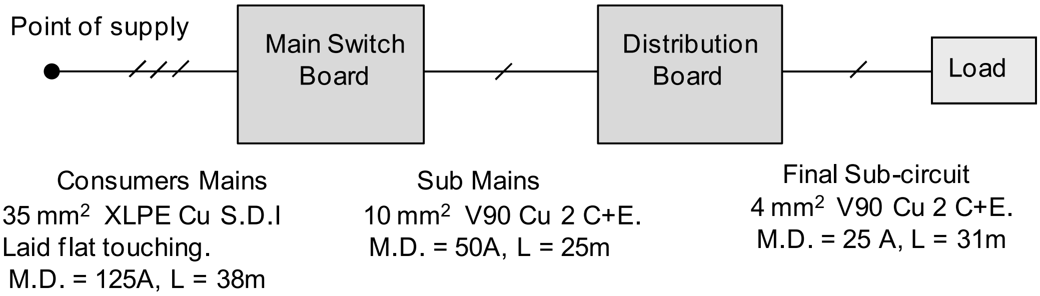


figure 3.

(a) Consumer's Mains V_d

(b) Sub Mains V_d

(c) F.s.c. V_d

(d) Total V_d

13. For the installation in figure 4 determine the;

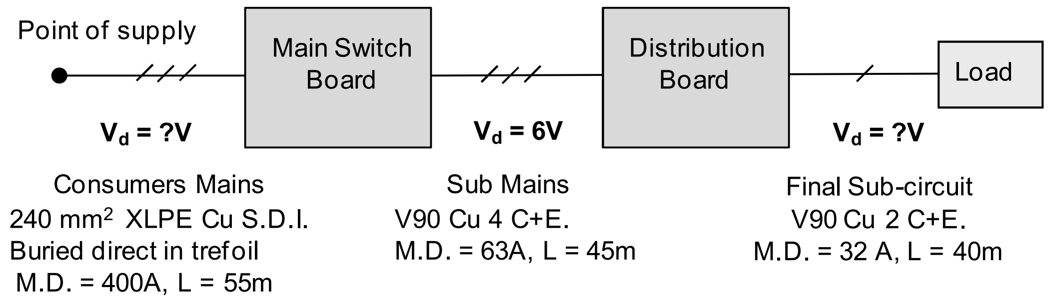


figure 4

(a) Consumer's Mains V_d

(b) Sub Mains c.s.a

(c) Final sub-circuit c.s.a.

14. For the installation of figure 5 determine;

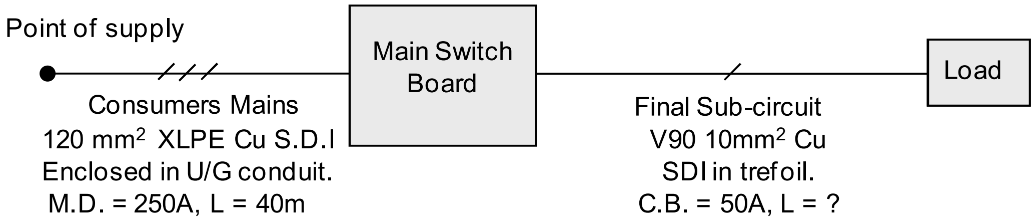


figure 5.

(a) Consumer's Mains V_d

(b) Final sub-circuit maximum length.

15. Calculate the voltage drop on the paralleled consumers mains in figure 6(hint see AS3000 clause 3.6.3)

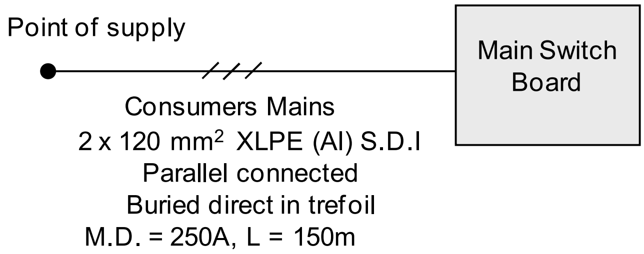


figure 6.

Section 8 - Cable selection based on earth fault loop impedance requirements

Topics

- Cable impedance tables in AS/NZS3008.1.1
- Earth fault loop impedance calculations
- Cable selection

Aim

Learners will be able to determine the maximum permissible impedance and length of a cable to satisfy AS3000 earth fault loop impedance requirements.

Learning objectives:

Learners should be able to meet the following learning objectives:

- Describe the AS/NZS 3000 requirements for maximum fault loop impedance in an installation.
- Locate appropriate tables in AS/NZS 3008.1.1 to determine cable impedances.
- Calculate the expected fault loop impedance for a given circuit arrangement.
- Select cables to satisfy fault loop impedance requirements in addition to current carrying capacity requirements and voltage drop requirements.
- Determine the maximum permissible length of a conductor based on earth fault loop impedance.

Introduction

In previous lessons we have examined the need to select conductor sizes based on current rating and voltage drop. In this lesson we will examine the effect of fault loop impedance on the selection of conductor sizes in circuits. Voltage drop limits the maximum length of conductors when current is flowing under normal operating conditions i.e. from phase to phase or phase to neutral.

Earth fault loop impedance limits the maximum length of conductors when current is flowing under earth fault conditions i.e. from phase to earth. The protective earthing conductor is usually smaller than the active or neutral conductors; its impedance will be higher than that of the active or neutral conductors. Under earth fault conditions the combined impedance of the fault path from active to protective earthing conductor will be higher than the impedance of a fault path from active to active, or active to neutral. In long cable runs because the higher impedance from active to protective earthing conductor the fault current will be lower than that of a fault on a cable of a shorter length. The lower the earth fault current, the longer the circuit protection device will take to operate. In the time that it takes to operate the circuit protection device a touch voltage will be present on the exposed conductive parts of the apparatus under fault. If a person is in simultaneous contact with the exposed conductive part and earth they said to be in "indirect contact with live parts"

One of the fundamental safety principles required by the 2007 edition of AS3000 is **fault protection** (protection from indirect contact with live parts). The most commonly used method for providing this protection is automatic disconnection of supply. Automatic disconnection of the supply **(AS3000 clause 2.4.2)** shall be achieved by:-

- provision of a system of earthing in which exposed conductive parts are connected to protective earthing conductors, and;
- automatic disconnection of the fault by an over-current protective device or an RCD within the disconnection time. (see AS3000 clause 2.4.2)

Each circuit in an electrical installation is to be protected such that automatic disconnection of supply will occur within the 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 the electrical installation.

This condition is met when the impedance of the path taken by the fault current, known as the earth fault-loop, is low enough to allow sufficient current to flow to cause the protective device to operate within the specified time.

The earth fault-loop in an MEN system comprises as shown in figure B5 of AS3000.

- The fault current flows from the supply transformer to the fault through the active conductors.
- It returns on the fault side of the installation MEN connection through the ______________________ conductor. (figure B5 of AS3000.)
- From the MEN the fault current returns along the _______________ conductor to the supply transformer.

Topic 1 - Cable impedance tables in AS/NZS3008.1.1

The total earth fault loop impedance will be the sum of the supply transformer impedance and the impedance of all cables in the path between the supply and the fault.

For the purpose of this subject, using cable ratings up to 400A, the reactance will be treated as negligible, calculations will be done using only the A.C. resistance. Cables less than (say 120mm^2) only have to consider resistance but larger cables should take reactance into account The A.C. resistance of conductors in any given combination of cables can be predicted before the cable is selected and installed by using tables 34 to 39 of Section 4 of as 3008.1.1 (2009).

Section	Purpose
Contents	Lists, sections, clause appendices tables and figures.
1	Scope, references and Section definitions.
2	Summary of cable selection procedure.
3	Cable selection based on current carrying capacity; includes Tables I to 29
4	Cable selection based on voltage drop; includes Tables 30 to 51.
5	Cable selection based on short circuit performance; includes Table 52 to 55
Appendices	Additional information to help apply the standard

The unit values in tables 34 to 39 are given in Ohms per kilo metre (Ω/km). To calculate the A.C. resistance of a given conductor use the equation;

where

R = the resistance of the cable in Ohms (Ω)

R_C = the table value in ohms per km (Ω/km)

L = the length of the conductor in meters (m)

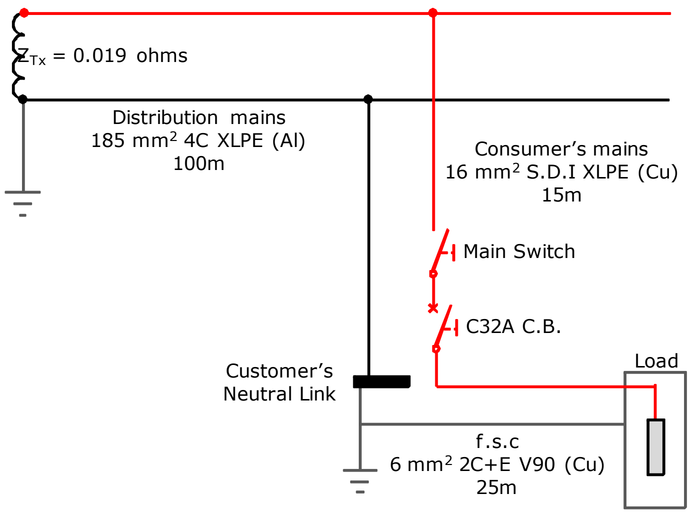
Activity 1 - Calculating cable A.C. resistance (R_C)

Read the suggested text or resource	AS 3008.1.1 (tables 34 to 39)	Write a response

Calculate the A.C. resistance of a single conductor in the following cable types and lengths (use normal operating temp.)	Table / Column Number
1. 1 mm² SDI V90 (Cu) cable, 30m long.	
2. 16 mm² SDI XLPE (Cu) cable, 45m long.	
3. 10 mm² 2C+E V90 (Cu) cable, 45m long.	
4. 10 mm² 4C+E V90 (Cu) cable, 45m long.	
5. 120 mm² 4C+E V90 (Cu) cable, 55m long.	
6. 120 mm² 4C+E V90 (Al) cable, 55m long.	
7. 240 mm² 4C+E XLPE (Al) cable, 55m long.	

Activity 2 – Total earth fault loop impedances (Z_S)

Using AS 3008.1.1 (tables 34 to 39) for the diagram below determine the:



1. Impedance of the distribution mains.	
2. Impedance of the consumer's mains.	
3. Impedance of the final sub-circuit.	
4. Total earth fault loop impedance.	

Topic 2 – Earth loop impedance calculations

Any circuit protected by an RCD satisfies the requirements of earth fault loop impedance. RCD’s that protect light and power circuits must have a rated residual current of not greater than 30mA (AS3000 section 2.6.3). Calculation of earth fault loop impedance to these circuits is pointless. The low current (<30mA) and extremely fast operation (<300mS) ensure automatic disconnection of supply within the required time. Type ‘S’ RCD’s which are have a rated residual current of in the range of 100 to 300mA (AS3000 clause 2.6.2.3) used to protect against the initiation of fire, will also satisfy earth fault loop impedance requirements.

Circuits **that require** additional protection by RCD’s (AS3000 section 2.6.3);

Residential (domestic) installations

- Socket outlets
- Lighting points
- Directly connected hand-held electrical equipment

Other electrical (non-domestic) installations

- Socket-outlets not exceeding 20A.
- Lighting circuits not exceeding 20 A.
- Final sub-circuits supplying directly connected hand-held electrical equipment, e.g. hair dryers or tools.

Circuits that are not RCD protected, which earth fault loop impedance should be applied to include;

- Socket outlets exceeding 20A.
- Fixed or stationary (mass exceeds 18 kg) equipment
- Sub-mains

Disconnection times

When an earth fault occurs a touch voltage appears on exposed conductive parts. This touch voltage will disconnected quickly if the earth fault loop impedance is low enough to ensure a large current flow occurs to operate the circuit protection quickly. This is done in miniature C.B.’s by the magnetic trip mechanism. If the fault current is too low the C.B. will trip by the thermal mechanism. The longer time a person is in contact with a touch voltage the greater the risk of injury to the person.

Clauses 1.5.5.3(d) and 5.7.2 of AS3000 specify time in which automatic disconnection of supply must occur.

Activity 3 - Protection by automatic disconnection of supply

Read AS 3000 clause 1.5.5.3

Read the suggested text or resource

Write a response

List the maximum disconnection times for circuits that supply;		RCD protected (Y/N)
1. Lighting points		
2. 10A socket outlets		
3. 32A socket outlets		
4. Hot plates		
5. An air conditioner rated at 18A per phase.		
6. A 80A sub-main		
7. An induction motor rated at 22A/ phase		
8. A hot water system		
8. A hard wired electric motor.		

The total earth fault loop impedance (Z_S) is calculated by a variation of ohms law (AS3000 section B4.5);

where

Z_S = the total earth fault loop impedance in Ohms (Ω)

U_O = the nominal phase voltage in volts (V)

I_a = current causing automatic operation of the protective device in amperes (A). Figure 2 shows values I_a for 0.4 and 5.0 second disconnection times.

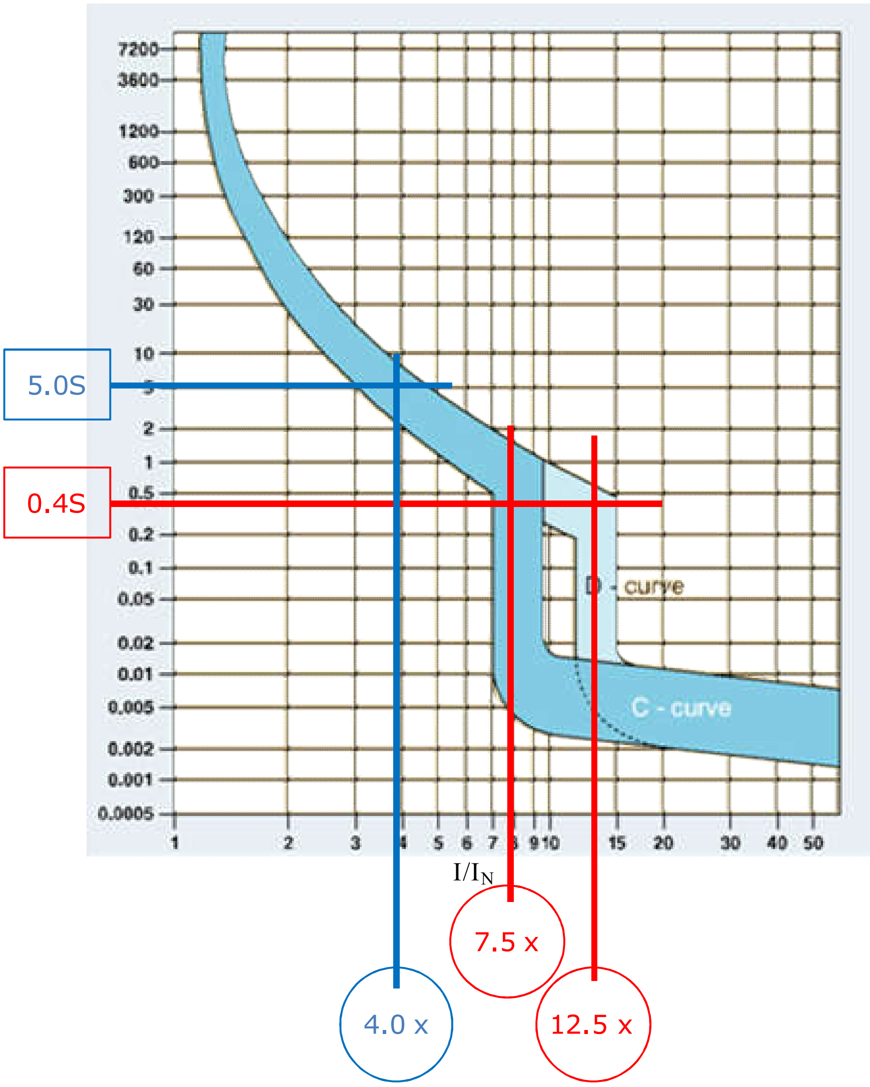


figure 2 – Clipsal 6 and 10 kA M.C.B. characteristic curve

- Type C circuit breakers - general use (most common)
- Type D circuit breakers - motor protection

When designing circuits for a 5 second disconnection time, the circuit protection manufacturers data must be used. Calculations and table data in AS3000 refers to a 0.4 second disconnection time. The value of 4 x in figure 2 is the current required to operate the circuit breaker within 5 seconds. This is not be confused with a type 'B' circuit breaker which will operate in 0.4 seconds if 4 times it rated current passes through it.

Activity 4 - Total earth fault loop impedance (Z_S)

Read AS 3000 section B4.5

Read the suggested text or resource

Write a response

1. Calculate the maximum permissible earth fault loop impedance (Z_S) of a circuit supplying a 32A three phase socket outlet that is protected by a type 'C' 32A M.C.B. in a 230/400 volt installation.

2. Calculate the maximum permissible earth fault loop impedance (Z_S) of a circuit supplying a hot water service type 'C' 20A M.C.B. in a 230/400 volt installation.

3. Calculate the maximum permissible earth fault loop impedance (Z_S) of a circuit supplying a motor protected by a type 'D' 40A M.C.B. in a 230/400 volt installation.

The maximum value of total earth fault loop impedance (Z_S) can also be found using table 8.1 of AS3000. Only 0.4 second disconnection times are shown for circuit breakers. If a earth fault loop impedance is required for a fixed or stationary appliance with a 5 second disconnection time it will have to be calculated.

Activity - 5 - Total earth fault loop impedance (Z_S)

Use Table 8.1 of AS3000. Read the suggested text or resource	Write a response
Determine the total earth fault loop impedance for the following circuits.	
1. A 25A socket outlet in data room protected b a 25A type C circuit breaker.	
2. A phase 63 A socket outlet for a welder protected by a 63A type C circuit breaker.	
3. A range circuit protected by a 20A H.R.C. fuse.	
4. A sub main protected by a 100A H.R.C. fuse.	

Internal Earth fault loop impedance (Z_{int})

The total earth fault loop impedance is made up of two parts. The **External** and **Internal** earth fault loop impedances (see figure B5 AS3000). In the vast majority of cases the impedance of the external section will be unknown. To simplify calculations it is assumed that at the circuit protection device (reference point) as shown in figure B5 AS3000, that at least 80% (0.8 x) of the nominal supply voltage (230V) is available under earth fault conditions. When calculating the internal earth fault loop impedance 80% of the nominal supply voltage is used. If a larger value of voltage is present, a higher earth fault current will flow. The operating time of the protection device will be shorter and disconnect the circuit automatically in less time than is required.

The **internal** earth fault loop impedance (Z_{int}) is calculated by a variation of ohms law (AS3000 section B5.2.1);

where

Z_{int} = the total earth fault loop impedance in Ohms (Ω)

U_O = the nominal phase voltage in volts (V)

I_a = current causing automatic operation of the protective device in amperes (A).

Activity 6 - Internal earth fault loop impedance (Z_{int})

Read AS 3000 sectionB4.5

1. Calculate the maximum permissible **internal** earth fault loop impedance (Z_{int}) of a circuit supplying a 32A three phase socket outlet that is protected by a type 'C' 32A M.C.B. in a 230/400 volt installation.

2. Calculate the maximum permissible earth fault loop impedance (Z_{int}) of a circuit supplying a hot water service type 'C' 20A M.C.B. in a 230/400 volt installation.

Once the maximum permissible internal earth loop impedance is known, the maximum length of the cable can be determined so that the impedance of the cable is less than or equal to the maximum permissible **internal** earth fault impedance.

Topic 3 - Cable selection based on earth loop impedance

The major impact that earth fault loop impedance has on a circuit is to limit its length for a given C.S.A. Tables 34 to 39 can be used to predict the earth fault loop impedance of a cable for a given length in the design stage.

In most cases if the cable has been selected correctly based on current carrying capacity and volt drop the earth fault loop impedance will not be an issue. Normally voltage drop is the most significant factor that limits the length of a cable. Long cables which are lightly loaded however can be an issue.

Activity - 7 - Internal earth fault loop impedance (Z_{int})

Use Table 35 of AS 3008.1.1.

The circuit supplying the 32A three phase socket in activity 6(1) of this section, is wired in 4 mm^2 4C+e V90 orange circular cable. The length of the cable run is 60m.

1. Determine the impedance of the cable between active and protective earthing conductors

2. Does the circuit comply with AS 3000 requirement for earth fault loop impedance (Y/N) and why?

3. Calculate the voltage drop on this section of cable.

Activity - 8 - Internal earth fault loop impedance (Z_{int})

Use Table 35 of AS 3008.1.1.

Read the suggested text or resource

Write a response

The circuit supplying the hot water system in activity 6(2) of this section, is wired in 2.5 mm^2 2C+e V90 orange circular cable. The length of the cable run is 60m.

1. Determine the impedance of the cable between active and protective earthing conductors

2. Does the circuit comply with AS 3000 requirement for earth fault loop impedance (Y/N) and why?

3. Calculate the voltage drop on this section of cable.

From the results of activities 7 and 8 it becomes obvious that voltage drop is the limiting factor on the length of the conductor.

A simpler way to determine the maximum length of a conductor is to use Table B1 of AS3000

Topic 4 - Maximum length based on earth loop impedance

Table B1 of AS3000 specifies maximum route lengths for a number of standard circuit protection device and cable size combinations. Only lengths relating to 0.4 disconnection times are shown.

Circuits supplying socket outlets and lighting points which are R.C.D. protected are not restricted in length by earth fault loop impedance, the R.C.D. will operate under active to earth fault conditions despite excessive earth fault loop impedance.

Voltage drop on the circuit must still be considered.

The circuits in the examples of activity 9 are of a type that are typically not R.C.D. protected and will have a 0.4 disconnection time.

Activity 9 – Maximum length of conductors

Use Table B1 of AS 3000 Read the suggested text or resource	Write a response
Determine the maximum route lengths based on earth fault loop impedance for the following circuits in a 230/400 volt installation.	
1. A 4mm^2 Cu 4C+e V90 circuit supplying a 32A three phase **socket outlet** that is protected by a type 'C' 32A M.C.B.	
2. A 25A **socket outlet** in data room protected b a 25A type 'C' circuit breaker wired in 4.0 mm^2 Cu V75 twin + E.	
3. A phase 63 A **socket outlet** for a welder protected by a 63A type 'D' circuit breaker wired in 16mm^2 Cu 4C+E	

Calculation of maximum length of conductors based on earth fault loop impedance.

If a cable / circuit breaker combination not listed in table B1 of AS3000 or the circuit supplied has a 5 second disconnection time the earth fault loop impedance must be calculated.

The **maximum route length** based on earth fault loop impedance (L_{max}) is calculated by (AS3000 section B5.2.2);

where

L_{max} = maximum route length in metres

U_O = the nominal phase voltage in volts (V)

ρ = resistivity at normal working temperature in Ω-mm^2/m

= 22.5 x 10^{-3} for copper

= 36 x 10^{-3} for aluminium

I_a = current causing instantaneous operation of the protective device in amperes (A).

= the current that assures operation of the protective fuse concerned, in the specified time

S_{ph} = cross sectional area of the active conductor of the circuit concerned in mm^2

S_{pe} = cross sectional area of the protective earthing conductor concerned in mm^2

This calculation was used to determine the maximum lengths of cables in table B1 of AS3000. If a circuit has a disconnection time of 5 seconds the mean tripping current of the protection device must be found from manufactures data (figures 2 to 6). The multiples of the nominal current are then applied to the nominal current rating to find I_a.

The characteristic curves of circuit breakers in the 5 second range vary widely. Activities 10 to 13 demonstrate this. The earth fault loop impedance must be calculated to suit the characteristic of the brand of circuit breaker actually used.

The 5 second trip characteristics of circuit breakers in the lower current ranges (10-63A) are very different to the characteristics of circuit breakers in the range of 250-400A.

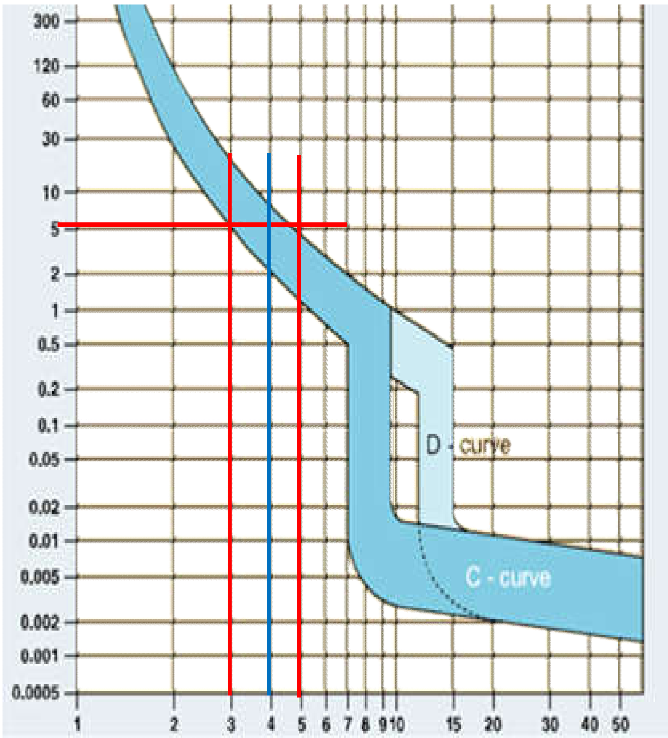


figure 3 - www.clipsal.com

Activity 10 – Maximum length of conductors

Read the suggested text or resource	Use Section B5.2.2 of AS 3000 to calculate the maximum route length based on earth fault loop impedance for A 4mm^2 2C+e V90 circuit supplying a cook top protected by a C25A Clipsal M.C.B. in a 230/400 volt installation.	Write a response
1. Maximum disconnection time		
2. Determine from manufactures data (figure 3) the current I_a		
3. Calculate the maximum length of the circuit based on earth fault loop impedance.		

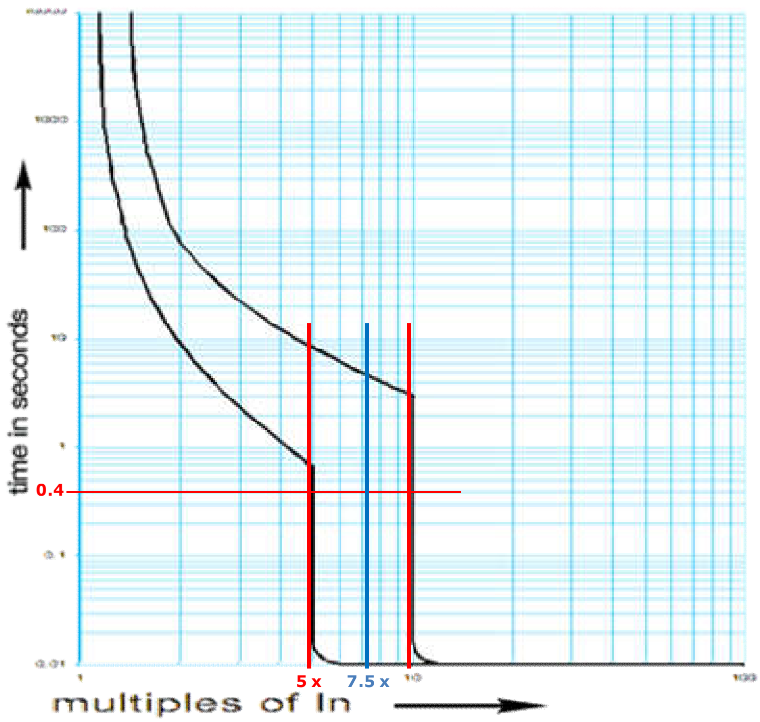


figure 4 – www.hagerbr.com.au

Activity – 11 – Maximum length of conductors

Read the suggested text or resource	Use Section B5.2.2 of AS 3000 to calculate the maximum route length based on earth fault loop impedance for A 6mm^2 4C+e V90 circuit supplying a 32A three phase **socket outlet** that is protected by a Hager C32A M.C.B. in a 230/400 volt installation.	Write a response
1. Maximum disconnection time		
2. Determine from manufactures data (figure 4) the current I_a		
3. Calculate the maximum length of the circuit based on earth fault loop impedance.		

Time/current characteristic curves

S125-NF

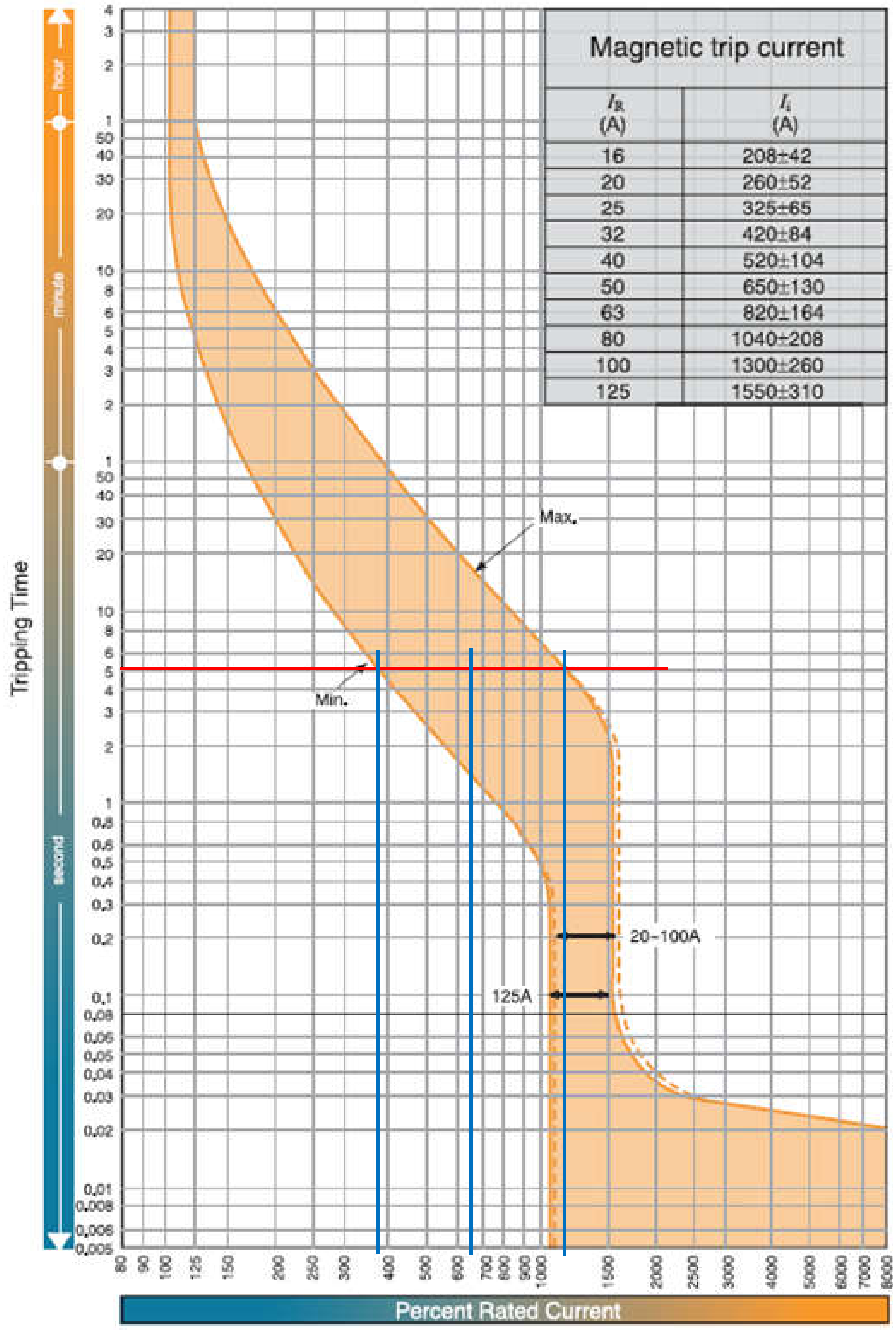


figure 5 – www.nhp.com.au/tembreak2/manuals/asp

Activity 12 – Maximum length of conductors

Read the suggested text or resource	Use Section B5.2.2 of AS 3000 to calculate the maximum route length based on earth fault loop impedance for a 16 mm^2 2C+E V90 circuit, supplying a single phase sub main protected by a single pole 63A Tembreak 2 C.B. in a 230/400 volt installation.	Write a response
1. Maximum disconnection time		
2. Determine from manufactures data (figure 5) the current I_a		
3. Calculate the maximum length of the circuit based on earth fault loop impedance.		

Time/current characteristic curves

E400-NJ, S400-CJ, S400-NJ, S400-GJ

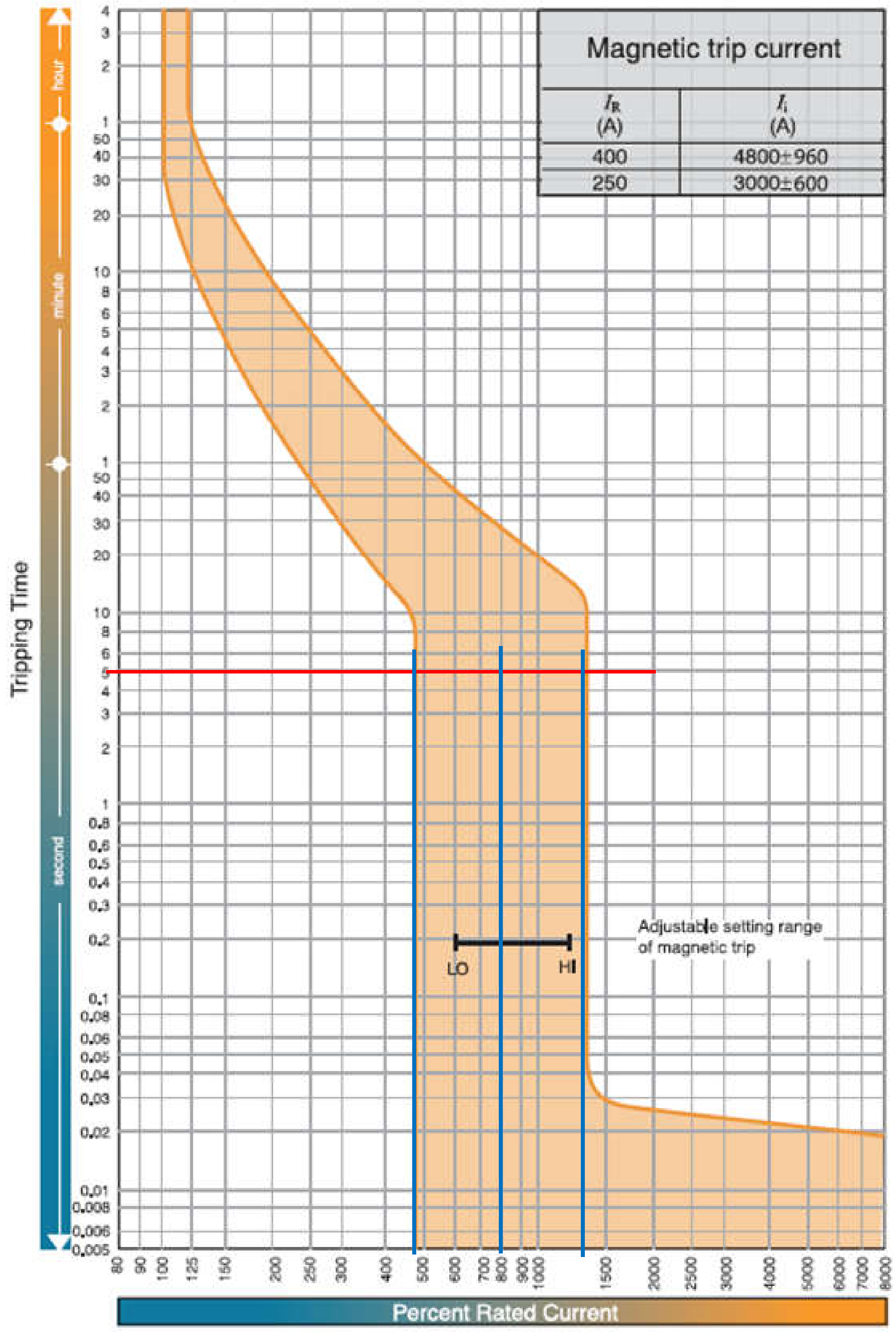


figure 6 - www.nhp.com.au/tembreak2/manuals/asp

Activity 13 – Maximum length of conductors

Read the suggested text or resource	Use Section B5.2.2 of AS 3000 to Determine the maximum route length based on earth fault loop impedance for a 150 mm^2 single core XLPE circuit, supplying a three phase sub main protected by a 400A type 'C' M.C.B. in a 230/400 volt installation.	Write a response
	1. Maximum disconnection time	
	2. Determine from manufactures data (figure 6) the current I_a	
	3. Calculate the maximum length of the circuit based on earth fault loop impedance.	

The situation can arise, on a long run of cable, where cable size has been increased to compensate for voltage drop, the maximum demand (I_B) will be much lower than the current carrying capacity of the cable (I_Z). Figure 7 below shows a scenario where both current carrying capacity and voltage drop comply with AS3000 requirements, but the earth fault loop impedance does not.

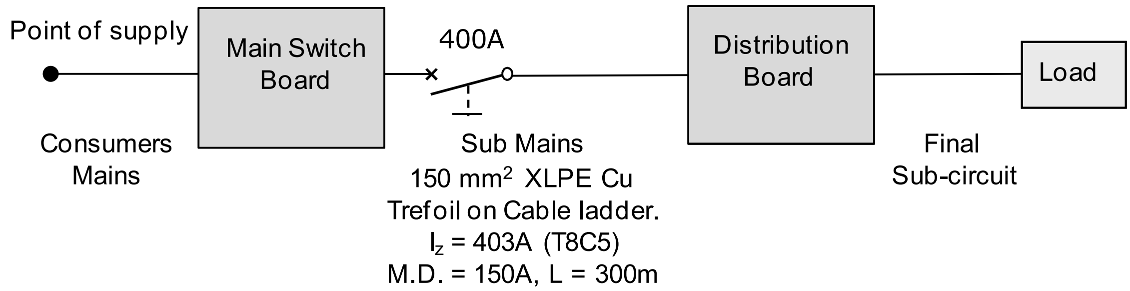


figure 7

Clause 2.5.3.1 AS3000 Protection against overload $I_B \leq I_N \leq I_Z$.

In this case I_B (150A) is less than I_N (400A) and I_N is less than I_Z (403A), so protection against overload is provided.

Clause 3.6.2 AS3000 Voltage drop should not exceed 5% of nominal supply voltage.

When calculating voltage drop it is permitted to use the lower maximum demand current rather than the rating of the circuit breaker.

$$\mathrm{Vd} = \frac{\mathrm{L} \times \mathrm{I} \times \mathrm{V_C}}{1000} = \frac{300 \times 150 \times 0.316}{1000} = 14.22\mathrm{V}$$

The voltage drop on the circuit is not excessive and complies with AS3000 requirements. While a 150A would be a more suitable rating of a circuit breaker, than the 400A device, it still complies with AS3000 requirements for overload protection and voltage drop.

Clause 1.5.5.3 AS300 Protection by automatic disconnection of supply

Circuits under fault conditions between active and earth must be automatically disconnected from the supply with the specified time. In this case for a sub-main, the required disconnection time is 5 seconds .

Clause 5.2.1 AS3000 Determination of maximum length $Z_{\mathrm{int}} = \frac{0.8 \times \mathrm{U_O}}{\mathrm{I_a}}$

From manufactures data such as the graph shown in figure 6 of this section, the current required to operate the 400A C.B. in 5 seconds would be 8 x 400A which equals 3200A.

$$Z_{\mathrm{int}} = \frac{0.8 \times \mathrm{U_O}}{\mathrm{I_a}} = \frac{0.8 \times 230}{8 \times 400} = 0.0575\Omega$$

From table 34 of AS3008.1.1

Active 150 mm^2

$$Z_{PH} = \frac{0.160 \times 300}{1000} = 0.048\Omega$$

Protective Earth 50 mm^2

$$Z_{PE} = \frac{0.494 \times 300}{1000} = 0.1482\Omega$$

$$Z_{\mathrm{Cable}} = Z_{\mathrm{PH}} + Z_{\mathrm{PE}} = 0.048 + 0.1482 = 0.1962\Omega$$

The combined impedance of the cables (active and protective earthing conductor) is larger than the permitted internal earth fault loop impedance (Z_{int}). The 400A circuit breaker would take longer than 5 Seconds to operate. **The circuit does not comply.**

Solution 1 – Decrease the rating of the circuit breaker to 150A (I_a also changes)

$$Z_{int} = \frac{0.8 \times U_O}{I_a} = \frac{0.8 \times 230}{7.5 \times 150} = 0.1635\Omega$$

The circuit still does not comply. The impedance of the cable is greater than the permissible internal earth fault loop impedance.

Solution 2 – Decrease the rating of the circuit breaker to 150A and increase the size of the protective earthing conductor.

$$Z_{PE} = Z_{int} - Z_{PH} = 0.153 - 0.048 = 0.105\Omega$$

Increase the protective earthing conductor to $70mm^2$.

$$Z_{PE} = \frac{0.342 \times 300}{1000} = 0.1026\Omega \text{ (AS3008.1.1 T34C5)}$$

$$Z_{Cable} = Z_{PH} + Z_{PE} = 0.048 + 0.1026 = 0.15062\Omega$$

The cable impedance (0.15062Ω) is now less than the permissible internal fault loop impedance (0.1635Ω). The circuit does comply.

Tutorial - Section 8

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

16. The internal earth fault loop path is from:

    (a) active to neutral conductor
    (b) active to phase conductor
    (c) active to protective earthing conductor
    (d) phase to functional earthing conductor.

17. The external earth fault loop path is from:

    (a) active to neutral conductor
    (b) active to phase conductor
    (c) active to protective earthing conductor
    (d) phase to functional earthing conductor.

3. The maximum permissible disconnection time to provide fault protection (protection against indirect contact), for a circuit supplying 10A socket outlets is:

    (a) 0.4 seconds
    (b) 1.45 seconds
    (c) 5 seconds
    (d) 1 hour

4. The device that will operate to provide fault protection (protection against indirect contact) in the shortest time on a circuit supplying 10A socket outlets is:

    (a) a H.R.C. fuse
    (b) an R.C.D
    (c) a thermal magnetic circuit breaker
    (d) a thermal overload

5. The maximum permissible disconnection time to provide fault protection (protection against indirect contact), supplying lighting points, is:

    (a) 0.4 seconds
    (b) 1.45 seconds
    (c) 5 seconds
    (d) 1 hour

6. The device that will operate to provide fault protection (protection against indirect contact) in the shortest time on a circuit supplying lighting points is:

   (a) a H.R.C. fuse
   (b) an R.C.D
   (c) a thermal magnetic circuit breaker
   (d) a thermal overload

7. The maximum permissible disconnection time to provide fault protection (protection against indirect contact), for a sub-main rated at 63A, is:

   (a) 0.4 seconds
   (b) 1.45 seconds
   (c) 5 seconds
   (d) 1 hour

8. The device that should not be used to provide fault protection, for a sub-main rated at 63A, is:

   (a) a H.R.C. fuse
   (b) an R.C.D
   (c) a thermal magnetic circuit breaker
   (d) a electronic circuit breaker

9. When calculating the internal earth fault loop impedance the voltage present at the circuit protection device (reference point) is:

   (a) 230V
   (b) 240V
   (c) 184V
   (d) 400V

10. The maximum value of earth fault loop impedance for a sub main protected by a 63 A H.R.C. fuse is:

   (a) 0.55Ω
   (b) 0.94Ω
   (c) 1.53Ω
   (d) 1MΩ

For tutorial questions 11 to 13 refer to figure 8.

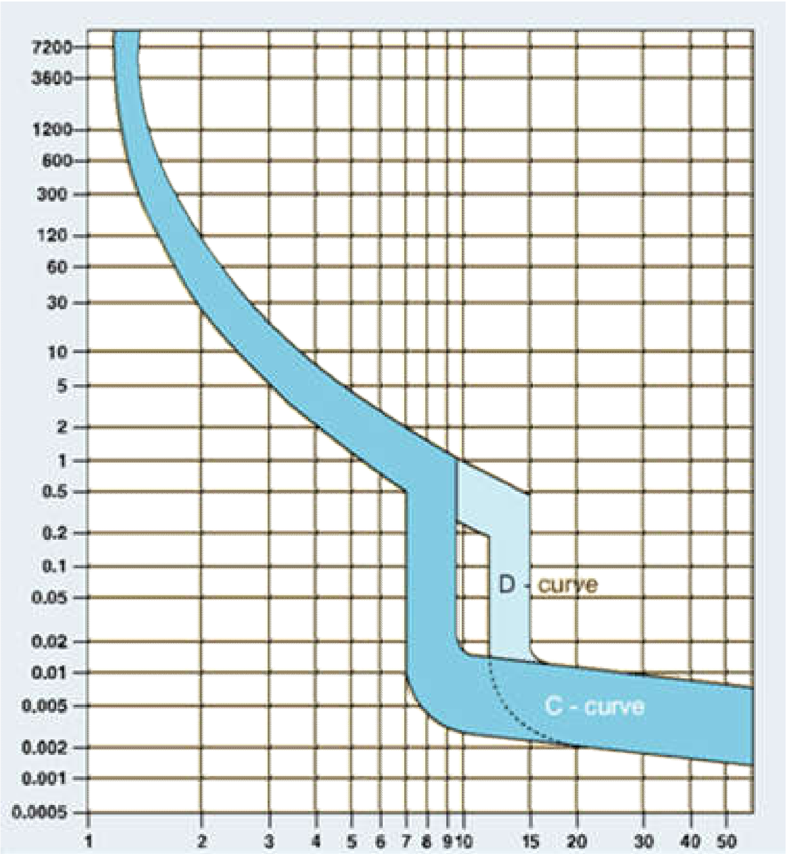


figure 8 – www.clipsal.com

11. Calculate the total earth fault loop impedance for circuit supplying a hot water system protected by a Clipsal 20A type 'C' circuit breaker.

12. Calculate the internal earth fault loop impedance for circuit supplying a hot water system protected by a Clipsal 20A type 'C' circuit breaker.

13. If the hot water system of question 12 is wired in 2.5mm^2 T+E with a circuit length of 35 m;

(a) Calculate the internal earth fault loop impedance of the final sub-circuit (hint use AS3008.1.1 to determine Z_{ph} and Z_{pe})

(b) Does the calculated internal earth loop impedance comply with AS3000?

(a) Calculate the voltage drop on the H.W.S. final sub-circuit.

(b) If 4.6V was lost on the consumers mains, does the final-sub circuit comply with AS3000 requirement for voltage drop? Y/N

14. A 50 mm^2 copper sub-main is protected by a 125A **H.R.C. fuse** with a route length of 80 m

(a) Determine from table 8.1 AS3000 the maximum permissible **internal** earth fault loop impedance.

(b) Use table B1 of AS3000 to determine if the route length is compliant.

Tutorial question 15 refers to figure 8.

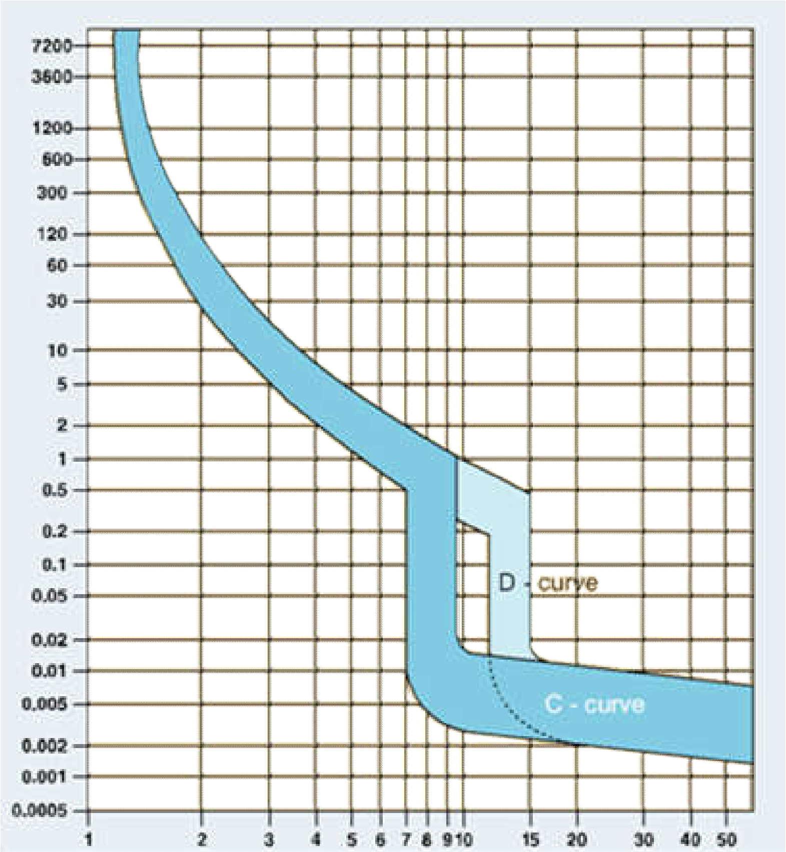


figure 8 – www.clipsal.com.au

15. An underground 25mm^2 XLPE copper sub main protected by a 100A Clipsal circuit breaker.

    (a) Determine the maximum permissible operating time.

    (b) Using figure 8 determine the current I_a.

    (c) Calculate the maximum permissible length to satisfy earth fault loop requirements.

Section 9 - Selecting protection devices

Topics

- Selecting overload protection devices
- Short-circuit hazards
- Selecting short-circuit protection devices
- Protection against indirect contact
- AS 3000 Requirements

Aim

Learners will be able to determine and meet the requirements of AS3000 when selecting devices to provide cable overload, short circuit and fault protection (protection against indirect contact).

Learning objectives

Learners should be able to meet the following learning objectives:

- Explain how the coordination between conductors and protection devices ensures the protection of cables from overheating due to over current.
- Apply AS/NZS 3000 requirements for selecting devices to protect against overload current for a range of circuits and loads.
- Describe the possible injuries to persons and livestock from hazards due to a short circuit.
- Apply AS/NZS 3000 requirements for selecting devices to protect against short-circuit current for a range of installation conditions.
- Outline acceptable methods of protection against indirect contact.
- Apply the AS/NZS 3000 requirements for selecting methods and devices to protect against indirect contact for a range of installation types and conditions.

Introduction

This section will cover 3 types of electrical faults that must be protected against;

- Overload — when simply **too much load** is applied to another wise undamaged circuit, causing a larger current to flow than under normal operation.
- Short Circuit — when a fault of negligible impedance occurs between live conductors, usually due to damage to insulation or failure of equipment. Known as the **'Prospective Short Circuit Current'** this is the largest of all electrical faults. Current will only be limited by the impedance of the cables and will be of an extremely high value.
- Earth Fault — when a live conductor comes in contact with conductive parts which are 'earthed'. Usually due to insulation failure. The current that flows will be of a lower value than the 'Prospective Short Circuit Current' as the earth fault loop impedance will be higher than the cable impedance of a phase to phase fault.

  Clause 1.5.5.1 **Fault protection** (protection against indirect contact) requires that one or more methods are used to prevent a touch voltage occurring on the conductive parts under fault. Automatic disconnection of supply is the most commonly used method. A combination of circuit protection and a protective earthing conductor is used to provide a low impedance path so that a sufficient current flows to operate the protection device in the required time.

Normal operation

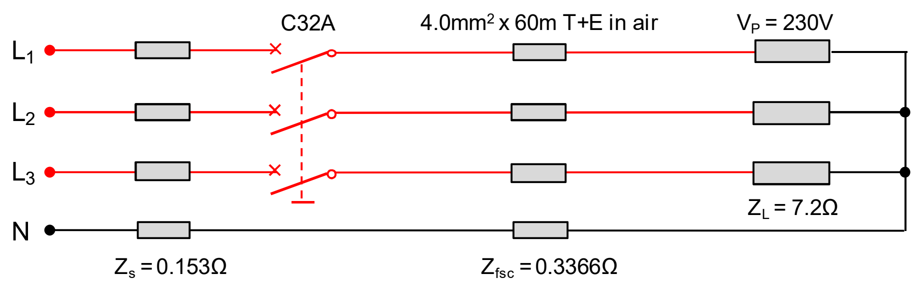


figure 1.

Figure 1 shows a normal healthy circuit. The current is limited by the impedance of the load. Under normal conditions the impedance of the cable is so low it is considered negligible. The current in the cable is calculated using ohms law. As the circuit is a balanced three phase load no current flows in the neutral. The current rating of the cable is 32A (I_Z).

The ratio of the current actually flowing through the circuit (I) to the nominal rating of the circuit protection device (I_N) give the multiples of rated current (I_M)

$$I_M = I/I_N$$

This ratio is used to predict the operating time of the protection device.

Activity – 1 – Normal operation

1. Calculate the Line current (I_L) for the circuit shown in figure 1.	
2. Calculate the multiple of the C32A C.B. rating.	
3. Is $I_B \leq I_N \leq I_Z$	Y / N
4. Draw on figure 2 a line to show the multiple of rated current. Will the circuit breaker operate (trip), if so in what time? Y / N	Max _______ Min _______

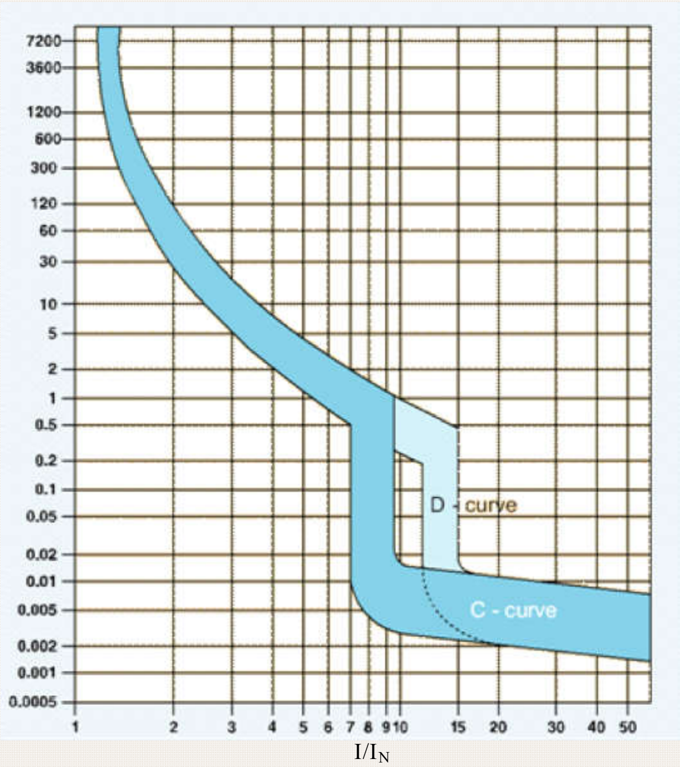


figure 2. – www.clipsal.com

Topic 1 - Selection of overload devices

Overload condition

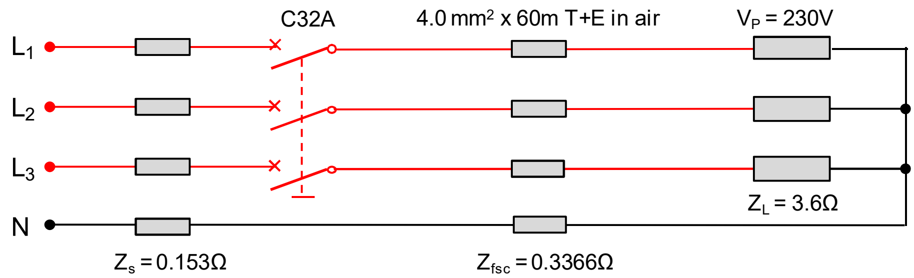


figure 3.

Figure 3 shows the same circuit in an overload condition. By adding more load in parallel to each phase, the circuit impedance has decreased from 7.2 to 3.6Ω. The cable impedance is still considered negligible. The circuit line current will increase to a value higher than the rated current of the cable (I_Z).

Figure 4 shows how a small increase in current above the maximum current carrying capacity will cause a large increase in the operating temperature of the conductor. The increased operating temperature over time will damage the insulation of the conductor. It will take several hours at these over loads for the temperature to reach those shown if figure 4.

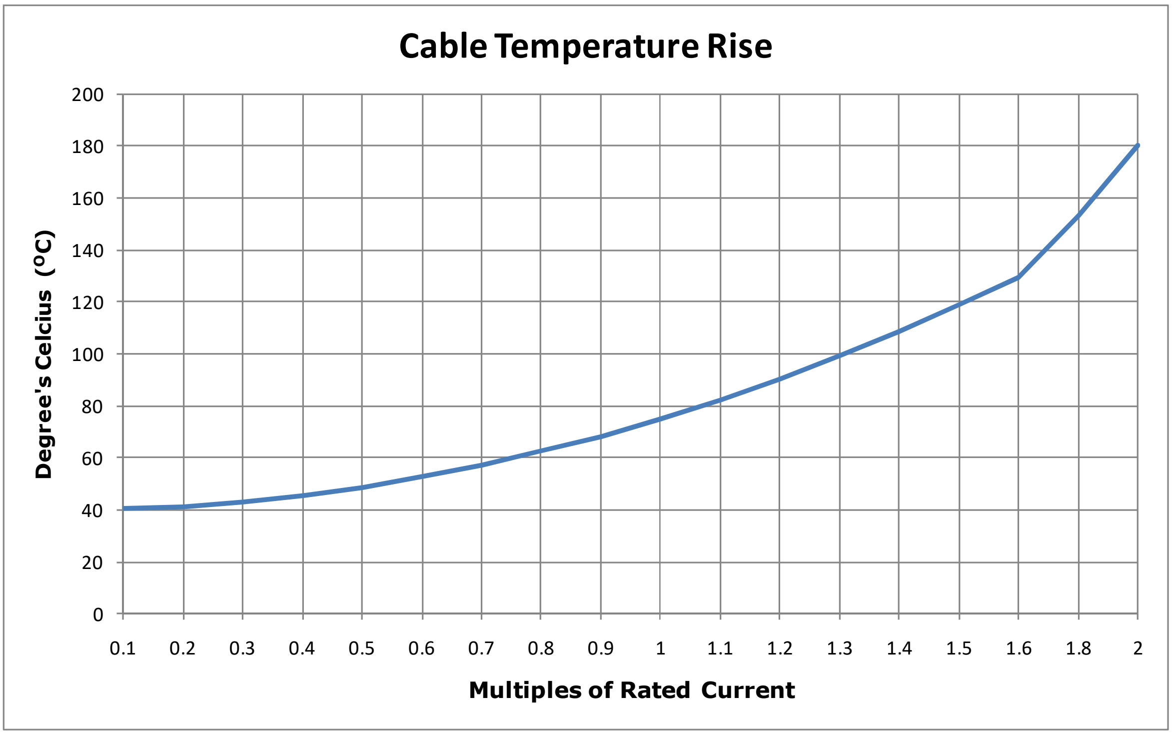


figure 4.

The graph of figure 4 is based on a copper V90 cable (maximum temperature 75°C) installed unenclosed in air with an ambient air temperature of 40°C. Calculated as per clause 4.4 of AS3008.1.1

To protect the cable from an overload the circuit protection device must operate in a suitable time so the cable does not operate above its maximum (normal) operating temperature for a prolonged period of time.

In section 6 it was shown that for cables to be protected against overload current **AS3000 rule 2.5.3.1** must be met.

Activity - 2 - AS3000 requirements - Overload

Read AS 3000 clause 2.5.3

If the following equations are true the circuit will operate correctly under normal conditions and the circuit protection will operate in the required time if the circuit is overloaded.

$$I_B \leq I_N \leq I_Z$$

where

I_B = the maximum demand of the circuit in Amperes

I_N = the current rating of the circuit protection device (fuse or C.B.) in Amperes.

I_Z = the current rating of the conductor after all applicable de-ratings have been applied.

and

$$I_2 \leq 1.45 \times I_Z$$

where

I_2 = the current ensuring effective operation of the protective device (causes protection device to operate in 1 hour (3600 seconds))

= 1.45 x I_N for Circuit Breakers.

= 1.6 x I_N for H.R.C. fuses.

I_Z = the current rating of the conductor after all applicable de-ratings have been applied.

As the thermal trip mechanism of a circuit breaker has a similar heating characteristic to that of the cable it protects, 100% of the cables current rating can be used. The statement $I_2 \leq 1.45 \times I_Z$ will always be true if $I_B \leq I_N \leq I_Z$ is true.

If a cable is protected by a **H.R.C. fuse** the cable must be de-rated by a factor of 0.9. The statement $I_2 \leq 1.45 \times I_Z$ will always be true if;

$$I_B \leq I_N \leq I_Z \times 0.9$$

Activity 3 – Overload condition

1. Calculate the Line current (I_L) for the circuit shown in figure 3.	
2. Calculate the multiple of the C32A C.B. rating.	
3. Is $I_B \leq I_N \leq I_Z$	Y / N
4. Draw on figure 5 a line to show the multiple of rated current. Will the circuit breaker operate (trip), if so in what time? Y / N	Max _______ Min _______

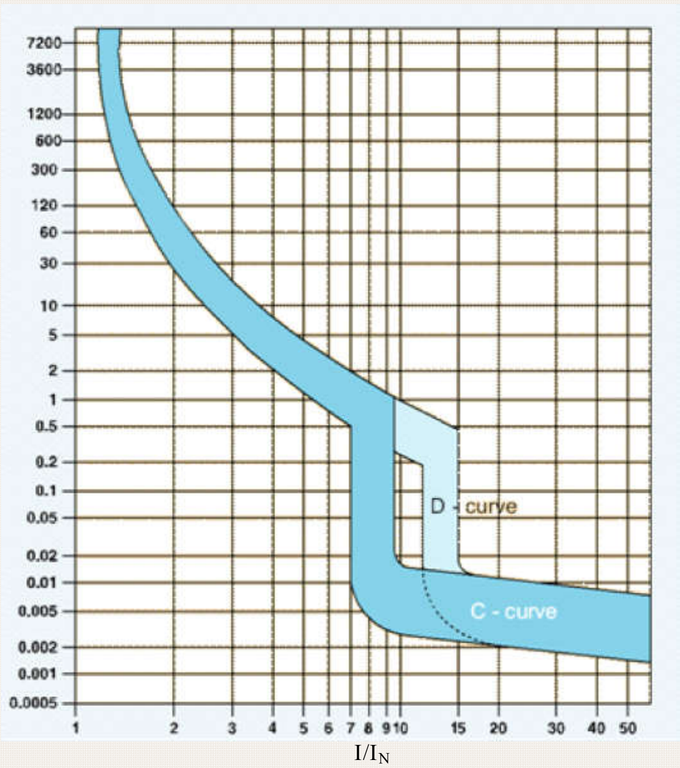


figure 5. – www.clipsal.com

Activity 4 – Over load protection

Read the suggested text or resource

Where possible, complete the following table using minimum possible current ratings.

Use AS 3000 Tables 8.1, 8.2 or B1 as a guide to preferred protection device ratings.

Write a response

	Type	Load Max Demand **I_B**	Circuit Protection Rating **I_N**	Minimum Cable Current Rating **I_Z**	De-rating factor	Cable Current Rating after D.R.	$I_B \le I_N \le I_Z$ **Y / N**	$I_2 \le 1.45$ x I_Z **Y / N**
1	C.B.	20A	20A	20A				
2	H.R.C. Fuse	20A	20A	20A				

Activity 4 – Over load protection (con't)

	Type	Load Max Demand **I_B**	Circuit Protection Rating **I_N**	Minimum Cable Current Rating **I_Z**	De-rating factor	Cable Current Rating after D.R.	$I_B \leq I_N \leq I_Z$ **Y / N**	$I_2 \leq 1.45 \times I_Z$ **Y / N**
3	H.R.C. Fuse	20A	20A	25A				
4	H.R.C. Fuse	30A		36A				
5	C.B.	90A		113A				
6	C.B.	150A				160A		

Activity 4 – Over load protection (con't)

	Type	Load Max Demand I_B	Circuit Protection Rating I_N	Minimum Cable Current Rating I_Z	De-rating factor	Cable Current Rating after D.R.	$I_B \leq I_N \leq I_Z$ **Y / N**	$I_2 \leq 1.45 \times I_Z$ **Y / N**
7	C.B.	250A				250A		
8	H.R.C. Fuse	250A	250A			250A		
9	C.B.	375A	400A					
10	H.R.C. Fuse	375A	400A					

Topic 2 - Short Circuit Hazards

Short Circuit condition

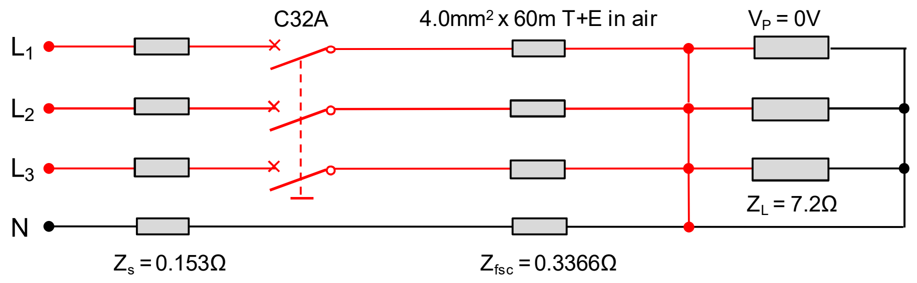


figure 6

Figure 6 shows a circuit condition known as a bolted symmetrical fault. The impedance of the fault is considered to be negligible. The only impedance remaining to limit the circuit current is the impedance of the cable. Interestingly the fault forms a star point on the supply side of the load, the cable impedances form a balanced star connected circuit. As the circuit is balanced no current will flow in the neutral, **the neutral conductor impedance is not included** when calculating the short circuit current.

The circuit protection device either circuit breaker or H.R.C. fuse must be capable of breaking this prospective short circuit current without damage to either the cables or the protection device itself.

Effects of Prospective Short Circuit Current

An un-interrupted prospective short circuit current will result in catastrophic failure and destruction of the installation, usually resulting in fire. Hazards associated with short circuit conditions include:

- extremely large currents
- cables reaching very high temperatures
- insulation failure
- destruction of protection devices
- ionisation of enclosures
- severe magnetic stresses on conductors and supports
- fatal injury to persons and livestock
- fire and explosion (Arc blasts).

Activity 5 – Short circuit condition

1. Calculate the Line current (I_L) for the circuit shown in figure 6.	
2. Calculate the multiple of the C32A C.B. rating.	
3. Is $I_B \leq I_N \leq I_Z$	Y / N
4. Draw on figure 7 a line to show the multiple of rated current. Will the circuit breaker operate (trip), if so in what time? Y / N	Max _______ Min _______

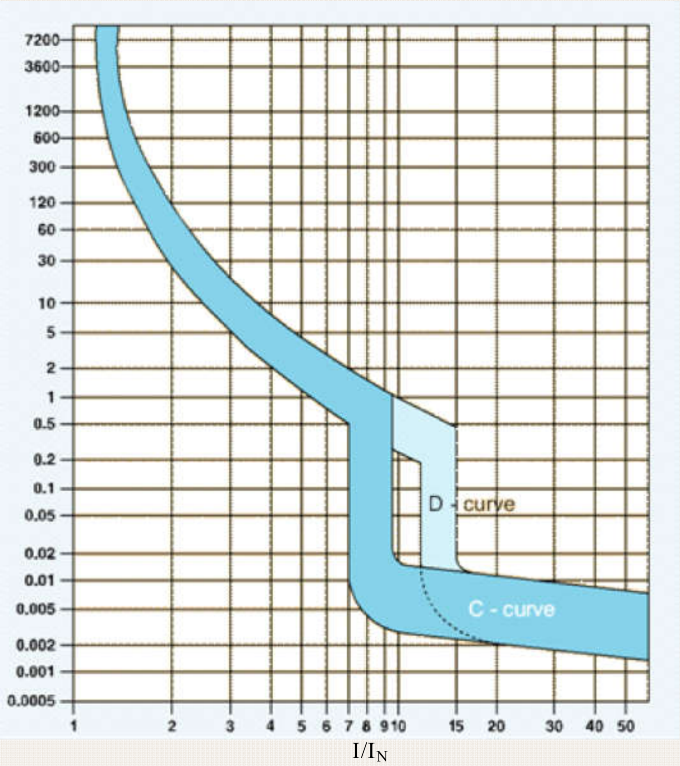


figure 7. – www.clipsal.com

Calculation of Prospective Short Circuit Current

The supply authority will give you information required to calculate the prospective short circuit current at the point of supply (their end of your consumer's mains). This information will either be:-

- as a prospective short circuit current, in kA or
- as an impedance per phase, in ohms or
- as a fault level, in MVA (mega volt amperes) or
- as an impedance percent (Z%), (similar to voltage regulation percent in a transformer) normally at the secondary of a transformer where the installation in fed from its own substation.

Activity - 6 – N.S.W. Service rules requirements

Read N.S.W.S.R. clause 1.10.4 Read the suggested text or resource	Write a response
1. List the nominal prospective short circuit current at the point of supply for services up to 400A in the following locations.	
a) Suburban residential areas	
b) Commercial and industrial areas	
c) Installations on railway land supplied by RailCorp	

Alert

Service and Installation Rules of New South Wales October 2009 Section 1.10.4 gives guidance on prospective short circuit current values at various locations. Refer to figures 1.1 to 1.2. for definition of point of supply.

Once the prospective short circuit current is known ohms law is used to calculate the impedance per phase of the supply;

$$Z_p = \frac{V_p}{I_p}$$

where

Z_p = the phase impedance in ohms (Ω)

V_p = the phase voltage in volts (V)

I_p = the phase current in amperes (A)

Activity - 7 – Supply impedance

1. Calculate nominal impedance per phase of the supply system at the point of supply for services up to 400A in the following locations.

a) Suburban residential areas	
b) Commercial and industrial areas	
c) Installations on railway land supplied by RailCorp	

Fault levels are effectively the apparent power supplied to the circuit under short circuit conditions. Recall the equation for Apparent power (S).

$$S = \sqrt{3} \times V_L \times I_L$$

where

S = the Apparent power in Volt Amps (VA)

V_L = the line voltage in volts (V)

I_L = the line current in amperes (A)

The equation above is used to calculate apparent power supplied by devices such as alternators and transformers. It can be transposed to find the line current supplied by such devices under normal operating conditions. The Apparent power output of supply authority transformers in usually given in kVA.

$$I_L = \frac{S}{\sqrt{3} \times V_L}$$

Activity 8 – Line current under normal conditions

1. Calculate maximum rated line current (I_L) for a 500kVA 400V supply authority distribution transformer.	Write a response

The same equation is used to express prospective short circuit values as VA rather than amperes. As the line current is extremely high in short circuit faults the fault level is also extremely high and usually specified in MVA rather than kVA.

$$I_{SC} = \frac{MVA \times 10^6}{\sqrt{3} \times V_L}$$

where

MVA = the Fault Level (Apparent power) in Mega Volt Amps (MVA)

V_L = the line voltage in volts (V)

$I_{S/C}$ = the prospective short circuit current (line current) in amperes (A)

Activity 9 – Prospective short circuit current

1. Calculate the prospective short circuit current for a 500kVA 400V supply authority distribution transformer with a fault level of 10MVA.	Write a response

Supply Authority transformers have a percentage impedance rating. To determine the percentage impedance the primary winding is short circuited and the secondary winding is connected to a variable supply. The voltage on the variable supply is increased from zero volts until the current in the primary reaches the maximum rated current for normal operation. The voltage on the secondary is recorded and converted to a percentage of the secondary nominal voltage. What has been found is what percentage of the nominal supply is required to cause the nominal full load current to flow under short circuit conditions. It can now be predicted what current will flow under short circuit conditions if the full nominal supply voltage was connected. This method is much safer and less destructive that shorting the secondary terminals of a 400 kVA transformer and trying to measure a real short circuit current.

The prospective short circuit current can be calculated using the equation:

$$I_{SC} = \frac{100 \text{ x kVA} \times 10^3}{Z\% \times \sqrt{3} \times V_L}$$

where

$I_{S/C}$ = the prospective short circuit current (line current) in amperes (A)

kVA = the maximum rated output (Apparent) power in kilo Volt Amps (kVA)

V_L = the line voltage in volts (V)

Activity 10 – Prospective short circuit current

1. Calculate the prospective short circuit current for a 500kVA 400V supply authority distribution transformer with percentage impedance of 5%.	Write a response

Whatever form the information comes in, it must be converted to an impedance per phase value at the point of supply (Z_S).

Once the impedances of each part of the supply system are known the prospective fault current may be calculated:-

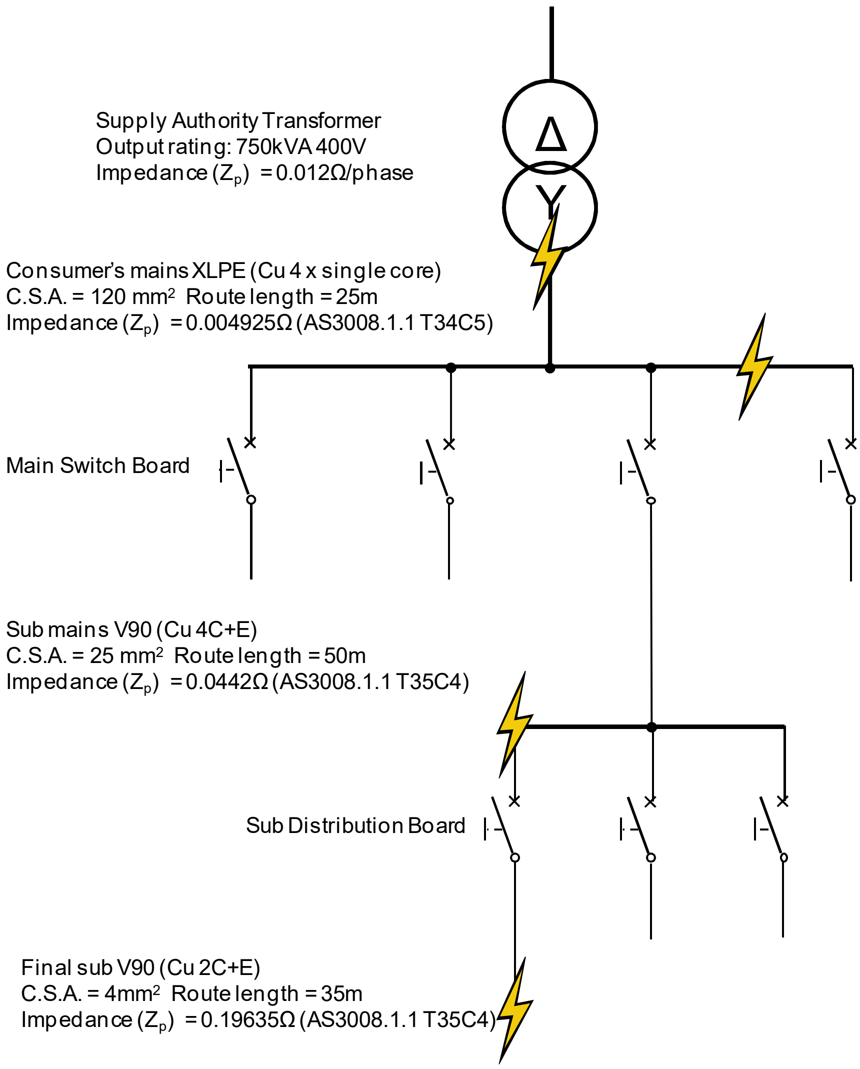


figure 8

Figure 8 show 4 short circuit faults at various locations in an industrial installation

Prospective short circuit current at transformer

$$I_{SC} = \frac{V_P}{Z_P} \qquad = \frac{230}{0.012} \qquad = 19166.6A$$

= 19.166kA

Prospective short circuit current at Main Switch Board

$$I_{SC} = \frac{V_P}{Z_P} \qquad = \frac{230}{0.012 + 0.004925}$$

$$= 13589.3A$$

= 13.589kA

Prospective short circuit current at sub distribution board

$$I_{SC} = \frac{V_P}{Z_P} = \frac{230}{0.012 + 0.004925 + 0.0442}$$

$$= 5196.6A$$

= 5.196kA

Prospective short circuit current at the end of the final sub-circuit.

$$I_{SC} = \frac{V_P}{Z_P} = \frac{230}{0.012 + 0.004925 + 0.0442 + 0.19635}$$

= 893A

The worked example above shows how as the prospective short circuit (P.S.C.) decreases as the location at which the fault occurs moves away from the supply transformer. The greater the distance from the supply transformer, the higher the impedance of the cable and the lower the prospective short circuit current that can flow at that location.

When selecting short circuit protection devices, the devices breaking capacity or "kA" rating, must be higher than the prospective short circuit current; otherwise the device may not be able to interrupt the fault or may be damaged in the process.

Figure 9 shows the result of selecting a protection device with a breaking capacity lower than the prospective short circuit current.

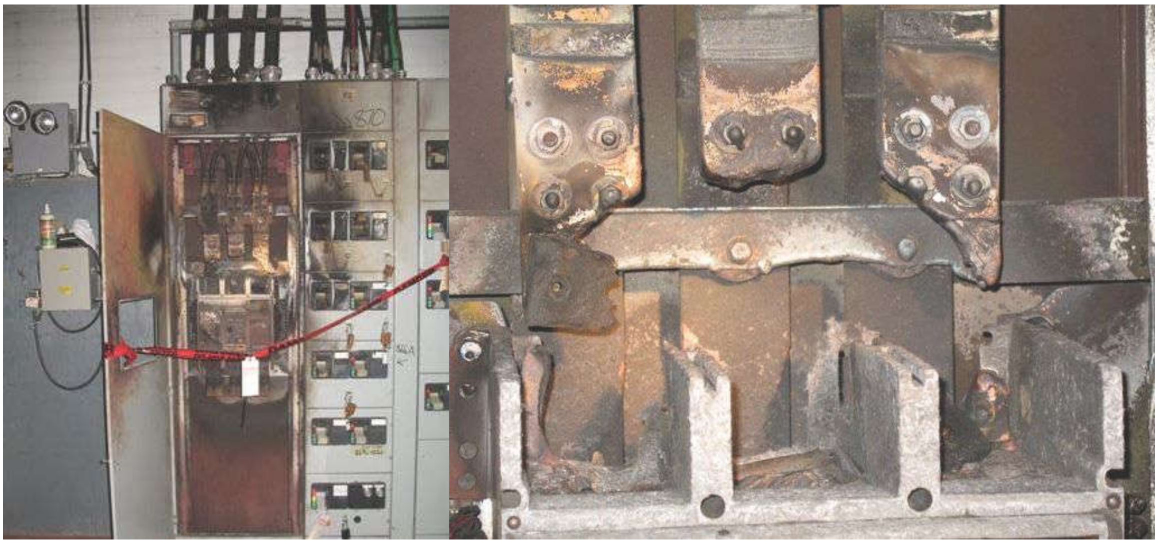


figure 9. - www.eleventrading.com.au

Topic 3 - Selecting Short Circuit Protection Devices

In practice the NSWSR requires prospective fault current rating of circuit at least;

- **25kA –** Industrial / Commercial installations
- **10kA** – Domestic / Residential installations
- **6kA –** Railcorp supplied installations at the point of supply.

It is possible that any time, the supply transformer may be upgraded. If the installation is only designed to withstand the prospective short circuit current supplied by the smaller supply transformer the installation would also require an upgrade. The values stated above are the minimum starting point for selecting protection devices and the cables they protect. Refer to Section 1, figure 1 N.S.W.S.R. – point of supply.

Activity 11 – Selection of device

1. Calculate the impedance of the supply at the point of supply shown in figure 10.

Write a response

2. Calculate the impedance of the active conductor of the consumers mains in figure 10 using table 35 of AS3008.1.1 (use 90^{0}C temperature)

3. Calculate the prospective fault current at the Service protection device.

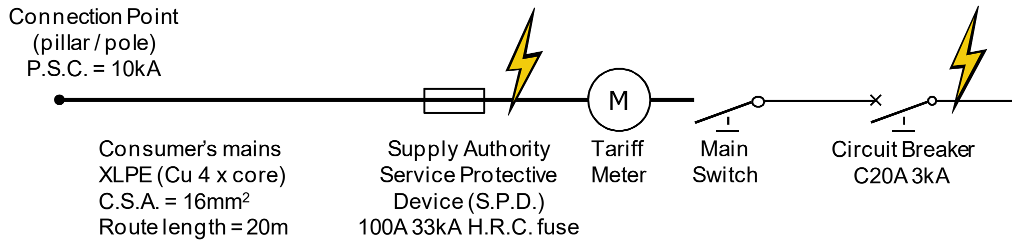


figure 10.

The P.S.C. determined in activity 11 is not the worst case example. Had the cable been unloaded, the cable would be at lower operating temperature than 75^{0}C, say an ambient temperature of 20^{0}C, the cable impedance would have been approximately 80% of the stated value. This in turn would have resulted in a larger P.S.C. To maintain consistency with **HB-301 "Designing to the Australian wiring rules"** (Appendix A and B) the initial cable temperature is assumed to be the cables maximum "Normal use" operating temperature.

Fault Current Limiters

A Fault Current Limiter (F.C.L.) is a device which limits the prospective fault current when a fault occurs. A suitably rated H.R.C. fuse or fault current limiting circuit breaker is placed "upstream" in series with protection devices which have a lower fault current breaking capacity than the F.C.L. This allows the downstream protection devices to be physically smaller and cheaper.

The fault current limiter protects the downstream protection devices by operating before the fault current rises above a value that may damage the downstream device. The fault current that flows until the F.C.L. operates is known as "let through", this is shown in figure 11. The downstream devices must be capable of interrupting the let through current of the upstream device.

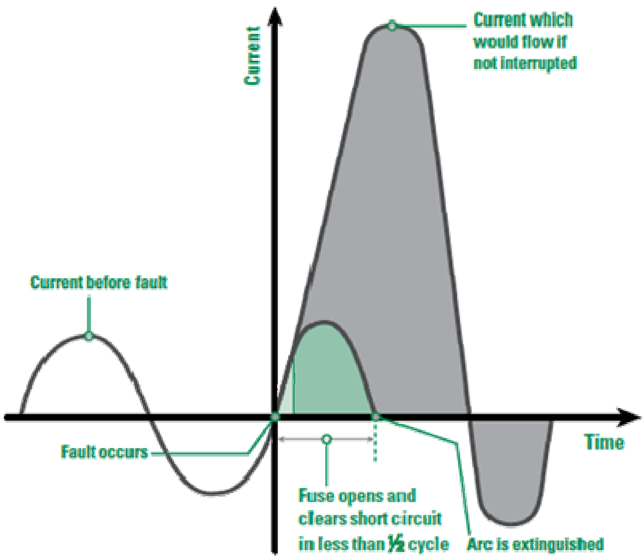


figure 11. - www.littelfuse.com

This is known as co-ordination or Back up protection. Figure 12 shows how the 100A Service protective device (service fuse) is co-ordinated with the 20A 3kA circuit breaker to limit the current the circuit breaker is exposed to approximately 2.5kA, lower than its breaking capacity rating.

In a domestic installation the Service Protective Device (S.P.D.), typically a 100A H.R.C. fuse with a breaking capacity of between 50 to 33kA is also used as a fault current limiter. The 100A nominal current rating is large enough to cover the maximum demand of most domestic installations. In figure 10 a 20A 3kA circuit breaker is located in a main switch board, which, from exercise 11 was found to have P.S.C. of 4.5kA. If a short circuit occurs in the final sub circuit, close to the main switch board a high fault current will flow in the final sub-circuit. The service protective device (S.P.D.) will operate before the 20A 3kA circuit breaker limiting the let through current to just 1.8kA, a value that will not cause damage to the downstream circuit breaker. When the S.P.D. operates supply to the entire installation will be lost.

Most faults occur away from the Main Switch Board. The increased distance from the main board decreases the fault current to a point where the lower current rated circuit breaker operates first. The fault is disconnected without loss of supply to the entire installation. This is known as "Selectivity" (Discrimination).

Fault current limiters are not expected to operate under overload conditions.

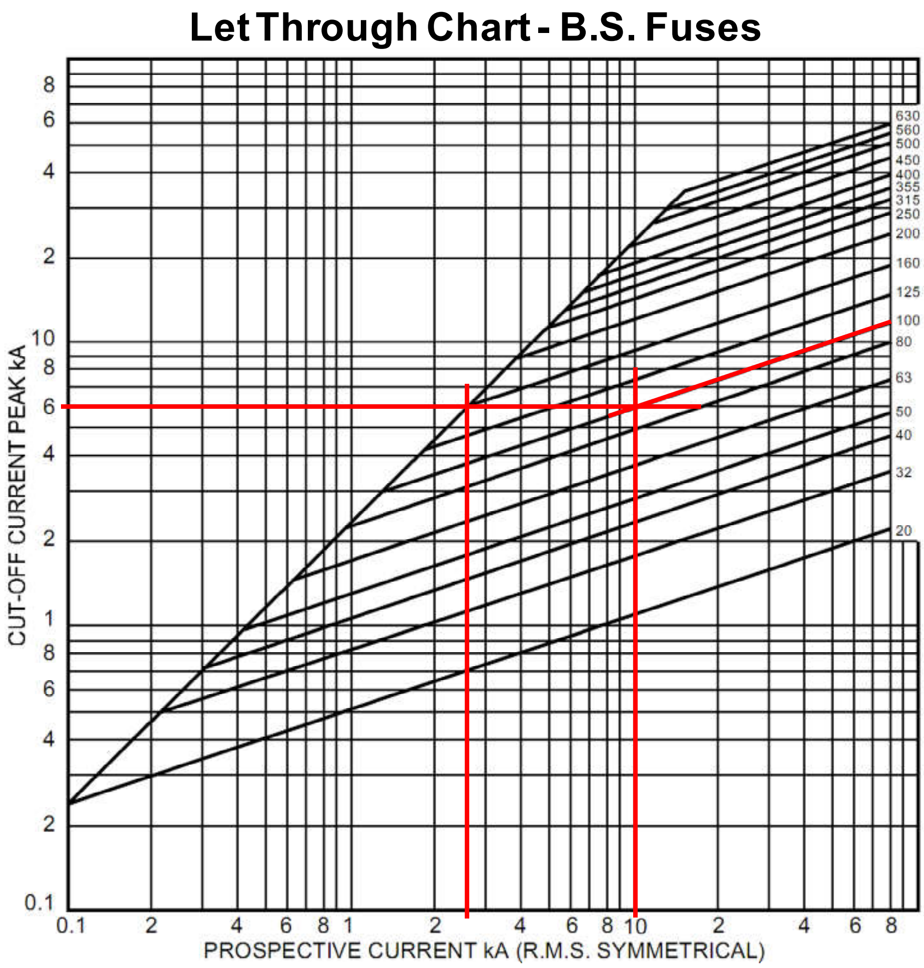


figure 12. - N.H.P. Fuse characteristics

Activity 12 – Selection of devices

Read the suggested text or resource	Use figure 12 to determine;	Write a response
1. The minimum breaking capacity of a M.C.B protected against a 10kA P.S.C. by a 160A H.R.C. fuse		
2. The minimum breaking capacity of a M.C.B protected against a 25kA P.S.C. by a 160A H.R.C. fuse		

Protective device manufacturers provide coordination tables and these demonstrate the combination of protective devices which may be connected in series to ensure that the short circuit ratings are achieved. Protection devices used should all be from the same manufacture. If different brands of protection devices are used the individual characteristic curves of the upstream and downstream devices must be compared to ensure effective protection

FUSE BACK-UP PROTECTION

Fuse fault current limiters for Power Range Circuit Breakers for fault levels up to 50kA at 415V.

Type C-Curve	Rating	Maximum Fuse Amps. BS 88 GEC Type T	MEM	DIN GEC NHG	Siemens 3 NAZ
4CBxxx/6 4CBxxx/10	1A to 50A	200	200	200	200
4CBxxx/25	20A to 63A	400	400	400	400
4CBxxx/20	80A to 100A	315	315	315	355
4CBxxx/15	125A	200	200	200	200

figure 13. -www.clipsal.com

Cascading (Back-up)

As well as using H.R.C. fuses, Circuit breakers which are rated as fault current limiters are also used to protect against prospective short circuit current. The nominal current ratings (I_N) of both the upstream and downstream devices must be carefully considered.

Cascading is achieved by using an upstream device to assist (back-up) a downstream device in clearing a fault current that happens to be greater than the breaking capacity of the downstream device.

In Cascading applications, the upstream device may have to trip (unlatch) in order to give sufficient protection to the downstream device, thus interrupting supply of power to all devices downstream. Therefore, cascading is generally used in applications involving the supply of non-essential loads, such as basic lighting. The main benefit of cascading is that circuit breakers with breaking capacities lower than the prospective fault level, can be safely used downstream provided it is backed-up by the relevant upstream breaker. This results in reducing the cost o the installation

Selectivity

Also known as "Discrimination", the most basic form of Selectivity is where two circuit breakers are connected in series. A higher amperage breaker is installed upstream, and a lower amperage breaker downstream. Should an overload or short circuit occur downstream, the downstream breaker will trip, but the upstream breaker will not, hence feeding parts of the system which are fault-free. This is the concept of Selectivity.

Selectivity is generally used, for example in critical applications, feeding essential loads. It is important to ensure total installation power is not lost due to a small or minor fault in a sub part of the overall electrical system, for example in a local distribution board. Total power loss could affect vital systems such as in Hospitals or Computer Centre's etc.

The principle of Selectivity (Discrimination) is based upon an analysis of several types of circuit breaker characteristics. These include tripping characteristics (time-current curves), Peak Let Through Current (I_{peak}) and Energy Let Through (I^2T).

Selectivity can be "enhanced" beyond the breaking capacity of the downstream device provided it is backed up by an appropriately selected upstream device, which should not trip (unlatch) under stated conditions.

Figure 14 shows how selectivity of circuit breakers can be achieved using manufactures tables.

POWER RANGE MCB SELECTIVITY

The following tables are provided as a guide for selection of Circuit Breakers fo Thermal Overload Selectivity.

They are based on manufacturers' time/current curves at their nominated temperature ratings.

If the level of cross over current is required, contact your Clipsal Representativ

Upline Protection: Power Range 6 & 10kA MCBs

Downline Protection	Current Rating (A)	1	2	4	6	8	10	12	16	20	25	32	40	50	63
Power Range 6 & 10kA MCBs	1	×	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	2	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	4	×	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	6	×	×	×	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes
	8	×	×	×	×	×	×	×	yes	yes	yes	yes	yes	yes	yes
	10	×	×	×	×	×	×	×	×	yes	yes	yes	yes	yes	yes
	12	×	×	×	×	×	×	×	×	×	yes	yes	yes	yes	yes
	16	×	×	×	×	×	×	×	×	×	×	yes	yes	yes	yes
	20	×	×	×	×	×	×	×	×	×	×	×	yes	yes	yes
	25	×	×	×	×	×	×	×	×	×	×	×	×	yes	yes
	32	×	×	×	×	×	×	×	×	×	×	×	×	×	yes
	40	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	50	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	63	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Power Range 15/20/25 MCBs	20	×	×	×	×	×	×	×	×	×	×	×	×	yes	yes
	25	×	×	×	×	×	×	×	×	×	×	×	×	×	yes
	32	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	40	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	50	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	63	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	80	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	100	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	125	×	×	×	×	×	×	×	×	×	×	×	×	×	×

Upline Protection: Power Range 15/20/25 MCBs

Downline Protection	Current Rating (A)	20	25	32	40	50	63	80	100	125
Power Range 6 & 10kA MCBs	1	yes	yes	yes	yes	yes	yes	yes	yes	yes
	2	yes	yes	yes	yes	yes	yes	yes	yes	yes
	4	yes	yes	yes	yes	yes	yes	yes	yes	yes
	6	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8	yes	yes	yes	yes	yes	yes	yes	yes	yes
	10	yes	yes	yes	yes	yes	yes	yes	yes	yes
	12	yes	yes	yes	yes	yes	yes	yes	yes	yes
	16	×	×	yes	yes	yes	yes	yes	yes	yes
	20	×	×	×	yes	yes	yes	yes	yes	yes
	25	×	×	×	×	yes	yes	yes	yes	yes
	32	×	×	×	×	×	yes	yes	yes	yes
	40	×	×	×	×	×	×	yes	yes	yes
	50	×	×	×	×	×	×	×	yes	yes
	63	×	×	×	×	×	×	×	×	yes
Power Range 15/20/25 MCBs	20	×	×	×	yes	yes	yes	yes	yes	yes
	25	×	×	×	×	yes	yes	yes	yes	yes
	32	×	×	×	×	×	yes	yes	yes	yes
	40	×	×	×	×	×	×	yes	yes	yes
	50	×	×	×	×	×	×	×	yes	yes
	63	×	×	×	×	×	×	×	×	yes
	80	×	×	×	×	×	×	×	×	×
	100	×	×	×	×	×	×	×	×	×
	125	×	×	×	×	×	×	×	×	×

Upline Protection: 8R 125A Frame Size MCCBs

Downline Protection	Current Rating (A)	8R3125/16	8R3125/25	8R3125/40	8R3125/63C	8R3125/80	8R3125/100	8R3125/125
Power Range 6 & 10kA MCBs	1	yes	yes	yes	yes	yes	yes	yes
	2	yes	yes	yes	yes	yes	yes	yes
	4	yes	yes	yes	yes	yes	yes	yes
	6	yes	yes	yes	yes	yes	yes	yes
	8	yes	yes	yes	yes	yes	yes	yes
	10	yes	yes	yes	yes	yes	yes	yes
	12	yes	yes	yes	yes	yes	yes	yes
	16	×	yes	yes	yes	yes	yes	yes
	20	×	×	yes	yes	yes	yes	yes
	25	×	×	yes	yes	yes	yes	yes
	32	×	×	×	yes	yes	yes	yes
	40	×	×	×	yes	yes	yes	yes
	50	×	×	×	×	yes	yes	yes
	63	×	×	×	×	×	×	yes
Power Range 15/20/25 MCBs	20	×	×	yes	yes	yes	yes	yes
	25	×	×	×	yes	yes	yes	yes
	32	×	×	×	yes	yes	yes	yes
	40	×	×	×	×	yes	yes	yes
	50	×	×	×	×	×	yes	yes
	63	×	×	×	×	×	×	yes
	80	×	×	×	×	×	×	×
	100	×	×	×	×	×	×	×
	125	×	×	×	×	×	×	×

Upline Protection: 8R 160A Frame Size MCCBs

Downline Protection	Current Rating (A)	8R3160/25 MIN SET	8R3160/25 MAX SET	8R3160/40 MIN SET	8R3160/40 MAX SET	8R3160/63 MIN SET	8R3160/63 MAX SET	8R3160/100 MIN SET	8R3160/100 MAX SET	8R3160/125 MIN SET	8R3160/125 MAX SET	8R3160/160 MIN SET	8R3160/160 MAX SET
Power Range 6 & 10kA MCBs	1	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	2	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	4	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	6	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	10	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	12	×	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	16	×	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	20	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes
	25	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes
	32	×	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes
	40	×	×	×	×	×	yes	yes	yes	yes	yes	yes	yes
	50	×	×	×	×	×	×	yes	yes	yes	yes	yes	yes
	63	×	×	×	×	×	×	×	yes	×	yes	yes	yes
Power Range 15/20/25 MCBs	20	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes
	25	×	×	×	yes	yes	yes	yes	yes	yes	yes	yes	yes
	32	×	×	×	×	×	yes	yes	yes	yes	yes	yes	yes
	40	×	×	×	×	×	yes	yes	yes	yes	yes	yes	yes
	50	×	×	×	×	×	×	×	yes	yes	yes	yes	yes
	63	×	×	×	×	×	×	×	yes	×	yes	yes	yes
	80	×	×	×	×	×	×	×	×	×	yes	×	yes
	100	×	×	×	×	×	×	×	×	×	×	×	yes
	125	×	×	×	×	×	×	×	×	×	×	×	×

Upline Protection	Current Rating (A)	Downline Protection: Power Range 15/20/25 MCBs									Power Range 6 & 10kA MCBs													
		125	100	80	63	50	40	32	25	20	63	50	40	32	25	20	16	12	10	8	6	4	2	1
8R 250A Frame Size MCCBs	8R3250/40 MIN SET	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/40 MAX SET	x	x	x	x	x	x	x	yes	yes	x	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/63 MIN SET	x	x	x	x	x	x	x	yes	yes	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/63 MAX SET	x	x	x	x	x	yes	yes	yes	yes	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/100 MIN SET	x	x	x	x	x	yes	yes	yes	yes	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/100 MAX SET	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/125 MIN SET	x	x	x	x	yes	yes	yes	yes	yes	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/125 MAX SET	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/160 MIN SET	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/160 MAX SET	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/200 MIN SET	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/200 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/250 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3250/250 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
8R 400A Frame Size MCCBs	8R3400/160 MIN SET	x	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/160 MAX SET	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/200 MIN SET	x	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/200 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/250 MIN SET	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/250 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/320 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/320 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/400 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3400/400 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
8R 630A Frame Size MCCBs	8R3630/250 MIN SET	x	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/250 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/320 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/320 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/400 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/400 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/500 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/500 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/630 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3630/630 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
8R 800A Frame size MCCBs	8R3800/500 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3800/500 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3800/630 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3800/630 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3800/800 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R3800/800 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
8R 1250A Frame size MCCBs	8R31250/500 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/500 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/630 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/630 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/800 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/800 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/1000 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/1000 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/1250 MIN SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	8R31250/1250 MAX SET	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

figure 14 - www.clipsal.com

I^2t Charts / Curves

The calculation of this current let through the circuit protection device is commonly referred to as the I^2t formula (current let through by the circuit protection device, squared multiplied by the time in seconds for which the current flows)

Clause 2.5.4.5 of AS3000 states that the energy let through by the circuit protection device must be less than the heat energy required by the cable to raise its insulation temperature to values set by AS3008.1.1 clause 5.5.2. (Table 53).

- 160^0C for V75 and V90 insulated cables.
- 250^0C for XLPE (X90) insulated cables.

To simplify the equations a series of constants have been assigned to commonly used cable insulation types in table 52 of AS3008.1.1

- 111 - to raise the insulation from a maximum normal use temperature of 75^0C to 160^0C (V75 and V90).
- 143 - to raise the insulation from a maximum normal use temperature of 90^0C to 250^0C (X90).

The time required for the short circuit current to heat the cable to cause the insulation to rise from maximum normal use temperature to the maximum permissible is calculated by the equation;

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

where

t = time duration in seconds

K = the constant value obtained from standards (111 for copper V90)

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

I^2 = the short-circuit current in amps (r.m.s)

The circuit protection device must operate is less time than calculated above. The heat energy that will be applied to the cable will be limited to an amount that will not cause the insulation temperature to rise above the limits set by AS3008.1.1. Figure 15 shows let through energy of Clipsal circuit breakers.

Activity 13 - AS3000 requirements - Protection against short circuit current

Read AS 3000 clause 2.5.4.5 	
Calculate the time required for the short circuit current to heat the cable to cause the insulation to rise from maximum normal use temperature to the maximum permissible for the following copper cables.	
1. 1.5 mm^2 V75 I_{SC} = 1.5kA	
2. 2.5 mm^2 V90 I_{SC} = 1.5kA	
3. 16 mm^2 X90 I_{SC} = 8kA	
4. 120 mm^2 X90 I_{SC} = 35kA	

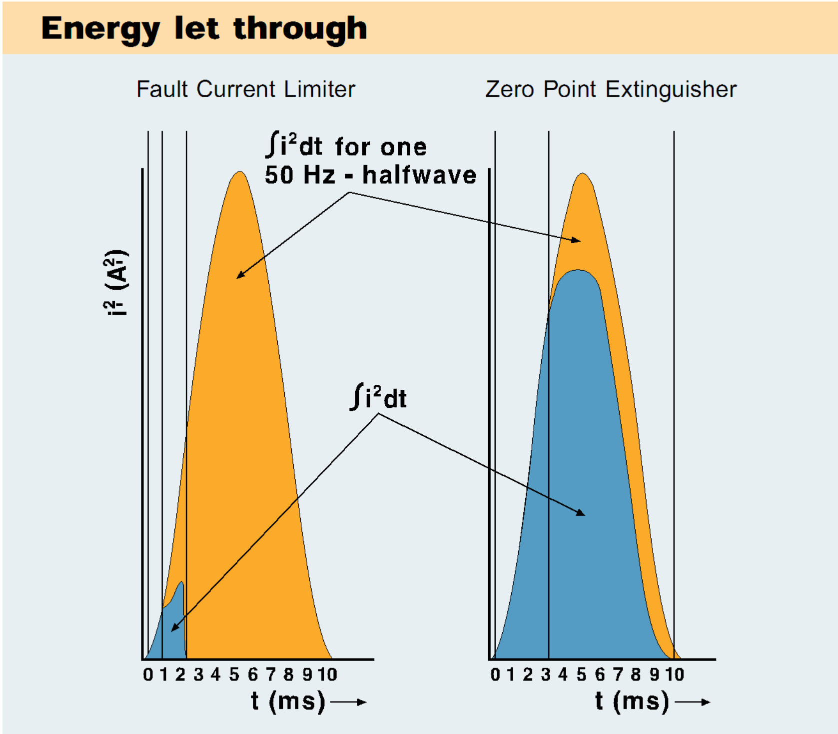


figure 15 - www.clipsal.com

Topic 4 - Protection against indirect contact

Earth fault condition

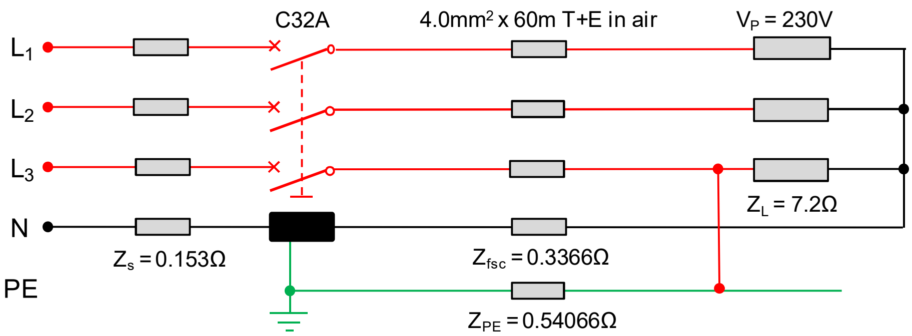


figure 16.

Figure 16 shows an earth fault. The current path flows from the active conductors to the fault, returning via the protective earthing conductors to the M.E.N. connection, then along the neutral conductors to the supply. The circuit is no longer balanced, so the impedances of the serial connected neutral and protective earth conductors must be included (earth fault loop impedance).

The resulting current flow will be much lower than that of a short circuit in the same cable. The lower current flow will increase the time the circuit protection device takes to operate. During the time the circuit protection takes to operate a touch voltage will be present between the earth electrode and the exposed conductive parts connected to that protective earthing conductor. Section 8 of this book covers the effects of earth fault loop impedance.

Activity 14 – Earth fault condition

1. Calculate the Line current (I_L) for the circuit shown in figure 16.	
2. Calculate the multiple of the C32A C.B. rating.	
3. Is $I_B \leq I_N \leq I_Z$	Y / N
3. Draw on figure 17 a line to show the multiple of rated current. Will the circuit breaker operate (trip), if so in what time? Y / N	Max _______ Min _______

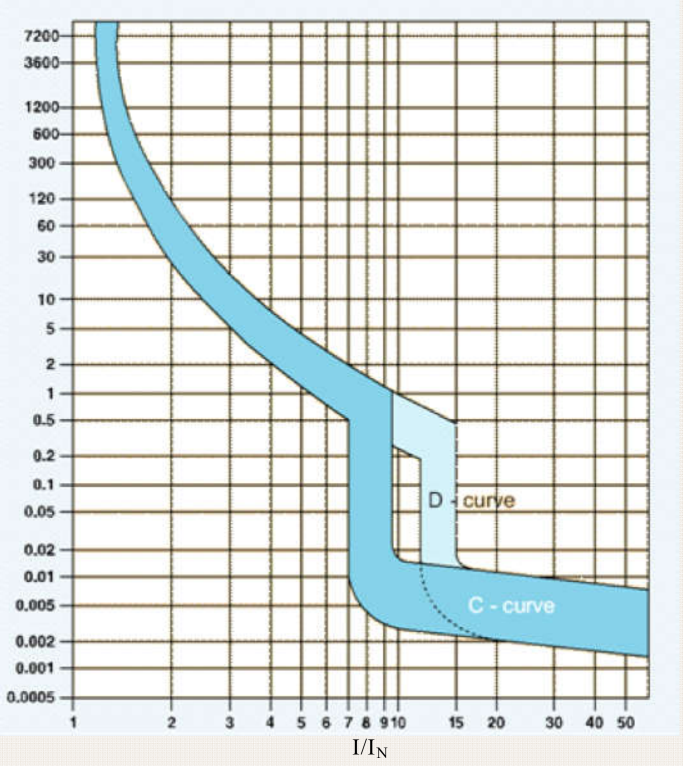


figure 17. – www.clipsal.com

Topic 5 - AS3000 requirements

Activity 15 - AS3000 requirements - Fault Protection

Read AS 3000 clause 2.4.1 Read the suggested text or resource	Write a response
1. List 3 recognized methods of fault methods of fault protection. Group discussion	a) ____________________ b) ____________________ c)____________________

Activity 16 - AS3000 requirements - Fault Protection

Read AS 3000 clause 2.4.2 Read the suggested text or resource	Write a response
1. How is protection by automatic disconnection of supply achieved? Group discussion	a) ____________________ b) ____________________ c) ____________________ d) ____________________

Activity 17 - AS3000 requirements - Fault Protection

Read AS 3000 clause 2.4.3

Read the suggested text or resource

Write a response

1. May a device that is capable of automatic reclosing be used as a device to provide automatic disconnection of supply?	Y / N
2. List 5 devices suitable to provide automatic disconnection of supply. Group discussion	a) ____________________ b) ____________________ c) ____________________ d) ____________________ e) ____________________

Activity 18 - AS3000 requirements - Protection against over current (over load)

Read AS 3000 clause 2.5.1

Read the suggested text or resource

Write a response

1. May a H.R.C. fuse be placed in a neutral conductor to protect against overload?	Y / N
2. Under what conditions may a circuit breaker be placed in a neutral conductor to protect against overload?	____________________ ____________________ ____________________

Activity 19 - AS3000 requirements - Unprotected consumer's mains

Read AS 3000 clause 2.5.1.1 Read the suggested text or resource	Write a response
1. What is meant by unprotected consumer's mains?	________________________________ ________________________________ ________________________________

Activity 20 - AS3000 requirements - Unprotected consumer's mains (over load)

AS 3000 clause 2.5.1.1 (note 6) Read the suggested text or resource	Group discussion

Nearly all installations **do not** satisfy this requirement. The simple solution to provide overload protection of the consumer's mains is to upgrade the installations main isolation switch to a circuit breaker. Selection of main switches is covered in section 10.

Activity 21 - AS3000 requirements - Protection against over current (over load)

Read AS 3000 clause 2.5.1.2 Read the suggested text or resource	Write a response
1. At what point should over current devices be placed to protect sub-mains and final sub-circuits?	

Activity 22 - AS3000 requirements - Protection against over current (over load)

Read AS 3000 clause 2.5.2 Read the suggested text or resource	Group discussion

Activity 23 - AS3000 requirements - Protection against over current (over load)

Read AS 3000 clause 2.5.3.3 Read the suggested text or resource	Write a response
1. In a switchboard the section of cable between the main switch and each circuit protection device is not protected against overload. Why is this permitted?	____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

Activity 24 - AS3000 requirements - Protection against short circuit current

Read AS 3000 clause 2.5.4.1 Read the suggested text or resource	Write a response
1. List 2 methods of determining the prospective short circuit current in an installation?	

Activity 25 - AS3000 requirements - Protection against short circuit current

Read AS 3000 clause 2.5.4.4 Read the suggested text or resource	Write a response
1. Under what conditions may consumer's mains **not** be provided with short circuit protection?	

Tutorial - Section 9

1. The coordination between conductors and protective devices shall be satisfied by which of the following equations?

   (a) $I_N \leq I_B \leq I_2$

   (b) $I_N \leq I_B \leq I_Z$

   (c) $I_B \leq I_N \leq I_Z$

   (d) $I_N \leq I_Z \leq I_B$

2. Every conductor shall have a current-carrying capacity in accordance with the AS/NZS 3008.1 series. The current carrying capacity that must:

   (a) be lower than the maximum demand current for which the circuit is designed (I_B)

   (b) be equal to or greater than the circuit breaker nominal rating (I_N)

   (c) be less than the current to be carried by the conductor

   (d) be based on an ambient air temperature of 45°C

3. In NSW, the nominal prospective short circuit current at the point of supply for low voltage services up to 400 Amps in suburban **residential** areas is:

   (a) 6kA unless otherwise advised by the electricity distributor

   (b) 10kA unless otherwise advised by the electricity distributor

   (c) 25kA unless otherwise advised by the electricity distributor

   (d) 30kA unless otherwise advised by the electricity distributor

4. The maximum permissible cable insulation temperature under short circuit conditions for V75 cable insulation is:

   (a) 75^0C

   (b) 110^0C

   (c) 160^0C

   (d) 250^0C

5. The maximum permissible cable insulation temperature under short circuit conditions for X90 (XLPE) cable insulation is:

   (a) 75^0C

   (b) 110^0C

   (c) 160^0C

   (d) 250^0C

6. When a H.R.C fuse is used to protect downstream circuit breakers and cable with lower nominal current ratings, the H.R.C. fuse is being used as:
   (a) an isolator
   (b) overload protection
   (c) a fault current limiter
   (d) a sub-main protection device

7. Selectivity has the same meaning as:
   (a) back up protection
   (b) short circuit protection
   (c) cascading
   (d) discrimination

8. Cascading is:
   (a) a fault current limiting circuit breaker protects circuit breakers and cables with lower current ratings.
   (b) a fault current limiting fuse protects circuit breakers and cables with lower current ratings.
   (c) a thermal magnetic circuit breaker protects circuit breakers and cables with lower current ratings.
   (d) a fault current limiting circuit breaker protects circuit breakers and cables with higher current ratings.

9. Selectivity in circuit protection means:
   (a) only the protection device of the circuit under fault operates.
   (b) the service protection device operates.
   (c) the current multiplier on a adjustable circuit breaker is set to match the current rating of the cable.
   (d) all circuit protection devices operate at the same time to reduce the risk of fire.

10. A short circuit occurs in a final sub circuit with in a switch board, causing a large P.S.C., the device/s that should operate will be;
   (a) the F.S.C. circuit breaker
   (b) the fault current limiter
   (c) both the F.S.C. circuit breaker and the fault current limiter
   (d) neither.

11. Complete the table below

	Type	Load Max Demand I_B	Circuit Protection Rating I_N	Minimum Cable Current Rating I_Z	De-rating factor	Cable Current Rating after D.R.	$I_B \le I_N \le I_Z$ **Y / N**	$I_2 \le 1.45 \times I_Z$ **Y / N**
1	H.R.C. Fuse	100A	100A					
2	H.R.C. Fuse	180A		230A				
3	C.B.	60A			0.7 Grouping			
4	C.B.	35A	32A	30A				

12. List 4 effects of a short circuit current.

(a) ____

(b) ____

(c)____

(d) ____

13. Calculate maximum rated line current (I_L) for a 750kVA 400V supply authority distribution transformer.

12. ____

13. ____

14. ____

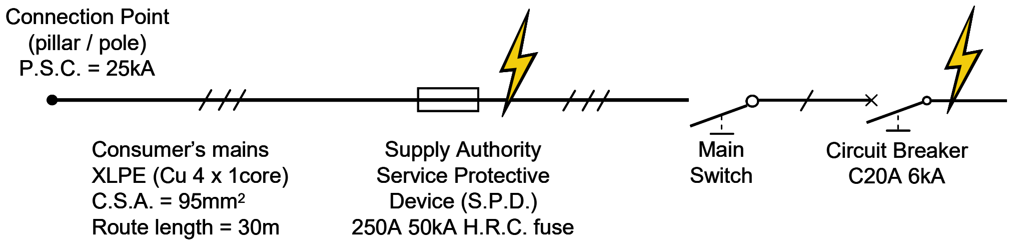
15. ____

16. ____

14. Calculate the prospective short circuit current for a 750kVA 400V supply authority distribution transformer with a fault level of 15MVA

15. Calculate the impedance of 750kVA 400V supply authority distribution transformer in question 14.

16. For figure 15, calculate the Prospective Short Circuit current at the Service protective device and the 20A circuit breaker, are the devices suitably rated? Hint refer to figure 13 of section 9.



17. figure 15.

Section 10 - Selecting devices for isolation and switching

Topics

- Requirements for provision of isolation
- Need for protection against mechanical movement
- Selecting devices

Aim

Learners will be able to determine and meet the requirements of AS3000 when selecting devices to provide isolation and switching.

Learning objectives

Learners should be able to meet the following learning objectives:

- Explain the requirements for the provision of the isolation of every circuit in an electrical installation.
- Explain the need for protection against mechanical movement of electrically activated equipment.
- Apply AS/NZS 3000 requirements for selecting devices for isolation and switching for a range of installations and conditions.

Topic 1 - Requirements for provision of isolation

Definition - 1.4.62 Isolation (isolating function)

Function intended to cut off the supply from the whole installation, or a discrete section of it, by separating it from every source of electrical energy for reasons of safety.

Activity 1 Control and isolation

Read AS 3000 clause 1.5.2 Read the suggested text or resource	Group discussion

Activity 2 Design of an electrical installation

Read AS 3000 clause 1.6.1(e) Read the suggested text or resource	Group discussion

Activity 3 Selection and installation

Read AS 3000 clause 2.1.2 Read the suggested text or resource	Group discussion

Activity 4 - Control of electrical installation

Read AS 3000 clause 2.3.1 Read the suggested text or resource	Group discussion

Activity 5 - Common requirements

Read AS 3000 clause 2.3.2.1 Read the suggested text or resource	Write a response
1. List 3 precautions which may be used to prevent electrical equipment from being inadvertently energized.	a) __________ b) __________ c) __________

Activity 6 - Common requirements

Read AS 3000 clause 2.3.2.1.1 Read the suggested text or resource	Write a response
1. In a 3 phase circuit how many active conductors are required to be switched by the isolation device?	
2. May an isolation device be placed in the neutral of a consumer's main or a P.E.N. conductor.	
3. What are the requirements for a isolation switch or C.B. installed in a neutral conductor?	
4. Is it permitted to place an isolation switch in a earthing conductor?	

Activity 7 - Common requirements

Read AS 3000 clause 2.3.2.1.2 	
1. In a d.c. circuit how many conductors are required to be switched by the isolation device?	
2. If one pole is connected to earth? If E.L.V. circuit?	

Activity 8 - Devices for isolation

Read AS 3000 clause 2.3.2.2.1 	
1. Is it permitted to semiconductor as an isolation device?	
2. What do the symbols "O" and "I" indicate?	
3. What current should the isolation device be able to interrupt?	

Main Switches

AS3000 rule 2.3.3 states that the purpose of Main (isolation) switches is to provide a means of disconnection of the electrical supply to the installation in the case of an emergency by emergency services personnel. Emergency services personnel would include:

- Fire services
- State Emergency services
- Local Supply Authorities

It is also logical that electricians would use Main switches to isolate supply for the purpose maintenance or repair.

The same rule also requires Main switches to be arranged so that supply can be cut to "general" parts of the installation while maintaining supply to **safety services** such as:

- Fire and smoke control equipment
- Evacuation equipment
- Lifts

Activity 9 - Safety services

Read AS 3000 clause 1.4.82 Read the suggested text or resource	Group discussion

Activity 10 - Main switches

Read AS 3000 clause 2.3.3.1 Read the suggested text or resource	Write a response
1. Where should main switches be located?	
2. What are the requirements for Main switches supplying safety services?	
3. How should Main switches be identified?	

Figure 1 shows the relationship between the tariff meter and the main switch.

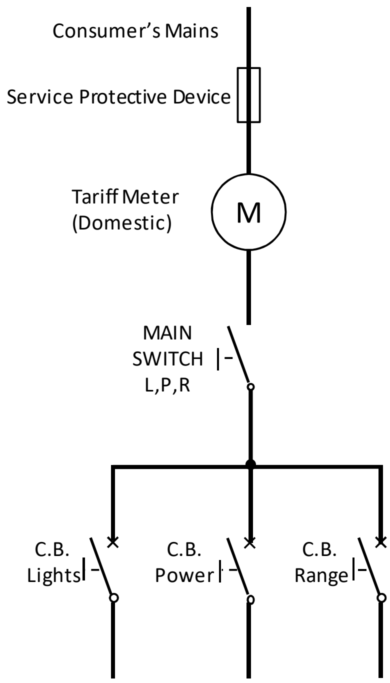


figure 1.

Figure 2 shows the relationship between general equipment, emergency services and the corresponding main switches.

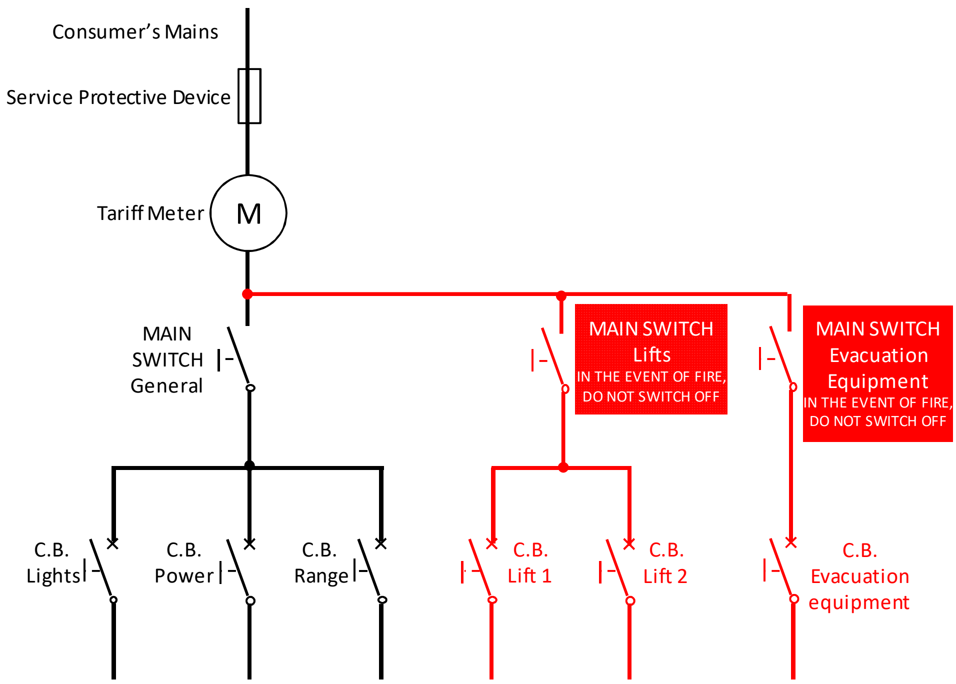


figure 2.

Activity 11 - Number of Main switches

Read AS 3000 clause 2.3.3.2 Read the suggested text or resource	Write a response
1. What is the maximum number of main switches per metered supplies in a domestic installation?	
2. How many main switches will be required if an installation has domestic and off peak 1 tariff meters?	

Activity 12 - Safety Services

See NSWSR page 4-19 fig 4.9 Read the suggested text or resource	Group discussion

Activity 13 - Location of Main switches

Read AS 3000 clause 2.3.3.3 Read the suggested text or resource	Write a response
1. What is the maximum permissible height above the ground floor or platform for a main switch?	
2. Why is it permitted to place the main switch for traffic lights on a pole?	
3. Is an isolation switch required within a unit of a multiple domestic, if the main switch board is normally locked?	

Activity 14 - Identification of Main switches

Read AS 3000 clause 2.3.3.4 Read the suggested text or resource	Write a response
1. Would the marking “M/S HWS” satisfy requirements?	
2. What are the requirements if there is more than one Main switch?	
3. What are the requirements if “back to grid solar panels” are installed?	

Safety Services

When fire or some other emergency occurs in a building emergency services must respond quickly and efficiently to prevent loss of life and/or injury. Main switches of buildings requiring safety services must arranged and identified to aid emergency services personnel to isolate only the general supply and leave safety services energised.

Activity 15 - Scope of Safety services

Read AS 3000 clause 7.2.1.1 Read the suggested text or resource	Write a response
1. What other names are safety services known as in previous standards or other codes?	

Activity 16 - Safety services main switches

Read AS 3000 clause 7.2.3.1 Read the suggested text or resource	Write a response
1. What must main switches that supply safety services be separate from?	

Activity 17 - Safety services - Main switches

Read AS 3000 clause 7.2.3.2 Read the suggested text or resource	Write a response
1. What is the maximum permitted number of main switches that supply safety services?	

Activity 18 - Safety services - Main switches arrangement

Read AS 3000 clause 7.2.4.1 Read the suggested text or resource	Write a response
1. Is it permitted to supply general electrical equipment from a main switch that controls safety services?	

Activity 19 Safety services - Main switches Identification

Read AS 3000 clause 7.2.6.2 Read the suggested text or resource	Write a response
1. List 3 identification requirements of main switches controlling safety services?	____ ____ ____ ____ ____

Isolation Switches

Some items require isolation for maintenance, repair or testing purposes. In these cases the load is isolated separately to reduce loss of supply and inconvenience.

Activity 20 - Additional isolating switches

Read AS 3000 clause 2.3.4.1 Read the suggested text or resource	Write a response
1. Is an isolation switch required in the switch board of a granny flat (outbuilding)?	
2. Is an isolation switch required in a distribution board of a factory within the same building?	

Activity 21 - Sub-mains and final sub-circuits

Read AS 3000 clause 2.3.4.2 Read the suggested text or resource	Write a response
1. What is the requirement for a sub-main or final sub-circuit greater than 100A?	
2. May a circuit breaker used to protect a sub-main or final sub-circuit greater than 100A be used as the isolation switch?	

Activity 22 - Appliances and accessories

Read AS 3000 clause 2.3.4.5 Read the suggested text or resource	Group discussion

Activity 23 - Isolation of socket outlets

Read AS 3000 section 4.4 Read the suggested text or resource	Group discussion

Activity 24 - Isolation of Cooking Appliances

Read AS 3000 section 4.7 Read the suggested text or resource	Group discussion

Activity 25 - Isolation of water heaters

Read AS 3000 clause 4.8.2.3 Read the suggested text or resource	Write a response
1. List two permissible locations for a hot water systems isolation switch.	
2. A C.B. is used as the circuit protection device on the main switch board for a H.W.S. Can the C.B also be used as the H.W.S. main and isolating switches?	

Activity 26 - Isolation of Room Heaters

Read AS 3000 section 4.9 Read the suggested text or resource	Group discussion

Activity 27 - Isolation of heating cables

Read AS 3000 section 4.10 Read the suggested text or resource	Group discussion

Activity 28 - Isolation of Electricity converters

Read AS 3000 section 4.12 Read the suggested text or resource	Group discussion

Topic 2 - Need for protection against mechanical movement

Activity 29 - Protection against mechanical movement

Read AS 3000 rule 1.5.13 Read the suggested text or resource	Group discussion

Activity 30 - Protection against mechanical movement - Isolation switches

Read AS 3000 clause 4.13.1.1 Read the suggested text or resource	Write a response
1. Isolation switches are not required for motors with a rating of less than what?	

Activity 31 - Protection against mechanical movement - Isolation switches rating

Read AS 3000 clause 4.13.1.1 Read the suggested text or resource	Write a response	
1. An isolation switch operating directly in the motor control circuit shall be capable of interrupting what multiple of the rated full load motor current?	A.C.	D.C.
2. Switches suitable for this application should be marked with the letter?		

Activity 32 - Shutting down for mechanical maintenance

Read AS 3000 clause 2.3.6.1 Read the suggested text or resource	Write a response
1. What is are suitable means of preventing operation of devices used to shut down for mechanical maintenance?	________________________________ ________________________________ ________________________________ ________________________________
2. When are locking facilities not required on devices used to shut down for mechanical maintenance?	

Activity 33 - Shutting down for mechanical maintenance - Devices

Read AS 3000 clause 2.3.6.2 Read the suggested text or resource	Write a response
1. List 3 requirements of devices used to shut down for mechanical maintenance.	________________________________ ________________________________ ________________________________

Activity 34 - Shutting down for mechanical maintenance - Installation

Read AS 3000 clause 2.3.6.3 Read the suggested text or resource	Write a response
1. List 3 devices that may be used to shut down for mechanical maintenance	________________________________ ________________________________ ________________________________

Activity 35 - Protection against mechanical movement - Identification

Read AS 3000 rule 2.3.6.4 Read the suggested text or resource	Group discussion

Activity - 36 - Functional (control) switching.

Read AS 3000 section 2.3.7 Read the suggested text or resource	Group discussion

Functional switches do not necessarily provide isolation. For example a lighting point wired using the loop from the light method is still live at the loop terminal even when the control switch is open.

Isolating devices such as plug sockets commonly used to isolate commercial cooking equipment cannot be used in "normal use" as they are not designed to perform a large number of operations.

Topic 3 - Selecting Devices

Unprotected Consumers Mains

The vast majority of consumer's mains are installed electrically **unprotected**. This means no upstream protection devices are provided. The only protection in fact in most cases in domestic installations with underground supply, is a 400A H.R.C. fuse, located some distance away at the distribution substation (transformer). Under fault conditions the substation fuse will offer no protection to consumer's mains.

Activity 37 - AS3000 requirements - Protection against over current

Read AS 3000 clause 2.5.1.1 Read the suggested text or resource	Group discussion

To compensate for the lack of electrical protection extra care must be taken to ensure consumers mains are installed so that the risk of mechanical damage to the consumer's mains is greatly reduced. AS3000 2.5.1.1 (c) makes provision that overload protection is permitted to located at the end of the consumer's mains rather than the origin. The requirement for short circuit protection is omitted because of the increased mechanical protection.

AS3000 clause 3.9.7.1.2. requires that "consumer's mains not provided with short circuit protection on the supply side be constructed in such a manner as to reduce the risk of short-circuit to a minimum". It lists suggested wiring systems to deemed to satisfy the requirement;

- Insulated and sheathed (XLPE) cables enclosed in heavy-duty insulating conduit to AS/NZS 2053.
- Insulated and sheathed (XLPE) cables installed in underground wiring enclosures.

Unprotected PVC cables are not permitted under NSWSR clauses 2.6.1 (underground) and 3.3.2 (over head). In the case of underground consumer's mains the heavy duty underground (orange) conduit must be continuous all the way to the switchboard enclosure.

It is the policy of both Energy Australia and Integral Energy to allow Insulated and sheathed (XLPE) cables without enclosure in heavy duty conduit as long as advantage of build construction is taken to protect the cable from mechanical damage. In other words the cable must be concealed in the eaves and cavity of the building. The entry of the cable into the building construction (facia) at the point of attachment must be protected with the likes of heavy duty flexible conduit.

Overload Protection of Unprotected Consumer's Mains

Not all consumer's mains are unprotected. Examples of protected consumer's mains include Consumer's mains protected by;

- pole fuses.
- inline fuses at the point of supply.
- protection devices located in a dedicated substation supplying large installations.

Activity - 38 - AS3000 requirements - Protection against over current (over load)

AS3000 clause 2.5.1.1 (note 6) Read the suggested text or resource	Group discussion

As stated in previous sections, if the sum of the total of the circuit protection devices current ratings is greater than the current rating of the consumers mains, overload protection must be provide or the consumer's mains. To provide overload protection of the consumer's mains, the installations main isolation switch can be upgraded to a circuit breaker.

The **calculated** maximum demand (I_B) of the installation should be less or equal to the rating of the circuit breaker (I_N).

$$I_B \leq I_N \leq I_Z$$

The Rating of the circuit breaker (I_N) should less or equal to the rating of the XLPE cable current rating selected from tables in AS3008.1.1.

However with the installation of the circuit breaker the maximum demand of the installation is now set by **limitation**. Should the maximum demand be slightly over the circuit breaker nominal rating, there is no need to increase to the next size circuit breaker or cable. In the unlikely event of an overload, the circuit breaker will protect the consumer's mains from overload (AS3000 clause 2.5.1.1 (note 6)).

If an installation has an off peak hot water system, the sum of the domestic and off peak circuit breakers / main switches may exceed the current rating of the consumer's mains. This situation does not comply with AS3000 clause 2.5.1.1 (note 6).

The solution to this problem is dealt with quite differently by the energy distributors.

Energy Australia and Country Energy Areas

On consultation with Energy Australia and Country Energy, EA and CE require a circuit breaker to be fitted between the service protective device (service fuse) and the metering. As the overload protection device is un-metered, its connection terminals must be sealable. It is marked as an "Unmetered Main Switch". The current rating is selected based on the size of the consumer's mains. Activities 39 to 42 show examples of how to determine the current rating of the overload device.

Integral Energy Areas

Policy in Integral Energy is the off peak H.W.S. demand should not be included. IE do not wish to remove supply from electronic meters, decreasing the current rating of the circuit breaker from say 63A to 40A would cause nuisance tripping, not to mention problems with discrimination.

Local electrical distributors should be consulted, as it is highly likely for this policy to change with time.

Activity 39 – Consumer's mains over load protection devices

Read the suggested text or resource	Use AS3008.1.1 and AS3000 to select suitable current ratings of circuit breakers to protect the following size and types of consumer's mains.	Write a response

Single Phase SDI XLPE AS3008.1.1 Table No ___________

Installation Method	16 mm^2 Cu	25 mm^2 Cu	35 mm^2 Cu
Partially Surrounded by thermal insulation			
Unenclosed in Air (laid flat touching)			
Enclosed in Under ground conduit.			

Activity 40 – Consumer's mains over load protection devices

Read the suggested text or resource

Use AS3008.1.1 an AS3000 to select suitable current ratings of circuit breakers to protect the following size and types of consumer's mains.

Write a response

Three Phase SDI XLPE AS3008.1.1 Table No ___________

Installation Method	16 mm^2 Cu	25 mm^2 Cu	35 mm^2 Cu
Partially Surrounded by thermal insulation			
Unenclosed in Air (laid flat touching)			
Enclosed in Under ground conduit.			

Activity 41 – Consumer's mains over load protection devices

Read the suggested text or resource

Use AS3008.1.1 and AS3000 to select suitable current ratings of circuit breakers to protect the following size and types of consumer's mains.

Write a response

Three Phase 4 Core XLPE AS3008.1.1 Table No ___________

Installation Method	16 mm^2 Cu	25 mm^2 Cu	35 mm^2 Cu
Partially Surrounded by thermal insulation			
Unenclosed in Air (laid flat touching)			
Enclosed in Under ground conduit.			

Activity 42 – Consumer's mains over load protection devices

Use AS3008.1.1 to select suitable current ratings of circuit breakers to protect the following size and types of consumer's mains. **All cables are 3 phase.**

Installation method /Cable	Circuit Breaker Rating	AS3008.1.1Table/Column
95mm^2 Cu XLPE SDI Partially Surrounded		
70mm^2 Cu XLPE SDI Unenclosed in Air (laid flat touching a surface)		
240mm^2 Al XLPE 4 Core Buried Direct		

Over Current Limiting of Consumer's Mains

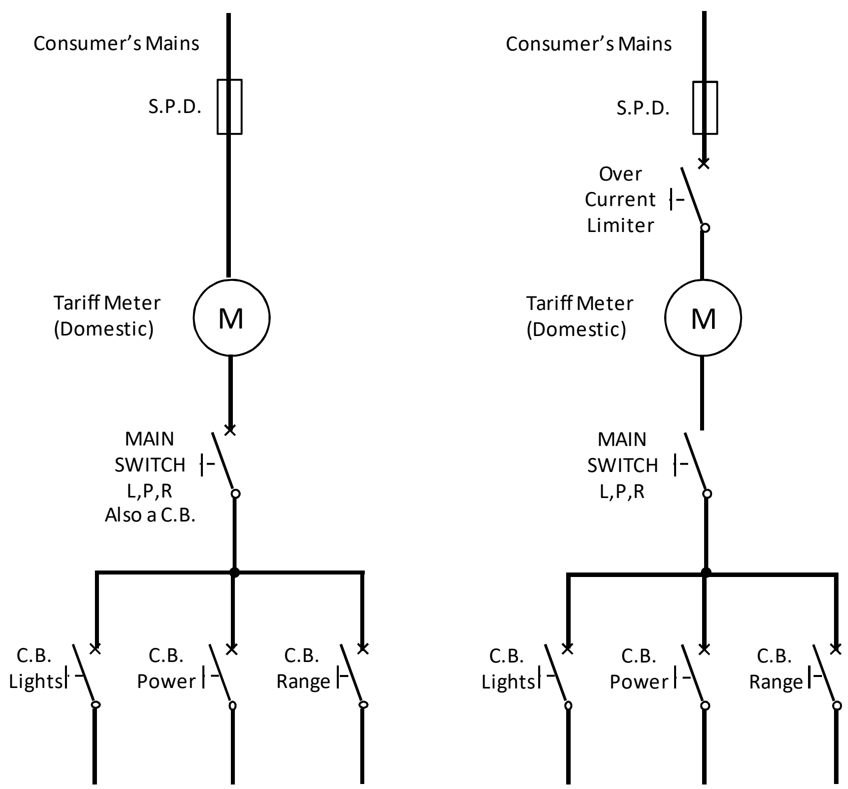


figure 3.

Selection of Isolation Switches

When selecting an isolator which is effectively a switch, it is import to understand how they are rated. The ratings of an isolator are indication of how much current can be interrupted by the isolator without damage to the device. Unlike circuit breakers nominal rating (I_N) which, if exceeded will cause the device to open circuit automatically, disconnecting the circuit from the supply. Isolators are not circuit protection devices. An isolator will not 'trip' like a circuit breaker.

In activity 8 of this section we looked at AS3000 rule number 2.3.2.2.1 which stated;

"Where a device for isolation is not capable of interrupting normal load current, suitable measures shall be taken to prevent it operating while carrying current."

Effectively this means the typical isolating switch will need to "break' the normal load current flowing in the circuit that it isolates. In most cases this will be the **maximum demand** of that circuit. Isolators for motors need to break the locked rotor current of the motor. Figure 3 shows examples and current ratings of isolators up to 100A.

1 Pole, 1 Module, 240V

Current (A)	Catalogue Number
40	4PSW140
80	4PSW180
100	4PSW1100

2 Pole, 2 Module, 415V

Current (A)	Catalogue Number
40	4PSW240
80	4PSW280
100	4PSW2100

3 Pole, 3 Module, 415V

Current (A)	Catalogue Number
40	4PSW340
80	4PSW380
100	4PSW3100

figure 4 - www.clipsal.com.au

In larger isolations switches the utilization category is also specified to match the isolator to the correct use. Figures 5 and 6 show further examples and technical data of larger isolators up to 1600A.

Load Break Vs Off Load disconnectors

Some large isolators are not rated to break the load current they can carry. They are given a Utilization Category of AC-20. Downstream circuit breakers must be opened first to interrupt the flow of current before the "disconnector" is opened.

A true isolator is given a Utilization Category of AC-21 or higher. Refer to figure 5 for more information relating to Utilization Categories

Load break switches

description
the HA series are a multi-pole load disconnector switch with manual operation. They enable making and breaking on load and safety isolation of any low voltage installation.

technical data
- visualised breaking
- double breaking per phase
- DIN rail mounting
- 3 or 4 pole
- padlockable handle
- auxiliary contacts
- rotary handles complete with extension shaft
- complying with IEC60947-3

HA302

HA307

HA354

description	width in 17.5 mm	characteristics	module mm	cat. ref	$ ex-GST	$ incl-GST
3 pole isolator 690V~	2	In 40A	36	**HA302**	75.50	83.05
	3	In 63A	54	**HA303**	102.60	112.86
3 pole isolator 400V~	6	In 80A	108	**HA304**	114.90	126.39
	6	In 100A	108	**HA305**	133.20	146.52
	6	In 125A	108	**HA306**	133.20	146.52
	8.5	In 160A	142	**HA307**	172.70	189.97
	8.5	In 200A	142	**HA308**	401.50	441.65
	8.5	In 250A	142	**HA309M**	410.00	451.00
3 pole isolator 400V~	-	In 250A	-	**HA354**	504.40	554.84
	-	In 400A	-	**HA356**	764.00	840.40
	-	In 630A	-	**HA358**	1188.10	1306.91
	-	In 800A	-	**HA360**	1477.90	1625.69
	-	In 1250A	-	**HA362**	2449.70	2694.67
	-	In 1600A	-	**HA364**	3094.90	3404.39
4 pole isolator 400V~	6	In 125A	108	**HA406**	390.90	429.99
	8.5	In 200A	142	**HA408**	459.20	505.12

figure 5 - www.hagerbr.com.au

cat ref	HA302	HA303	HA304	HA305	HA306	HA307	HA308	HA309M	HA354	HA356	HA358	HA360	HA362	HA364
thermal current Ith	**40**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**250**	**400**	**630**	**800**	**1250**	**1600**
insulation voltage Ui (V)	800	800	800	800	800	800	800	800	800	1000	1000	1000	1000	1000
impulse withstand voltage Uimp (kV)	8	8	8	8	8	8	8	8	8	12	12	12	12	12
rated operation current (A)	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B
400VAC[1] AC-21A / AC-21B	40/40	63/63	80/80	100/100	125/125	160/160	200/200	200/250	250/250	400/400	630/630	800/800	1250/1250	1600/1600
AC-22A / AC-22B	40/40	63/63	80/80	100/100	125/125	160/160	200/200	200/200	250/250	400/400	630/630	800/800	1250/1250	1600/1600
AC-23A / AC-23B	32/32	63/63	80/80	100/100	125/125	160/160	200/200	200/200	250/250	400/400	500/630	800/800	1250/1250	1250/1250
690VAC[2] AC-20A / AC-20B	40/40	63/63	80/80	100/100	125/125	160/160	200/200	200/250	250/250	400/400	630/630	800/800	1250/1250	1600/1600
AC-22A / AC-22B	40/40	63/63	40/40	40/40	40/40	160/160	160/160	160/160	200/250	400/400	500/500	800/800	1000/1000	1000/1000
AC-23A / AC-23	20/20	50/50	25/25	25/25	25/25	63/80	63/80	63/80	125/160	250/315	315/315	800/800	1000/1000	1000/1000
220VDC DC-20A / DC-20B	40/40	63/63	80/80	100/100	125/125	160/160	200/200	200/250	250/250	400/400	630/630	800/800	1250/1250	1600/1600
operational power (kW)														
400 VAC	11	18	40	51	63	80	100	100	132/132	220/220	280/280	450/450	710/710	710/710
690 VAC	11	18	33	33	33	150	150	150	90/110	150/185	150/185	185/220	475/475	475/475
short time withstand current 1 sec (kA rms)	1.25	1.5	2.5	2.5	2.5	4	4	4	9	13	13	26	50	50
short circuit making capacity (kA peak)	6	10	12	12	12	16	16	16	30	45	45	55	110	110
connection														
max cable section (mm)	16	50	50	50	50	95	95	95	150	240	2X300	2X300	4X185	6X185
max busbar width (mm)	-	-	-	-	-	20	20	20	32	40	50	63	100	100

(1) A/B = category with index - A = frequent operation / B = infrequent operation

(2) with terminal shrouds or phase barriers

Application condition & utilisation category, according to IEC 60947-3

Utilisation category AC	Utilisation category DC	Use	Application
AC20	DC20	off-load making & breaking	disconnector
AC21	DC21	resistive loads including moderate overloads	switches at installation head or for resistive circuits (lighting)
AC22	DC22	inductive & resistive mixed loads including moderate overloads	switches in secondary circuits or reactive circuits (capacitor banks)
AC23	DC23	loads made of motors or other hightly inductive loads	switches feeding one or serveral motor or inductive circuits (series motors, magnetic brakes)

figure 6 - www.hagerbr.com.au

Activity 43 - Selection of Isolation switches

Use figures 4, 5 and 6 to select a suitable isolation switch for the following situations. Specify the; • number of poles • current rating. • type of device C.B. or Isolator • utilisation Category	Write a response
1 An isolation switch for a distribution board in garage of a single phase domestic installation with a maximum demand of 33A.	
2 An main switch for a three phase domestic installation with a maximum demand of 50A per phase.	
3 The isolation switch in the distribution board of a single phase town house with a maximum demand of 55A.	
4 The isolation switch in the distribution board of a three phase factory unit with a maximum demand of 100A per phase.	
5 The main switch for a factory unit complex with a maximum demand of 370A per phase.	

Figure 7 shows an example of a typical domestic installation containing a sub main to a garage or granny flat. Both of these situations would be regarded as a separate outbuilding (not attached to the main house). The out building is then regarded as separate installation and requires an Isolation switch. If DB1 was located and supplying load within the main house an isolation switch within DB1 is not required as the circuit breakers can be used as isolators. It is however still good design practice to include the isolation switch as shown.

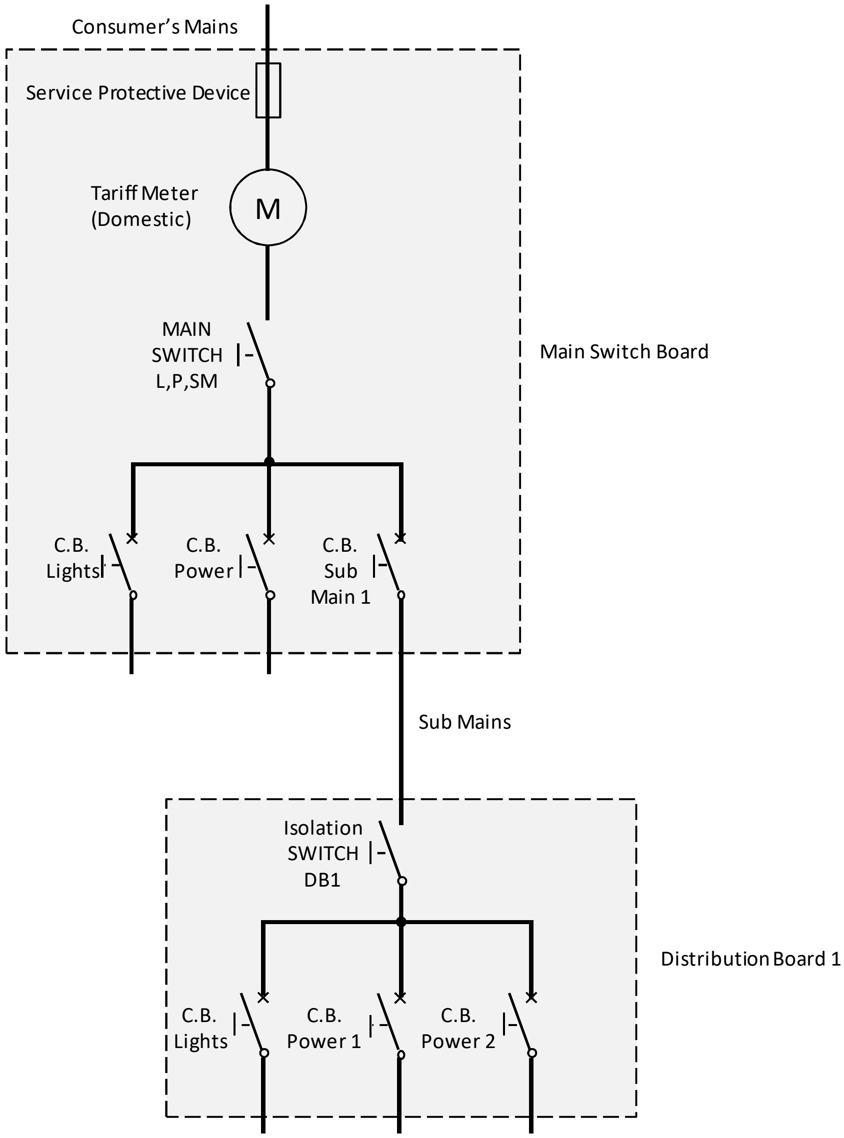


figure 7.

Figure 8 shows 1 unit of a multiple domestic installation. It is assumed the main switch board is locked. Main switches are required for each metered tariff. Circuit breakers are used in the M.S.B. as both circuit protection and isolation devices.

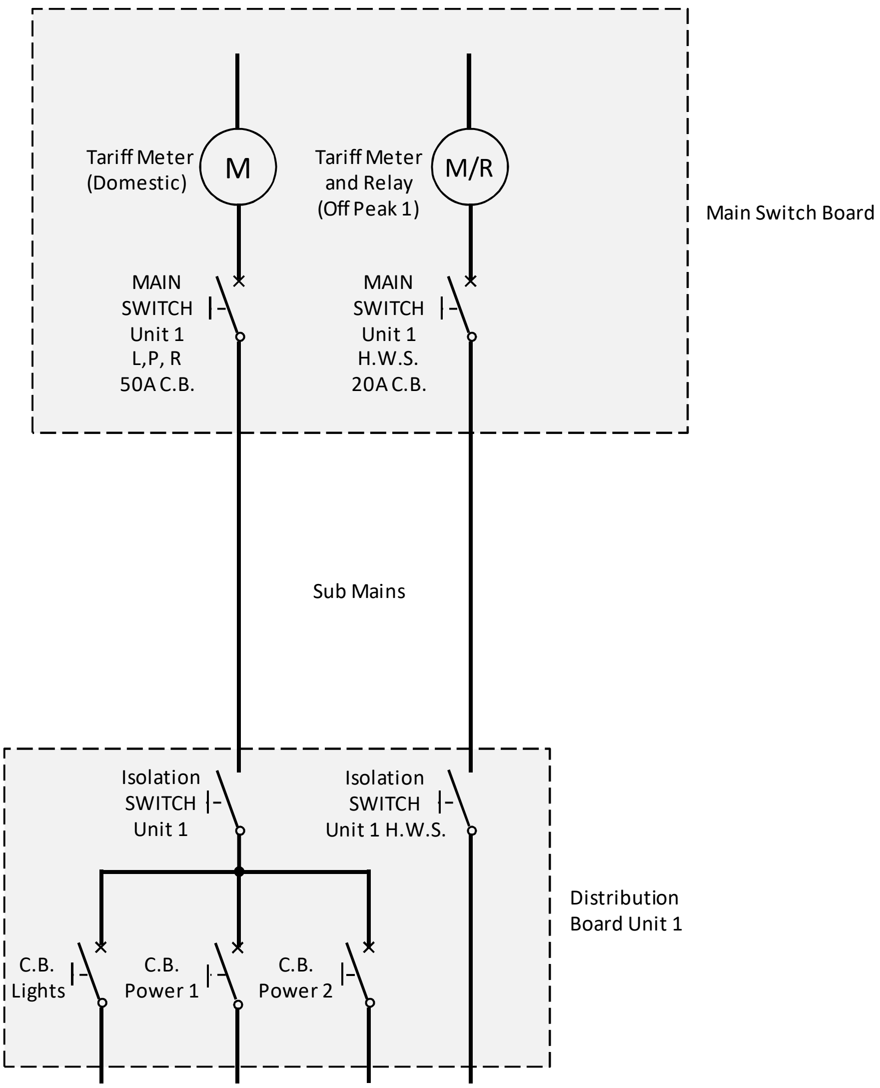


figure 8.

Isolation switches are provided in the distribution board of each unit for both the general and hot water system sub mains. If the units are town houses (outbuildings) they are treated as separate installations. The general isolation switch is required by Australian standards. The H.W.S. isolation switch is provided so the H.W.S. can be isolated without gaining access to the M.S.B.

Combination Switched Socket Outlets

- Versions from 250V 10A to 500V 50A.
- All internal phase connections between switches and sockets are factory wired.
- Sockets include a dustproof and hoseproof flap with snap latch.

Surface Socket Outlets

- Versions from 250V 10A to 500V 50A.
- Sockets include a clear dustproof and hoseproof flap with snap latch.
- Tough polyester terminal housings.

Appliance Inlets

- Screwed lock ring secures extension sockets and appliance connectors and ensures IP rating.
- Impact resistant and UV stabilised housings.
- Downward facing, angled pin housing available on 500V units.

Surface Switches

- Versions from 250V 10A to 500V 63A.
- Positive rotary switch action.
- Provision for 2 padlocks.

Key Operated Switches

- Versions from 250V 20A to 500V 50A.
- Available in 3 versions - Standard Security, Medium Security and High Security.
- Locking in 'off' and 'on' positions.

figure 9 - www.clipsal.com.au

Circuit breakers that have provisions for either tagging or lock outs may used to isolate an entire circuit, but this can be inconvenient due to lack of access to the switch board or the loss of supply to other points on the same circuit.

Individual loads can such as motors, air conditioners, illuminated signs etc for convenience can be isolated using either plug sockets or isolation switches such as those shown in figure 9.

Figure 10 shows typical markings of 56 and 66 series isolation switches.

20 AMP 50Hz
500V
IP66
M150

figure 10.

20 AMP Indicates current that the switch can carry under normal use for a prolonged period of time. The current rating is limited by the build up of heat over time.

50Hz Rated Frequency

500V Voltage Rating

IP66 International Protection Rating

M150 Locked rotor motor current breaking capacity.

Catalogue Number	No. of Switched Poles	I_{the} (A)	U_i / U_e (V)	I_e (A) Utilisation Category			M Rating	Conductor Terminal size in mm²		IP Rating	O/A* Dims. (H) x (W) X (D)
				AC21A	AC22A	AC23A		Min.	Max./cont.		
56SW110	1	10	250	10	8	8	M80	1.5	6	66	107x101x80
56SW110HD	1	10	250	10	10	10	M100	6	16	66	107x101x104
56SW110/2~	1	10	250	10	8	8	M80	1.5	6	66	107x101x80
56SW115	1	15	250	15	8	8	M80	1.5	6	66	107x101x80
56SW115HD	1	15	250	15	15	15	M100	6	16	66	107x101x104
56SW115/2~	1	15	250	15	8	8	M80	1.5	6	66	107x101x80
56SW110/I~	1	10	250	10	8	8	M80	1.5	6	66	107x101x80
56SW120	1	20	250	20	20	20	M150	2.5	16	66	107x101x104
56SW132	1	32	250	32	32	28	M180	4	16	66	107x101x104
56SW150	1	50	250	50	50	25	M250	10	25	66	107x101x104
56SW163	1	63	250	63	63	25	M250	16	25	66	107x101x104
56SW220	2	20	500	20	20	20	M150	2.5	16	66	107x101x104
56SW232	2	32	500	32	32	28	M180	4	16	66	107x101x104
56SW250	2	50	500	50	50	25	M220	10	25	66	107x101x104
56SW263	2	63	500	63	63	25	M220	16	25	66	107x101x104
56SW310	3	10	500	10	10	10	M100	1.5	16	66	107x101x104
56SW320	3	20	500	20	20	20	M150	2.5	16	66	107x101x104
56SW332	3	32	500	32	32	28	M180	4	16	66	107x101x104
56SW350	3	50	500	50	50	25	M200	10	25	66	107x101x104
56SW363	3	63	500	63	63	25	M200	16	25	66	107x101x104
56SW363/2	3	63	500	63	63	25	M200	16	25	66	204x101x104
56SW320C	AS 56SW320 + 2A CHANGEOVER AUX. LATE MAKE EARLY BREAK							2.5	16/2.5	66	107x101x104
56SW332C	AS 56SW332 + 2A CHANGEOVER AUX. LATE MAKE EARLY BREAK							4	16/2.5	66	107x101x104
56SW350C	AS 56SW350 + 2A CHANGEOVER AUX. LATE MAKE EARLY BREAK							11	25/2.5	66	107x101x104
56SW420	4	20	440	20	20	20	-	2.5	6	66	107x101x104

figure 11. - www.clipsal.com.au

Care should be taken when selecting isolation switches for motors. A motor which has a line current of 20A will have a locked rotor current of 8 times the line current. The locked rotor current will actually be 160A. If an isolation switch rated at 20A is used to isolate the motor, the "M" rating for the device is only 150A (referring to figure 11) . An isolation switch with a rating of 32A should be used.

Activity 44 - Selection of Isolation switches

Use figure 10 to select a suitable isolation switch for the following situations. Specify the; • number of poles • current rating. • Utilisation Category	Write a response
1 An isolation switch for a 230V hot water system, current rated at 20A.	
2 An isolation switch for a shops 230V neon sign with a primary current of 8A.	
3 The isolation switch for a group of 3 phase 400V Metal Halide flood lights with a line current of 25A per phase.	
4 The isolation switch for 3 phase motor with a line current of 50A per phase.	
5 The isolation switch for 3phase motor with a line current of 21A per phase.	

Tutorial – Section 10

1. The switch used to isolate a 12.5 kW range (cook top and oven) that is connected to two phases and neutral, would have as a minimum:

   one pole

   two poles

   three poles

   four poles

2. A separate isolating switch must be installed to control a sub-main or final sub-circuit outgoing from a switchboard if the circuit maximum demand per phase exceeds:

   25A

   (b) 32A

   (c) 75 A

   (d) 100A

3. 3. For a single domestic installation, with a maximum demand of less than 100 A, the maximum number of main switches per tariff is:

   (a) 1

   (b) 6

   (c) 10

   (d) no limit

4. A main switch should be located:

   (a) as close as possible to the load it isolates.

   (b) at the main switch board

   (c) at the distribution board.

   (d) point of supply

5. Which is not a safety service:

   (a) lifts

   (b) security lighting

   (c) fire sprinkler booster pumps

   (d) fire and smoke control equipment

6. Installations that contain safety services:

(a) have separate main switches for the general supply and each type of safety service.

(b) are only permitted one main switch that controls the whole installation.

(c) are not required to have main switches for safety services.

(d) have one main switch for the general supply and one main switch that isolates all safety services.

7. 7. Which device is most commonly used as the isolation switch of a 4.4kw H.W.S in domestic installation, is a:

(a) plug socket

(b) circuit breaker, located at the main switch board.

(c) functional switch located within 2 meters of the tank

(d) 10A architrave switch located in the kitchen

8. 8. The maximum permissible height for a main switch for a main switch above the ground, a floor or platform is:

(a) 0.6m

(b) 1.2m

(c) 2.0m

(d) 2.5m

9. It is not permitted to install an isolation switch in:

(a) Active conductors

(b) Neutral conductors

(c) Protective Earthing conductors

(d) Switch wires

10. 10. A isolation switch used to isolate a electric motor is required to have a Utilization Category of:

(a) AC-20

(b) AC-21

(c) AC-22

(d) AC-23

11. 11. In an A.C. circuit, what conductors must an isolation device operate in?

____

AS 3000 Reference (Clause number ______________)

12. Under what conditions may an isolation switch be placed in a neutral conductor?

13. ____

14. ____

15. ____

AS 3000 Reference (Clause number _______________)

16. What is the difference between Isolation and functional switches?

17. ____

18. ____

19. ____

20. Is it permitted to semiconductor as an isolation device?

____

AS 3000 Reference (Clause number _______________)

21. Is it permitted to semiconductor as a functional switch?

____

AS 3000 Reference (Clause number _______________)

22. An electrical installation has an electric cook top. What are the requirements for the functional switch and in what position must the switch be located?

23. ____

24. ____

25. ____

AS 3000 Reference (Clause number _______________)

26. Does a wall oven require a functional switch?

____

AS 3000 Reference (Clause number _______________)

27. You are asked to install the wiring for the pumps of an automatic fire sprinkler system. The pumps are located a short distance from an existing distribution board. Is it permissible to run a final sub-circuit from the distribution board? Give a reason for your answer.

____

____

____

AS 3000 Reference (Clause number _______________)

28. Main switches controlling fire and smoke control equipment and lifts must indicate the equipment they control, identified with what other wording?

____

____

____

AS 3000 Reference (Clause

Section 11 - Switchboards

Topics

- AS 3000 and local requirements
- Tariff structures
- Main switchboard equipment
- Layout for whole current metering
- Layout for CT metering (up to 400 A per phase)

Aim

Learners will be able to determine and meet the requirements of AS3000 when designing switchboards with a current capacity of up to 400A.

Learning objectives

Learners should be able to meet the following learning objectives:

- State the AS/NZS 3000 and local supply authority requirements for switchboards.
- Explain the tariff structures for the supply of electricity.
- List the equipment installed at main switchboards with capacities up to 400 A per phase.
- Sketch the layout of a main switchboard for an installation supplied with single phase single tariff whole current metering.
- Sketch the layout of a main switchboard for an installation supplied with single phase multiple tariff whole current metering.
- Sketch the layout of a main switchboard for an installation supplied with multiphase single tariff whole current metering.
- Sketch the layout of a main switchboard for an installation supplied with multiphase multiple tariff whole current metering.
- Sketch the layout of a main switchboard for a multiple tenancy installation with whole current metering.
- Sketch the layout of a main switchboard, including metering, for an installation supplied with three phase CT metering

References AS3000.2007 (Amd 1)

New South Wales Service Rule (Jan 2010)

The type of switchboard used for a particular installation will depend on:-

- load requirements
- number of circuits
- fault level protection requirements
- metering and equipment arrangement
- location
- AS 3000 requiurements
- supply authority requirements.

Topic 1 - AS3000 and local requirements

AS/NZS 3000 Requirements.

The general requirements for switchboards are covered in Section 2.9 of AS3000.

Activity 1 – Location of switchboards

Read AS 3000 clause 2.9.2.1 Read the suggested text or resource	Write a response
1. List 3 requirements for the location of switchboards	______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Activity 2 – Accessibility and emergency exit

Read AS 3000 clause 2.9.2.1 Read the suggested text or resource	Write a response
1. What are the minimum dimensions of the door to a room housing a switchboard?	
2. What are the dimensions of a standard door? (general knowledge)	
3. In relation to the switchboard which way should the door to a room housing a switchboard open?	
4. Do the requirements for doors of switch rooms and for emergency exit facilities apply to single domestic electrical installations.?	

Activity 3 – Location of main switchboard

Read AS 3000 clause 2.9.2.3 Read the suggested text or resource	Write a response
1. What are the general requirements for a main switchboard, or a panel for the remote control of main switches?	
2. Can the main switchboard be located within an individual unit of a group of villas?	

Activity 4 – Identification of main switchboard

Read AS 3000 clause 2.9.2.4 Read the suggested text or resource	Write a response
1. What must the main switchboard, of an installation be marked?	
2. Is the main switchboard of a single domestic installation required to be marked?	
3. List 3 examples of installations in which the main switch board must be identified?	__________ __________ __________

Activity 5 – Restricted locations

Read AS 3000 clause 2.9.2.5 Read the suggested text or resource	Write a response
1. In general what is the minimum height above floor or platform or a switchboard?	
2. What are the requirements for switchboards installed in cupboards?	__________ __________ __________ __________ __________
3. Is it permitted to install a switchboard in a fire isolated stairwell?	

Activity 6 – Construction

Read AS 3000 clause 2.9.3.1 Read the suggested text or resource	Write a response
1. Is it permissible in a non-domestic installation to install a switchboard less than 1.2m above the ground, floor or a platform, **if it is lockable?**	

Activity 7 – Construction

Read AS 3000 clause 2.9.3.4 Read the suggested text or resource	Write a response
1. What is the requirement for circuit breakers mounted in the same row of a switchboard?	______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Activity 8 – Bars and Links

Read AS 3000 clause 2.9.4.2

Where tunnel type terminals are used in a bar or link, if the screws have an outside diameter of less than 80% of the tunnel diameter, what is the minimum required number of screws for the;

1. Main incoming neutral conductor	
2. Main earthing conductor	
3. Connection between the main earthing terminal/connection or bar and the neutral bar (MEN connection)	
4. Neutral conductor used as a combined protective earthing and neutral (PEN) conductor for protective earthing of any portion of an electrical installation.	

Activity 9 – Neutral Bars and Links

Read AS3000 clause 2.9.4.3 Read the suggested text or resource	Write a response

1. What is the minimum current carrying capacity of a service neutral link supplied from a 100A service	
2. What is the minimum current carrying capacity of a service neutral link supplied from a 200A service	
3. What is the minimum current carrying capacity of a service neutral link supplied from a 400A service	
4. What is the minimum current carrying capacity of a consumer's neutral link for an installation with a maximum demand of 63A?	
5. Is it permitted to mount neutral links on the rear of a hinged panel? (Y/N)	
6. Is it permitted to have the neutral conductors of two different circuits in the same terminal of a neutral link? (Y/N)	

Activity 10 - Equipment Identification (marking)

AS3000 clause 2.9.5.1 Read the suggested text or resource	Group discussion

Activity 11 – Relationship of electrical equipment

Read AS3000 clause 2.9.5.2

Read the suggested text or resource

Write a response

1. Does the relationship of switches, circuit-breakers, fuses, RCDs, and similar electrical equipment to the various sections of the electrical installation need to be marked on the switchboard itself?

Activity 12 – Terminals of switchboard equipment

Read AS 3000 clause 2.9.5.4

Read the suggested text or resource

Write a response

1. Which terminals require marking at the consumer's main neutral bar or link?

Activity 13 – Common Neutral

Read AS3000 clause 2.9.5.4

Read the suggested text or resource

Write a response

1. What are the requirements when a common neutral is used?

New South Wales Service Rule Requirements

As well as satisfying the requirements of AS3000 switchboards must also be designed and constructed to meet the requirements of the New South Wales Service Rules

The general requirements for the location of switchboards for single installations up to 100 amperes per phase are covered in Sections 4.1 to 4.13 of the New South Wales Service and Installation Rules.

Activity 14 – NSWSR – General Requirements

Read NSWSR clause 4.2 Read the suggested text or resource	Write a response
1. To provide and maintain adequate space in front of the service and metering equipment panel or cabinet, what **vertical** distance is required?	
2. To provide and maintain adequate space in front of the service and metering equipment panel or cabinet, what **horizontal** distance is required?	
3. When a hinged meter panel is extended on its hinge to the 90^0 open position, what clearance is required between the front face of the panel and any fixed object?	

Activity 15 – NSWSR – General Requirements

Read NSWSR clause 4.2 Read the suggested text or resource	Write a response
1. If service and metering equipment is to be located on the side of a house, what is the maximum permissible distance from the front corner of the house?	
2. Is it recommended that the service and metering equipment be located on a wall adjacent to a bedroom?	

Activity 16 – NSWSR – Metering Locations

Read NSWSR sections 4.2 & 4.3

Read the suggested text or resource

Write a response

Answer yes or no if the following locations are suitable for metering and service equipment.

1. In the general area inside a shop in a single premises that is open retail hours.	
2. A shops display window in a group of retail outlets.	
3. A grouped metering point on the 3rd floor of a multi storey shopping complex.	
4. A grouped metering point on the 3rd floor of a block of home units.	
5. A grouped metering point within the yard of an individual unit of a group of town houses.	
6. Within a factory unit within a group of factory units.	
7. Remotely read metering within a factory complex.	
8. A driveway	
9. In pool or spa areas.	
10. A carport	
11. A dog run	
12. On a pole belonging to the supply authority	

Activity 17 – Service Protective Devices

AS3000 clause 4.5.9 Read the suggested text or resource	Group discussion

Service Protective Devices (S.P.D.) are provided at the end of the consumers mains to provide

- Prospective short circuit current protection.
- An isolation point.
- Overload protection of whole current metering.

The current ratings of service protective devices are given in table 4.1 of the NSWSR. Suitable current ratings of service protective devices are selected based on the rating of the service supplying the installation, which is determined by the maximum demand of the installation.

Activity 18 – Service Active Links

AS3000 section 4.9 Read the suggested text or resource	Group discussion

Clause 4.14.1. for multiple installations allows up 4 customers to be connected to one service fuse, service active links extend the number of terminals available to make connections.

Activity 19 – Service & Metering Neutral Links

NSWSR section 4.10 Read the suggested text or resource	Group discussion

Activity 20 – NSWSR – Whole current metering

Read NSWSR clause 4.11 Read the suggested text or resource	Write a response
1. What is the maximum permissible current per active conductor when using whole current metering?	
2. What is the maximum permissible height for the top edge of a meter above the ground floor or a platform?	
3. What is the minimum permissible height for the bottom of a meter above the ground floor or a platform?	

Topic 2 - Tariff Structures

The Electricity Supply Act 1995 provides for the Independent Pricing and Regulatory Tribunal (IPART) to set regulated retail prices for small retail customers (currently those using less than **160 MWh** of electricity per year, equivalent to an annual bill of around $20,000) that are not supplied under a negotiated contract.

Since the introduction of full retail contestability, the NSW Government has asked the Tribunal to continue to determine regulated retail prices during the transition to a competitive market. The reviews on this page relate to these determinations.

Regulated Retail Tariffs

The NSW Government has introduced competition into the retail market. Currently all customers may choose their supplier of electricity.

The Tribunal has determined regulated retail tariffs for small retail customers (ie, those customers who use less than **160 MWh** per year who do not choose to enter a negotiated contract). In NSW as of July 2010 there is three regulated retail suppliers;

- Country Energy
- Energy Ausralia
- Integral Energy

As well the regulated retailers listed above, it is also possible purchase electricity under a negotiated contract from interstate suppliers. Regardless of which electricity retailer is used the tariff structures are similar.

Clause 2.3.3.2 (a) of AS3000 states each separately metered supply requires a separate main switch.

Domestic / Residential

Premises used wholly or principally as private dwellings. A private dwelling is a;

- house
- flat
- home unit
- town house or similar premises
- places of worship and includes

Residential sections of:

- Boarding houses
- Bed and breakfast
- Nursing homes
- Hospitals
- Educational institutions
- Approved caravan parks whose consumption does not exceed 160MWh per year.

General / Business Rate

These prices are generally applicable to;

- factories
- warehouses
- hotels
- motels
- shops and offices
- schools
- sheds
- irrigation pumps
- sporting and social clubs whose consumption does not exceed 160MWh per year.

Off Peak 1 / Controlled Load 1

The supply of electricity is controlled by means of the retailer/distributor's service equipment, either a ripple control relay or time clock. The supply will not usually be available between 7 am and 10 pm Monday to Friday. Supply is usually available weekends. This tariff is intended for use with;

- Storage hot water systems with a heating element rated at 4.8kW and a capacity of **250L** or more.
- Thermal Storage Space Heaters (Heat Banks) and Under Floor Heaters rating must be not less than 3 kW.

- Ice Storage Systems rating must be not less than 3 kW.
- Heat pump storage H.W.S. **are not** permitted or use with this tariff.

Off Peak 2 / Controlled Load 2
The supply of electricity is controlled by means of the retailer/distributor's service equipment so that supply will be available for restricted periods generally not exceeding 17 hours in any period of 24 hours. Generally supply is not available between 5 p.m. to 10 p.m. Loads which are permitted to be supplied by this tariff include:

- Storage hot water systems with a heating element rated at 4.8kW and a capacity of **100L** or more.
- Heat pump storage H.W.S.
- swimming pool pumps
- pool heating equipment
- dishwashers
- clothes dryers
- washing machines and other appliances (other than those described above).

Some of these devices may also be connected to off peak 1 tariff, but because the short time supply is available connection to of peak 2 will not be practical.

Dual Element "Big Blue" Tariff

Special "Big Blue" hot water systems, equipped with two **non-simultaneous** heating units, are installed to meet Integral Energy's minimum tank size requirements as follows:

Number of Bedrooms	Minimum Capacity H.W.S.
1 or 2	250 litres
3	315 litres
4 or more	400 litres

In this case, supply is made available to the bottom-heating element outside the period between 7 am and 10 pm. However, the top element can be heated at any other time (at Off-Peak 1) to satisfy customer needs for hot water.

Time of Use

Time of Use prices (TOU) are available for business or residential supply. The Time of Use option enables financial benefits for controlled usage at predetermined time, periods as listed in definitions below.

- PEAK PERIOD is from 7.00 am to 9.00 am and 5.00 pm to 8.00 pm on weekdays.
- SHOULDER PERIOD is from 9.00 am to 5.00 pm and 8.00 pm to 10.00 pm on weekdays.
- OFF-PEAK PERIOD is at all other times.

All times are Eastern Standard Time and Summer (daylight saving) Time as appropriate.

Network Access /Supply charge

A daily charge per tariff is applied to each tariff available to a customer. Typical billing period for a residential / domestic account is 90 days. The billing period or a business / general account is 30 days. Network access / Supply charges vary from retailer to retailer and can make a substantial contribution to the total bill.

Activity 21 – Tariffs

Refer to Tariffs for your locality 	
1. What is the Business / General rate?	
2. What is the Business / General network access / supply charge?	
3. What is the Residential / Domestic rate?	
4. What is the Residential / Domestic network access / supply charge?	

Topic 3 - Main Switchboard Equipment

Equipment installed on main switchboards includes;

- Service Protective Device – can be a H.R.C. use or circuit breaker.
- Energy meters - whole current up to 100A per phase
- Load control relays / time clocks
- Main Switch/es
- Active links
- Circuit protection devices
  - H.R.C. fuses.
  - Circuit breakers
  - Residual Current Devices
  - over voltage (surge diverters)
- Service and metering neutral links
- Consumers neutral links (unprotected and R.C.D. protected)

Activity 22 – Conductor sizes

AS3000 clause Read the suggested text or resource	Write a response

A single phase installation has a maximum demand of 60A. It is supplied by a 100 A overhead service. The consumer's mains are unprotected 16mm^2 XLPE SDI copper cables. List the CSA of the flowing conductors.

Conductor	CSA	AS 3000 Clause
1. Main Earth		
2. M.E.N. link		
3. Equipotential bond to switchboard enclosure		
4. Equipotential bond to water pipe.		

If the installation has a maximum demand greater than 100A per phase, the main switch board will also house;

- Energy meters - current transformer type required if > 100A per phase.
- Current transformers
- Potential fuses
- Test links

Activity 23 – Conductor sizes

AS3000 clause Read the suggested text or resource	Write a response

A three phase installation has a maximum demand of 320A. It is supplied by a 400A underground service. The consumer's mains are protected 240mm^2 XLPE 4 core aluminium cables. List the CSA of the flowing conductors.

Conductor	CSA	AS 3000 Clause
1. Main Earth		
2. M.E.N. link		
3. Equipotential bond to switchboard enclosure		
4. Equipotential bond to water pipe.		

Topic 4 - Layout Diagrams for Whole Current Metering

Activity 24 – Whole Current Metering Layouts

NSWSR Figures 4.4 to 4.6 Read the suggested text or resource	Group discussion

Single Phase Single Tariff

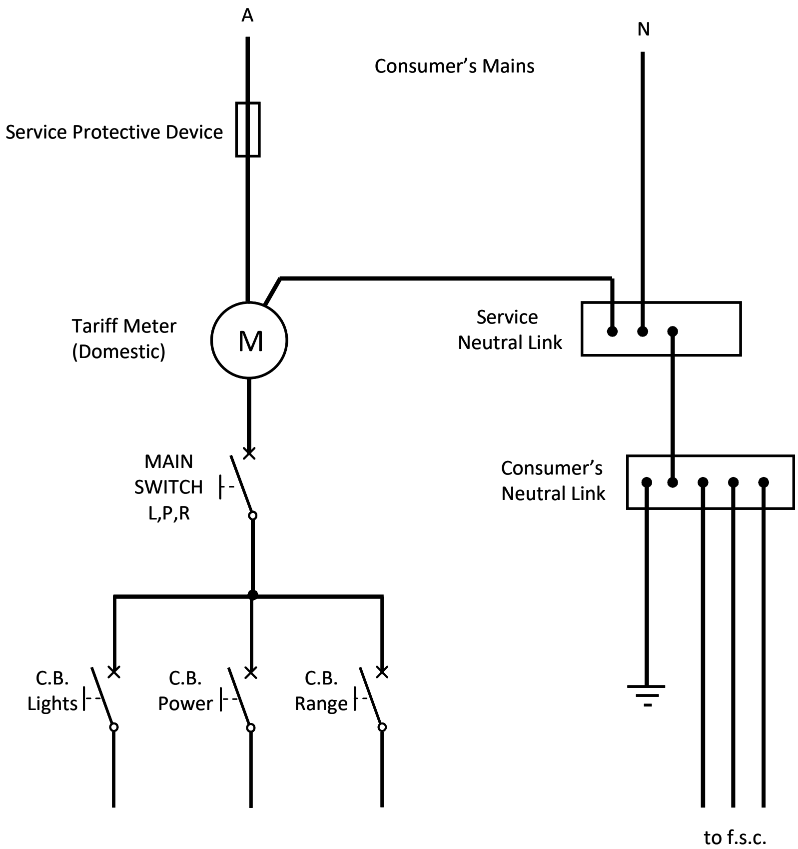


figure 1.

Figure 1 shows the most basic of switchboard arrangements. It is important to be familiar with it as all other arrangements are simple variations of figure 1.

Figure 2 shows how an additional tariff meter and load control relay are added the single tariff meter.

Figure 3 shows the connections using a dual tariff "E2" meter.

Figure 4 shows the connections of a three phase single tariff switchboard using 3 separate single phase "E1" meters

Figure 5 show the same switch board connections using a polyphase meter.

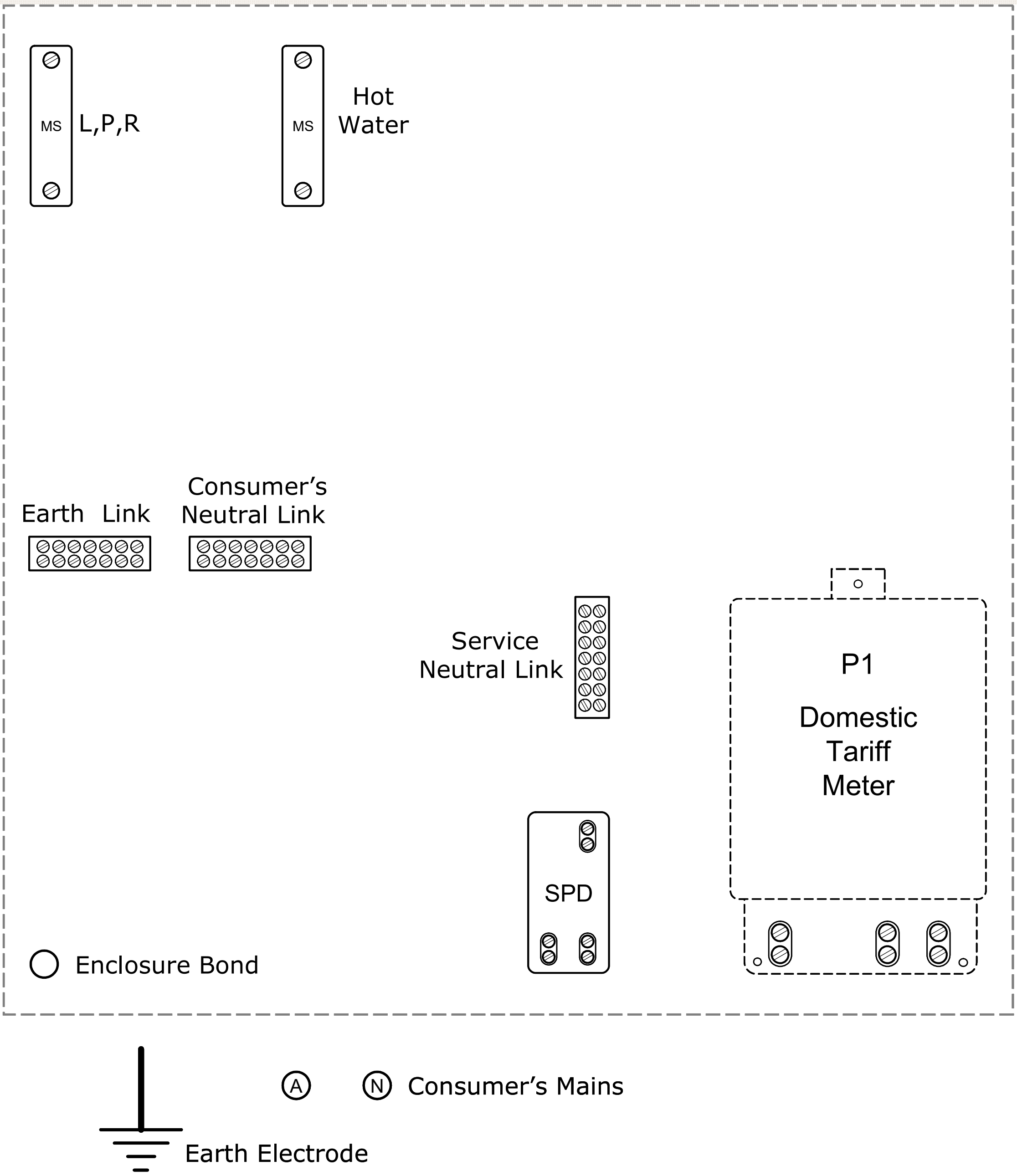
Activity 25 – Single Phase Single Tariff

NSWSR figure 4.5

Read the suggested text or resource

Write a response

Draw in the required connections to complete the main switch board.



Single Phase Dual Tariff

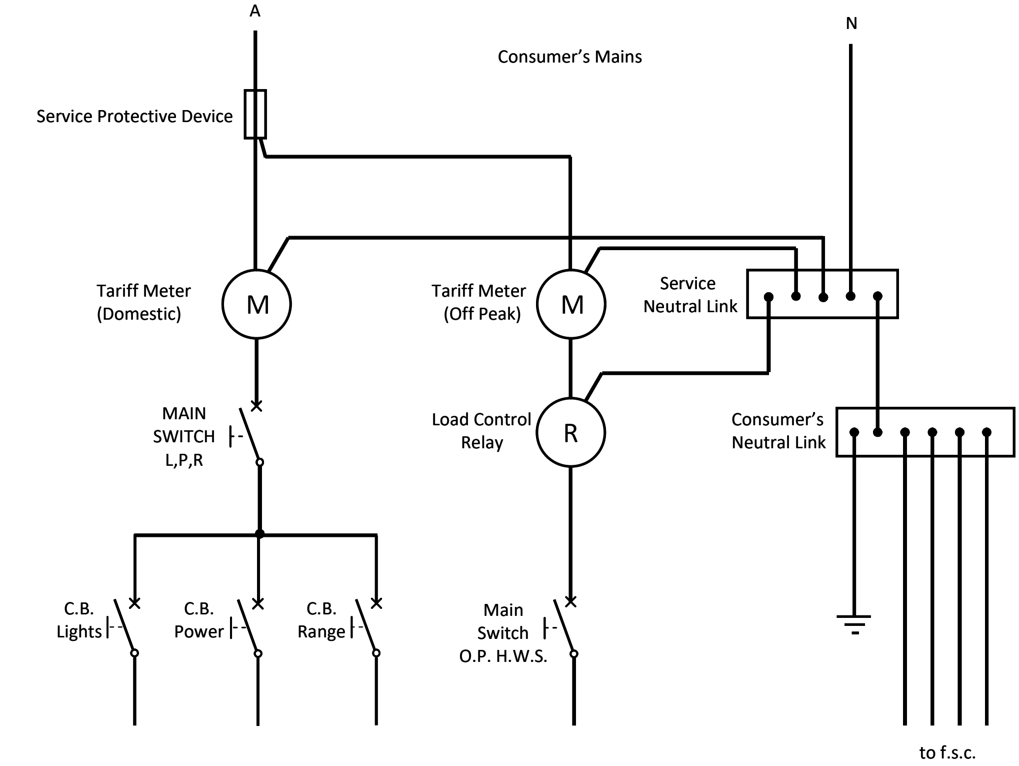


figure 2.

Single Phase Dual Tariff "E2" Meter

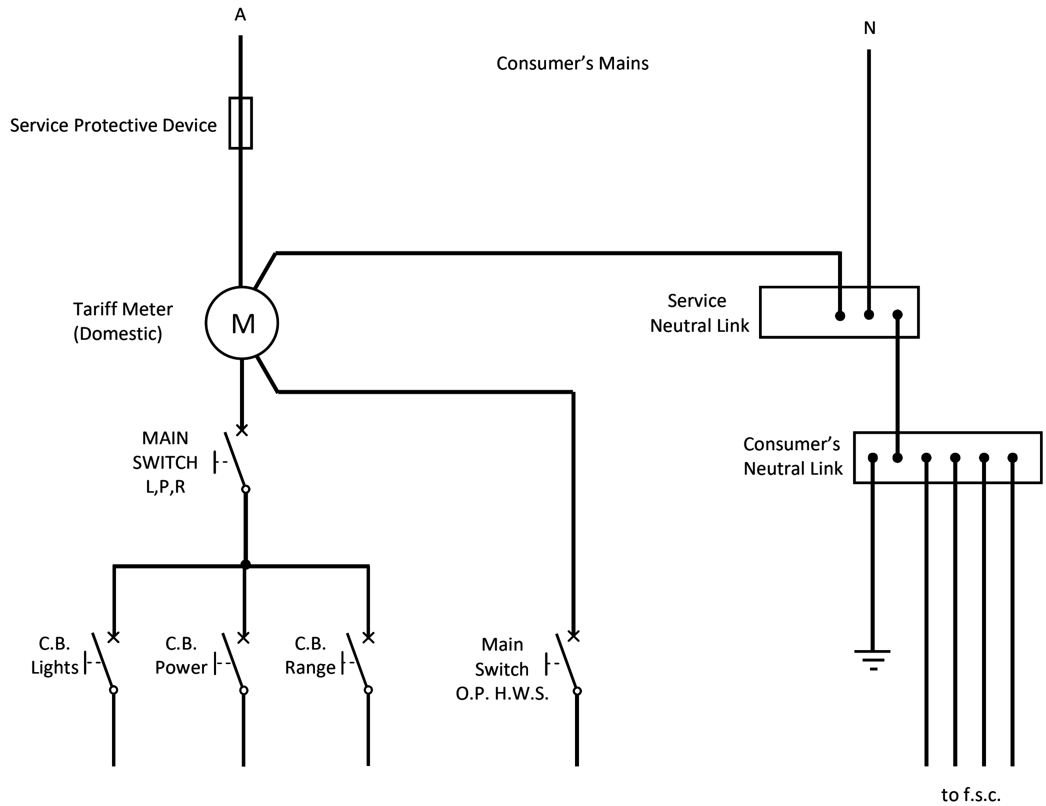


figure 3.

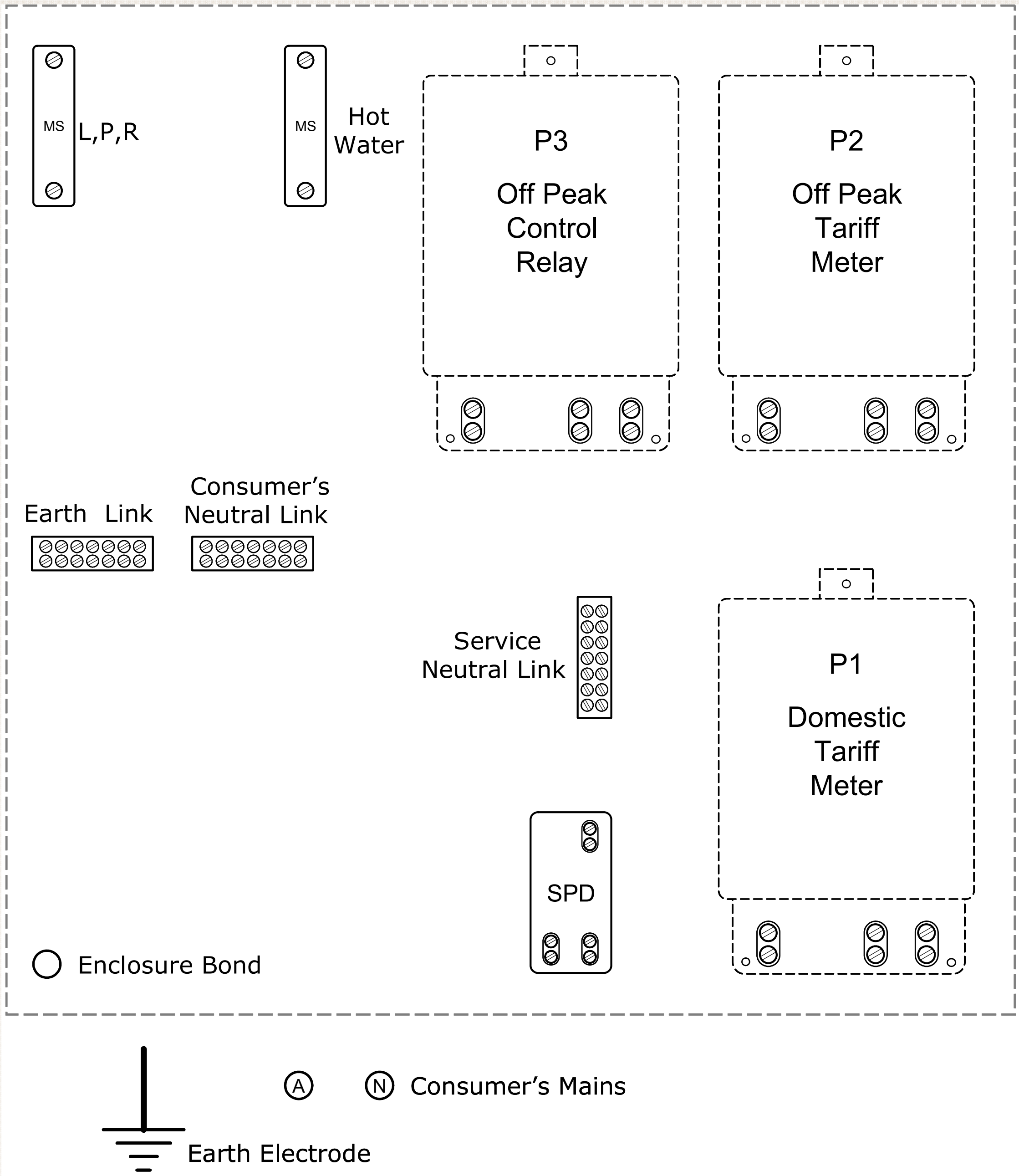
Activity 26 – Single Phase Dual Tariff

NSWSR figure 4.5

Read the suggested text or resource

Write a response

Draw in the required connections to complete the main switch board.



Three Phase Single Tariff

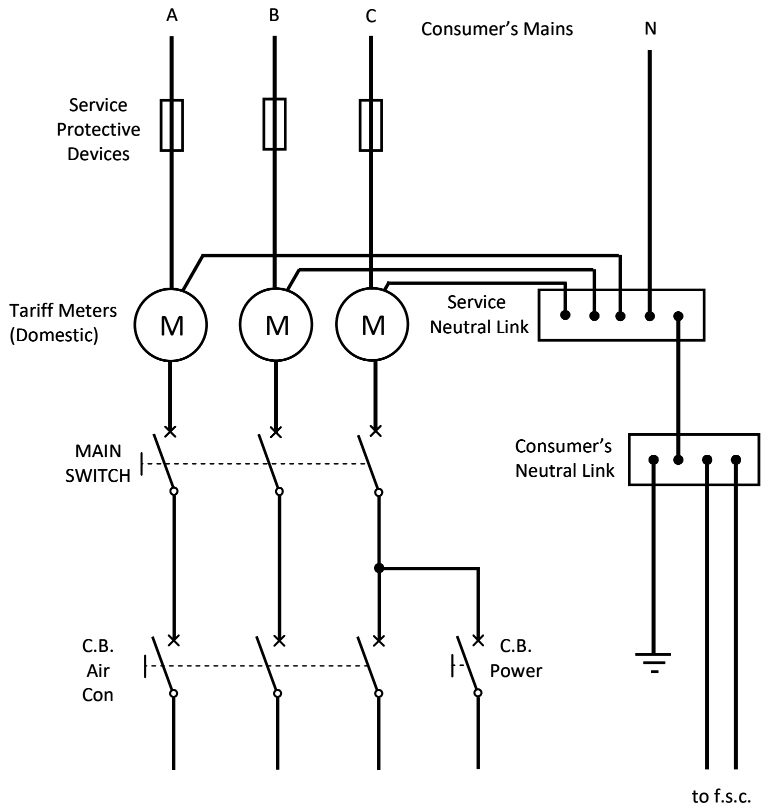


figure 4.

Three Phase Single Tariff (Polyphase meter)

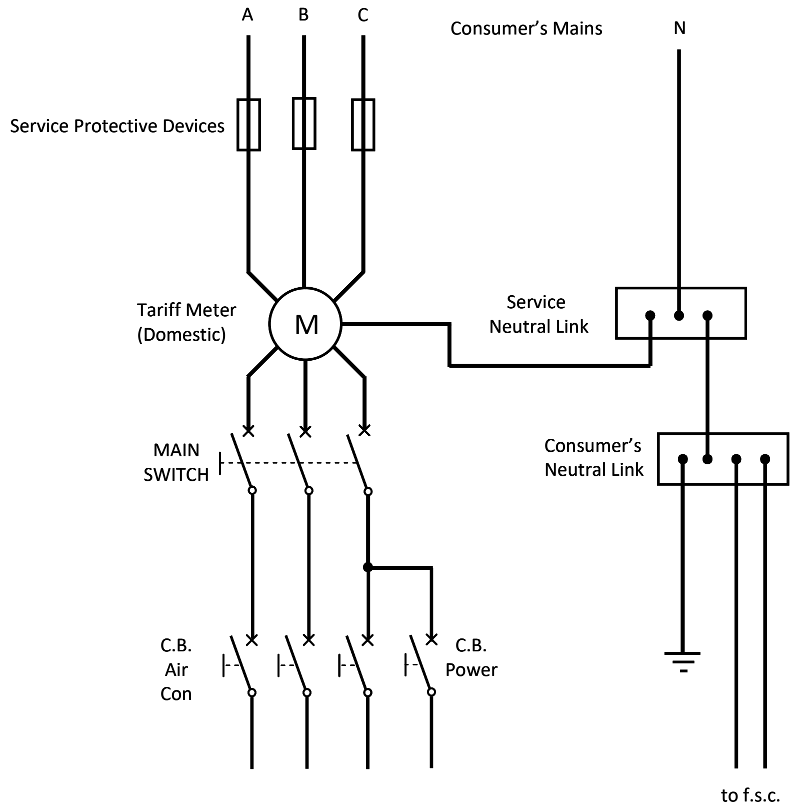
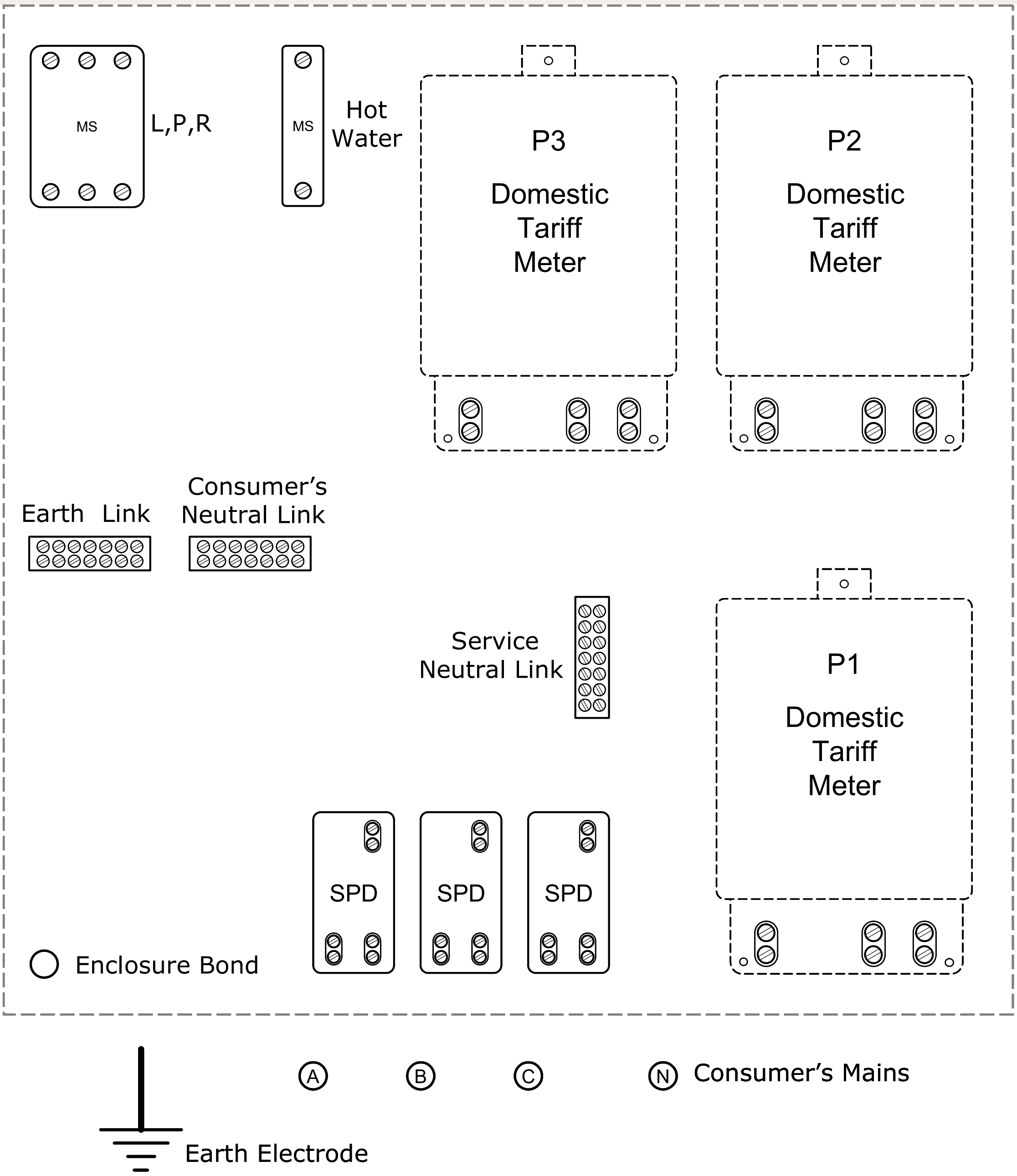


figure 5.

Activity 27 – Three Phase Single Tariff E1 Meters

NSWSR figure 4.4 Read the suggested text or resource	Write a response

Draw in the required connections to complete the main switch board.



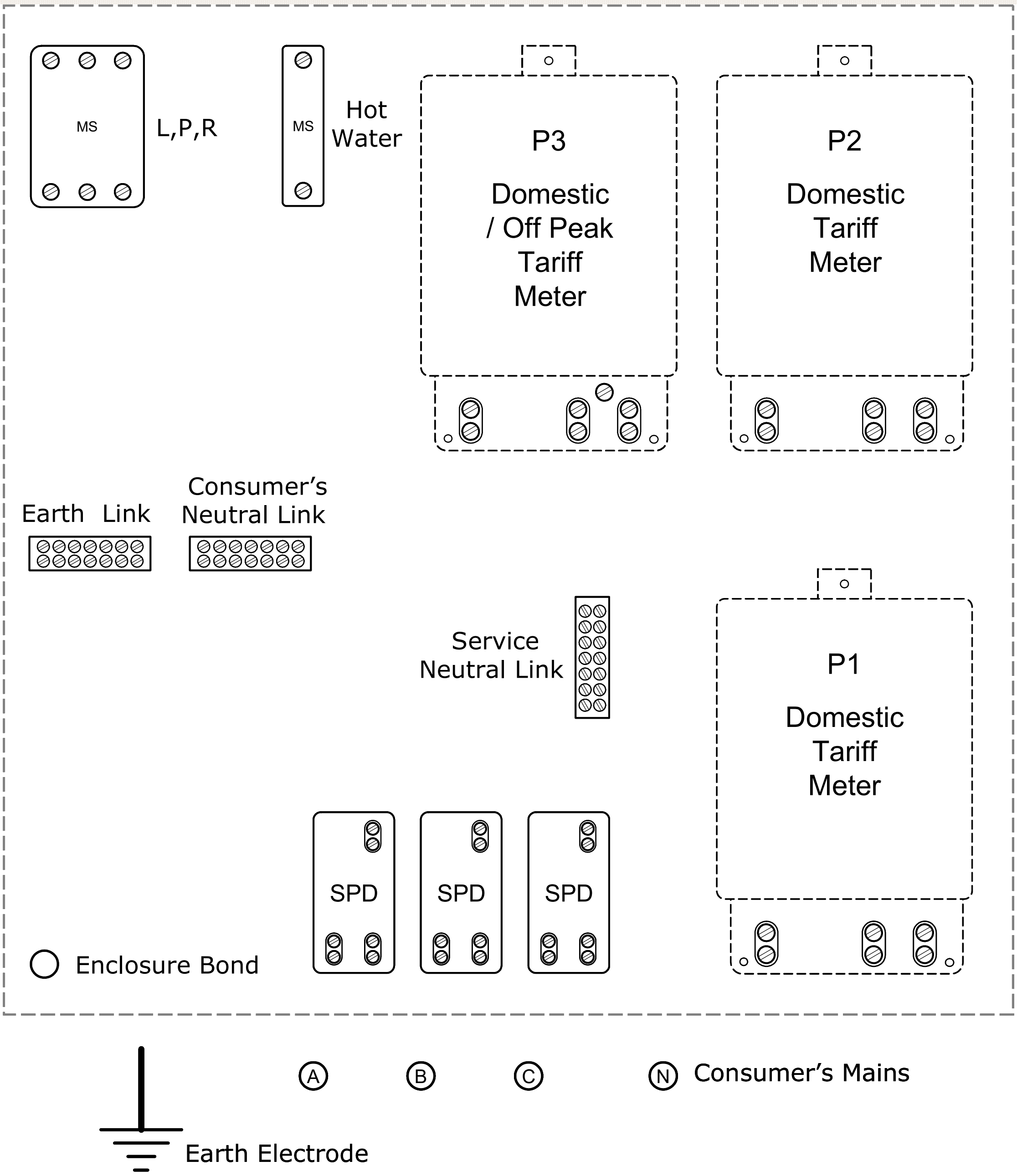
Activity 28 – Three Phase Dual Tariff E2 Meters

NSWSR figure 4.4

Read the suggested text or resource

Write a response

Draw in the required connections to complete the main switch board.



Multiple tenancy installation

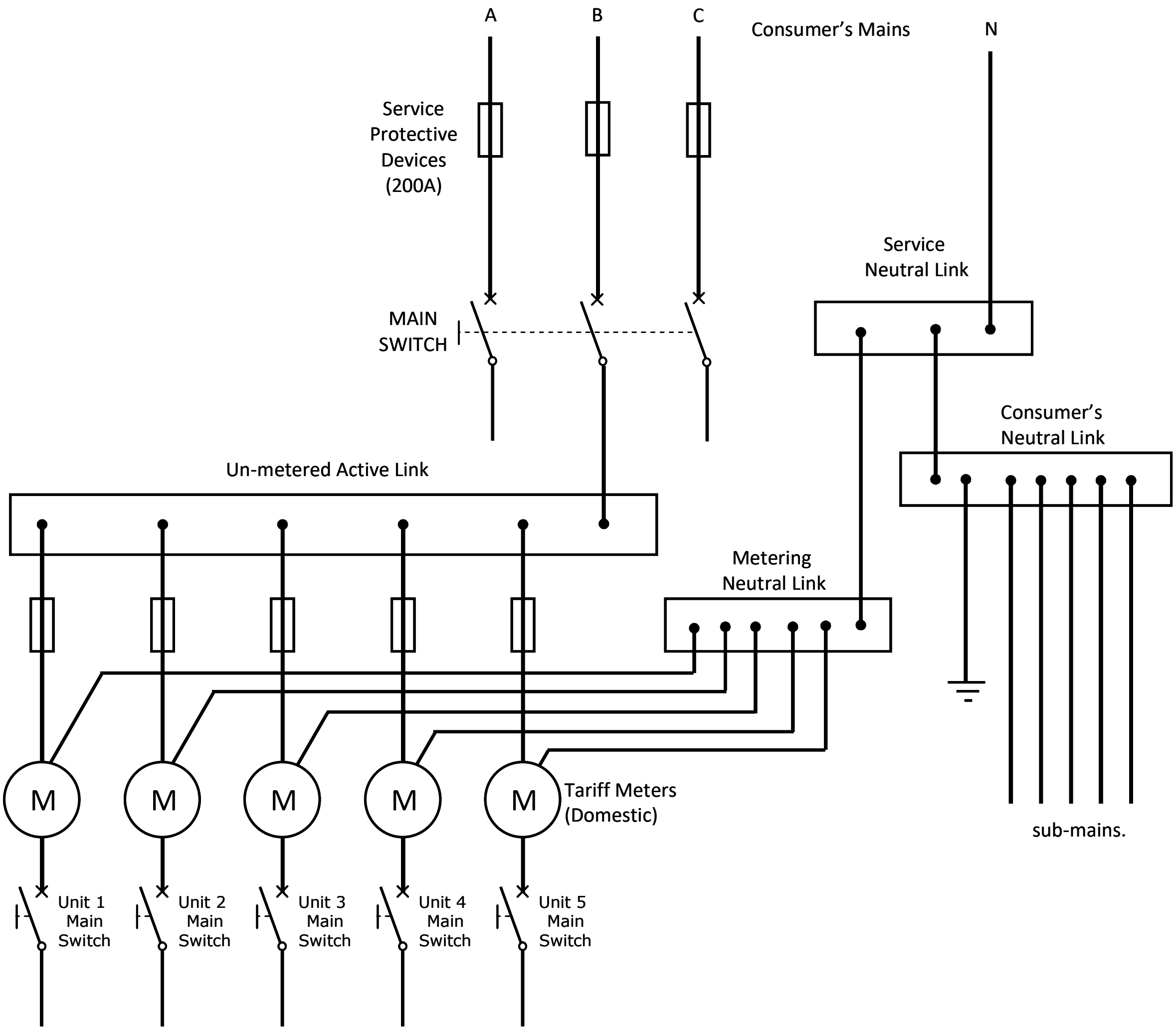


figure 6.

Figure 6 shows single phase single tariff multiple domestic installation, only one phase is show to keep the drawing simple.

Switchboards for multiple domestic installations are usually constructed on banks of 600 x 600 mm hinged or fixed standard panels. Alternately custom built switchboards can be installed. Distribution boards in each unit are usually self contained load centres.

Activity - 29 – C.T. Metering Layouts

NSWSR Section 4.17 Read the suggested text or resource	Group discussion

Activity 30 – C.T. Metering NSWSR Figure 4.15

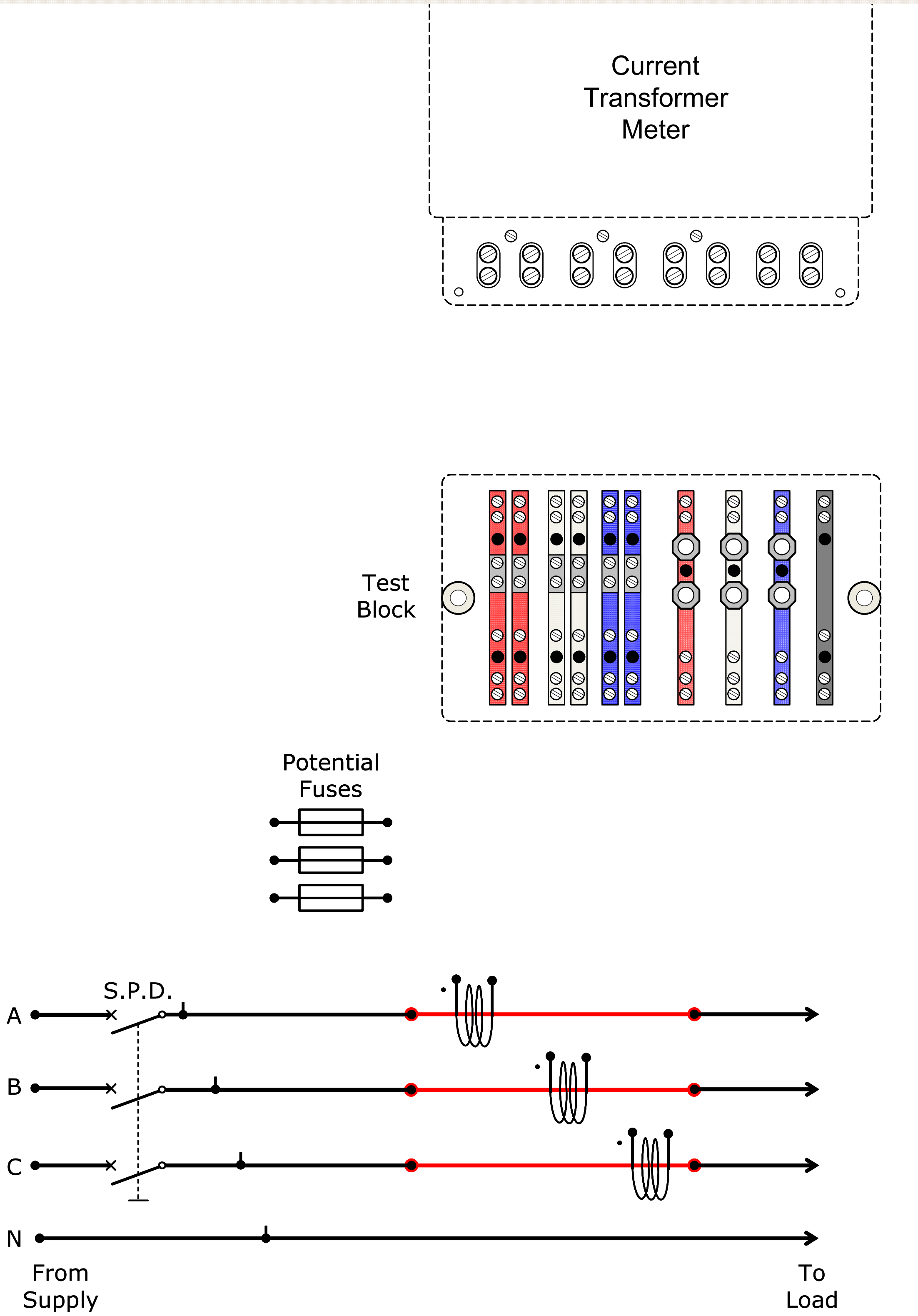


figure 7.

Tutorial – Section 11

1. For the requirements of the NSW Service and Installation Rules, the maximum number of non-domestic customers that may be connected to a 100 A service fuse is:

   1

   2

   4

   No limit

2. Before removing a meter connected to a current transformer, it is essential to:

   open circuit the CT secondary at the metering links

   short circuit the CT secondary winding at the metering links

   short circuit the CT primary winding at the metering links

   short circuit the CT primary to the secondary at the metering links

3. If a three-phase installation (single tariff) has a maximum demand that exceeds 100 A per phase:

   CT metering must be installed

   Whole current metering must be installed

   Off-peak meters must be installed

   125 Amp relays must be installed

4. 4. Generally, the maximum height above ground, floor or platform which a main switch may be installed on the main switchboard is:

   (a) 1.2 metres

   (b) 2.0 metres

   (c) 2.5 metres

   (d) 3.0 metres

5. 5. Generally, the minimum height above ground, floor or platform which a main switchboard of a domestic installation is;

   (a) 1.2 metres

   (b) 2.0 metres

   (c) 2.5 metres

   (d) 3.0 metres

6. When installing energy meters in low voltage installations not exceeding 100 A per active conductor, it is important to ensure the top edge of the meter is no more than:

(a) 1.8 m above the ground, floor or platform and the bottom edge is at least 0.6 m above the ground, floor or platform.

(b) 2 m above the ground, floor or platform and the bottom edge is at least 0.3 m above the ground, floor or platform.

(c) 2 m above the ground, floor or platform and the bottom edge is at least 0.6 m above the ground, floor or platform.

(d) 2.2 m above the ground, floor or platform and the bottom edge is at least 0.5 m above the ground, floor or platform.

7. The minimum current rating of an installations service neutral link is:

(a) 32A

(b) 63A

(c) 100A

(d) 150A

8. According to the NSW service and installation rules, the minimum height of a service protective device above finished floor (AFFL) level is:

(a) 2.0 metres

(b) 1.2 metres

(c) 0.6 metres

(d) 0.5 metres

9. According to the NSW service and installation rules, a 400A service will require what type of current transformer:

(a) type 'S'

(b) type 'T'

(c) type 'U'

(d) type 'W'

10. According to the NSW service and installation rules, the minimum size for a C.T. meter panel is:

(a) 900mm x 600mm

(b) 600mm x 600mm

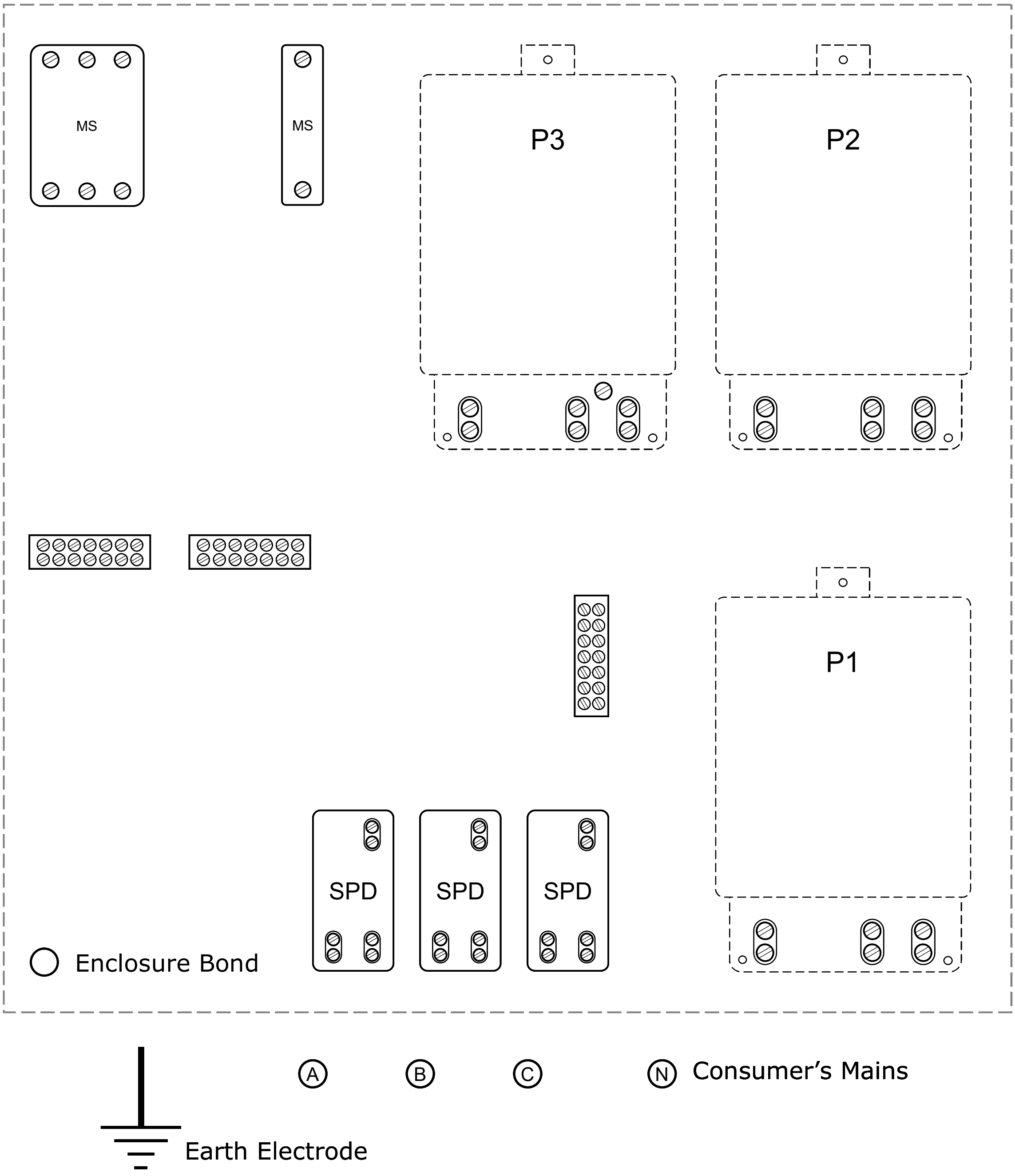
(c) 580mm x 580mm

(d) 380mm x 300mm

11. Draw in all the required connections for a three phase dual tariff main switchboard. Consumer's mains are unprotected 4 core XLPE copper cable.

Label all equipment

Specify all cable sizes



Tutorial Answers

Section 1

1	D
2	D
3	D
4	C
5	A
6	D
7	C
8	B
9	D
10	D
11	C
12	A
13	B
14	D
15	A

12. 16. Methods

(a) Automatic disconnection of supply

(b) Class II

(c) Separation

(d) Limit fault current

(Clause number 1.5.5.2)

13. 17. Factors in Designing an Installation (any 3)

(a) protect persons, livestock and property from harmful effects

(b) function correctly as intended

(c) connect, operate safely and be compatible with the electricity distribution system, or other source of supply, to which the electrical installation is to be connected

(d) minimize inconvenience in the event of a fault

(e) facilitate safe operation, inspection, testing and maintenance.

(clause number 1.6.1)

14. 18.Protection against direct contact by enclosures or barriers.

(a) (a) IP2X or IP4X for horizontal surfaces

(b) (Clause number 1.6.1)

(c) (b) 12.5mm for IPX2, 1.0mm for IP4X

(Clause number Table G1)

15. 20. Factors in Determining the number of circuits (any 3)

(a) (a) The relationship of the equipment,

(b) (b) The load and operating characteristics

(c) (c) The limitation of consequences of circuit failure including loss of supply

(d) (d) The facility for maintenance work

(clause 2.2.1.1)

16. 21. Methods of determining maximum demand

(a) (a) calculation

(b) (b) assessment

(c) (c) measurement

(d) (d) limitation

(clause 2.2.2)

17. 22. Selection and installation of equipment (any 2)

(a) (a) Provide control or isolation of the electrical installation, circuits or individual items

(b) (b) Enable automatic disco of supply in the event of an overload, short-circuit or excess earth leakage current

(c) (c) Protection of the electrical installation against failure from overvoltage or undervoltage conditions.

(d) (d) Provide for switchgear and controlgear to be grouped and interconnected on switchboards, enclosed against external influences, and located in accessible positions.

(e) Provide for switchgear and controlgear to be grouped and interconnected on switchboards

(f) enclosed against external influences, and located in accessible positions.

(clause 2.1.2)

23. Redundant cables must be terminated at both ends the same as live cables.

(clause 1.5.11.4)

24. Protection of equipment at different voltages

(a) segregation

(b) devices for protection against overvoltages.

(clause 1.5.11.2)

25. Protection against mechanical movement – devices must disconnect or isolate electrical equipment, as may be necessary to prevent or remove danger.

(clause 1.5.13)

26. Maximum hole is 50mm

(clause 3.9.9.3)

Section 2

1	C
2	C
3	B
4	B
5	D
6	C
7	C
8	C
9	B
10	A

11. Point per final sub circuit

Circuit number	Purpose / load	Protection Device / Rating (A)	Number of points per circuit
1	Light 1	10A	11
2	Light 2	10A	11
3	Power 1 – 10A S/O	20A	16
4	Power 2 – 10A S/O	20A	16
5	Power 3 – 15A S/O	16/20A	1
6	A/C	20A	1
7	H.W.S	20A	1

12. Schedule

Pos.	**Amps**	**Designation**	**Pos.**	**Amps**	**Designation**
1	**10A**	**Light 1 (RCD)**	**2**	**10A**	**Light 1 (RCD)**
3	**20A**	**Power 1 (RCD)**	**4**	**20A**	**Power 2(RCD)**
5	**20A**	**Power 3(RCD)**	**6**	**20A**	**Air Conditioner**
7	**20A**	**Hot Water System**	**8**		**Spare**

13. Factory points per final sub circuit

Circuit number	Purpose / load	Protection Device / Rating (A)	Number of points per circuit
1	Light 1 – High Bays	16A	5
2	Light 2 – High Bays	16A	5
3	Power 1 – 10A S/O	20A	4
4	Power 2 – 10A S/O	20A	4
5	Power 3 – 10A S/O	20A	4
6-9	15A 3ϕ S/O	20A	1
10-13	20A 3ϕ S/O	20A	1
14-15	32A 3ϕ S/O	20A	1

14. Factory points per final sub circuit

Pos.	Amps	Designation	No.	Amps	Designation
1	16A	Light 1 – High Bays (RCD)	**2**	20A	20A 3ф Socket outlet 1 (RCD)
3	16A	Light 2 – High Bays (RCD)	**4**	20A	20A 3ф Socket outlet 1 (RCD)
5		Spare	**6**	20A	20A 3ф Socket outlet 1 (RCD)
7	20A	Power 1 (RCD)	**8**	20A	20A 3ф Socket outlet 2 (RCD)
9	20A	Power 2 (RCD)	**10**	20A	20A 3ф Socket outlet 2 (RCD)
11	20A	Power 3 (RCD)	**12**	20A	20A 3ф Socket outlet 2 (RCD)
13	20A	15A 3ф Socket outlet 1 (RCD)	**14**	20A	20A 3ф Socket outlet 3 (RCD)
15	20A	15A 3ф Socket outlet 1 (RCD)	**16**	20A	20A 3ф Socket outlet 3 (RCD)
17	20A	15A 3ф Socket outlet 1 (RCD)	**18**	20A	20A 3ф Socket outlet 3 (RCD)
19	20A	15A 3ф Socket outlet 2 (RCD)	**20**	20A	20A 3ф Socket outlet 4 (RCD)
21	20A	15A 3ф Socket outlet 2 (RCD)	**22**	20A	20A 3ф Socket outlet 4 (RCD)
23	20A	15A 3ф Socket outlet 2 (RCD)	**24**	20A	20A 3ф Socket outlet 4 (RCD)
25	20A	15A 3ф Socket outlet 3 (RCD)	**26**	32A	32A 3ф Socket outlet 1
27	20A	15A 3ф Socket outlet 3 (RCD)	**28**	32A	32A 3ф Socket outlet 1
29	20A	15A 3ф Socket outlet 3 (RCD)	**30**	32A	32A 3ф Socket outlet 1
31	20A	15A 3ф Socket outlet 4 (RCD)	**32**	32A	32A 3ф Socket outlet 2
33	20A	15A 3ф Socket outlet 4 (RCD)	**34**	32A	32A 3ф Socket outlet 2
35	20A	15A 3ф Socket outlet 4 (RCD)	**36**	32A	32A 3ф Socket outlet 2

Section 3

1	C
2	A
3	B
4	D
5	C
6	C
7	D
8	A
9	B
10	C

11	A
12	B
13	A
14	C
15	D
16	B
17	A
18	B
19	C
20	C

21	C
22	D
23	C
24	B
25	A

Section 4

1	C
2	A
3	B
4	D
5	C
6	C
7	D
8	A
9	B
10	C

15. Maximum demand single domestic (AS3000 Table C1 Col2)

Load Group	Load	Calculation	Demand
A(i)	Lights (32 points)	3 + 2 =	5
A(ii)	External Lights (3 points)	1500/230 x 0.75 =	4.9
B(i)	Socket outlets + A/C (59 + 1 points)	10 + 5 + 5 + 5 =	25
F	H.W.S.	4400/230	19.1
C	Range	10200/230 x 0.5 =	22.1
D	A/C	included in load group (Bi)	-
		Maximum Demand	**76.1A**

12. Maximum demand - multiple domestic (AS3000 Table C1 Colum 5)

No of Units A phase ___**21**___ B phase ___**21**___ C phase ___**21**___

Load Group	Load	Calculation	A	B	C
A(i)	Lights	21 x 0.5 =	10.5	10.5	10.5
B(i)	Socket outlets	50 + (21 x 1.9) =	89.9	89.9	89.9
C	Range	21 x 2.8 =	58.8	58.8	58.8
F H	H.W.S Community Lighting	100 + (21 x 0.8) = (48 x 0.22) + (10 x 0.15) =	116.8 12.06	116.8	116.8
I	Community Power	2 x 2 =	4		
			292A	276A	276A

Maximum Demand = 292A (balance complies less than 25A)

Section 5

1	C
2	A
3	B
4	D
5	C

6. Non Domestic maximum demand (AS3000 Table C2 Colum 3)

Load Group	Load	Calculation	A	B	C
A	Lights - high bays	6 x 2.6 =	15.6	15.6	15.6
B(i)	10A socket outlets	<u>1000 + (21 x 750)</u> = 230	72.8	72.8	72.8
B(iii)	4 x 32A socket outlets	32 + (3 x 32 x 0.75) =	104	104	104
B(iii)	3 x 20A socket outlets	3 x 20 x 0.75 =	45	45	45
D	motor 1	42 x 100% =	42	42	42
D	motor 2	42 x 75% =	31.5	31.5	31.5
D	motor 3	28 x 50% =	14	14	4
H	welder 1	full rated current	18	18	
H	welder 2			18	18
		Total	342.9	**360.9**	342.9

Maximum Demand = 360.9A (balance complies less than 25A)

7. Maximum demand multiple domestic (AS3000 Table C1 Colum 4)

No of Units A phase ___**11**____ B phase __**11**_____ C phase ____**11**____

Load Group	Load	Calculation	A	B	C
A(i)	Lights	5 + (11 x 0.25) =	7.75	7.75	7.75
B(i)	Socket outlets	15 + (11 x 3.75) =	56.25	56.25	56.25
C	Range	11 x 2.8 =	30.8	30.8	30.8
F	H.W.S	11 x 6 =	66	66	66
D	A/C	11 x 14 0.75 =	115.5	115.5	115.5
H	Community Lighting	(24 x 0.22) + (10 x 0.15) =		6.78	
	Community Power	10 x 2 = 20A (15A max)		15	
		Total	276.3	**298**	276.3

Maximum Demand = 298A (balance complies less than 25A)

8. Maximum demand single domestic (AS3000 Table C1 Colum 2)

Load Group	Load	Calculation	Demand
A(i)	Lights (22 points)	3 + 2 =	5
B(i)	Socket outlets (36 points)	10 + 5 =	15
C	Range	8000/230 x 0.5 =	17.4
F	H.W.S.	4400/230	19.1
D	A/C	14 x 0.75 =	10.5
		Maximum Demand	**67A**

Section 6

1.

13. No **13** Column No **5** Cable Size **95mm²**
PE Size **25mm²**

14. I_B = **172A** I_N = **200A**
I_Z = **213A** $I_B \le I_N \le I_Z$ (**Y**/N)

2.

15. No **5** Column No **18**
Cable Size **25mm²** PE Size **6mm²**

16. I_B = **80A** I_N = **80A**
I_Z = **90A** $I_B \le I_N \le I_Z$ (**Y**/N)

3.

17. $$I = \frac{I_N}{D.R.} = \frac{200}{0.9} = 222A$$

18. $$I_Z = 230 \times 0.9 = 207A$$

19. No **7** Column No **8**
Cable Size **95mm²** PE Size **25mm²**

20. I_B = **185A** I_N = **200A**
I_Z = **207A** $I_B \le I_N \le I_Z$ (**Y**/N)

4.

21. $$I = \frac{I_N}{D.R.} = \frac{160}{0.9} = 177.8A$$

22. $$I_Z = 183 \times 0.9 = 164A$$

23. No **7** Column No **15**
Cable Size **95mm²** PE Size **25mm²**

24. I_B = **141A** I_N = **160A**
I_Z = **164A** $I_B \le I_N \le I_Z$ (**Y**/N)

5.

25. No **10** Column No **15** Cable Size **6mm²**
PE Size **2.5mm²**

26. I_B = **27A** I_N = **32A**
I_Z = **35A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

6.

27. No **4** Column No **15** Cable Size **6mm²** PE Size **2.5mm²**

28. I_B = **35A** I_N = **80A**
I_Z = **90A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

7.

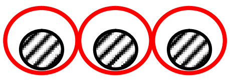
29.

30. No **14** Column No **24** Cable Size **95mm²**
PE Size **25mm²**

31. I_B = **188A** I_N = **200A**
I_Z = **210A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

8.

32.



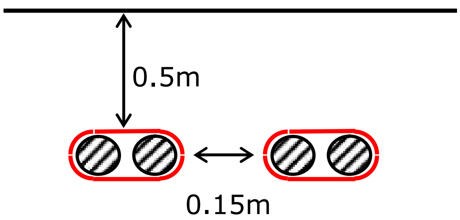
33.

34. No **7** Column No **27**
Cable Size **240mm²** PE Size **95mm²**

35. I_B = **400A** I_N = **400A**
I_Z = **422A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

9.

36. $I = \frac{I_N}{D.R.} = \frac{20}{0.9 \times 0.87} = 25.6A$



37. $I_Z = 30 \times 0.9 \times 0.87 = 23.5A$

38. De-rating Table **25(2)**

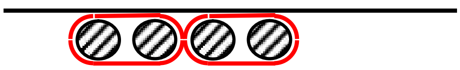
Column No **5** D.R. **0.87**

39. No **10** Column No **23**
Cable Size **2.5mm²** PE Size **2.5mm²**

40. I_B = **20A** I_N = **20A**
I_Z = **23.5A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

10.

41. $I = \frac{I_N}{D.R.} = \frac{40}{0.81} = 49.4A$



42. $I_Z = 60 \times 0.81 = 48.6A$

43. De-rating Table **22**

Column No **5** D.R. **0.81**

44. No **10** Column No **5**
Cable Size **10mm²** PE Size **4mm²**

45. I_B = **34A** I_N = **40A**
I_Z = **48.6A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

11.

46. $I = \frac{I_N}{D.R.} = \frac{63}{0.65} = 96.9A$

47. $I_Z = 112 \times 0.65 = 72.8A$

48. De-rating Table ____**22**______

Column No ___**7**____ D.R. __**0.65**__

49. No __**13**_ Column No ___**11**____
Cable Size **50mm²** PE Size **16mm²**

50. I_B = __**54A**____ I_N =___**63A**_____
I_Z = __**72.8A**___ $I_B \le I_N \le I_Z$ (**Y**/N)

12.

51. HFI-90-TP =75 C (table 1 AS3008.1)

52. $I = \frac{I_N}{D.R.} = \frac{125}{0.9 \times 0.74} = 187.7A$

53. $I_Z = 211 \times 0.9 \times 0.74 = 140A$

54. De-rating Table ____**25(2)**______

Column No ___**3**____ D.R. __**0.74**__

55. No __**10**_ Column No ___**23**____
Cable Size **50mm²** PE Size **16mm²**

56. I_B = __**34A**____ I_N =___**40A**_____
I_Z = __**48.6A**___ $I_B \le I_N \le I_Z$ (**Y**/N)

13.

57. $I = \frac{I_N}{D.R.} = \frac{32}{0.82} = 39A$

58. $I_Z = 46 \times 0.82 = 37.8A$

59. De-rating Table **26(2)**

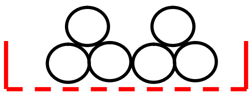
Column No **3** D.R. **0.82**

60. No **9** Column No **16**
Cable Size **4mm²** PE Size **2.5mm²**

61. I_B = **32A** I_N = **32A**
I_Z = **37.8A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

14.

62. $I = \frac{I_N}{D.R.} = \frac{50}{0.89} = 56.2A$



63. $I_Z = 58 \times 0.89 = 51.6A$

64. De-rating Table **23**

Column No **7** D.R. **0.89**

65. No **7** Column No **5**
Cable Size **10mm²** PE Size **4mm²**

66. I_B = **42.5A** I_N = **50A**
I_Z = **51.6A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

15.

67. $I = \frac{I_N}{D.R.} = \frac{180}{0.9} = 200A$

68. $I_Z = 217 \times 0.9 = 195A$

69. De-rating Table **28(2)**

Column No **2** D.R. **0.9**

70. No **14** Column No **25** Cable Size **95mm²**
PE Size **25mm²**

71. I_B = **175A** I_N = **180A**
I_Z = **195A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

16.

72. $I = \frac{I_N}{D.R.} = \frac{400}{0.9} = 444A \quad \frac{444}{2} = 222A$

73. $I_Z = 233 \times 0.9 \times 2 = 419A$

74. De-rating Table **26(2)**

Column No **2** D.R. **0.9**

75. No **14** Column No **25** Cable Size **95mm²**
PE Size **25mm²**

76. I_B = **400A** I_N = **400A**
I_Z = **419A** $I_B \leq I_N \leq I_Z$ (**Y**/N)

17(a).

77. $I = \frac{I_N}{D.R.} = \frac{400}{1.11} = 360.4A$

78. $I_Z = 411 \times 1.11 = 456.2A$

79. De-rating Table **27(2)**

Column No **2** D.R. **1.11**

80. No **14** Column No **25** Cable Size **240mm²** PE Size **95mm²**

81. I_B = **390A** I_N = **400A**
I_Z = **456.2A** $I_B \le I_N \le I_Z$ (**Y**/N)

17(b).

82. $I = \frac{I_N}{D.R.} = \frac{400}{1.11} = 360.4A$

83. $I_Z = 365 \times 1.11 = 405A$

84. De-rating Table **27(2)**

Column No **2** D.R. **1.11**

85. No **14** Column No **27** Cable Size **300mm²** PE Size **70mm²**

86. I_B = **390A** I_N = **400A**
I_Z = **405A** $I_B \le I_N \le I_Z$ (**Y**/N)

Section 7

1	C
2	C
3	D
4	C
5	B
6	D
7	A
8	C
9	D
10	B

11.

87. (a) Consumer's Mains

88. $V_C = 0.285$ mV/A.m (T41C8)

89. $V_d = \frac{L \times I \times V_c}{1000} = \frac{50 \times 350 \times 0.285}{1000} = 4.98V$

90. (b) Sub Mains

91. $V_C = 0.457$ mV/A.m (T40C8)

92. $V_d = \frac{L \times I \times V_c}{1000} = \frac{60 \times 250 \times 0.457}{1000} = 6.86V$

93. (c) Final Sub Circuit

94. $V_C = 15.6$ mV/A.m (T42C6)

95. $V_d = \frac{L \times I \times V_c}{1000} = \frac{30 \times 20 \times 15.6}{1000} = 9.36V$

96. (d) $V_T = V_{CM} + V_{SM} + V_{fsc}$

97. $= 6.86 + 9.36 + 9.36$

98. $= 21.2V$

99. Installation does not comply $V_T >$ 5% of 400V (20V)

100.

12.

(a) Consumer's Mains

V_C = 1.18 mV/A.m (T41C8)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{38 \text{ x } 125 \text{ x } 1.18}{1000} = 5.6V$$

(b) Sub Mains

V_C = 3.86 x 1.155 = 4.4583mV/A.m (T42C6)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{25 \text{ x } 50 \text{ x } 4.4583}{1000} = 5.6V$$

(c) Final Sub Circuit

V_C = 9.71 x 1.155 = 11.215mV/A.m (T42C6)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{31 \text{ x } 25 \text{ x } 15.6}{1000} = 8.69V$$

(d) $V_T = \frac{V_{CM}}{\sqrt{3}} + V_{SM} + V_{fsc} = \frac{5.6}{\sqrt{3}} + 5.6 + 8.69 = 17.5V$

Installation does not comply V_T > 5% of 230V (11.5V)

13.

(a) Consumer's Mains

V_C = 0.227 mV/A.m (T40C8)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{55 \text{ x } 400 \text{ x } 0.227}{1000} = 4.99V$$

(b) Sub Mains

$$V_c = \frac{1000 \text{ x } V_d}{L \text{ x } I} = \frac{1000 \text{ x } 6}{45 \text{ x } 63} = 2.116mV/A.m$$

C.S.A. = 25mm^2 (1.54mV/A.m) T42C6

(c) Final Sub Circuit

$$V_p = \frac{5\% \text{ x } 400 - (V_{CM} + V_{SM})}{\sqrt{3}} = \frac{20 - (4.99 + 6)}{\sqrt{3}} = 5.2V$$

$$V_c = \frac{1000 \text{ x } V_d}{L \text{ x } I} = \frac{1000 \text{ x } 5.2}{40 \text{ x } 32} = 4.06mV/A.m$$

C.S.A. = 10mm^2 (3.86mV/A.m) T42C6

14.

(a) Consumer's Mains

V_C = 0.385mV/A.m (T41C8)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{55 \text{ x } 400 \text{ x } 0.385}{1000} = 3.85V$$

(b) Final Sub Circuit length

Vc = 3.86 1.155 = 4.4583mV/A.m (T40C6)

$$V_p = \frac{5\% \text{ x } 400 - V_{CM}}{\sqrt{3}} = \frac{20 - 3.85}{\sqrt{3}} =$$

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} \therefore V_d \text{ x } 1000 = L \text{ x } I \text{ x } V_c$$

$$\therefore L = \frac{V_d \text{ x } 1000}{I \text{ x } V_c} = \frac{9.32 \text{ x } 1000}{50 \text{ x } 4.4583} = 41.8m$$

15.

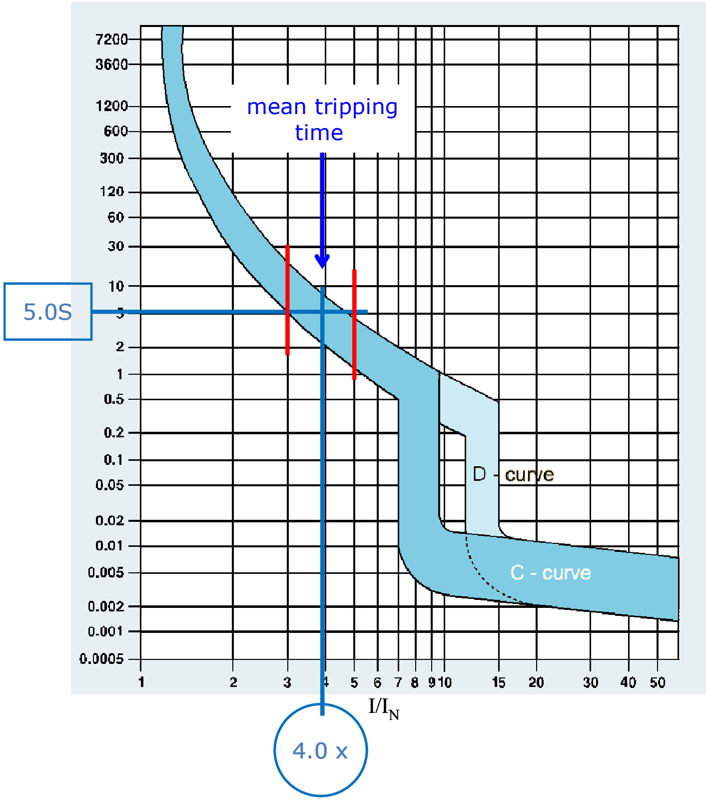
Consumer's Mains – use 0.5 x of maximum demand (I) because of parallel connection.

V_C = 0.582 mV/A.m (T43C8)

$$V_d = \frac{L \text{ x } I \text{ x } V_c}{1000} = \frac{150 \text{ x } 125 \text{ x } 0.0.582}{1000} = 10.912V$$

1	C
2	A
3	A
4	B
5	C
6	B
7	C
8	B
9	C
10	B

11.



101. figure 8

102. mean tripping current ≈ 4 x C.B. Rated current

103. (I_a = 4 x I_N)

104. $Z_S = \frac{U_o}{I_a} = \frac{230}{4 \times 20} = 2.875\,\Omega$

12.

105. mean tripping current ≈ 4 x C.B. Rated current

106. (I_a = 4 x I_N)

107. $Z_{int} = \frac{U_o \times 0.8}{I_a} = \frac{230 \times 0.8}{4 \times 20} = 2.3\,\Omega$

108. or

109. $Z_{int} = Z_s \times 0.8 = 2.875 \times 0.8 = 2.3\,\Omega$

13.

(a) Active and Protective earthing conductor impedance

2.5mm^2 Rc = 9.01Ω/km (AS3008.1 Table 35 Col4) assume 75 C

$$R = \frac{R_c}{1000} \times L \times 2 = \frac{9.01}{1000} \times 35 \times 2 = 0.01802\ \Omega$$

(b) Yes less than 2.3Ω (from question 12)

(c) V_C = 15.6 x 1.155 = 18.018mV/A.m (T42C6)

$$V_d = \frac{L \times I \times V_c}{1000} = \frac{35 \times 20 \times 18.018}{1000} = 12.6V$$

(d) $V_d = V_{cm} + V_{fsc}$ = 4.6 + 12.6 = 17.2V > 11.5V **Does Not comply with AS3000**

14.

(a) 5 section disconnection time
(AS3000 clause 1.5.5.3(d))

Z_S = 0.43Ω

(AS3000 Table 8.1)

$Z_{int} = Z_S$ x 0.8 = 0.43 x 0.8 = 0.344Ω

(b) L_{max} = 90m

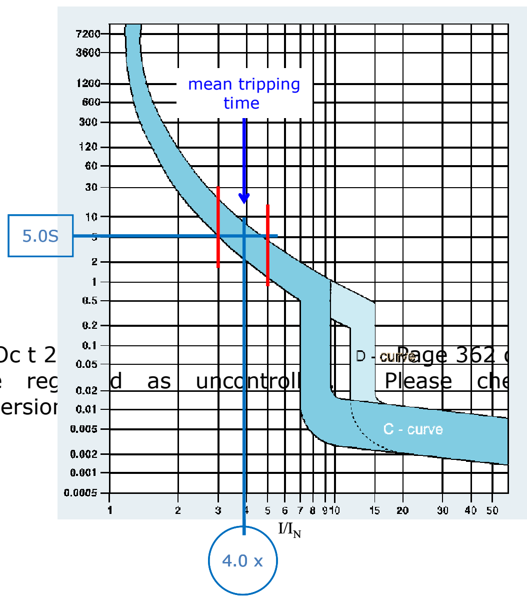
(AS3000 Table B1)

80m complies with A3000

15.

(a) 5 section disconnection time
(AS3000 clause 1.5.5.3(d))

(b) Ia ≈ 4 x I_N = 4 x 125 = 500A



(c)

$$L_{max} = \frac{U_o \times 0.8 \times S_{ph} \times S_{pe}}{I_a \times \rho \times (S_{ph} + S_{pe})}$$

$$= \frac{230 \times 0.8 \times 25 \times 6}{500 \times 22.5 \times 10^{-3} \times (25 + 6)}$$

$$= 79.1\text{m}$$

Section 9

1	C
2	B
3	B
4	C
5	D
6	C
7	D
8	A
9	A
10	A

11.

Cable Current Rating after D.R.	$I_B \le I_N \le I_Z$ **Y / N**	$I_2 \le 1.45 \times I_Z$ **Y / N**
100A	Y	Y
207A	Y	Y
63A	Y	Y
30A	N	N

Circuit Protection Rating I_N	Minimum Cable Current Rating I_Z	De-rating factor
100A	111.1A	0.9 x
180A		
63A		
32A		

	Type	Load Max Demand I_B
1	H.R.C. Fuse	100A
2	H.R.C. Fuse	180A
3	C.B.	60A
4	C.B.	35A

12

4 effects of short circuit (any 4)

- Extremely large currents.
- Cables reaching very high temperatures.
- Insulation failure.
- Destruction of protection devices.
- explosion (Arc blasts).
- Ionisation of enclosures.
- Severe magnetic stresses on conductors and supports.
- Fatal injury to persons and livestock.
- Fire

13.

$$I_L = \frac{S}{\sqrt{3} \text{ x } V_L} = \frac{750 \text{ x } 10^3}{\sqrt{3} \text{ x } 400} = 1{,}082.5\text{A}$$

14.

$$I_{S/C} = \frac{MVA}{\sqrt{3} \text{ x } V_L} = \frac{15 \text{ x } 10^6}{\sqrt{3} \text{ x } 400} = 21{,}650\text{A}$$

15.

$$Z_{Tx} = \frac{V}{I_{S/C}} = \frac{230}{21650} = 0.0106\Omega$$

16.

(a) $Z_{S/C} = \frac{V}{I_{S/C}} = \frac{230}{25000} = 0.0092\Omega$

(b)Rc = 0.248Ω/km (AS3008.1 T35C5) @90 C

$$Z_{CM} = \frac{R_c}{1000} \times L \quad = \frac{0248}{1000} \times 30 \ = 0.00744\ \Omega$$

(c) $Z_T = Z_{S/C} + Z_{CM} = 0.0092 + 0.00744 = 0.01664\Omega$

(d) $I_{S/C} = \frac{V}{Z_T} = \frac{230}{0.01664} = 13{,}822A\ (13.822kA)$

(e) No the 20A 6kA does not have the breaking capacity to interrupt 13.8kA and the fault current limiter should not be rated at more than 200A. A larger kA rating is required.

Section 10

1	B
2	D
3	A
4	B
5	B
6	A
7	B
8	C
9	C
10	D

11.

All active conductors of an a.c. circuit shall be capable of being isolated by a device for isolation.

(clause number 2.3.2.1.1(a))

12.

A switch in a neural conductor is not permitted in consumer's mains and all types of PEN conductors. In all other cases the isolator must switch all active conductors at the same time as the neutral conductor.

(clause number 2.3.2.1.1(b))

13.

Functional switching is required for operational control only and not for safety reasons. Functional switches do not necessarily isolate the supply. Functional switches must be capable of a very large number o operations compared to a isolation switch.

(clause number 2.3.7.1)

14.

No.

(clause number 2.3.2

.2.1)

15.

Yes

(clause number 2.3.7.1)

16.

The cook top must be provided with a switch, operating in all active conductors, mounted near the appliance in a visible and readily accessible position. The switch should be mounted within two metres of the cooking appliance, but not on the cooking appliance, in such a position that the user does not have to reach across the open cooking surface.

(clause number 4.7.1)

17.

No.

(clause number 4.7.1)

18.

No. The safety service must be controlled by a separate main switch. General equipment is not permitted to be supply controlled by a safety service main switch

(clause number 7.2.4.1)

19.

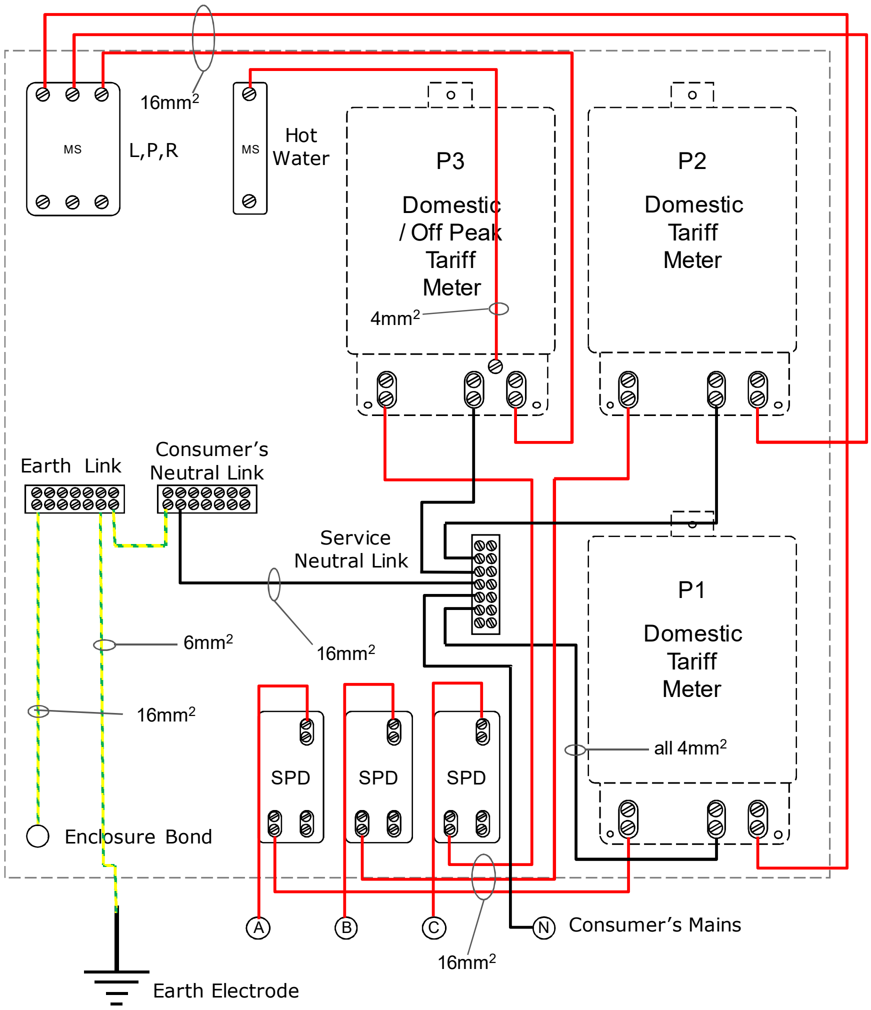
Main switches controlling safety services shall be marked “IN THE EVENT OF FIRE, DO NOT SWITCH OFF”

(clause number 7.2.6.2)

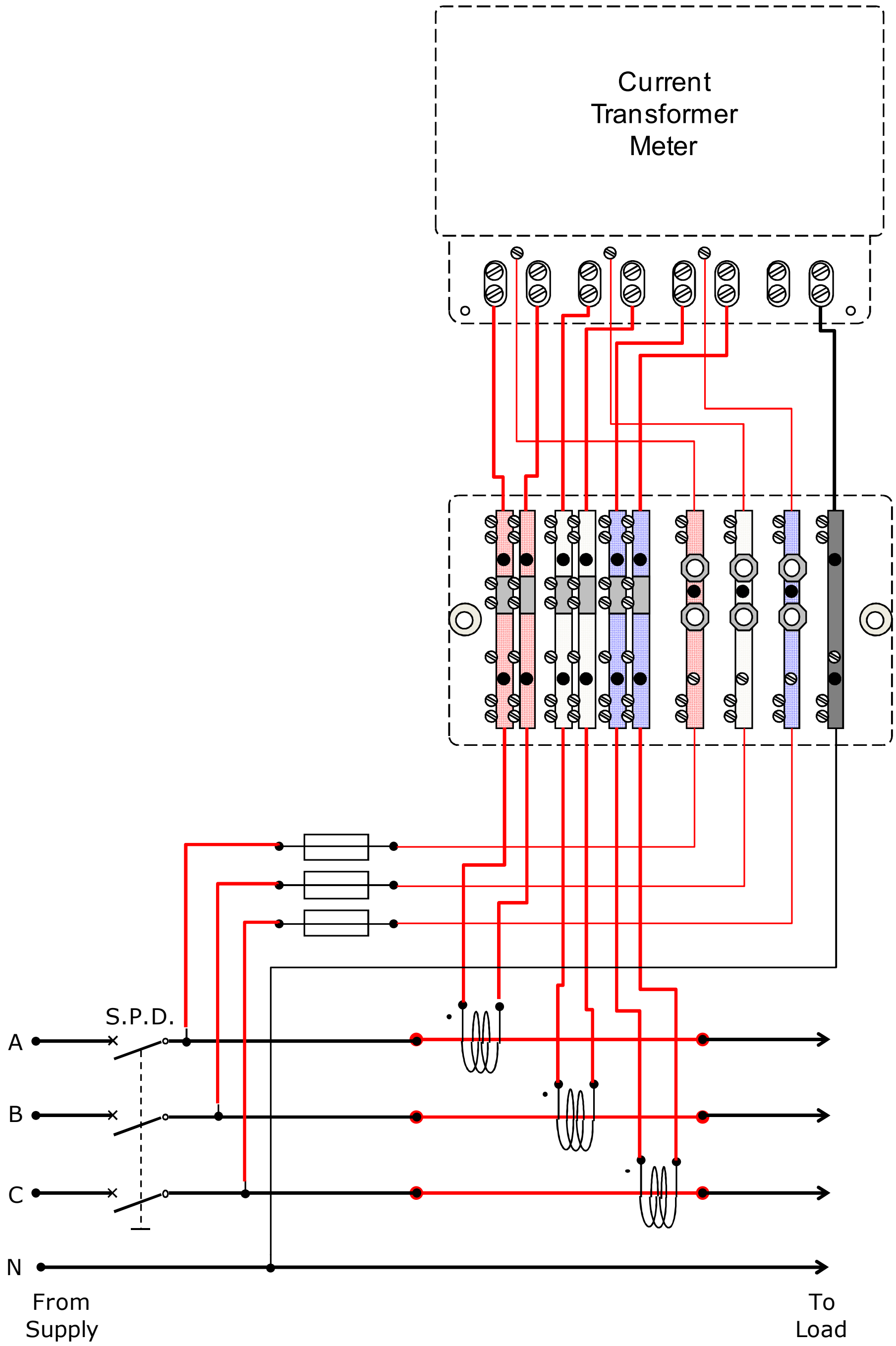
Section 11

1	C
2	B
3	A
4	B
5	A
6	C
7	C
8	D
9	A
10	C

11.



12.



13.

(a) 50mm^2 (AS3000 Table 5.1)

(b) 50mm^2 (AS3000 Table 5.1)

(c) 50mm^2 (AS3000 Table 5.1)

(d) 2.5mm^2 (NSWSR Table 4.5)

(e) 4.0mm^2 (NSWSR Table 4.5)

Is it permissible for a switchboard be installed in a stairwell of a multiple domestic high rise type building?

Is it permissible for the main switchboard of a multiple domestic installation to be located in any given unit within the complex?

List forms of identification required when installing fire and smoke control main switches in multi domestic installations.

What is the minimum current carrying capacity of a neutral link if the switchboard is supplied by 100 A active and neutral conductors?

12. The protected consumer's mains of figure 8 are 240mm^2 4 core XLPE Aluminium cables, protected by 400A H.R.C. fuses in the distribution transformer. The metering panel is located 12m from the C.T. cubical. Specify the cable size of the:

(f) Main Earth

(g) M.E.N. link

(h) Main Switch Board Equipotential Bond

(i) Metering potential circuit wiring

(j) Metering current circuit wiring

13. Draw in all the required connections for a 400A C.T. metering main switchboard shown in figure 8.

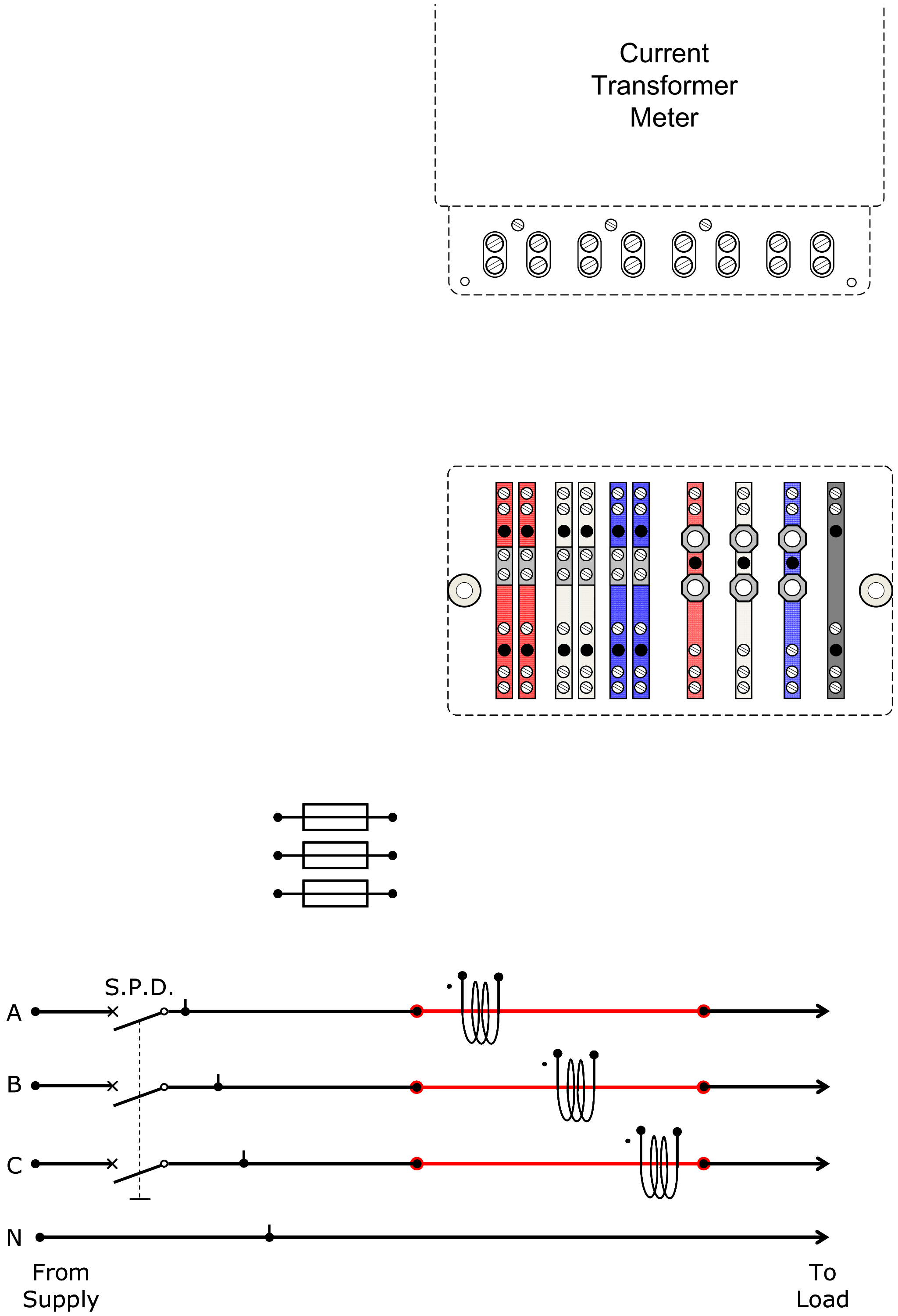


figure 8.