GOVERNMENT OF WESTERN AUSTRALIA

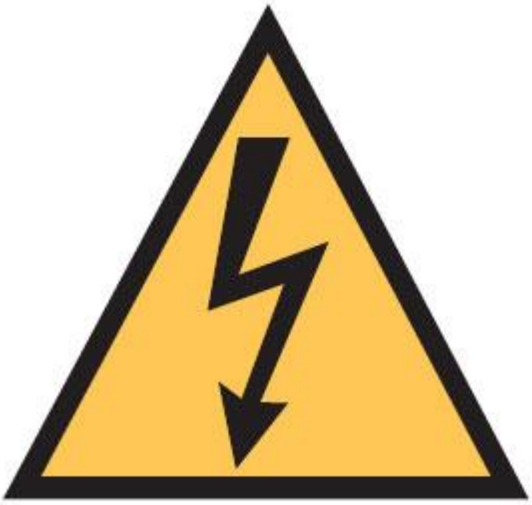
TAFE WA North Metropolitan

RTO Code: 52786

Resource Book

UEEEL0047

Identify, shut down and restart systems with alternate supplies



UEE Training Package Support Material

Based on:
National Electrotechnology Industry Standards

North Metropolitan TAFE
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Acknowledgements

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CONTENTS

References

- Electrical (licensing) Regulations 1991.
- Work Health and Safety Act 2020.
- Work Health and Safety (General) Regulations 2022.
- Electrical Trade Practices (3thed.) Phillip Chadwick
- Code of Practice for persons working on or near energised electrical installations.
- St John's First Aid and C.P.R. Available library and or St Johns .
- AS/NZS 3000 Electrical Installations Wiring Rules
- AS/NZS 4777(series) Grid connection of energy systems via inverters
- AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays
- AS/NZS 3010 Electrical installations - generating sets
- AS/NZS 4509 (series) Stand-alone power systems
- AS 3011(series) Electrical installations - Secondary batteries installed in buildings
- AS/NZS 5139 Electrical installations - Safety of battery systems for use with power conversion equipment
- AS/NZS 4836 Safe working on or near low-voltage and extra-low voltage electrical installations and equipment

UEE30820 Certificate III in Electrotechnology Electrician

UEEEL0047 - Identify, shut down and restart systems with alternate supplies

Pre-requisite Unit

UEECD0007 Apply work health and safety regulations, codes and practices in the workplace

UEECD0019 Fabricate, assemble and dismantle utilities industry components

UEECD0020 Fix and secure electrotechnology equipment

UEECD0051 Use drawings, diagrams, schedules, standards, codes and specifications

UEEEL0003 Arrange circuits, control and protection for general electrical installations

UEEEL0020 Solve problems in low voltage a.c. circuits

UEEEL0023 Terminate cables, cords and accessories for low voltage circuits

UEEEL0019 Solve problems in direct current (d.c.) machines

UEEEL0021 Solve problems in magnetic and electromagnetic devices

and

UEECD0043 Solve problems in direct current circuits

or

UEECD0044 Solve problems in multiple path circuits

UEECD0046 Solve problems in single path circuits

Elements and Performance Criteria

ELEMENTS		**PERFORMANCE CRITERIA**	
Elements describe the essential outcomes.		Performance criteria describe the performance needed to demonstrate achievement of the element.	
1	**Prepare to work on systems with alternate supplies**	**1.1**	Nature of the installation is obtained from appropriate written documentation, electrical drawings and/or relevant person/s to determine the scope of work
		1.2	WHS/OHS workplace procedures are obtained, interpreted and applied
		1.3	Hazards are identified, risks are assessed, and control measures are implemented
		1.4	Tools, equipment and circuit testing devices are obtained and checked for correct operation and safety in accordance with workplace procedures
		1.5	Work supervisor is consulted to ensure work is coordinated effectively with others
2	**Identify and isolate alternate supplies**	**2.1**	Labelling indicating generation system/s connected on site is located, interpreted and checked against electrical diagrams
		2.2	Switchboard, circuits and known supply are identified

		2.3	Site procedures for isolation and shutdown are obtained and interpreted
		2.4	Circuit to be isolated is identified and tested
		2.5	Shutdown procedures are completed in accordance with industry standards and workplace procedures
		2.6	Isolation of energy sources is completed and proved in accordance with workplace procedures, industry standards and regulatory requirements
		2.7	Systems are inspected and tested for compliance with industry and regulatory standards
		2.8	Battery storage system integrity is checked in accordance with industry standards and regulatory requirements
		2.9	System is re-instated after isolation
3	**Complete work and document records**	**3.1**	WHS/OHS work completion risk control measures and procedures are followed
		3.2	Worksite is cleaned and made safe in accordance with workplace procedures
		3.3	Work completion is documented, electrical drawings are updated, and relevant personnel are notified in accordance with workplace procedures and regulatory requirements

Performance Evidence

Evidence required to demonstrate competence in this unit must be relevant to and satisfy all of the requirements of the elements, performance criteria and range of conditions on at least two separate occasions and include:

- applying work health and safety (WHS)/occupational health and safety (OHS) workplace procedures
- identifying and assessing hazards and risks, including hazards based on supply system labelling, and implementing control measures
- obtaining and checking required tools, equipment and testing devices
- reading and interpreting electrical documentation, labelling and drawings
- identifying alternative supply arrangements and configurations
- applying safe shutdown procedures
- isolating energy sources in accordance with workplace procedures and regulatory requirements, including:
    - applying safe isolation practices
    - identifying correct isolation device
    - identifying and checking operation of control device/s
    - identifying live conductors
    - identifying known source of electromotive force (EMF) for testing purposes
    - correctly using a voltage tester
    - isolating multiple supplies, where required
    - isolating under no loads
    - ensuring all energy sources are isolated
    - de-energising charging sources, including:

- solar charge controllers
- battery chargers
  - proving systems are isolated
  - tagging-out all supplies
- ensuring all installation work complies with relevant industry standards and legislation to which the selection, installation and control equipment of each type of system must comply
- checking battery storage system integrity is in accordance with industry standards and regulatory and manufacturer requirements, including ventilation, correct isolation devices and installation position
- safely re-instating generation system to operational mode according to site documentation and manufacturer instructions
- completing required documentation and forwarding to relevant parties.

Knowledge Evidence

Evidence required to demonstrate competence in this unit must be relevant to and satisfy all of the requirements of the elements, performance criteria and range of conditions and include knowledge of:

- working safely with alternate supplies, including identifying hazards and controlling risks in compliance with regulatory and enterprise requirements
- main types, arrangements and configurations of alternative supplies (generating system), including renewable and non-renewable generating systems
- fundamental requirements, including:
  - connection methods of alternative supplies
  - local supply authority requirements
  - characteristics and operation of uninterruptable power supplies (UPS)
  - direct current (d.c.) polarity requirements, including switching, correct rating of d.c. switches and protection devices
  - importance of replacing components like-for-like
  - inverter principles, including operation and interaction with the installation, anti-islanding and islanding requirements and testing requirements
  - identification and labelling requirements and their purpose
  - arrangement for connecting an alternative supply to an installation, including automatic and manual changeover switches, multiple main switches and switchboard wiring
  - earthing arrangements, including equipotential bonding, and earthing methods and requirements for stand-alone systems and generators
- safe isolation of the generator/energy source, including:
  - anti-islanding
  - auto changeover/auto start
  - backup – external power supply (EPS)/UPS mode or backup mode
  - earth fault alarm
  - voltage rise
  - voltage parameters AS/NZS 4777 Grid connection of energy systems via inverters
  - no loads
  - deenergising charging sources such as solar charge controllers, and battery chargers
  - AS/NZ 4836 Safe working on or near low-voltage electrical installations and equipment
- labelling and identification of alternate supply systems
- battery storage systems, including regulatory and manufacturer requirements
- relevant industry standards to which the selection, installation and control equipment of each type of system must comply, including:
  - AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules) relating to the requirements for electricity generation systems installation and electricity converters

  - AS/NZS 4777(series) Grid connection of energy systems via inverters
  - AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays
  - AS/NZS 3010 Electrical installations - generating sets
  - AS/NZS 4509 (series) Stand-alone power systems
  - AS 3011 Electrical installations - Secondary batteries installed in buildings
  - AS/NZS 5139 Electrical installations - Safety of battery systems for use with power conversion equipment
- site and regulatory documentation requirements.

Assessment Conditions

Assessors must hold credentials specified within the Standards for Registered Training Organisations current at the time of assessment.

Assessors must also hold the occupational licence for the jurisdiction the assessment is occurring where the activity being assessed requires a licence to practice.

Assessment must satisfy the Principles of Assessment and Rules of Evidence and all regulatory requirements included within the Standards for Registered Training Organisations current at the time of assessment.

Assessment must occur in workplace operational situations where it is appropriate to do so; where this is not appropriate, assessment must occur in simulated workplace operational situations that replicate workplace conditions.

Assessment processes and techniques must be appropriate to the language, literacy and numeracy requirements of the work being performed and the needs of the candidate.

Resources for assessment must include access to:

- a range of relevant exercises, case studies and/or other simulations
- relevant and appropriate materials, tools, equipment and personal protective equipment (PPE) currently used in industry
- applicable documentation, including workplace procedures, equipment specifications, manufacturer instructions, regulations, codes of practice and operation manuals.

Links

Companion Volume Implementation Guides are found in VETNet - https://vetnet.gov.au/Pages/TrainingDocs.aspx?q=b8a8f136-5421-4ce1-92e0-2b50341431b6

Training Guide

Activity	Topic	Primary Reference	Page
1	Working Safely with alternate supplies	Resource Book	
2	Types of arrangements & configurations of alternatives supplies	Resource Book	
3	Fundamental requirements	Resource Book	
4	Safe Isolation	Resource Book	
5	Identification & labelling of alternative supplies	Resource Book	
6	Battery Storage systems	Resource Book	
7	Regulations and standards	Resource Book	
8	Site and regulatory documentation requirements	Resource Book	

Assessment Strategy

Conditions of Assessment:

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

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

Assessment Methods:

Written Knowledge Assessment – based on the Knowledge Evidence, to be deemed competent you are required to achieve a Satisfactory Result in the Knowledge Assessment.

Observed Skills Assessment – based on the Elements and Performance Evidence of this Competency Unit UEEEL0047to be deemed competent you are required to achieve a Satisfactory Result in the Skills Assessment

LABORATORY INSTRUCTIONS

Students working in laboratories at North Metropolitan TAFE Campus's do so on the condition that they agree to abide by the following instructions. Failure to observe the safety instructions may result in disciplinary action up to and including cancellation of your training contract with NMTafe.

1. No circuit is to be plugged in or switched on without the specific permission of the lecturer in charge of the class. A circuit must be switched off, isolated and tested for ZERO VOLTS before any supply leads are removed. The DANGER TAG PROCEDURE must be used at all times.
2. Do not leave any circuit switched on any longer than necessary for testing. Do not leave any circuit switched on unattended.
3. Check each item of equipment before using. Report any broken, damaged or unserviceable equipment to your Lecturer.
4. All wiring must be disconnected at the end of each practical class or as each project is completed.
5. Make all connections in a safe manner with an appropriate connecting device. Unshielded 4mm banana plugs are not to be used for wiring.
6. Switch off, remove the plug from the socket and attach your DANGER TAG to the plug top before working on any project. It is not sufficient to simply turn the switch off.
7. When disconnecting your wiring from a connection made under a screw, undo the screw to remove the wiring, do not cut the wire off.
8. Observe the correct colour code for all wiring projects.
9. Test your circuit for short circuits with your multimeter before asking your Lecturer to switch circuit on. Test the Tester before and after EACH test.
10. Where an activity sheet is issued for a project, complete each step in the Procedure before moving to the next step. Advise your Lecturer when you have completed the activity.
11. Draw ALL DIAGRAMS in PENCIL so that they can be easily changed or corrected. Mark off each connection on your diagram as it is made.
12. Check the range before taking a reading with a multimeter.
13. Make sure that it is YOUR plug before inserting plug into an outlet.
14. Always switch multimeter OFF, or to the highest possible AC VOLTS range when you have finished using it.
15. Report any unexpected situations or events to your Lecturer.

DANGER TAG PROCEDURE for ELECTRICAL TRADE LABORATORIES

THE FOLLOWING PROCEDURE IS COMPULSORY

1. The student is to attach a DANGER TAG on to the plug top of the project lead before proceeding with the allocated project. A danger tag must be attached to the plug top at all times, when the lead is NOT plugged into the supply outlet. Plug tops or leads are not to be connected to the supply outlet WHILE A DANGER TAG is attached.

2. The student is to assemble the project according to project instruction procedure and lecturer's directions in its isolated and de-energised state and report to the lecturer as necessary and on completion.

3. The lecturer is to: -

   a. Check the project for safety and

   b. Ensure that the student has performed a safety check, including a short circuit test using the recommended procedure.

4. When the lecturer is satisfied that the project is safe to connect and energise the lecturer is to instruct the student to REMOVE the DANGER TAG from the plug top.

5. The student is to plug in the project and switch it on in the presence of the lecturer.

6. The lecturer is to determine whether or not the project is operating satisfactorily.

7. If the project operates satisfactorily the student may take measurements using correct meters with regard to the safety risks associated with using the particular item of test equipment including;

   a. Selecting correct meter function,
   b. Holding meter probes correctly during measuring with fingers behind knurls (finger guards) at all times.

   This is to be done under general supervision of lecturer. The student is NOT to modify, disassemble or carry out ANY unsafe act.

8. If the circuit is to be modified the student must:

   a. Switch the circuit off,
   b. Disconnect the project from the supply,
   c. Attach the DANGER TAG to the plug top,
   d. Report to the lecturer for instructions,
   e. In the lecturer's presence the student is to: -
   f. TEST and VERIFY for ZERO VOLTAGE.
   g. Restart the DANGER TAG procedure from step 2 above.

9. When the student is satisfied that the project has been completed the student is to: -

   a. Switch the project off,
   b. Remove the plug,
   c. Replace the DANGER TAG on the plug top,
   d. Report to the lecturer for instructions,

   In the lecturer's presence the student is to: -

   e. TEST and VERIFY for ZERO VOLTAGE.

   The lecturer is then to instruct the student to: -

   f. Disassemble the project
   g. Remove the DANGER TAG and store the equipment in its designated place.

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

Identify shut down and restart systems with alternative supplies

Task:

To identify different types of power supplies available within the electrical industry, understand basic concept of how alternative supply produce energy. Working safely with alternative supplies and identifying hazards and incorporating risk control to meet current regulations. Safely isolate and re- energize electrical systems with alternative supplies, identification of labelling to alternative supply systems. Basic concept of battery storage.

Why:

Alternative supplies are becoming more common with in the electrical industry, these can come in form of renewable such as solar panel PV, wind turbines to engine driven alternator and generators, over past few decades these alternative energy supplies have become more available to general consumer, due to low manufacturing cost, government grants and ease of use. Due to the increase of alternative supplies, we are required to be aware of the additional hazard when carrying out electrical maintenance/installation on these systems.

Resources

AS/NZS 3000 Electrical installations – Wiring Rules

AS/NZS 4777(series) Grid connection of energy systems via inverters

AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays

AS/NZS 3010 (series) Electrical installations - generating sets

AS/NZS 4509 (series) Stand-alone power systems

AS 3011 Electrical installations - Secondary batteries installed in buildings

AS/NZS 5139 Electrical installations - Safety of battery systems for use with power conversion equipment

AS/NZS 4836 Safe working on or near low-voltage electrical installations and equipment

Western Australian Service and Installation Requirements

Western Australian Electrical Requirements

Working Safely with alternate supplies

Risk Assessment

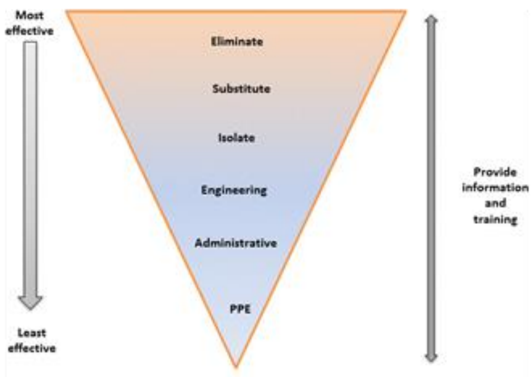
When starting any installation work on an electrical system, it is essential to identify any risk while de-energizing a systems, however with the increase of different alternative power source which are available to the consumers it is essential that an electrical worker must be able to identify these systems An electrician needs to be able to identify and isolate numerous different systems, this can be done via correctly installed labels, isolation procedures and to carry out testing that the electrical installation they are processing to work on is safe and isolated.

Below tables is a Risk Rating Matrix, this is a simple way to identify any potential risk before carrying out work on an electrical installation.

Risk Rating Matrix

		1	2	3	4	5
Consequence		Rare The event may occur in exceptional circumstances	Unlikely The event could occur sometimes	Moderate The event should occur sometimes	Likely The event will probably occur in most circumstances	Almost Certain The event is expected to occur in most circumstances
1	Insignificant No injuries or health issues	LOW	LOW	LOW	LOW	MODERATE
2	Minor First aid treatment	LOW	LOW	MODERATE	MODERATE	HIGH
3	Moderate Medical treatment, potential LTI	LOW	MODERATE	HIGH	HIGH	CRITICAL
4	Major Permanent disability or disease	LOW	MODERATE	HIGH	CRITICAL	CATASTROPHIC
5	Extreme Death	MODERATE	HIGH	CRITICAL	CATASTROPHIC	CATASTROPHIC

1. **Eliminate** – if it is possible, the hazard should be removed completely. For example, get rid of dangerous machines.
2. **Substitute** – replace something that produces the hazard with something that does not produce a hazard. For example, replacing solvent based paint with water based paint. Risk assessment on the substitution must be conducted to ensure that it will not pose another hazard.
3. **Engineering control** – isolate a person from the hazard by creating physical barrier or making changes to process, equipment or plant to reduce the hazard. For example, install ventilation systems.
4. **Administrative control** – change the way a person works by establishing policies and procedures to minimise the risks. For example, job scheduling to limit exposure and posting hazard signs.
5. Use **personal protective equipment** (PPE) – protect a person from the hazard by wearing PPE. For example, wearing gloves, safety glasses, hard hats and high-visibility clothing. PPE must be correctly fitted, used and maintained to provide protection.



Hierarchy of control

Risk to consider when assessing an electrical installation for isolation.

Before undertaking any electrical work, it is essential that a thorough risk assessment be undertaken. The purpose of which is to determine potential hazards associated with the work. There are a range of risks to consider, which includes (but not limited to):

- Immediate risk of electric shock to person undertaken the work and others
- Fire or explosion from arcs and sparks
- Release of poisonous fumes or gas from heat or fire
- Oxygen depletion from insulating gases (SF6) or other gases and fumes displacing air in confined spaces
- Electric shock from stored energy sources such as battery banks
- Conductors or other electrical equipment becoming live from unexpected sources such as:
    - Automatic, inadvertent or remote switching
    - Portable generators
    - Photovoltaic arrays
    - Uninterruptible power supply systems (UPS).

After identifying possible hazards, it is necessary to put in place preventative control measures to mitigate the incidence of potential hazards. The aim of risk mitigation is to eliminate the risk. If the risk assessment indicates that it is not possible to sufficiently reduce the risk to a level that allows the work to proceed, then the work is not commenced.

The three principles of risk management involve:
1 identifying potential hazards
2 assessing and ranking the associated risks
3 applying suitable control measures to mitigate or reduce the risk.

What additional Risk should we look for with alternative supplies?

Alternative electricity power sources pose additional risks in that one or more of these generation systems could still be live after isolating the normal supply, below note's additional hazards which could occur if an electrical worker does not understand the operation of the system.:

Batteries - Supply is connected to switchboard via an inverter, generally work via a changeover switch, this monitors the normal supply and activates the UPS/battery when the normal supply stops. Switches which are dead can become live without warning if this happens. Additional hazard around batteries are the potential to explode when in a fault state, batteries are also made up from hazardous materials. Large battery banks can also emit noxious gases, areas containing batteries should well ventilated.

Motor generator set – Generators generally work on a changeover switch, this monitor when the normal supply stop and engages the motor, so isolating the normal supply may trigger the generator to start. This poses the risk of rotating machines starting without warning. Generators will generally use petrol or diesel to run the motor, this will produce exhaust gases which can deplete oxygen if not correctly vented, the fuel itself is hazardous, and become explosive if not contained within a suitable storage device.

Solar photovoltaic (PV) may only be outputting a supply during normal daylight hour, but weather can also affect the output (dark clouded day or fog)and when isolating the supply a false reading can be given. Supply is connected to switchboard via inverter.

Hydro powered generator – Supply is connected to switchboard via an inverter, can be live at all times.

Wind powered generator - Supply is connected to switchboard via an inverter, can be live at all times.

What danger can occur from Alternative supplies?

Electrical Shock

Electrical hazard or Electric Shock may be defined as "Dangerous event or condition due to direct or indirect electrical contact with energized conductor or equipment from which a person may sustain electrical injury from shock or which may cause damage to the workplace environment, damage to property or both.

When working with or nearby electrical installations an electrical shock, arc flash or arc blast can occur and a current can go through the body, due to the following situations:

1. Direct contact with live parts of the installation (exposure to live parts)
2. Contact with parts that normally are not live, but because of a fault become live accidentally (indirect contact)
3. Existence of potential difference of voltage between exposed conductive parts.

The hazardous of electrical shock are the following:

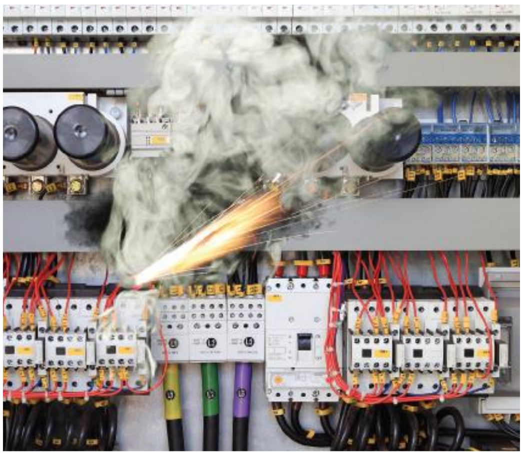
Loss of motion control
Respiratory arrest
Pain
Physical fatigue
Ventricular fibrillation
Cardiac arrest
Burns

Protective Actions to Avoid & to Reduce Electric Hazardous

1. Identification and safe isolation procedure.
2. Where required a safety observer shall be used.
3. Correct testing before carrying any electrical work, ensure that all tests are carried out with the correct test equipment and setting.
4. Wearing correct Personal Protective Equipment (PPE) for electrical work.
5. Ensure you or others working on the electrical system are trained/competent and can identify the systems and possible hazards which could occur.

Arc flash and Arc Blast

An arc flash is a release of electrical energy that causes an explosion which can reach temperatures of up to 20,000 degrees Celsius.



An arc flash usually occurs in large switchboards but can also occur in smaller switchboards, electricity supply pillars or large electrical equipment.
Common causes of arc flash include:

- unsafe work practices and procedures
- foreign materials
- breakdown of busbar insulation
- electrical equipment failure such as a switch, circuit breaker or loose cables
- contacting energised equipment with uninsulated tools
- using test equipment not designed or rated for the job.

What are the risks of arc flash?
An arc flash can happen in a split-second, causing serious burns, injury and death as well as damage to property and equipment.

The arc blast is the pressure wave created after an arc fault. These can be strong enough to throw a fully grown technician to the ground or cause additional equipment damage. Arc blasts can cause damage to your hearing, vision or brain functions.

Type of arrangement and configurations of alternative supplies.

There are a number of technologies and methods used to produce usable electrical power. We are seeing a shift away from a reliance on burning fossil fuels as the source of energy towards renewable energy sources using technologies such as wind generators and photovoltaic panels. Common technologies used for alternative electrical power supplies are:

- Engine-driven alternators and generators
- Photovoltaic panels
- Wind-driven alternators and generators
- Personal or micro hydroelectric systems
- Batteries

Engine-driven alternators and generators

Engine-driven alternators and generators have been the stalwart of the production of electrical energy utilising the basic concept of moving a conductor through a magnetic field. Engine-driven alternators and generators find application as:

-Back-up supply to the electricity grid for critical installations such as hospitals and data centres
-Standalone generation units to supply electrical power for remote communities and industries such as mining
-Temporary power source during installation and maintenance work on the electricity network.

Types of prime mover

The type of prime mover depends largely on the output rating, size, location and local requirements. Low VA rated portable alternators, like that shown in frequently utilise a small petrol-driven engine to provide the mechanical input. Larger VA alternators, are capable of providing back-up power in the event of loss of normal supply, and have a diesel engine as the prime mover as these provide for greater fuel efficiency and reliability.

Photovoltaic (PV) arrays

Photovoltaic (PV) arrays are made of a number of individual cells, which use semiconductor materials to convert radiant energy in the form of sunlight directly into electricity. Silicon is the most common form of semiconductor material used in the manufacture of solar cells. The power produced by a single solar cell is in the order of 1.5 watts and the typical open circuit voltage of a single cell is about 0.58 volts when exposed to full sunlight. It is necessary to combine individual solar cells together in series and parallel combinations to obtain higher power capabilities by increasing both potential difference across the cell and the current capability. A commercially available photovoltaic panel, is constructed using between 32 and 48 individual solar cells in series to give a panel capable of charging a 12 V d.c. battery. PV panels utilise a modular technology that facilitates the interconnection of a number of panels to form solar arrays that can have ratings in hundreds of megawatts, as is the case of solar farms. Solar arrays generate direct current (d.c.) electricity. A single solar panel, depending on the technology and the module size, can generate between 12 and 100 volts and be capable of delivering a current in excess of 8 amperes. Solar panels connected together to form a solar array can have an open circuit potential difference in the order of hundreds of volts. It is important, therefore, to exercise due care when working with or around solar panel installations. The output of a solar panel is normally described using what is referred to as the 'nominal power' rating, which is the amount of power the panel will produce if operated at the standard test conditions. The standard test conditions relate to the panel being exposed to a solar radiation equivalent to 1000 W/m2 at a temperature of 25 °C. An installed and operational panel will unlikely be subject to these conditions and therefore produce a power much less than the quoted 'nominal power'. This reduction is attributable to installation conditions having a temperature exceeding 25 °C and variations in the amount of solar radiation to which the panel is exposed. Solar cells are a source of 'green energy' in that they do not produce any greenhouse gases (GHG) such as carbon dioxide (CO2) or any other gases that are harmful to the environment while operating.

Wind-driven alternators and generators

For centuries the power in wind was used by windmills to produce mechanical power in the form of torque, which was then used directly for pumping water or grinding corn. A recent adaption of this concept comes from modifying the windmill to generate electrical power, which can be used for heating and lighting, by using the sails or blades of the windmill to drive an electrical generator via the rotating shaft connected to the windmill's sails. As the sun heats the planet unevenly it makes the air hotter around the Equator and colder near the poles. As air is a gas, heating it causes it to expand and conversely cooling it causes it to contract. Wind is created from differences in atmospheric pressure. Warm air at the Equator rises higher into the atmosphere and travels toward the poles. This creates what is known as a low-pressure system. Conversely, cooler, denser air from the poles moves over Earth's surface toward the Equator to replace the heated air, creating a high-pressure system. It is the difference in air pressure that creates wind, which generally blow from high-pressure areas towards low-pressure areas. Wind is considered to be 'air in motion' and is extremely variable in velocity.

A modern-day windmill, known as a wind turbine, is capable of converting the kinetic energy contained in the wind into both mechanical and hence electrical energy. Wind turbines are a form of wind generator that operate differently and more efficiently from a conventional sail windmill. Like solar panels, it is possible to cluster multiple wind turbines to capture large amounts of wind energy. A 'wind farm' is the name given to such a cluster. The wind energy is then converted into electrical energy and the combined electrical energy is fed into the electricity grid. Wind farms may be located on flat land, mountain tops or offshore. While wind turbines look like an extremely large fan, they comprise many complex mechanical and electrical components. The wind turbine rotor blades rotate around a central hub, which turns a low-speed gearbox shaft that in turn drives a generator at a higher speed and generates electricity. The electrical generator is the component that converts the kinetic energy from the rotating blades into electrical energy. Wind turbines have a number of air foil shaped rotor blades that are similar to aeroplane propellers, which makes them more efficient than the original windmills that usually had several flat blades or sails. Blade rotation in a wind turbine is due to the wind creating both lift and drag.

Wind turbines are available in a number of different configurations but generally fall into one of two configurations:

1. vertical-axis wind turbines (VAWTs), which have blades that rotate about a vertical axis,

2. horizontal-axis wind turbines (HAWTs), which have blades that rotate about a horizontal axis parallel to the wind,

(a) HAWT (b) VAWT

Both configurations have their advantages and disadvantages, but each is available in designs capable of generating electrical power from a few hundred watts to many kilowatts. Both configurations comprise:

- A support mechanism such as a tower that supports the rotors, gearbox, generator and axillary equipment
- The wind turbine with two or more rotor blades which captures the wind energy
- A mechanical gearbox, which increases the rotational speed to the generator
- A generator or alternator that produces the electrical energy
- Various sensors and control electronics to monitor and regulate the speed and output
- Electrical cables that connect the generator or alternator to the load

The output of a wind generator can be either a.c. (from an alternator) or d.c. (from a generator) depending on their design. The most common type is the wind-driven alternator, which produces a sinusoidal a.c. output. While this output is a.c. it is not generally of a quality suited for exporting to the electricity grid. It is therefore necessary to modify the output by feeding the alternator's a.c. output into a rectifier to convert the a.c. to d.c. for battery charging, or feeding the alternator's a.c. output through a converter to match the generated output to the grid specifications.

Small-scale generation

Many residential, roof-mounted wind turbines are able to operate with a wind velocity from around 15 km/h up to a maximum of around 100 km/h. On a calm windless day, the turbine sits idle and the blades do not rotate. As the wind velocity increases, it eventually reaches the cut-in velocity of the turbine of around 15 km/h. At this wind velocity, the turbine blades will spin up to their cut-in operating speed and allow the attached generator to commence generating electrical energy and as the wind velocity increases further, the rotor blade velocity increases and the generator output also increases.

Wind turbine generators deliver maximum power at a wind velocity of around 60 km/h. This means that a generator having a rated (nameplate) output of 50 kW, will be capable of supplying 50 kW of electrical power at the rated wind velocity. The same generator will deliver less than 25% of rated output power at the cut-in wind velocity of only 15 km/h. At a wind velocity exceeding 60 km/h the generator maintains its rated capacity until the wind velocity approaches 100 km/h where the turbine reaches its cut-out speed and the in-built protection will cease generating electrical power. The wind velocity is a very important consideration for the safe and proper operation of a wind turbine generator. Historical wind velocity data is used in the calculation of wind power when determining proper placement of a wind turbine generator – whether this be on the ground or on a roof.

Advantages of wind-driven alternators and generators

The main advantages of wind-driven alternators and generators include:

• Energy harnessed from the wind is a clean and renewable energy that does not release pollutants, emissions or by-products into the atmosphere during operation

• wind turbine generators can be located in remote areas and on scales ranging from small personal and residential use to large full-sized wind farms, which means it is possible to have electrical energy available in locations that would normally be considered as ‘off grid’

• The design of wind turbines affords them to operate within a wind velocity usually between 15 km/h and 100 km/h

• Larger land-based installations can be used simultaneously for wind generation, crop cultivation, animal grazing, and the like.

Disadvantages of wind-driven alternators and generators

The main disadvantages of wind-driven alternators and generators include:

• Wind farms are considered as unsightly man-made structures that have a negative visual impact – viewed as a form of visual pollution

• Wind farms require large expanses of land or are placed in environmentally sensitive areas to take advantage of stronger and constant wind

• The wind turbine does not generate any useful electrical energy in calm conditions

• Wind farms can injure and kill birds or disturb the flight patterns of migratory and predatory birds

• Wind turbines can produce noise pollution as they produce a low frequency ‘whooshing’ sound as the blades rotate

• The best locations for siting wind farms are usually far from populated urban areas, which necessitates the transportation of electrical energy over long cable distances

• Although annual winds and power output from a wind turbine are relatively predictable, hourly and daily wind energy output levels are not as wind speed does not remain constant giving little power output in low winds.

Personal or micro hydroelectric systems

Personal or micro hydroelectric generating systems utilise the kinetic energy of flowing water to produce localised electrical generation for particular situations. They are a low-maintenance and emission-free source of electrical energy. These small-scale hydro-electric generating systems can be used to supply electrical energy to nearby installations. These systems are generally suited to localised applications that are close to the energy source. Micro hydroelectric systems have declined in popularity due to the significant and ongoing reduction in the cost of PV systems.

Standalone Power Systems

A stand-alone power system (SAPS or SPS), also known as remote area power supply (RAPS), is an off-the-grid electricity system for locations that are not fitted with an electricity distribution system. Typical SAPS include one or more methods of electricity generation, energy storage, and regulation.

Electricity is typically generated by one or more of the following methods:

- Photovoltaic system using solar panels
- Wind turbine
- Geothermal source
- Micro combined heat and power
- Micro hydro
- Diesel or biofuel generator
- Thermoelectric generator (TEGs)

Storage is typically implemented as a battery bank, but other solutions exist including fuel cells. Power drawn directly from the battery will be direct current extra-low voltage (DC ELV), and this is used especially for lighting as well as for DC appliances. An inverter is used to generate AC low voltage, which more typical appliances can be used with

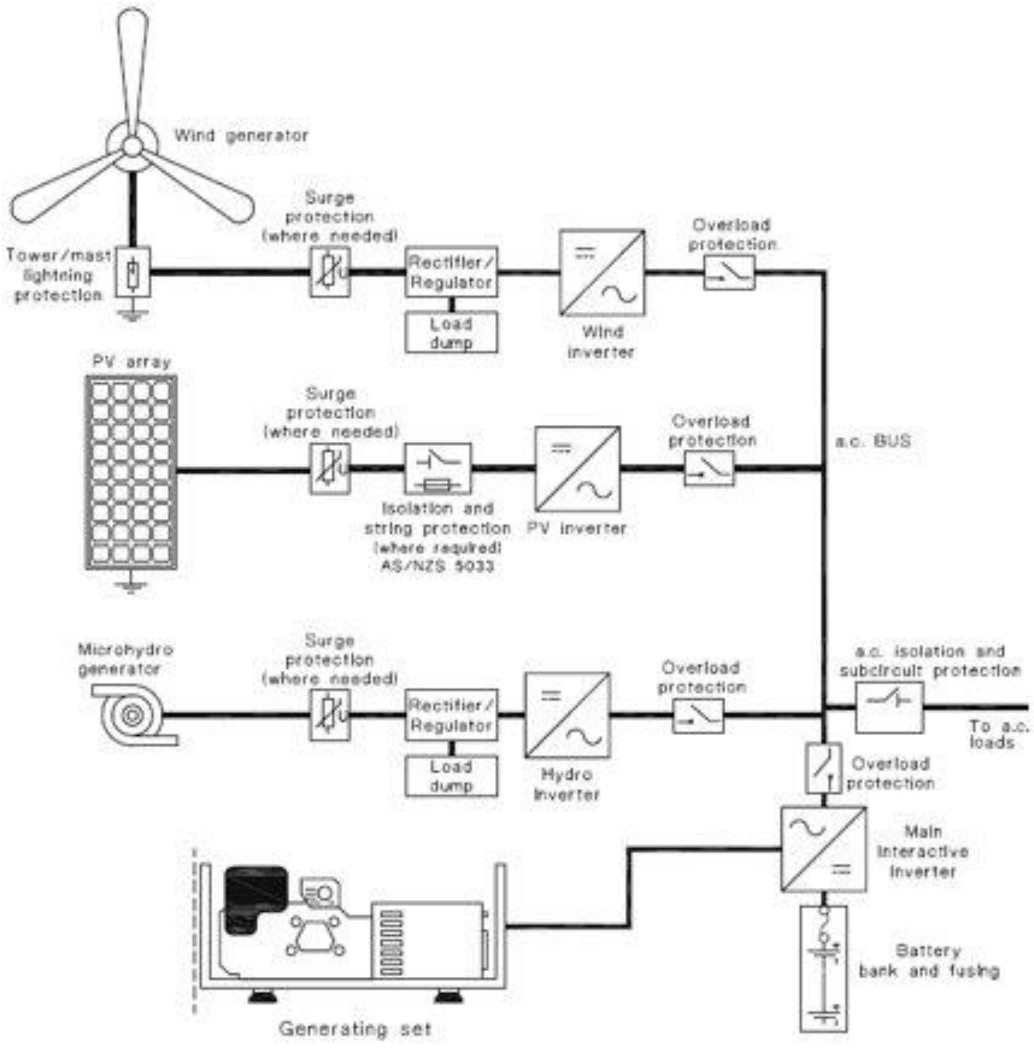


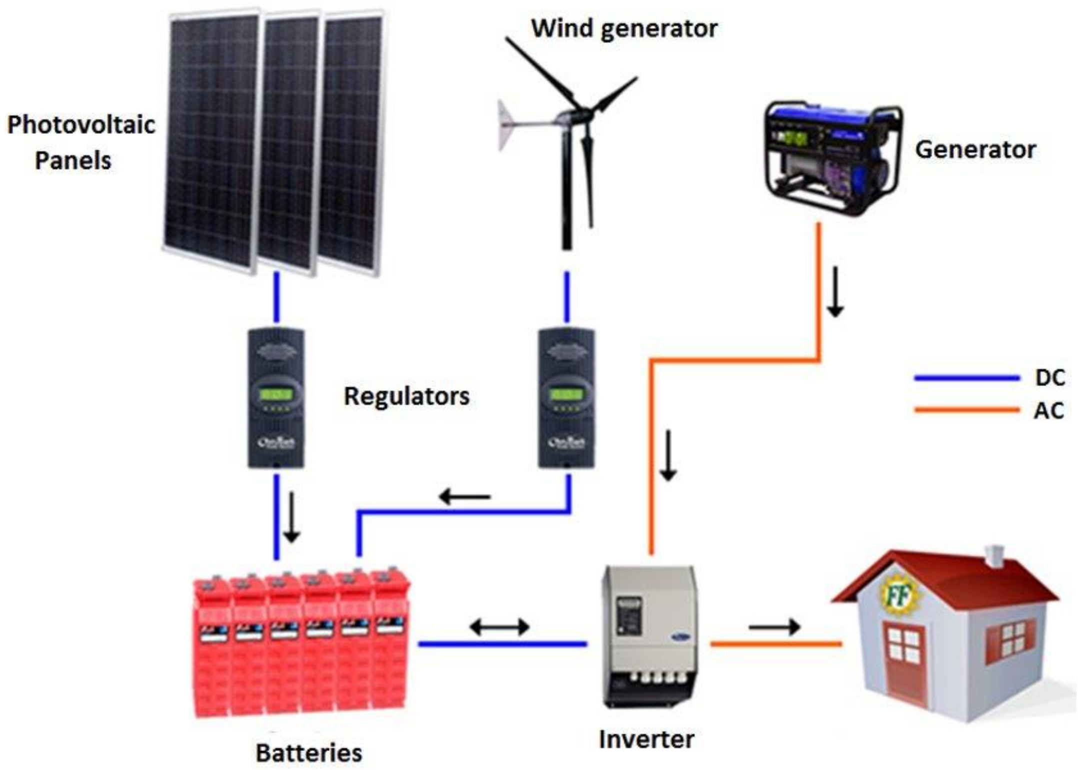
FIGURE 1B EXAMPLE OF A.C. COUPLED ENERGY INPUTS AND CONTROLS SWITCHBOARD DETAILS

Fundamental Requirements

Where an electrical installation integrates an alternative supply system with the normal (grid-connected) supply, there are a number of regulatory considerations. **Section 7.3 of AS/NZS 3000:2018 *Wiring Rules*** details the requirements for the connection of alternative systems of electrical supply.

The following electricity generation systems are recognised as alternative supplies in the *Wiring Rules*:

- Alternative and supplementary supply where a motor generator set:
  - **–** provides an alternative or stand-by a.c. electrical supply if the normal electrical supply to the installation should fail
  - **–** forms the primary electrical supply to an electrical installation
  - **–** forms part of a standalone electrical system.
- Standalone power system that does not connect to the power distribution system of a network provider and may include:
  - **–** PV array
  - – Wind turbine or mini-hydro turbine
  - – Engine driven generator set in the form of an a.c. supply or a d.c. supply.
- An inverter system that provides a.c. electrical power from an interactive inverter, which itself is supplied from a renewable energy source, such as PV array, wind turbine or mini-hydroelectric turbine.
- A battery system that provides an electrical supply from an alternative energy source, such as a PV array, wind turbine, generator set or mini-hydroelectric turbine, for the purpose of charging a battery bank and provide a d.c. supply to an electrical installation.



Control

It is a requirement of the *Wiring Rules* that a main switch or switches can control the alternative supply system at the installation switchboard to which the alternative supply system connects. Any installed main switch must be appropriate for starting and stopping the alternative supply system. If control is via multiple devices these devices must be grouped and clearly identified as to what they control.

Unless allowed by the electrical energy supplier, an alternative supply system will not supply energy upstream of the point of connection to the installation either directly or indirectly. This is known as co-generation, where an alternative supply system export electrical energy into the upstream network under specific conditions. Accepted examples of co-generation include grid-connected inverter-based systems (such as PV systems) or engine-driven generating systems intended to operate in parallel with the network. It is essential to ensure that if the alternative supply system is providing electrical energy to the installation that all necessary electrical connections required for basic and fault protection within the installation, such as the MEN connection, remain intact.
Every alternative supply system must have an isolating switch, which:

- is either installed adjacent to, or on, the source of alternative supply so that anyone operating the switch can see anyone who may be working on the alternative supply system; or has a securing method such that the device when in the isolated position requires a deliberate action to engage or disengage
- may incorporate overcurrent protection
- complies with **AS/NZS 3000:2018 *clause 4.13*** if an electric motor is incorporated in the alternative supply system
- is under manual control
- cannot be overridden or bypassed by programmable control systems or the like.

(AS/NZS 3000:2018 Clause 7.3.4.1 a-e)

Requirements for earthing

Clause 7.3.6 of the *Wiring Rules* requires all alternative supply systems rated at 25 kVA or greater to employ the
MEN system of earthing and must comply with **Section 5 of the *Wiring Rules***. Alternative supply systems that are not rated more than 25 kVA can be arranged as a separated supply complying with **clause 7.4 of the *Wiring Rules***.
Furthermore, all exposed conductive parts of an alternative supply system must connect to the main earthing conductor at the main switchboard.

Connection to electrical installation

Clause 7.3.8 of the *Wiring Rules* requires that the incoming neutral to a MEN switchboard shall not be switched. The MEN must be in the main switchboard, and this may require that the neutral-earth connection within a genset to be disconnected, so neutral and earth conductors don't end up being in parallel with each other.

For connections to Western Power's distribution network, **Section 15 of the Western Australian Service and Installation Requirements (WASIR)** requires the main switch(es) for the consumer's electrical installation to be a circuit breaker.

Changeover switches

A changeover switch ensures effective electrical separation between the normal electrical supply to the installation and the alternative supply system. The purpose of the changeover switch is to ensure that electrical energy from each supply cannot connect to the installation at the same time as it is likely that the line voltages, frequencies and phase positions will be different. A changeover switch incorporates a mechanical interlock that prevents both supplies simultaneously connecting to the installation. The changeover switch can be of the manual or automatic switching type with some devices incorporating over-current protection in the form of a circuit breaker.

There are specific requirements stipulated in **AS/NZS 3010:2017** for the installation of a three-pole/three-pole automatic transfer switch (ATS):

- The MEN link and the ATS is both installed in the main switchboard.
- The neutral conductors of the normal supply(mains) and alternative supply are not switched
- The neutral conductor of the normal·(mains) supply connects directly to the MEN link
- The neutral conductor of the alternative supply connects directly to the MEN link
- Over-current protection for the alternative supply has three-phase protection without neutral protection.

Uninterruptible power supplies (UPS)

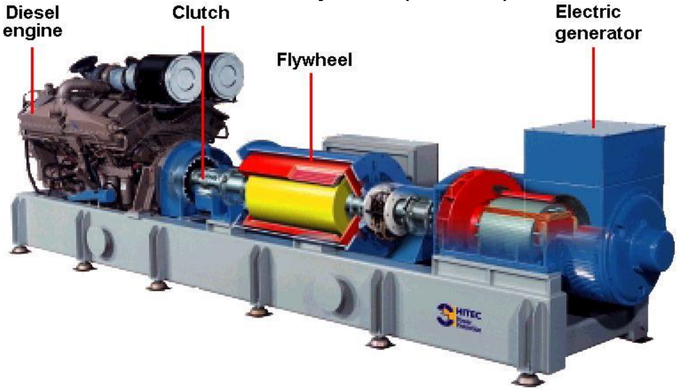
An uninterruptible power supply, which is usually referred to as a UPS, is an item of electrical equipment that can supply electrical power to a load should the normal electrical power source fail. A UPS can range in capacity from a few VA, which is intended to supply electrical power to a personal computer for a sufficient period to allow it to shut down gracefully, to several MVA, which is intended to keep operating theatres and other critical hospital areas functioning for extended periods of time. Where auxiliary or emergency power systems or stand-by generators take a period to commence supplying an electrical installation, a UPS provides near instantaneous protection from disruptions to the normal electrical power source. It does this by supplying energy that is stored in batteries, supercapacitors, or flywheels to
the electrical installation as a.c. power.

Battery-based UPS

A battery-based UPS is typically used to protect hardware such as computers, data centres, telecommunication equipment or other critical electrical equipment where an unexpected power disruption may cause injuries, fatalities, serious business disruption or data loss. A battery-based UPS located in Hornsdale, South Australia is touted as the world’s first big battery capable of providing essential electricity grid-support services. The first 100 MW/129 MWh was completed in November 2017. In September 2020, a 50 MW/64.5 MWh expansion was completed. This 150 MW capacity is being upgraded to include Tesla’s Virtual Machine Mode, which enables the battery to provide inertia support services to the national electricity grid.

Rotary UPS

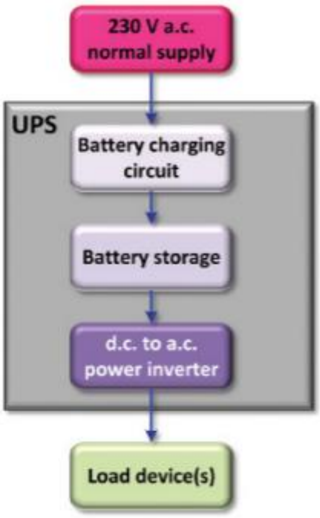
A rotary UPS uses flywheel energy storage to provide short-term ride-through in the event of power loss. The rotating mass of the flywheel not only stores rotational energy but can act as a buffer to smooth spikes and sags in the normal power source. This is due to the fact that these power events of short duration do not significantly affect the rotational speed of the high-mass flywheel. This type of UPS has been around for several decades making it one of the oldest designs, predating electronic power devices. The rotary UPS is considered ‘on-line’ as under normal operating conditions it is continuously rotating. The rotating UPS can generally maintain electrical supply for up to 20 seconds before inertia in the flywheel decreases to a point where electrical supply cannot be maintained. It is expected that a diesel engine or similar has started and is able to maintain rotational energy. Figure below details a diesel rotary UPS (DRUPS).



The decision to install a rotary UPS is not taken lightly as these are expensive installations, which are generally reserved for applications needing more than 10 000 W of protected load capability. It is possible to increase the initial run-time by installing a larger flywheel or having multiple flywheels operating in parallel.

The flywheel provides a source of mechanical energy that can, when coupled through a gearbox, be used to start a diesel engine. Once running and up to speed, the diesel engine can spin the flywheel directly to provide emergency electrical power.
A rotary UPS has an expected operational life of about 30 years, which is far in excess of a purely electronic UPS.
In order to achieve this longevity, they do, however, require periodic downtime for mechanical maintenance, such as replacing ball bearings. Battery-based UPS designs do not require downtime if it is possible to hot swap the batteries. Advances in machine technology mean that technologies such as magnetic bearings and air-evacuated enclosures, when employed on rotary UPS, increase stand-by efficiency and reduce maintenance to very low levels.

Many UPS topologies are available, and each provide varying levels of power quality, protection time, sensitivity, as well as complexity. The simplest form of battery-based UPS is known as in-line systems, which use a battery charger to provide d.c. electrical energy to the battery or batteries; the d.c. from the battery is converted to grid comparable alternating by an inverter. Figure below shows the power flow through an online UPS.



(Hampson, J.; Hanssen, S., 2022, p. 462)

A type of online UPS, known as line interactive, provides a level of line conditioning where the battery source provides power and the unit disconnects from the normal supply if this supply voltage is too high or too low. When the normal supply is within range, it is fed through to the load. Switched systems are similar but they switch to battery power after the normal supply has failed. This type of system provides a back-up power supply.

Installation requirements

As with electrical installations, it is necessary to install UPS in accordance with the relevant Australian Standards and the requirements of Local Service and Installation Rules. For safety, it is essential that circuits within the electrical installation and the electricity grid do not become unintentionally ‘live’ in the event of failure of the normal electrical supply. It is imperative when designing a UPS installation to consider which loads will connect to the UPS and how the associated circuit wiring is configured to ensure that circuit wiring and attached equipment having the possibility of being live during failure or isolation of the normal supply are not inadvertently considered a conventional circuit.
All parts of a UPS must be suitably housed to protect them from the environment and protect end users from the possibility of receiving electric shock. This is particularly important for battery banks, which have the possibility of supplying high short-circuit energy. The applicable Australian Standard is AS/NZS 4777 series that requires that any grid-protection devices installed for a UPS do not isolate the neutral or earth conductors. **AS/NZS 4777.1:2024** and **AS/NZS 4777.2:2020** identify additional requirements for UPS systems, which are additional to the requirements for standard grid-connected inverter systems.

These requirements include:

- The UPS must only ‘supply an identifiably separate set of circuits’
- These circuits should originate from a separate switchboard or load centre

- warning signs are provided at the main switchboard and any other relevant switchboards to indicate that some circuits within the installation may be live when the main switchboard is isolated, which may include any neutral or earth conductor within the installation.

Polarity requirements for d.c. components

Appendix Q D.C Circuit Protection Application Guide of the *Wiring Rules* provides guidance on the polarity requirements for circuit protection and switching devices that operate on a d.c. supply. Installers should refer to this Appendix for detailed information. Polarised and non-polarised isolators and circuit breakers used to isolate solar panels and d.c. generating equipment, are reasonable to use. There are, however, some issues that can lead to very dangerous conditions. A polarised circuit breaker or isolator needs the electric current to flow with a specific polarity within the device. This is due to the method employed for arc suppression within the device where a permanent magnet is used to draw the arc from the opening contacts into the arc chute where it lengthens and subsequently weakens. If the device is connected with reverse polarity, then the electric current will flow in the wrong direction causing the arc to move away from the arc chute and deeper into the body of the device. This may result in a fire within the device, which may occur regardless of the disconnection method – whether a deliberate manual switching operation or automatic should there be an overload.

This situation is not present in a non-polarised circuit breaker or isolator, which employs a polarity independent electro-magnetic blowout rather than polarity dependent permanent magnet. Non-polarised circuit breakers and isolators are the preferred option. Installers must follow the manufacturer's installation instructions to ensure these devices work safely as intended. It is a requirement of AS/NZS 4509.1 for over-current protection of battery systems to be of the non-polarised type. A typical application of a polarised circuit breaker is a distribution switchboard that supplies d.c. operated equipment. With this arrangement current flow is unidirectional (one way). A typical application of a non-polarised circuit breaker is for over-current protection of a battery system in which the current flow can be in opposite directions; from supply to the battery when being charged, and from the battery when being discharged by the load or when the d.c. charging source not outputting. In all jurisdictions it required to locate the d.c. isolator or circuit breaker at the d.c. to a.c. inverter. In some jurisdictions there is an additional requirement to locate a d.c. isolator at the solar panels. If you consider that solar panels are producing d.c. energy while exposed to solar radiation, isolating at the inverter means that the cables supplying the inverter from the solar panels are in a 'live' state. Coming into contact with conductors within these cables upstream of the inverter isolator presents an unacceptable risk of electric shock. This risk is greatly mitigated by having a d.c. rated isolator at the solar panel end of the cables supplying the inverter. It is important to bear in mind that the cables interconnecting the individual panels are still 'live'. To date there is no satisfactory way of isolating the individual solar panels and making them safe.

Component replacement

It is important to ensure that failed or a faulty equipment or component (part) is replaced on a 'like-for-like' basis. This means that the part is replaced with a part, which is the same or similar in design, function, use and maintenance.

It may not necessarily be from the same manufacturer and requires no additional alteration or modification of existing parts to install and occupies the same or similar footprint of the part it is replacing.

An example would be in replacing a circuit breaker. Consider a circuit breaker that has the following information supplied by the manufacturer:

- Non-polarised, suitable for PV applications
- **T**ested according to AS/NZS 60947-2
- Rated short-circuit breaking capacity Icu 10 kA
- Rated operating voltage Ue 180 V DC per pole
- Tripping characteristics K.

A suitable replacement would have the same parameters. The critical specifications being Icu = 10 kA;

Ue = 180 V DC per pole; and Tripping characteristic = K.

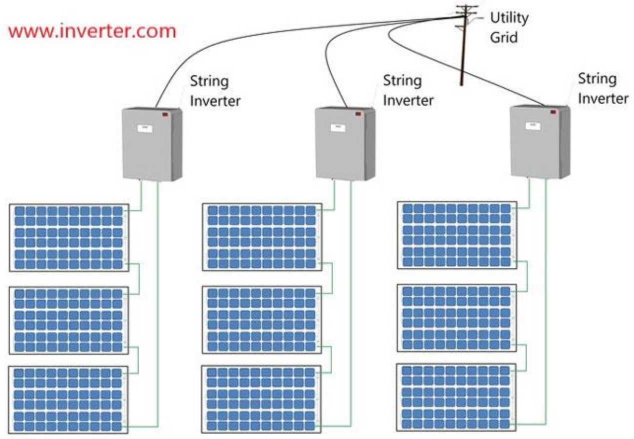
Earthed d.c. supply

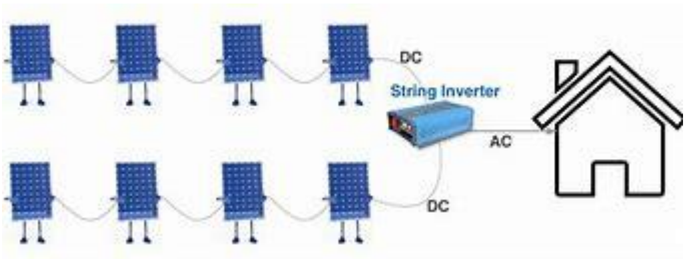
The d.c. supply may operate as a separated or isolated system, which requires that all switching or overload devices to operate in all unearthed conductors. To this end all multiple pole devices should have their actuator linked so that all contacts will operate simultaneously. It is also possible to operate a d.c. supply where one pole of the d.c. supply connects to earth. In this system, any switching device only needs to operate in the unearthed conductor.

Inverter principles

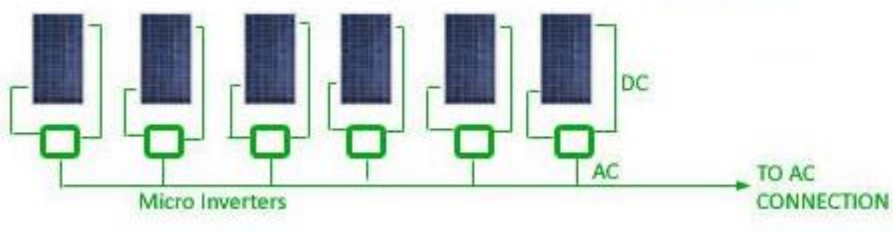
The inverter is the item of equipment responsible for converting the direct current produced by an alternative energy source such as solar panels into alternating current for use in a home or business (normal singlephase supply is 230 V a.c). There are four types of inverter most commonly used for small-scale installations up to 5 kW per phase:

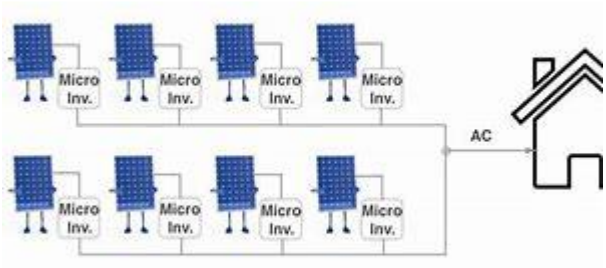
1 String inverters, as shown below, are single units that connect to a string of solar panels, which are the most common type for households.





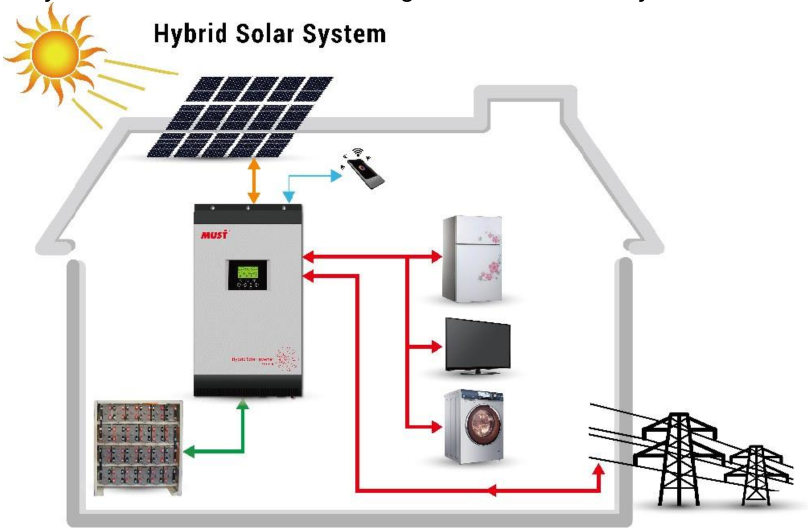
2 Micro inverters connect to each panel and represent a good option when some panels are frequently shaded. These are more expensive than string inverters.





3 Battery-only inverters are paired with battery chargers to store ‘surplus’ electrical energy in a battery bank and release it later when it is more useful or economically viable.

4 Hybrid inverters combine a string inverter and battery inverter into a single unit.



Standalone inverters

Standalone inverters range in size from as little as 100 watts to several kilowatts. Small-scale inverters are popular with campers who like the creature comforts of modern life. These inverters are able to convert the 12 V d.c. battery supply available from the vehicle’s battery to 230 V 50 Hz a.c. to power low energy devices such as televisions.
Specialised systems, specifically aimed at campers, connect to portable PV arrays and are capable of providing up to 2.4 kW.
Similar to battery-based UPS, standalone inverters are available with an output that is either a modified sine wave or a true sine wave. Modified sine wave inverters generally produce a very poor-shaped sine wave that is acceptable for equipment with switch-mode power supplies and lighting but is unsuitable for most applications including motors, transformers and voltage-sensitive equipment. Shows oscilloscope graphs of a modified sine wave and a pure sine wave. For standalone systems it is important to use a true sine wave inverter that is capable of supplying grid-quality sine wave output (230 V at 50 Hz).

Grid-connected inverters

Grid-connected inverters are intended for operation on the normal electricity grid supply and can supply electrical energy back into the network. The design of these systems ensures that they do not operate without first synchronising with the normal electrical supply. The output characteristics of the inverter are automatically matched to those of the normal electrical supply. In the event of the normal electrical supply failing, the inverter will automatically cease outputting energy. The inverter will generally wait a pre-determined time after restoration of the normal electrical supply before outputting energy to the ‘grid’. This functionality is known as ‘anti-islanding’ and it is a requirement of **AS/NZS 4777.1:2024**.
A grid-connected inverter must comply with the requirements of AS/NZS 4777 series of standards. As such, a compliant inverter will have the following electrical characteristics:

- grid voltage of 230 V single-phase measured between line and neutral
- power factor within the range of 0.8 leading to 0.95 lagging (unity power factor is common)
- voltage tolerance within the range of +10% to −6%
- frequency of 50 Hz
- total harmonic distortion not exceeding 5%.
- Maximum d.c. voltage can be up to 1000 V d.c for domestic installations
- Maximum d.c. voltage can be up to 1500 V d.c. for other electrical installations

Multi-mode inverters

Multi-mode inverters are capable of providing both off-grid and on-grid solutions. When normal supply is available, they operate as a grid-connected inverter – importing and exporting electrical energy as the installation demands.

When combined with an energy storage system such as a battery bank, multi-mode inverters function as a standalone or off-grid system. They offer the flexibility to import and export electricity depending on installation needs, as well as providing a complete standalone system when coupled with an energy storage system. This flexibility can also allow the unit to provide the installation with an uninterruptible power supply and load-shifting adjustable export control.

Regulatory requirements for inverters

The installation of grid-connected and multi-mode inverters with associated solar panels must comply with the relevant Australian Standard and, depending on the local supply authority, Local Service and Installation Rules. In most jurisdictions these installations require individual inspection, which may include the associated energy metering that allows both the import and export of energy associated with the electricity grid connection. There are a number of applicable requirements detailed in the *Wiring Rules* pertaining to the safe and effective installation of inverters. In particular Section 4.12 relates to the selection, control, isolation, overcurrent protection and earthing. Section 7.3 has further requirements for inverters as energy-generation systems. The AS/NZS 4777 series of standards details requirements for the installation of grid-connected inverters while AS/NZS 4509 for details requirements for standalone power systems. Appendix Q of the *Wiring Rules* also recommends that unless the inverter is marked as providing full electrical isolation, then all parts of the d.c. supply system should be insulated and screened.

Safe Isolation

An important work practice for an electrician carrying out electrical tasks is isolation and lockout. Correct isolation and lockout procedures will minimise the dangers of unintentional or unexpected energisation of circuits and the start-up of electrical equipment. All electrical equipment and conductors must be considered as live until isolated and proven de-energised. Work must not be carried out on, or near, electrical circuits or equipment until an electrical worker has:

1. Confidently identified the work task including circuit and any connected electrical equipment. In addition, any additional energy sources (capacitors, batteries, UPS) for connected equipment must also be identified. Finally, suitable isolation points must be noted. Any test instruments used must be confirmed to be 'in-test'.

2. Turned OFF all sources of supply and securely locked out these supplies from providing service, and in addition, danger tagged all switches and controls for the equipment being worked on.

3. Secured the electrical inaccessibility of the circuit or equipment by testing for service at all identified isolation points. This step checks that the electrical circuit and equipment is de-energised and electrically safe, and then prove correct operation of any test instruments used.

4. Provided and identified a safe area of work for electrical workers. The safe area of work should be identified by erecting a barricade or warning signs or by other suitable means.

Further information on isolation and safe work methods for working on or near low-voltage and extra-low voltage installations and equipment can be found in AS/NZS 4836 and also the Code of Practice for persons working on or near energised electrical installations from the Western Australian Government – Building and Energy website.

Testing tools and equipment

For all low-voltage electrical installation verification and testing work, electrical persons should, as a minimum, have the following range of test instruments: loop impedance tester, multimeter, clamp ammeter, insulation continuity tester and Category IV test leads. It is suggested that all testers and leads should be Category IV and should be the preferred choice of electrical persons due to their higher fault capabilities.

Apart from the testing requirements of the Wiring Rules, certain alternate supplies will specify additional testing as required by their respective standards. For example, **AS/NZS4777.1:2024 Grid connection of energy systems via inverters Installation requirements**, require the following additional testing to be performed, where applicable.

Clause 8.3.2 – Additional testing substitute supply
Clause 8.3.3 – Additional testing alternative supply
Clause 8.3.4 – Additional testing independent supply
Clause 8.3.5 – Additional testing portable IES (Inverter energy System)

Shutting down alternative energy source

The proper shutdown procedure should be located onsite. The location should be clearly indicated on a prominent sign similar to that shown in The generic process for an engine-driven generator set is outlined below.

Diesel generator set correct shutdown operation method

The following procedure is an effective way to prevent the development of faults, and has direct impact on extending its service life.

1. Prior to stopping it is necessary to remove the electrical load and then reduce the speed to about 750 rpm.
2. After about 3 to 5 minutes of this load speed operation, turn the stop handle to stop and bring the system to rest.
3. For a 12-cylinder V-type diesel engine, turn the electric key to the intermediate position after shutdown to prevent battery current from flowing back.
4. Switch the battery isolator to the OFF position and place Danger Tag and padlock onto battery isolator.

Grid connected Inverter system shutdown procedure

Shutdown procedures are required to be provided for all Grid connected inverter systems as per **AS/NZS4777.1:2024 Section 7**, which details the documentation requirements that should be readily available to customers, inspectors, maintenance service providers and emergency service personnel. The following procedure is suitable for shutting down grid connected inverter systems.

1. Locate the solar supply main switch and turn the switch to the off position.
2. If the solar power inverter is more than 3 metres away from the switchboard, locate the switch marked, solar AC isolator. This will be located next to the inverter. If the inverter and switchboard are within 3 metres of each other, disregard this step.
3. Go to the inverter and locate the switch marked **PV Array and DC Isolator**. Turn this switch to the **off** position (in some cases there will be two switches). **4** The inverter may have a switch marked Inverter Isolator. If present, turn this switch to the off position. Skip this step if the system does not have this isolator.
4. The solar PV system should now be completely switched off. All lights and screen displays will be extinguished. Keep the system off for a minimum of five minutes.
5. To re-start the system, follow this guide in reverse order.

Stand Alone Power System Isolation Procedure

The following procedure is suitable for shutting down Stand Alone Power Systems (SAPS);
Turn off all supplied loads
Turn off “Main Switch” in MAIN SWITCHBOARD
Disable “Auto Start” at GENERATOR
Turn off “Battery Isolator” at GENERATOR
Turn off “Main Switch” at GENERATOR
Turn off “Generator Isolator” at INVERTER
Turn off Inverter output “AC Isolator”
Turn off Inverter
Turn off “Inverter Battery Isolator” at INVERTER
Turn off “PV Array Isolator” at CHARGE CONTROLLER
Turn off “PV Array Isolator” at PV ARRAY
Disconnect “Battery Fuses “at BATTERIES

Energisation Procedure
Insert “Battery Fuses” at BATTERIES
Turn on “PV Array Isolator” at PV ARRAY
Turn on “PV Array Isolator” at CHARGE CONROLLER
Turn on “Inverter Battery Isolator” at INVERTER
Turn on Inverter
Turn on Inverter output “AC Isolator”
Turn on “Generator Isolator” at INVERTER
Turn on “Main Switch” at GENERATOR
Turn on “Battery Isolator” at GENERATOR

Enable "Auto Start" at GENERATOR
Turn on "Main Switch" in MAIN SWITCHBOARD
Turn on supplied loads as required

Anti-islanding protection

Anti-islanding protection is an important safety feature integral to all grid-connected inverters. A grid tie inverter has sophisticated monitoring circuits capable of detecting the loss of normal power supply from the grid and within a few milliseconds automatically power down the inverter.
AS/NZS4777.2:2020 Section 4 Protective functions for connection to electrical installations and the grid, details the two methods used for monitoring anti-islanding protection, these are referred to as Active and Passive methods.
Active methods involve injecting test signals into the grid to determine if it is still present. By monitoring the response of these signals, any changes or anomalies can be detected. One commonly used active method is frequency shift modulation (FSM), where a low-frequency signal is injected into the grid and observed for any deviations. Another active method is voltage unbalance detection, which monitors the voltage imbalance between phases to identify potential islanding situations.
On the other hand, passive methods rely on monitoring grid parameters without actively injecting signals. These methods analyse various electrical characteristics such as voltage level, frequency, phase angle, and harmonic content. By continuously monitoring these parameters, any significant deviations from normal operating conditions can indicate an islanding event.
Both active and passive methods have their advantages and limitations. Active methods provide real-time detection capabilities but may require additional hardware for signal injection and analysis.
Passive methods, on the other hand, do not require additional equipment but may have longer detection times compared to active techniques.
In practice, a combination of both active and passive methods is often employed to enhance the reliability of islanding detection in solar anti-islanding systems. This allows for comprehensive monitoring of grid parameters while also actively testing the connection status between PV systems and the utility grid.
By utilizing these active and passive detection techniques together with advanced algorithms and control strategies, solar anti-islanding systems can effectively detect islanding events and ensure safe operation within interconnected power grids.
Remember the inverter is still supplied with direct current electricity from the solar panels, wind turbine generator or similar. The term 'islanding', refers to a condition where the electricity grid does not provide power but some installations are supplying electrical energy into the grid, transmitting electrical energy back into the otherwise inactive electricity supply lines. This creates a potentially hazardous situation:
• In the case of network failure, systems that are feeding energy back into the grid create a hazardous situation for service personnel trying to fix the cause of the network failure.
Tabel 4.1 and 4.2 in AS/NZS4777.2:2020 show the passive anti-islanding voltage and frequency limit values.

Automatic transfer switch

An automatic transfer switch (ATS) is an automatic power switching device that utilises dedicated control logic to perform intelligent switching operations. The primary function of an ATS is to ensure the continuous delivery of electrical energy from one of two sources of electrical energy to a connected electrical load, which is typically the critical portions of an electrical installation. The control logic or automatic controller is microprocessor-based and constantly monitors the electrical parameters of voltage and frequency of primary and alternate power sources. If the normal (primary) supply fails, the ATS will automatically transfer (switch) the load circuit to the alternate energy source (if it is available). Most automatic transfer switches attempt to connect to the primary energy source (utility power) by default and will only attempt to connect to the alternate energy source (engine-generator, back-up utility) if the primary source were to fail or requested to do so through manual switching command. Typically, the operation of an ATS is as follows:
1 The normal utility power source fails.
2 The ATS shifts the load to the emergency power source when power from the generator or back-up utility feed is stable and within prescribed voltage and frequency tolerances. The transfer process may be automatic or manually initiated, depending on the requirements of the particular installation.
3 The ATS returns the load from the emergency power source to the normal power source when utility power is restored. Again, the process may be automatic or manually initiated.

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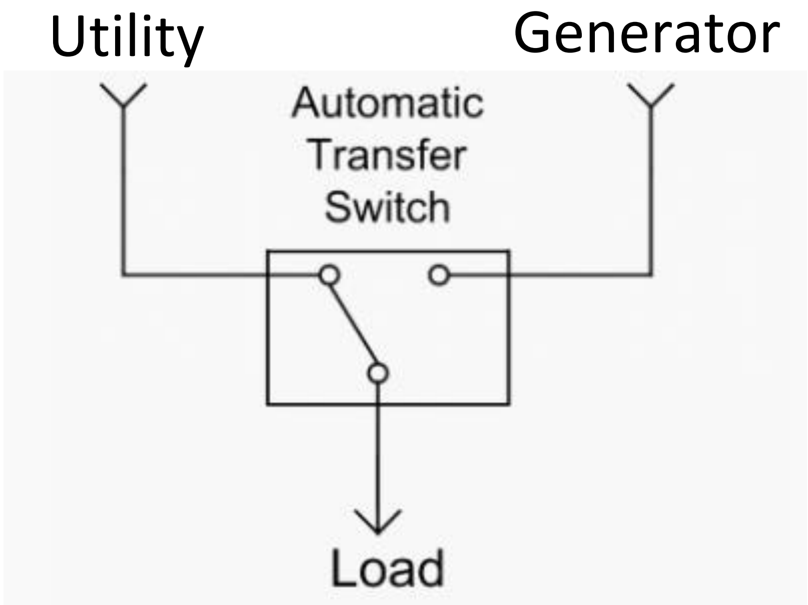
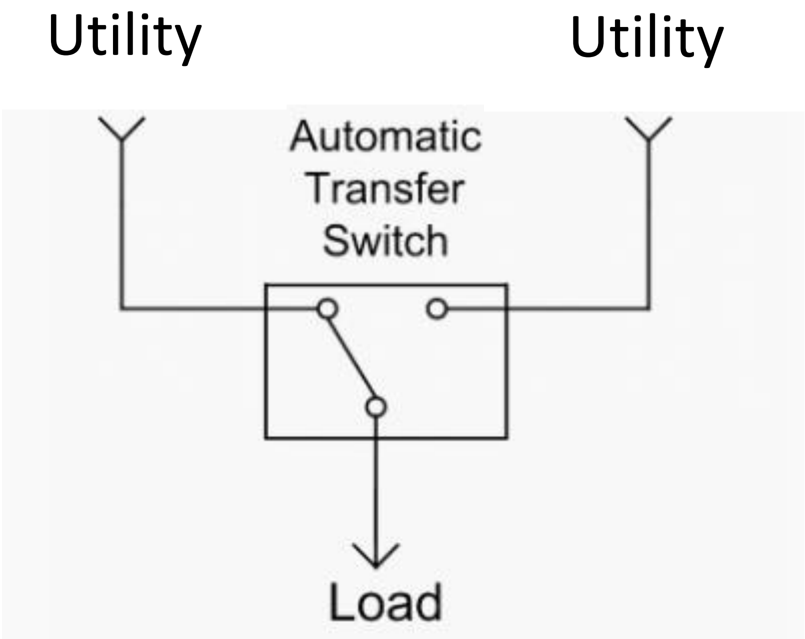
ATS switching configurations.

Two common switching arrangements are:

1 Utility–Generator as shown below



2 Utility–Utility as shown below



Utility power to back-up generator transfer

The standard transfer switch configuration includes a supply from an electricity distributor's network and a backup generator for normal and emergency power sources respectively. This system arrangement is typically referred to as an emergency standby generator system. The single generator depicted in the diagram may be several engine driven generator sets operating in parallel.

Utility power to utility power transfer

This configuration utilises electrical supply from electrical distribution networks that provide redundancy in the distribution system and allows for quick restoration of service to the installation should an upstream equipment failure occur. The two sources can be independent of each other, requiring the public utility company to provide dual electric services, or they can originate from a single electric service that is distributed through redundant paths within the facility.

Earth fault alarm

It is not usually the case to reference d.c. supplies to earth, so earth fault risk is commonly overlooked. Should the d.c. supply connect to an operating inverter that does not have a transformer, the potential difference between the d.c. supply and earth can exceed 400 V d.c. This means a d.c. supply cable that is secured to the rail, usually with sharp stainless steel cable ties, has a 400 V d.c. potential to the rail. A failure in this cable's insulation, wherever it occurs on the solar installation, creates an earth fault. An earth fault may cause the solar generating system to stop operating. It also poses the risk of someone working on the roof to receive an electric shock. If multiple faults occur simultaneously, then a person working on a roof could receive an electric shock sufficient enough to throw them off the roof. An earth fault alarm is capable of detecting this type of fault and depending on the system, instigate appropriate action, which can be combined with online inverter monitoring.
AS/NZS4777.1:2024 Clause 4.3.7 details the requirements of earth fault detection, protection and alarm.

Solar voltage rise

The nominal grid potential in Australia is 230 volts. This potential will vary and fluctuate throughout the day depending on the demand on the grid and how much energy from solar inverters is being fed into the grid. It is common to see this potential fluctuate 10 volts throughout the day. The electricity distributor will endeavour to maintain this potential between about 217 volts and 253 volts. Maintaining the potential below 253 volts is becoming more of a challenge for the electricity distributors.

When a solar system is producing more energy than is being used, it feeds the excess back into the grid. In order for power to flow from an electrical installation to the grid, the potential from the solar inverter has to be higher than the grid potential. This situation creates what is known as solar voltage rise.

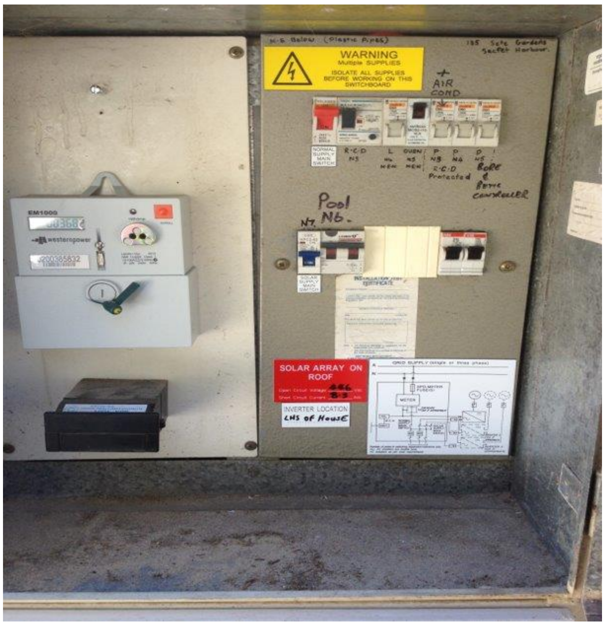
AS/NZS4777.1:2024 Clause 3.3.3 states that overall voltage rise from the point of supply from the grid to the inverter a.c. terminals shall not exceed 2% of the terminal voltage at the point of supply from the grid.

Identification and labelling of alternative supplies

Apart from ensuring all equipment is identified as per **clause 2.10.5 of the *Wiring Rules***, signs and labels are required to provide clear indication that an electrical installation is served by multiple supplies and to identify the affected circuits. Signs pertaining to inverter energy systems (IES) need to be placed on the switchboard to which the IES connects. Additional signage may be needed to direct emergency services and these would be located on the fire indicator panel. If the IES connects to a switchboard other than the main switchboard, then additional signage is needed alerting to this fact. Any signage must be legibly and indelibly printed in English and be of suitable size. Examples of warning labels as shown and these sample labels and appropriate locations for fixing are identified in **AS/NZS 4777.1:2024 Section 6** and **Appendix A**. According to **AS/NZS 5033:2021 Clause 4.3.5.2.2**, Switches that are non-load break (must be switched either on or off under no load) shall be marked and not be able to be operated without the use of a tool

Above; Example of IES label which may affixed to a switchboard with alternative supplies.

Below; Typical WA domestic switchboard, labelling show that alternative solar supply is present.



Battery storage systems

A major drawback to solar power installations is that they only produce electrical energy in daylight hours and grid connected systems only produce this energy when the grid is operating. It is therefore necessary to store surplus energy to use later. Battery systems are used for the storage of electrical energy for use at a later time.
'Isolation switches for batteries must be located no greater than 3 metres from the main terminals of the battery and be readily available as per **AS3011.1 and AS3011.2 clause 3.3.5 (for both)**

Lithium-ion batteries

These are the most popular grid-connected battery chemistry, which is the same type of technology used in mobile phone and laptop batteries. There are different types of lithium chemistry; common types are nickel manganese- cobalt (NMC) or iron phosphate (LiFePO/ LFP). LFP batteries are safer but less efficient than NMC batteries. Lithium batteries are popular because they:

- have a long lifespan (expected to be more than 10 years, and researchers are working to further extend this)
- can be used to almost their full capacity (discharged to almost zero from a full charge)
- work in a wide range of climates.

Lead-acid batteries

Lead-acid batteries are commonly used in automobiles. They are cheaper than lithium-ion batteries but bulky and provide less flexibility. They have a slow charge cycle and are sensitive to high temperatures. Sometimes these batteries can be coupled with a supercapacitor for a faster charge cycle.
This technology is often used in back-up power supplies, which cycle batteries only occasionally. Lead-acid batteries are still popular for standalone (off-grid) power systems, although lithium-ion batteries are taking over this role as their lifetime performance becomes better understood. Lead-acid batteries may be either of the wet cell (vented) or sealed (valve-regulated) type. Vented batteries use liquid electrolyte while unvented batteries use either a gel or liquid electrolyte absorbed into fibreglass matt. Vented batteries are typical for renewable energy systems, but sealed batteries are becoming more common due to their safer operation and ease of maintenance.

Hazards

Batteries and battery banks present significant safety hazards. Battery storage systems have the ability to delivery very high current, which is the case of a short circuit occurring across the terminals of the battery or the battery is heavily loaded. While being able to supply high current to fluctuating loads may be desirable, it creates hazards such as fire, injury to personnel and magnetic stresses. Lead-acid batteries were for decades the battery of choice for providing back-up power to installations such as telephone exchanges, emergency lighting and other essential services. Some of the hazards associated with these installations include the production of hydrogen gas both during charging and discharging cycles, acid spillage and associated burns, and potential short circuiting of the battery terminals. The rooms containing lead-acid batteries were normally negatively pressured to prevent the hydrogen gas escaping into the working environment. While modern battery installations are less hazardous, they still harbour the potential for serious harm and should be treated as such. Lithium-ion batteries have received bad press in relation to batteries in mobile phones and other portable devices igniting. Most lithium-ion batteries have in-built protection for both over-current and overtemperature protection. The applicable standards are AS 3011.1:2019 for vented cells and AS 3011.2:2019 for sealed cells, which provide guidance for the installation of battery systems.

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Regulations and Standards

There are numerous Australian Standards and regulations that cover alternative energy and renewable energy systems. The purpose of these documents is to ensure the safe design and installation of these systems as well as stipulating required system performance. The Australian Clean Energy Council (CEC) publishes additional guidelines covering the design and installation of grid connected PV and standalone power systems. All electrical systems, whether connected to the normal supply grid or standalone electrical supply systems, must comply with the *Wiring Rules*. Furthermore, the installation of wiring and equipment must comply with the relevant WHS and safe work practice requirements. Any installation involving alternate supply systems may be required to comply with any or all of these Standards. Those involved with the design, installation and maintenance of these systems have a responsibility to keep up to date with current requirements of their work practices.

AS/NZS 3000 Electrical installations – Wiring Rules
AS/NZS 4777(series) Grid connection of energy systems via inverters
AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays
AS/NZS 3010(series) Electrical installations - generating sets
AS/NZS 4509 (series) Stand-alone power systems
AS 3011 Electrical installations - Secondary batteries installed in buildings
AS/NZS 5139 Electrical installations - Safety of battery systems for use with power conversion equipment
AS/NZ 4836 Safe working on or near low-voltage electrical installations and equipment
Western Australian Service and Installation Requirements (WASIR)
Western Australian Electrical Requirements (WAER)

Site and Regulatory documentation requirements

Where an electrical installation integrates an alternative supply system with the normal (grid-connected) supply, it is necessary to consult the relevant Service and Installation Rules for the specific jurisdiction. The Service and Installation Rules for most jurisdictions will detail:

- Stand-by generating plant
  - Conditions of use
  - Spacing for conductors
  - Changeover equipment for non-parallel operation
  - Switching the neutral
  - Multiple generators
- Requirements for stand-by generator synchronise close transfer trip
  - Operating procedure
  - Additional protection
- Requirements for generator parallel operation
  - Operating procedure
  - Additional protection
- Small-scale parallel customer generation (via inverters)
  - Responsibilities
  - Export limiting systems
  - Approvals documentation
  - Metering requirements
  - Construction permits
  - Islanding
  - Multi-phase generating systems
  - Power factor setting
  - d.c. isolation
  - Generator connection arrangement
  - Switching requirements
  - Conductor size requirements
  - Islanding protection equipment
  - Reconnection procedure
  - Generator supply main switch
  - Shutdown procedure
  - Storage systems
- Labelling.

The relevant Service and Installation Rules should be consulted in conjunction with the relevant Australian Standards as well for site and documentation requirements.