Notes covering unit 15852 and 29468 and part EE3102 Isolate and test 19,20

Contents

Isolation and testing of low voltage electrical sub-circuits

Introduction

These notes contain procedures for isolating the electrical supply to complete installations, sub-circuits, or plant, equipment and fitting, ensuring the supply stays isolated to protect the safety of those working on the equipment and to protect the public in general.

The reasons for testing and the procedures to follow before and after working on electrical equipment are also covered in these notes.

Essentially this is to ensure **no harm occurs to people**, and or **no damage occurs to property**.

The types of electrical equipment that needs to be isolated can be divided into 4 general groups

1) The supply system

This includes the cables both underground and overhead, the transformers, pylons and poles that bring the electricity to the buildings. This part of the electrical system is installed and maintained by the lines companies and is called “the works”. This area is usually at high voltage and special training and permits are required to work in this area. Lines mechanics work in this area.

2) The installation

The main supply cable that enters the building that goes to the main switch at the first switchboard is considered the start of the electrical system of an installation. The main switch turns off the electricity to the whole building.
The building has the wiring arranged into sub-circuits which leave the switch boards from designated fuses, circuit-breakers, residual circuit-breakers or switches. These sub-circuits supply lighting systems, heating systems and outlets each with their own control systems. Electricians are trained to work in this area.

3) Permanent load

This could include fixed heaters, lights, hot water heaters, ovens and stoves. These appliances that consume electricity are wired directly to the sub-circuit wiring. Electricians and electrical service technicians both can work on these types of equipment.

4) **Electrical appliances**

These items are plug in appliances such as a TV, play station, toaster, power tool, computer etc. Electricians, ESTs and electrical appliance servicepersons can all work on these plug in appliances.

Appliances are defined as electrical fittings that consume or convert electrical energy. Electrical fittings are all the items used to convey, connect or consume electricity.

Generally all appliances are connected in parallel in order to keep the same common voltage. Usually this is 230v single phase or 400v 3 phase.

Classification of voltage levels

Below 120 volts DC or 50V AC is termed **extra low voltage**
Above extra low to 1500 volts DC or 1000 volts AC is termed **low voltage**
Above low voltage is **high voltage**
There is no medium voltage

Series or parallel

Switches and control devices are usually wired in series with the load as this controls the load.
Outlets and lamps are usually wired in parallel in order for all loads to operate at the same voltage

Electrical appliance

An electrical appliance means any appliance that uses or consumes electricity

Fitting

A fitting means everything used, or designed or intended for use in or in connection with the generation, conversion, transformation, conveyance or use of electricity

Mechanical isolation

In addition to electrical isolation other systems may contain energy that needs to be contained or controlled while work is carried out.

This includes

1) Hydraulic oil systems under pressure
2) Spring loaded systems
3) Gas or air pressured systems
4) Steam pressure systems
5) Gravity systems where a mass can fall.

PPE Gear

Any work that is on an un-livened system and has a surety of not becoming live would only require PPE gear that would be common to most trades

If there is any chance of the system becoming live PPE gear becomes critical and often specialised.

Linesmen or live line work at high voltage requires special tools, training and PPE to withstand high voltages, high current forces and high temperature flashovers.

At low voltage work on switchboards, especially if all or parts are livened PPE is important.

Safety glasses to protect against flashover explosions
Full face mask may be a better option with some tasks

Insulated gloves to protect from shock

Insulated footwear to protect against shock

Fire rated clothing to protect against flashover burns
Including under garments

Ear protection may be needed if the work area is excessively noisey

Associated equipment

This is equipment needed to carry out the job but can be shared

Ladders need to be considered for insulation around live equipment

Tools need to rated for 1000v use

Test instruments need to be cat rated to protect the user should a fault occur

Insulating mats reduce the chances of contact with live parts

Safety barriers warn others away from live areas to protect you and them

The electrical supply system

A **Multiple Earthed Neutral** (MEN) system of electricity supply is used in New Zealand. The neutral conductor is connected to the earth at the source of supply (at the distribution transformer) and at every consumer's main switch board. This is seen as a link from the neutral to the earth bar.

The linking of neutral to earth at each consumers premises results in a low resistance return path – via the neutral conductor - for any earth fault currents. This results in a high current being drawn through the protective devices (fuses and circuit breakers) leading to a quick disconnection. This limits the risk of fire and shock.
The connection to earth at each premise will limit the possible touch voltage of any exposed conductive parts should a supply neutral become disconnected or a high resistance joint develop.

Distribution boards are usually fed with a 3 core cable from the main switchboard (MEN). Distribution boards do not have a MEN link, unless fed by a long 2 core feed in rural areas.

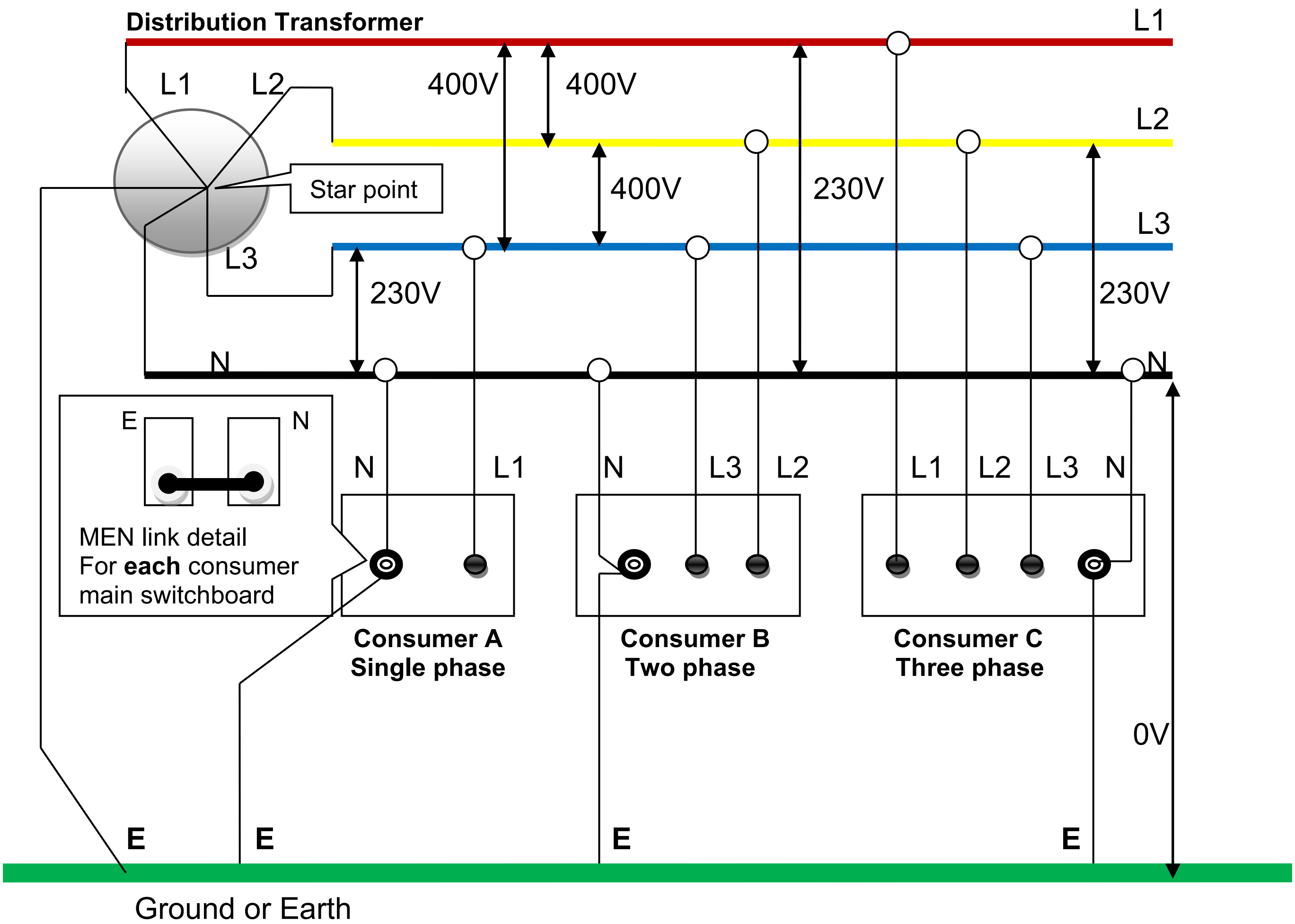


Fig 1. Typical supply to consumers premises from the distribution transformer

Single phase, two phase and three phase systems

We have three different common systems of supply
A house usually has a **single phase system**.
Two phases may be fed to a house with a long supply cable or a larger building to reduce volt drop.
Three phase is used for larger current drawing premises or places that use three phase equipment.
We need to understand what voltage levels exist in any particular installation or appliance

Single phase

There is only one active conductor, (one phase) and the neutral are fed from the street to the consumer. An earth cable is run from a stake in the ground and connected to the earth bar, which is linked to the neutral.
The neutral and earth are now theoretically at a ground voltage of zero volts.

230 volts exists between phase and neutral.
230 volts exists between phase and earth.
Zero volts exists between earth and neutral.

Two phase

Two active conductors are used to bring 400 volts phase to phase into an installation. A neutral is brought in with the phases.
This gives two single phase supplies sharing the same neutral.
The line current is shared between both active conductors, reducing volt drop.

400 volts exists line to line or phase to phase.
230 volts exists between any phase and neutral.
230 volts exists between any phase and earth.
Zero volts exists between earth and neutral.

Three phase

All three phases are cabled into an installation along with a neutral.
A neutral will be needed for metering in an installation and for any single phase loads used there. An earth will be needed for all installations.
A three phase machine requires all three phases
There may or may not be a neutral to a three phase machine.
An earth is needed for all class one appliances or machines.
With no earth or neutral there is still 230 volts from any phase to ground.

400 volts exists any line to any other line or phase to phase.
230 volts exists between any phase and neutral.
230 volts exists between any phase and earth.
Zero volts exists between earth and neutral.

Expected voltage levels when testing

To ensure electrical isolation we need to test the combinations listed below. Ten independent readings may need to be taken.

L1 to L2
L1 to L3
L2 to L3 these three measurements should all show 400 volts if not isolated

L1 to N
L2 to N
L3 to N these three measurements should all show 230 volts if not isolated

L1 to E
L2 to E
L3 to E these three measurements should all show 230 volts if not isolated

N to E this should always measure 0v

When testing for isolation all these tests must read zero volts

It is a good idea to test and record all voltage levels and combinations before disconnecting as a starting reference.

The Safety Tag system

The electricity regulations 2010 (regulation 106) require warning notices to be placed to safeguard against unintentional livening of an installation, sub-circuit or electrical equipment. If there is a lockable means of disconnection provided then that must also be used in conjunction with a warning notice. A warning notice can also be called a safety tag. These are mandatory requirements if there is a risk of unintended reconnection.

The safety tag is placed to primarily protect the person working on the electrical system from becoming inadvertently electrocuted. There could also be a hazard from mechanical, pneumatic or heat from a system being inadvertently operated.

A **safety tag** is fitted at the point of isolation by the person who has isolated the system and is about to work on that system. A lock is also fitted if there is a locking facility. The person's name, date and time are added to the tag. That person is the only person allowed to remove the tag and liven the system. A supervisor may personally investigate the situation is the tag owner is unavailable to ensure safety if the equipment is required to be livened.

If more than one person is at risk from unintentional switching then all workers at risk will fit their own personal tags. This means all tag owner must remove their tags personally before livening. A multiple lock can be used which ensures the switch cannot be operated until all locks are removed.

Isolating procedures

Switching off vs isolation

Switching off can be termed functional switching. For example a light switch is a functional switch. It turns the light off. It however does not isolate it as the light fitting being worked on will become live again by turning the switch on

Isolation is a higher level of disconnection. It stops the inadvertent livening of the system being worked on or the inadvertent livening of a system left unlived for safety reasons.

Plug in appliances are isolated by turning off the machine and pulling out the plug.

Fixed wired appliances are more complicated.

1. The correct appliance needs to be identified and the person in charge advised that there may be other equipment turned off.
2. Permission gained to remove electricity and the expected time of power down and relivening
3. The appliance then needs to be identified as single, two or three phase.
4. The machine should be turned off to eliminate load arcing at contacts, especially withdrawing fuses or damage to you or the fuses may occur.
5. If a local isolator is used, this needs to be switched off, tagging to indicate it must be left off and locked if it is able to be by design.
6. If there is **no suitable local isolator** the circuit will need to be traced back to a switchboard. Before withdrawing fuses or operating circuit breakers the person in charge needs to be advised other equipment in the installation may be powered down. This can be a disaster if a floor of computers is suddenly shut down.
7. The fuse carriers or circuit breakers (1 for 1 phase, 2 for 2 phase, 3 for 3 phase) must be tagged and locked out if possible.
8. If you cannot lock out and assess the isolation as insecure you should remove the load side sub-circuit tails, labelling for reconnection.
9. Lastly “prove - test – prove “ all combinations to ensure not live

Installations are similar to fixed wired appliances and the same procedures followed.

Switches that are not acceptable for achieving safe and continued isolation include

Control systems that are not locked off or tagged.
Stop start stations.
Emergency stop buttons

Testing for isolation

This can be your last line of defence, failure to understand this properly or correctly test for all possibilities has killed many electrical workers.

You need to **"test before touch".**
This means that you have to test with an appropriate test instrument, all possible combination to ensure electrical isolation before you touch any electrical parts that could be live.

You need to use the **"prove - test - prove"** method when testing.
This means you will **prove** the test instrument reads correctly on a known voltage source, then carry out the **testing** for isolation, then **prove** the test instrument again to ensure it was working during the test.

Your test instrument should be a able to read and display 450v, have a high fault tolerance rating or high cat rated, solenoid type tester such as a Duspol or similar for reliability. High impedance meters may confuse with induced voltages.

You need to test for all combinations as previously listed on **page 10** under **expected voltage levels when testing**

When isolation goes wrong

You may find after testing that the voltage levels are not what you expect. A hazardous voltage may still exist after you have turned off switches, pulled fuses, turned off breakers and removed tails.

What may have gone wrong

- You may have misinterpreted the situation, and isolated the wrong circuit
- The labelling may be wrong or unclear
- A neutral may be switched instead of an active conductor
- There may be a cross connection causing feeding from 2 separate circuit breakers or fuses
- Connections may be transposed
- The wiring may be faulty or damaged
- Fittings may be faulty
- Not all phases are isolated on a 2 or 3 phase system
- A light fitting is still live after a switch is turned off due to 3 plating

What are the consequences of not correctly isolating your work

- Failure to correctly isolate can lead to
- An electric shock
- An injury due to equipment still running unexpectedly
- Damage to user equipment
- An arc flash causing injury on current carrying circuits
- Damage to electrical fittings due to arcing

Dangers of transposing connections

Transposing is a common mistake that has been proven to kill. A recent case involved a mains cable that was transposed phase to neutral. This was not picked up and corrected at the testing stage or the inspection stage. The home owner was later found electrocuted under his house due to the metal work on the hot water system being live.

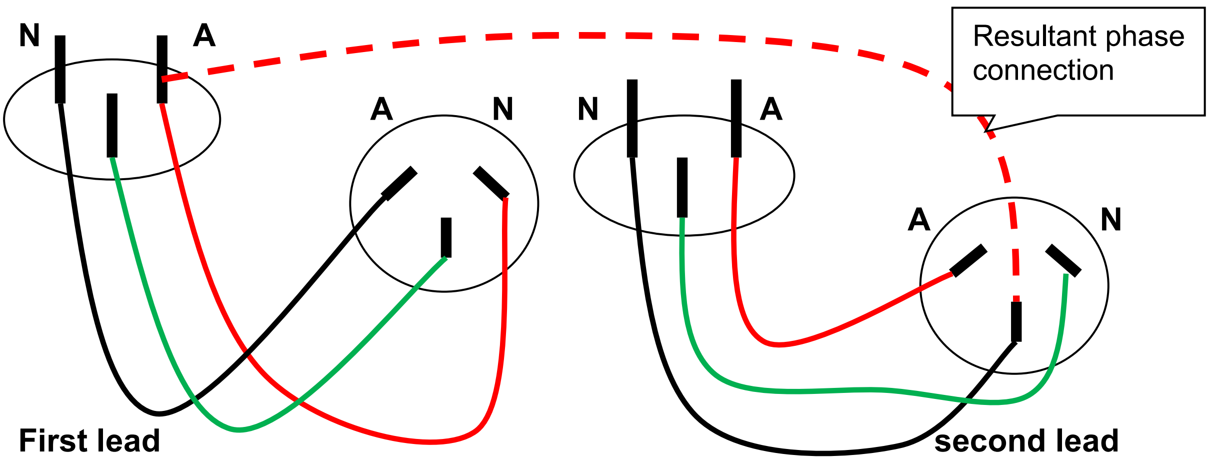
Transposed conductors are when the cables are incorrectly connected.

Shown below are the consequences of three of these errors which can commonly occur at plugs, sockets and fixed wired terminations.

Testing picks this up

Cord set example

The first lead is transposed phase and neutral
The second lead is transposed neutral and earth
Both plugged together puts phase from the first lead on to the earth pin of the second cord connector



Appliance connection examples

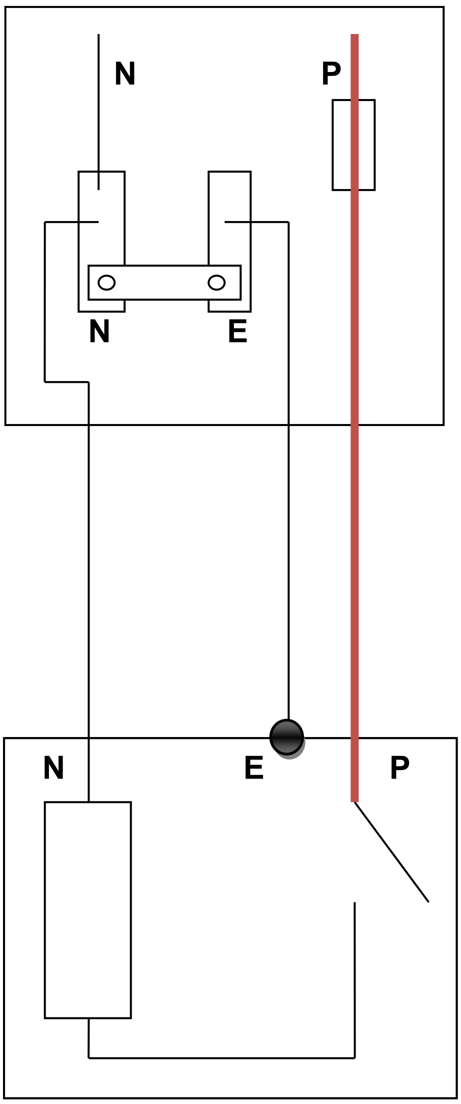


Fig 1 Correctly wired

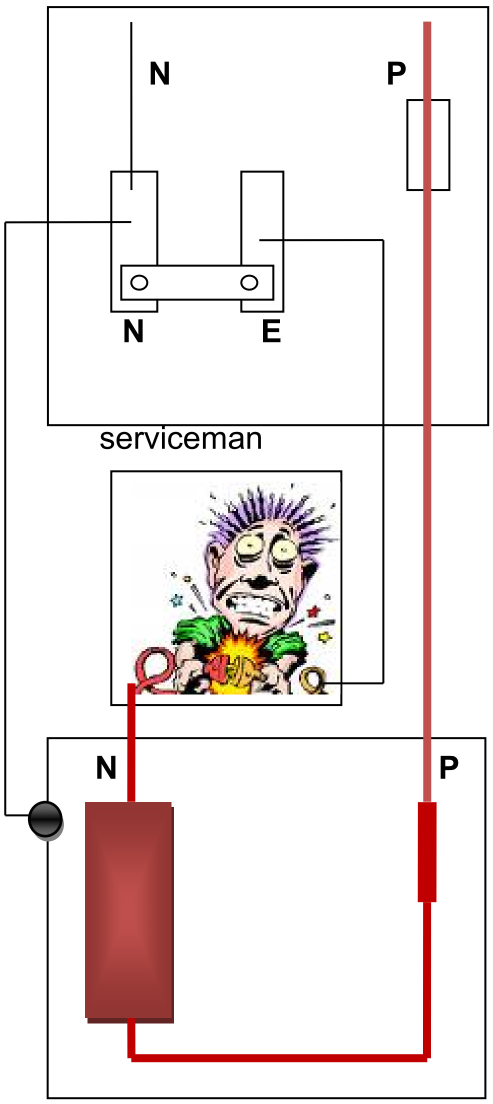


Fig 2 Earth and neutral transposed

When the switch is turned off most of the internal circuitry is isolated. The case is connected to the protective earthing conductor

If you disconnect the earth connection you may find this green wire live to ground

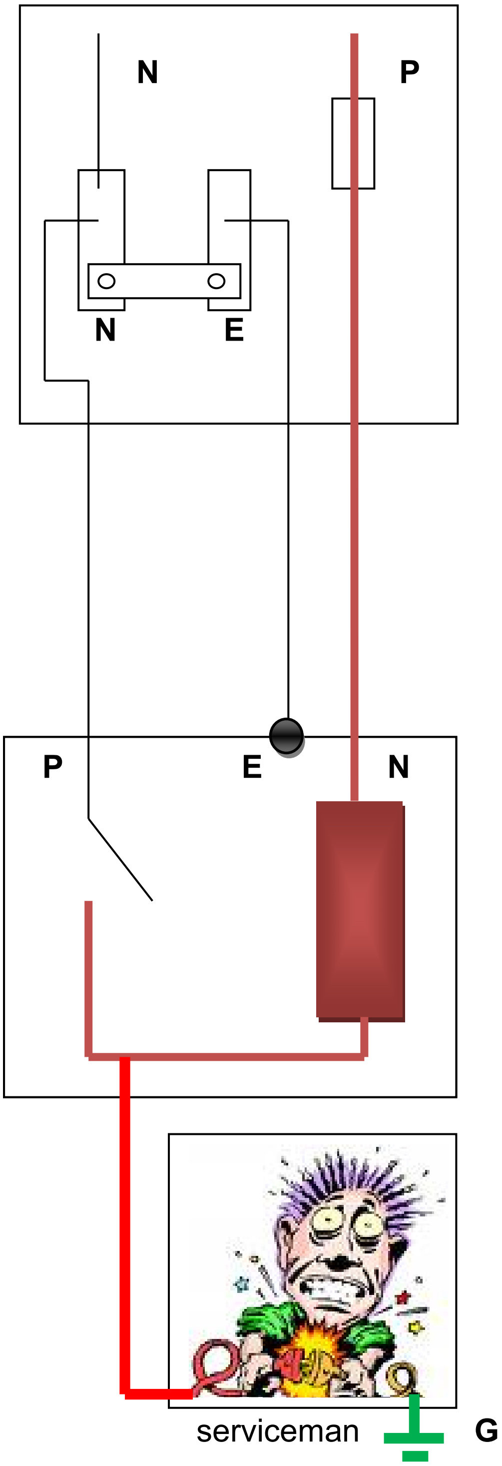


Fig 3 Transposed phase and neutral

With the switch opened most of the internal circuits of the machine are **still live**.

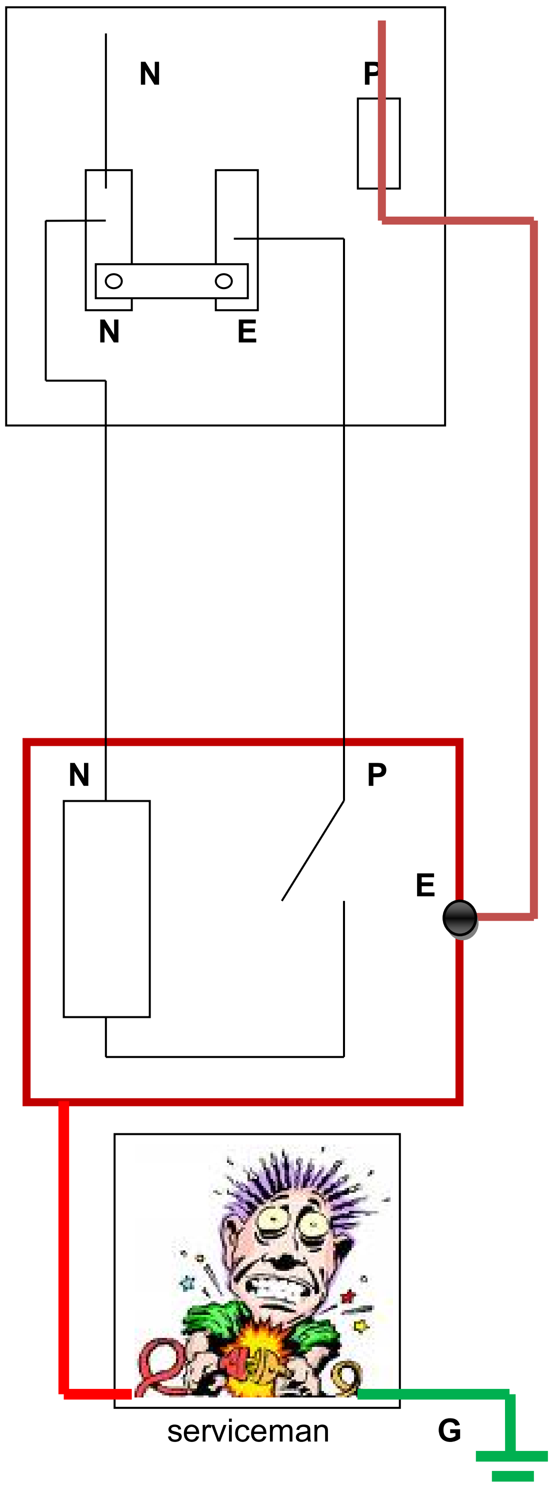


Fig 4 Transposed phase and earth

The metal framework on the appliance is **live all the time**

Testing prior to reconnection

After working on an electrical appliance, **Regulation 90** states that it must be tested to AS/NZS 5762. Using **AS/NZS 3760** is stated in 5762 as the means to comply with this testing requirement

Likewise for a new installation or an addition or alteration to an existing installation, **regulation 65** points to the mandatory use of **AS/NZS 3000 wiring rules** – section 6

These requirements consist of **visual inspections** and **testing with instruments**.

Re-commissioning plant or equipment

Recommissioning is the process of re-livening an electrical system, ensuring it is performed safely throughout, is tested according to regulations and works to design. A basic re-commissioning plan should be made. For a simple task of a single appliance is straight forward and may not be in writing, but an installation after many trades have worked on plant may require a large detailed sequence checked and recorded in the manner of a pilots pre-flight test to ensure safety throughout the procedure.

The person in charge of the plant needs to be informed and anyone at risk before it is livened.
A clear understanding of what will happen when the plant is livened and what hazards will be present at that time needs to be communicated to all involved.
Any tags and locks need to be removed by the persons who have fitted them so they are safe and aware of the situation.
Appropriate PPE gear needs to be used.
Appropriate test equipment needs to be employed.

Un-livened tests are carried out first and results documented.

Live tests such as RCD operation and earth loop impedance testing are then carried out if applicable and results documented.

Operational tests are lastly performed to ensure the equipment works safely and to design

AS/NZS 3760

In-service safety inspection and testing of electrical equipment

This standard requires electrical equipment to be **tested** and **visually inspected**.
Generally the equipment would have been serviced, tested and then tagged with the test results.

The **visual inspection** would cover things like.

a) Check for obvious damage or defects
b) Indications of overheating
c) Anchoring of cords
d) Inner cores not exposed
e) External sheaths not cut or damaged exposing inner cores
f) Operating controls are in good working order
g) Covers and guards are secured to design
h) Ventilation grills are unobstructed
i) Pins on plugs are undamaged
j) Pin shrouds are undamaged

Note that the equipment is not pulled to pieces and can therefore be carried out by a competent person, which could be an apprentice.

This standard is **NOT for an installation.**

The tests required under AS/NZS 3760

Protective earth continuity test (for class 1 equipment)

This involves testing the resistance of the protective earthing conductor in the supply lead to ensure the resistance from the earth pin on the plug to the exposed metalwork on the frame does not exceed 1 ohm.
A low ohmmeter is used for this test.

Insulation resistance test

The phase and neutral pins on the supply plug are linked together and an insulation test is performed from there to the earth pin, with the equipment switched on. The resistance must be greater than 1 megohm. An insulation resistance tester with a 500v output is used for this test.

Polarity Test

This test is to ensure the terminals have the correct cable connections to the phase, neutral and earth wires.
The phase conductor is the only one switched.
Edison screw fittings are phased for the centre terminal.

Operation of RCD

This test verifies that any RCD operates correctly. the integral test button should trip the breaker without delay or a timing test can be carried out if required. Portable RCD’s need to be reset after de-energising

Why do the tests?

Firstly it is a legal requirement, but more importantly it is to ensure lives are not at risk to electrocution or property at risk of fire.

The protective earth carries the fault current back through the fuse or circuit breaker if the metal case becomes livened, and a high current will ensure a quick disconnection time. A high resistance lead may cause a delay in disconnection or even leave the case in a livened state.

Poor insulation can lead to a breakdown in the insulation, livening metal cases or causing overheating of cables.

Incorrect polarity could put the active conductor onto the case, without causing the protection device to work. The earthing system could be carrying the load current. The active and neutral reversal may leave most of the appliance live after it is switched off at the appliance.

AS/NZS 3000 wiring rules

Section 8 - Testing and verification

Testing of an installation, a power outlet, or a **fixed wired** appliance involves a similar regime to a plugged in appliance, and is performed by a **registered person** and documented on a **certificate of compliance**.

The tests required are summarised below.

1) The main earth must be less than 0.5 ohms.
2) The bonding conductors must be less than 0.5 ohms.
3) The protective earth conductors must allow the operation of the protective devices within 400mS.
4) The insulation resistance tests must be greater than 1 megohm from the bridged live conductors to earth. An allowance of 10 kilohms for heating elements can be used.
5) The earth or neutral conductors must not be switched.
6) The polarity of earth, neutral and phase must be correct throughout the installation.
7) Earth conductors must not normally carry a current.
8) There are no short circuits between conductors.
9) There is no interconnection between circuits.
10) RCD's must be tested with either the integral test button or with a tester to verify tripping at 30mA and 300mS for AC and pulsed DC.

Test equipment

Testing instruments are used for two main reasons.
To verify if a circuit is live or not and or to obtain an accurate value.

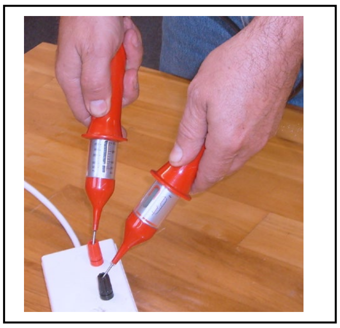
Testing for isolation requires an instrument that is reliable, robust and accurate enough to avoid a wrong conclusion as to whether a circuit is correctly wired or isolated.

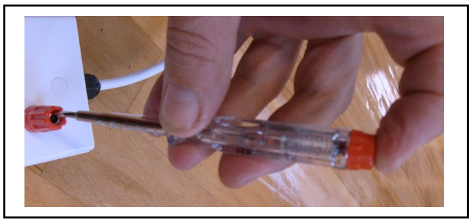
Consideration needs to be given to the cat rating of the test instrument and the leads so that a fault in that situation will keep the user safe.

Poor lighting and a noisy situation make some testers unclear.

Overleaf are some examples of testers and their advantages or disadvantages.

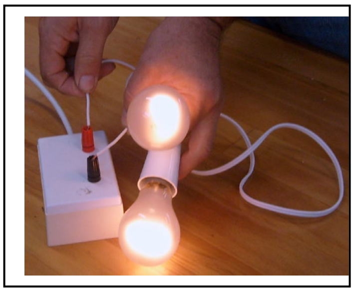
Examples of testers

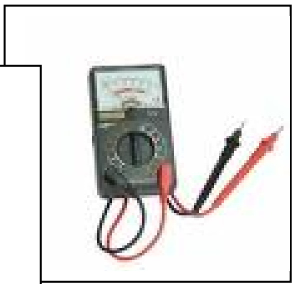




A **neon screw driver** can test for a voltage without the need of a neutral reference. Hard to read in poor light and no voltage level is indicated

Solenoid testers are robust and draw enough load to trip an RCD. They make a noise and vibrate as well as indicating the voltage level.
An ideal tester for testing for isolation.





Test lamps are dangerous due to low rated leads. Globes are easily broken. No values of voltage

Meters will give accurate reading of voltage values. Digital meters are more robust than analogue meters. Care needs to be taken to read the correct scale. High input impedance (resistance) meters can lead to false readings

Volt sticks work off the effect from the electric field around the fitting or cable. This may be misleading to the unwary. There is no voltage level reading

Outlet testers are claimed to detect incorrectly wired outlets but can be wrong if the mains is transposed