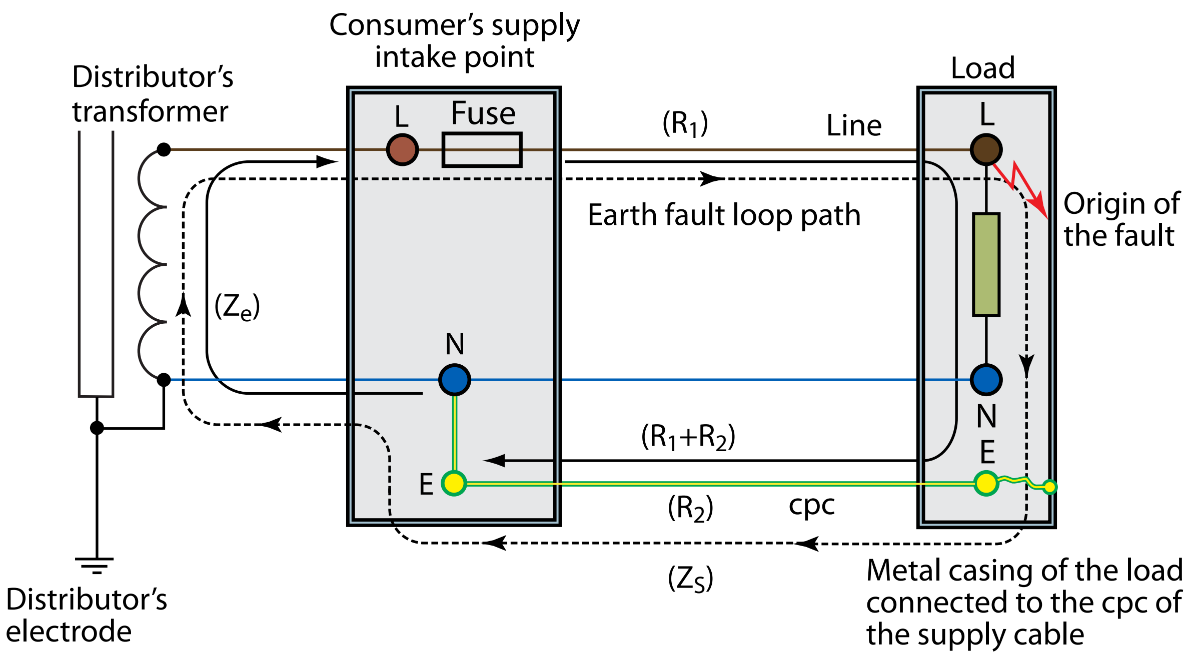
Level 3 Diploma
in
Installing Electrotechnical Systems & Equipment

associates ltd

C&G 2357

Unit 307 - Principles, practicies and legislation for the inspection, testing and commission etc, of electrical systems



B&B Training Associates Ltd
Learning Materials for the Electrical Industry

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Disclaimer

Every effort has been made to ensure accuracy and up-to date information but no responsibility can be accepted for any errors, misleading information or omissions.

The documents and presentations that make up this learning package do not constitute either fully or partially the full and final information on all aspects of the City and Guilds Level 3 NVQ Diploma in Installing Electrotechnical Systems and Equipment (Buildings, Structures and the Environment) (2357-13/91). They do not show full representation of Health and Safety aspects or full knowledge of any job descriptions.

Materials

The course does require you to possess certain items. Other than the need for pens, calulators and pencils, these include:

- a copy of BS 7671: 2008 (2011)
- a copy of IET Guidance Note 3
- a copy of the Memorandum of guidance on the Electricity at Work Regulations 1989

Aims

Outcome 1

- State the requirements of the Electricity at Work Regulations for safe inspection of electrical systems and equipment in terms of those carrying out the work and those using the building during the inspection
- Specify and undertake the correct safe isolation procedure
- State the implications of carrying out safe isolations to
  - other personnel
  - customers/clients
  - public
  - building systems(loss of supply)
- State the implications of not carrying out safe isolations to
  - self
  - other personnel
  - customers/clients
  - public
  - building systems (presence of supply)
- identify all Health and Safety requirements which apply when inspecting, testing and commissioning electrical installations and circuits including those which cover:
  - working in accordance with risk assessments / permits to work / method statements
  - safe use of tools and equipment
  - safe and correct use of measuring instruments
  - provision and use of PPE
  - reporting of unsafe situations.

Outcome 2

- State the purpose of and requirements for initial verification and periodic inspection of electrical installations
- Identify and interpret the requirements of the relevant documents associated with inspection, testing and commissioning.
- Specify the information that is required to correctly conduct initial verification of an installation in accordance with the IEE wiring regulations and IEE Guidance Note 3.

Outcome 3

- identify the items to be checked during the inspection process for given electrotechnical systems and equipment, and their locations as detailed in the IEE wiring regulations
- state how human senses (sight, touch etc) can be used during the inspection process
- state the items of an electrical installation that should be inspected in accordance with IEE Guidance Note 3
- specify the requirements for the inspection of the following:
  - earthing conductors
  - circuit protective conductors
  - protective bonding conductors:
  - main bonding conductors
  - supplementary bonding conductors.
  - isolation
  - type and rating of overcurrent protective devices.

Outcome 4

- state the tests to be carried out on an electrical installation in accordance with the IEE wiring regulations and IEE Guidance Note 3
- identify the correct instrument for the test to be carried out in terms of:
  - the instrument is fit for purpose
  - identifying the right scale/settings of the instrument appropriate to the test to be carried out.
- specify the requirements for the safe and correct use of instruments to be used for testing and commissioning
- explain why it is necessary for test results to comply with standard values and state the actions to take in the event of unsatisfactory results being obtained
- explain why testing is carried out in the exact order as specified in the IEE wiring regulations and IEE Guidance Note 3

- state the reasons why it is necessary to verify the continuity of circuit protective conductors, earthing conductors, bonding conductors and ring final circuit conductors
- specify and apply the methods for verifying the continuity of circuit protective conductors and ring final circuit conductors and interpreting the obtained results
- state the effects that cables connected in parallel and variations in cable length can have on insulation resistance values
- interpret and apply the **procedures** for completing insulation resistance testing
- explain why it is necessary to verify polarity
- interpret and apply the procedures for testing to identify correct polarity
- specify and apply the methods for measuring earth electrode resistance and correctly interpreting the results
- identify the earth fault loop paths for the following systems:
    - TN-S
    - TN-C-S
    - TT.
- state the methods for verifying protection by automatic disconnection of the supply
- specify the methods for determining prospective fault current
- specify the methods for testing the correct operation of residual current devices (RCDs)
- state the methods used to check for the correct phase sequence
- explain why having the correct phase sequence is important
- state the need for functional testing and identify items which need to be checked
- specify the methods used for verification of voltage drop
- state the cause of volt-drop in an electrical installation
- state the appropriate procedures for dealing customers and clients during the commissioning and certification process.

Outcome 5

- explain the purpose of and relationship between:
    - an electrical installation certificate
    - a minor electrical installation works certificate
    - schedule of inspections
    - schedule of test results.

- state the information that must be contained within:
  - an electrical installation certificate
  - a minor electrical installation works certificate
  - schedule of inspections
  - schedule of test results.
- describe the certification process for a completed installation and identify the responsibilities of different relevant personnel in relation to the completion of the certification process
- explain the procedures and requirements, in accordance with the IEE wiring regulations, IEE Guidance Note 3 and where appropriate customer/client requirements for the recording and retention of completed:
  - electrical installation certificates
  - minor electrical installation works certificates
  - schedule of inspections
  - schedule of test results.

At the start of each chapter a list of objectives will be highlighted. By the end of each chapter you will have the opportunity to demonstrate how well the specific objectives have been understood by answering end of session assessment questions.

1: Why do we need to isolate?

In this session the student will:

- State the implications of carrying out safe isolation.
- State the implications of not carry out safe isolation.

Reasons for isolating systems and equipment

Every year, people working with electricity suffer electric shock and burn injuries some of which, tragically, are fatal. Isolating equipment correctly before working on or near it should eliminate these unnecessary deaths. The law also recognises the dangers of working with electricity and has set out rules and regulations which must be obeyed. In the event of an accident occurring to have proved you have carried out the rules is your only defence in court.

It is VITAL that you understand the importance of the role you undertake when inspecting and testing, because when you sign the documents to say the system or equipment is safe, you are responsible if you are WRONG. Getting it wrong could result in electric shock, burns or fire occurring, any of these could be fatal and you could end up in prison.

Legislation

The Health and Safety at Work etc. Act 1974 sets out the general health and safety duties of employers, employees and the self-employed. The Electricity at Work Regulations 1989, which were made under the Act, requires precautions to be taken against the risk of death or personal injury from electricity in work activities.

Duties are placed on employers to ensure, amongst other things that employees engaged in such work activities on or near electrical equipment implement safe systems of work, have the technical knowledge, training or experience to carry out the work safely, and are provided with suitable tools, test equipment and personal protective equipment.

Safe isolation

Safe isolation, amongst other things, is done to prevent people receiving electric shocks

To receive a shock you must form part of a circuit. If no circuit is present then there can be no shock.

To help prevent shocks, before working on or near electrical circuits and equipment, we isolate.

Isolation is defined in BS 7671 as:

> "A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation from every source of electrical energy."

The Electricity at Work Regulations gives information on the requirements of safe isolation. The regulation we are concerned with are;

Regulation 12

Where necessary to prevent danger, suitable means must be available to cut off supplies of electrical energy to equipment and the equipment must be isolated, defined as the secure disconnection of the electrical equipment from every source of electrical energy.

Regulation 13

The means of disconnection of the electrical must be secured in the OFF position, with a warning notice or label at the point of disconnection, and proving dead at the point of work with an approved voltage indicator.

Regulation 14

Dead working should be seen as the normal method of carrying out work on electrical equipment or circuits. Live work should only be carried out in particular circumstances where it is unreasonable to work dead.

Regulation 16

Requires that no-one shall engage in work with electricity unless they are competent to do so.

Health and safety requirements

All work must be carried out safely, this means not only keeping yourself safe, but others and the building you are working in. To do this you need to follow health and safety guidelines.

Risk assessment

In any work involving electricity a risk assessment **must** be carried out no matter how big or small the task is. It is yours or someone else's life at risk. The HSE web site has a full description of how to carry out a risk assessment if you are not sure.

- **Step 1 Identify the hazards**
- Working at height - working in an enclosed space - members of the public present etc

- **Step 2 Decide who might be harmed and how**
- Members of public- other work force members-clients- self, working at height etc

- **Step 3 Evaluate the risks and decide on precautions**
- Need for barriers-working at height equipment- etc

- **Step 4 Record your findings and implement them**
- Write down your findings and the actions you plan to take and the methods you plan to use to make the task safe.

- **Step 5 Review your assessment and update if necessary**
- This may not be necessary if you are only testing for a short while, but on larger inspections it might be.

When thinking about your risk assessment, remember:

- **a hazard** is anything that may cause harm, such as chemicals, electricity, working from ladders, an open drawer etc;

- **the risk** is the chance, high or low, that somebody could be harmed by these and other hazards, together with an indication of how serious the harm could be.

Method statements

After completing the risk assessment the next step is to construct a method statement.
A method statement is written series of steps, take to complete a task at work in a safe manner. It should be written by someone who is experienced in the work to be carried out as they should know what is involved and the possible risks that might occur. It will usually specify the level of training needed to be competent to carry out the task, i.e. hold a C&G 2394 certificate or above.

When the method statement is prepared, the risks are identified and steps are taken to minimise or remove the risks.

A plan covering how the work should be carried out should be written in steps that can be followed by the person carrying out the procedure. This should include all health and safety aspects such as PPE tools and equipment and safety equipment such as barriers. The method statement should be discussed amongst those involved so that everyone is aware of the work to be carried out and the sequence of activities.

Permits to work

The permit-to-work is a documented procedure that authorises certain people to carry out specific work within a specified time frame. It sets out the precautions required to complete the work safely, based on a risk assessment. It describes what work will be done and how it will be done.

The permit-to-work requires signing by the people authorising the work and those carrying out the work. It will require a declaration from the person authorising the permit –to- work that the system is ready for normal use when the task is completed.

Tools and equipment

All tools and equipment must be safe to use, maintained and be appropriate for the task.
Before using measuring instruments when testing, you must be trained to use the instrument so that you understand and can interpret the information given, this will allow you to fill in the appropriate documentation.

PPE needed will vary from site to site; you are required to wear all PPE provided to you. When inspecting and testing this will probable consist of goggles, safety hat and boots. However insulated gloves and an insulated mat maybe needed.

If at any time you are unhappy with the task given to you, the equipment or procedures this must be reported to your supervisor. Never work in unsafe conditions!

Considering others

There are people to consider such as your fellow workers, your customers/client, the public and the effect on the building and its users if power is cut off.

You should ensure that when isolating the circuit that others who are working around you are warned that the supply will be turned off and you should allow ample time for them to finish what they are doing. You are not going to be very popular if you cut of the power to drills, leave everyone in the dark etc.

Customer / Clients

Every effort should be made to notify the client well in advance of any loss of supply and for commercial installations, effort should be made to try to arrange any shut down during hours when the impact will be minimised. There are certain types of machinery and plant which could be damaged if suddenly switched off, the impact of going from full power to none could rip bolts from fixings, send potentially dangerous goods and equipment flying. Machinery using magnetic clamps would lose grip of the objects.

In domestic situations, there may be venerable people such as the elderly and very young children who need light and heat.

Public

Any area that the general public may occupy and the effect an interruption in the electrical supply will have on them needs to be considered. Lighting in areas such as shopping centres, underpasses, car parks and other public access points need to be maintained so that the public are able to move around in or exit the buildings safely. The working area must be maintained in a safe condition with no danger to the public. Before removing power to lifts, escalators or any public area, the area must be checked and warning notices positioned first.

Yourself the inspector

Before you begin the process of isolating systems or equipment, you must be competent, that means; trained in the procedure, understand what you are going to do, have the correct equipment and PPE etc.

Building systems

Prior warning needs to be given to users of buildings as loss of power to lighting, power, air conditioning, building management systems, security, fire alarms, lifts and escalators, computers and IT systems can have serious consequences. They all need to be maintained, as far as possible, to keep a building operating. Some systems can continue operating by using back up supplies provided by generators or other UPS arrangements. Sudden loss of power could lead to critical data loss on computers, potentially lethal effects to medical premises and panic if lifts or lighting suddenly fail. UPS systems can cause problems, as isolating the mains will bring the UPS system back on line.

Remember that Photovoltaic supplies are live all the time, so special precautions are necessary when dealing with these

Possible effects from failing to isolate

Consequences
Two electricians suffered life-threatening injuries when they were engulfed by a fireball at a factory as they were about to clean debris from a damaged fuse box. One of the electricians is still undergoing treatment for his burns, nearly five years on, and will never be able to return to work. There had been a fire in the fuse box during the previous afternoon but live cables had been routed through it so that the cooling equipment at the factory could continue to operate. This meant the company avoided having to shut down the plant for 36 hours. A suitable risk assessment had not been carried out for the work and management at the company had allowed the work to go ahead without the electricity supply being isolated, even though this went against their own work procedures. A subcontractor fell more than five metres from a ladder after suffering an electric shock when he made contact with a live three-phase 415 V conductor that was the main power channel to the overhead crane that he had been about to repair. The company had not marked it or isolated it prior to the subcontractor starting his work. A young electrician was holding two ends of an open flex thinking they were dead. He touched the neutral held in one hand and at the same time touched the line conductor in the other. Fortunately, a trainee, who was with him, was alert enough to hit him repeatedly with a wooden brush handle to get him to let go. The electrician was hospitalised and off work for a time.

There are, as can be seen, serious consequences when safe isolation is not carried out.

Exercise 1

1. Explain how not giving sufficient warning that you are going to remove the power supply could affect your fellow workers. Briefly give at least two examples of what the effect might be.

2. Describe how the loss of power might affect your clients.

3. Describe how the loss of power might affect the general public

4. Describe how the loss of power might affect buildings in general.

2: Safe isolation

In this session the student will:

- Be able to specify and undertake the correct procedure for completing safe isolation.

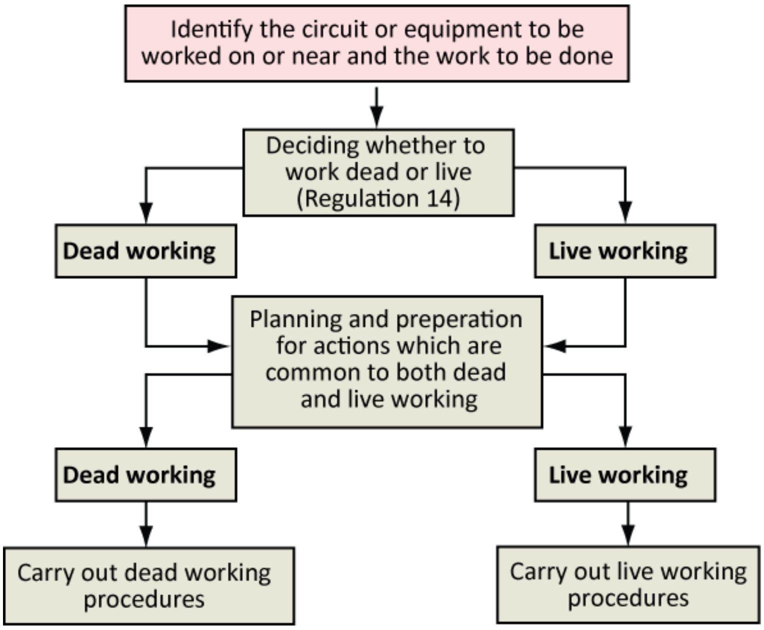
The correct procedure for completing safe isolation

The HSE produce a booklet HSG85 which gives guidance on the key elements that need to be considered when devising safe working practices for people who carry out work on or near electrical equipment.

The figure below illustrates the sequence of the planning steps. The procedure can be divided into stages as follows:

- deciding whether to work dead or work live

- planning and preparation for actions which are common to both dead and live working



Actions common to both dead and live working

- Identify the circuit or equipment to be worked on or near and the work to be done
- Plan the work
- Specify correct system of work (preferably written)
- Specify level of supervision and whether accompaniment is necessary
- Select and instruct competent workers
- Ensure correct working methods
- Provide and ensure use of appropriate protective equipment
- Provide appropriate information and suitable tools and instruments for workers. Ensure they are fully instructed
- Make arrangements for management checks and supervision of work

Implement DEAD or LIVE working procedures

Dead working procedures

- Identify circuit or equipment to be worked on
- Cut off supply, isolate and secure isolation
- Retain keys. Post ‘caution’ and ‘danger’ notices
- Prove circuit or equipment dead
- Apply circuit main earth(s) where necessary
- Take precautions against adjacent live parts where necessary
- Issue permit-to-work where necessary
- Apply local earth(s) where necessary

Work on or near live conductors should rarely be permitted (Regulation 14). Many accidents to electricians, technicians and electrical engineers occur when they are working on equipment that could have been isolated.

Regulation 14 requires that three conditions are met for live working to be permitted where danger may arise. It is stressed that if just one of those conditions cannot be met, live working cannot be permitted and dead working is necessary.

- it is unreasonable in all the circumstances for the conductor to be dead; and
- it is reasonable in all the circumstances for the person to be at work on or near that conductor while it is live; and
- suitable precautions (including, where necessary, the provision of personal protective equipment) have been taken to prevent injury.

It is unreasonable for the work to be done dead

There are some circumstances where it is unreasonable to make equipment dead because of the difficulties it would cause (regulation 14). For example, it may be difficult, if not impossible, to commission a complex control cabinet without having it energised at some time with parts live (but not exposed so that they may be easily touched). Also it may not be realistic to monitor the operation and performance of a control system or to trace a malfunction of such equipment with it dead, i.e. fault-finding.

Justifying live working

Providing the other requirements of Regulation 14 have been met, live working can still only be justified if suitable precautions are taken to prevent injury arising from risks identified in the assessment (Regulation 14(c)).

The possibility of anyone touching parts at dangerously different potentials at the same time should be avoided by installing temporary insulation or protective barriers. This may mean putting temporary insulating screens over live parts and/or applying insulation to parts that are at earth potential. Temporary screens etc can also help to prevent the risk of accidental short circuit from tools, components, conductors etc.

When work is to be carried out ‘near’ rather than ‘on’ live equipment (eg near an overhead line), the essential precautions will often be directed towards ensuring that appropriate and adequate safety clearances are established and maintained.

The people doing the work must be adequately trained and experienced in the type of live work being undertaken (Regulation 16).

Live working procedures

- Identify the circuit or equipment to be worked on or near and the work to be done
- Ensure suitable precautions are taken and that suitable protective equipment is used
- Ensure adequate working space, access and lighting. Restrict access to area of live work
- Ensure accompaniment is provided if necessary. Accompaniment to be trained to give assistance

Identification of circuits to be isolated

In many cases actual physical identification will be necessary and this may be aided by the use of appropriate drawings, diagrams and other written information. You should never assume that the labelling or drawings are correct without having proved that the circuit is dead.

Suitable points of isolation

For work on LV electrical equipment or circuits, it is important to ensure that the correct point of isolation is identified, an appropriate means of isolation is used and the supply cannot inadvertently be reinstated while the work is in progress. Caution notices should also be applied at the point(s) of isolation, and the conductors must be proved to be dead at the point of work before they are touched.

The means of isolation can be an adjacent local isolation device such as a plug and socket, switch-disconnector, circuit breaker, fuse etc, as appropriate, which is under the direct control of the competent person carrying out the work. These devices can be used without further precautions provided there is no foreseeable risk that the supply could be reinstated by others.

When there is no such local means of isolation or there is a risk of reinstatement of the supply as above, the circuit or equipment to be worked on should be securely isolated by one of the following methods.

Isolation using a main switch or distribution board (DB) switch-disconnector

Isolation of equipment or circuits using the main switch or DB switch-disconnector is the preferred method. The point of isolation should be locked off using a unique key or combination retained by the person carrying out the work. In the case of multiple isolations on a DB, a multi-lock hasp can be used to prevent access to a main isolator until such time that all persons working on a system have completed their work and removed their padlocks from the hasp.

If locking-off facilities are not provided on the relevant switch then a locked DB door or locked switch-room door is acceptable provided the key or combination is unique, and is retained by the person doing the work. Again, multi-lock hasps can be used to control multiple isolations, although a key box or similar system may be needed to retain and control access to the main door key.

Safe Isolation Practice

Where it is intended that more than one person will be working on circuits supplied from a DB, (i.e. multiple isolations) and a multi-lock hasp cannot be used to secure the main point of isolation, individual isolation of each circuit is recommended, to prevent inadvertent reinstatement of the supply.

The principle is that each person carrying out such work should have control of their own point(s) of isolation and not rely on others to prevent inadvertent switching on.

Neutral conductors

All live conductors must be isolated before work can carried out including the neutral conductor as this is a live conductor. The practice of 'borrowing' neutrals is not permitted by the BS 7671 but it is not uncommon.
Lighting and control circuits are the most common example, the neutral conductor can become live if an energised load on another circuit is added to it.

Isolation of individual circuits

Where it is not practical to isolate a distribution board, individual circuits supplied from it can be isolated by one of the methods described below, depending on the type of protective device used.
It should be remembered that work carried out inside a live DB is regarded as live working when there is access to exposed live conductors. In this case the appropriate precautions should be taken.

Isolation of individual circuits protected by circuit breakers

Where circuit breakers are used the relevant device should be locked-off using an appropriate locking-off clip with a padlock which can only be opened by a unique key or combination. The key or combination should be retained by the person carrying out the work.

Isolation of individual circuits protected by fuses

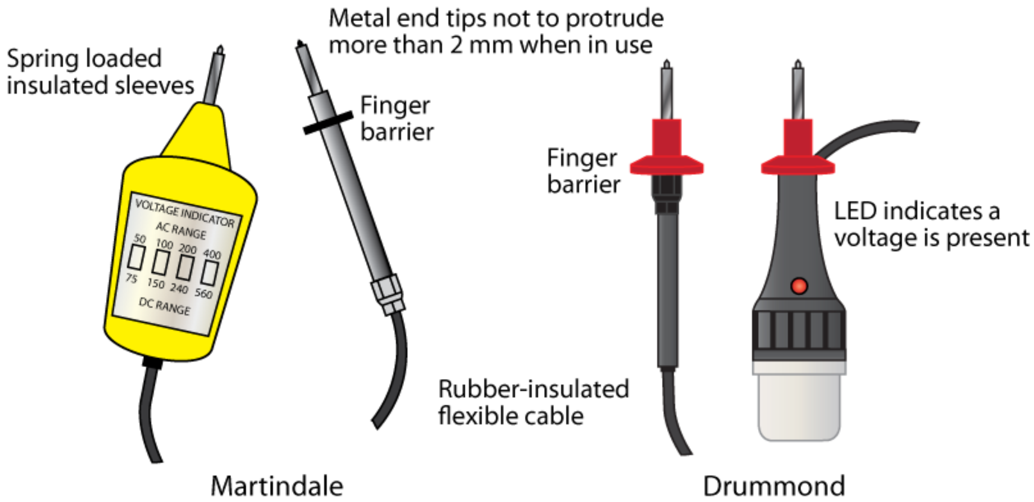
Where fuses are used, the simple removal of the fuse is an acceptable means of disconnection. Where removal of the fuse exposes live terminals that can be touched, the incoming supply to the fuse will need to be isolated. To prevent the fuse being replaced by others, the fuse should be retained by the person carrying out the work, and a lockable fuse insert with a padlock should be fitted as above. A caution notice should also be used to deter inadvertent replacement of a spare fuse.

Testing equipment

For the testing of a potentially live source, two pieces of test equipment are required. These are:

- **Approved voltage tester**
- **Voltage proving unit**.

There are many varieties of voltage tester and as long as they meet the requirements of GS 38 then you will be fine. We will look at these in more detail later.

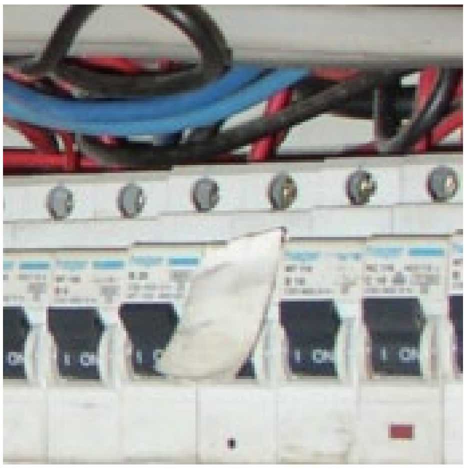


A tester is no use if we cannot guarantee its effectiveness. This is where the proving unit comes into its own. All equipment should be regularly checked to make sure it is good safe working order.

The process of safe isolation

The process for safe isolation of a complete isolation is to find the point to be isolated, decide on the means of isolation, then check that it is safe to isolate, if necessary get permission to isolate.

The process for safe isolation on individual circuits is similar, but you may need permission to remove any loads.

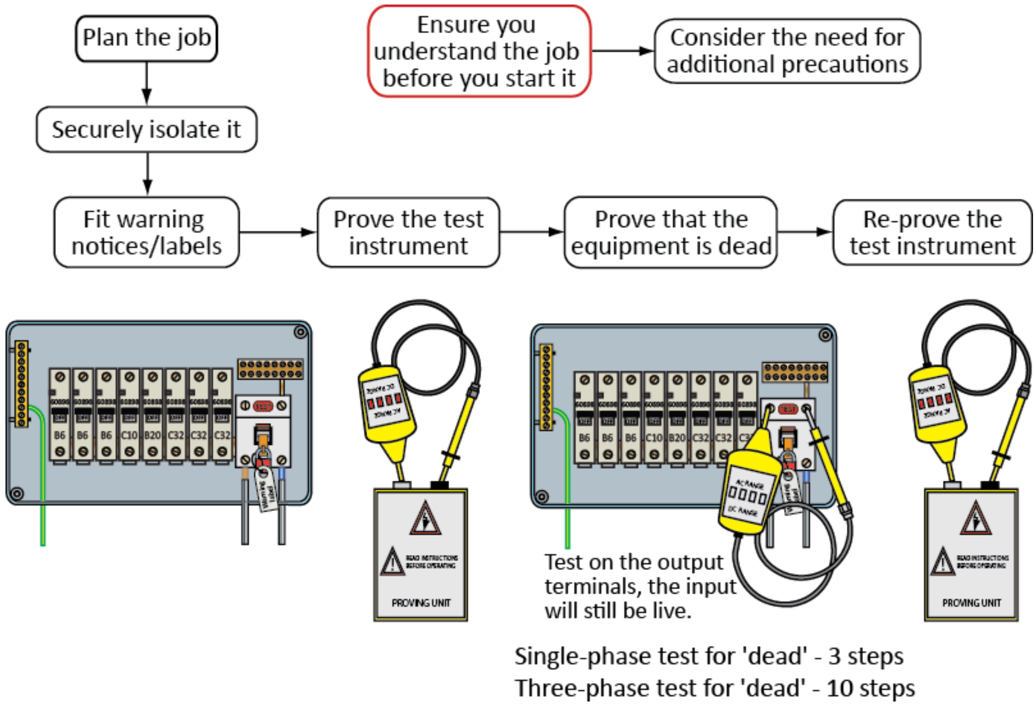


What is wrong with this picture?

Can you think of a different method of isolating that circuit?

Should that strip of insulation tape have been red!

The diagram below shows the procedure you should use for the safe isolation of a piece of equipment or plant.



Warning notices and locking devices for secure isolation

The implications of carrying out safe isolation to self, other personnel, customers the public and building systems are great.

The correct procedures must be carried out at all time. Plenty of notification needs to be given before any circuit is isolated. The consequences could be disastrous if for example you left an operating theatre in darkness or a computer suite with sensitive or irretrievable data which wasn't backed up

In some circumstances machinery might suddenly start or stop without warning causing danger to operatives or those using it.

To keep yourself and others safe, no short cuts must be made, the isolation procedures have been developed for a reason.

Re-energising equipment or a circuit

Before re-energising equipment or a circuit you should Inspect and test the work that has been carried out and then inform others where necessary.

Exercise 2

1. Briefly describe of the process of carrying out safe isolation.

2. Name two items used to make sure an isolated circuit cannot be accidently switched back on.

3. What item of equipment would be used to make sure your voltmeter or similar device is operating correctly before carry out a test?

4. Regulation 16 of the EWR states that, ‘No person shall be engaged in any work activity where technical knowledge or experience is necessary to prevent danger or, where appropriate, injury, unless he possesses such knowledge or experience, or is under such degree of supervision as may be appropriate having regard to the nature of the work.
    a) What do the terms ‘injury’ and ‘danger’ mean?
    b) What do the terms ‘technical knowledge’ or ‘experience’ include?

5. The *Health and Safety at Work etc. Act 1974* lays a number of responsibilities upon employers. Name three of them.

6. Can a typical voltmeter (voltage range on a multi-meter) be used to check for presence of supply voltage?

3: Reasons for inspection and testing

In this session the student will:

- State the purpose of initial verification and periodic inspection of electrical installations.
- Identify and interpret the relevant documents associated with inspection and testing of electrical installations.
- Specify the information required to correctly conduct initial verification of an electrical installation in accordance with the IEE regulation and GN3

Before we go any further, what do we mean by initial verification and periodic inspection and testing?
With an initial Verification we are looking at a new installation to make sure that it is safe to use, meets the design specifications and is fit for purpose. It must also meet the requirements of BS 7671.

Initial verification is carried out on a new installation; **before** it is put into service.
The purpose is to confirm by inspection and testing both during construction and on completion that the installation complies, both with the design and construction requirements and the relevant aspects of BS 7671.

Periodic inspection and testing is done to provide information on which to decide, whether an **existing installation** is in a satisfactory condition to continue to be used safely.
A detailed visual examination of the installation is required, along with appropriate tests to confirm that the disconnection times stated in Chapter 41 are met.
The periodic inspection and testing is carried, so far as is reasonable practical for:

1. The safety of persons and livestock against the effects of electric shock and burns
2. Protection against damage to property by fire and heat arising from an installation defect
3. Confirmation that the installation is not damaged or deteriorated so as to impair safety
4. Identification of the installation defects and departures from the requirements of BS 7671 that might give rise to danger.

Periodic inspection and testing is necessary because all electrical installation deteriorate due to wear, tear, corrosion excessive loading, ageing and environmental influences.

BS 7671 requirements for initial verification

610.1

"Every installation shall during erection and on completion before being put into service, be inspected and test to verify, so far as is reasonably practical, that the requirements of the regulations have been met".

611.1

"Inspection shall proceed testing and will normally be done with that part of the installation under inspection disconnected from the supply".

611.2

"The inspection shall be made to verify that the installed electrical equipment is:

i. In compliance with the requirements of Section 511 and
ii. correctly selected and erected in accordance with the regulations, taking into account the manufacturer's instructions
iii. Not visibly damaged or defective so as to impair safety"

This means the initial inspection will check whether;

- All equipment and material is of the correct types and complies with the current requirements of BS 7671 or equivalent.
- All parts of the installation are correctly selected and erected
- No part is visible damaged or otherwise defective
- The equipment and materials used are suitable for the environmental condition present.

Large parts of an electrical installation are hidden once the building fabric has been completed so conduit and, cable tray and trunking need visually inspecting as well.

BS 7671 requirements for Periodic inspection and testing

621.1 requires that the installation is inspected and tested to determine whether it is in a satisfactory condition for continued service. Any previous documentation should be taken into account.

621.2 requires that periodic inspection comprising of a detailed examination of the installation shall be carried out without dismantling, or with partial dismantling as required, supplemented with other tests from Chapter 61 to show that the requirements for disconnection times, as set out in chapter 41 for protective devices are complied with.

621.3 requires that precautions are made to ensure that the periodic inspection and testing shall not cause danger to persons or livestock, and shall not cause damage to property or equipment and methods should be chosen in accordance with the relevant parts of BS EN 61557.
621.4 requires that the extent and results of the periodic inspection and testing of an installation or any part of it shall be recorded.
621.5 requires that the periodic inspection and testing shall be done by a competent person.

Required relevant documentation
To help you in the inspection and testing process you are required to be familiar with the following documentation.
These include

- Electricity at Work Regulations
- BS 7671: 2008 Amendment 1:2011
- IET Guidance Note 3
- HSE Guidance

For domestic installations the current edition of the non statutory BS 7671 is the main documentation. For commercial installations statutory regulations such as The Electrical Supply Regulations and the Electricity at Work Regulations will apply.
Complying with BS 7671 will in most cases satisfy statutory regulations such as the EWR.

Electricity at Work Regulations (EWR)
The *Electricity at Work Regulations 1989* applies to EVERYONE while they are at work.
The regulations require that;
'As may be necessary to prevent danger, all systems shall be maintained so as to prevent, as far as is reasonably practicable, such danger'.

Whilst there is no specific regulation within the EWR that requires inspection and testing to be carried out, there are many regulations that require maintenance to be performed, and part of this maintenance process can only be performed where tests are carried out and records made. Therefore, one of the effects of the introduction of the EWR is that failure to carry out an appropriate assessment of an electrical installation has more serious consequences than previously existed.
In general, equipment that has been properly designed, constructed, installed and maintained does not present a risk of electric shock or burn injury when properly used.

EWR requires all systems and equipment to be designed, constructed and installed so that they can be used safely. The standard mainly covers systems and equipment that operate at low voltage (up to 1000 V ac). Equipment should also be suitable for the environment, in which it is used.

Defence

If you test and inspect a building, system or piece of equipment and sign the documentation to say it is safe, and if , for whatever reason it is not, YOU ARE LIABLE. **You become the duty holder.**

Your only defence is Regulation 29.

Regulation 29 provides a defence for a 'duty holder' who can establish that he/she took all reasonable steps and exercised all due diligence to avoid committing an offence under regulations 4(4), 5, 8, 9, 10, 11, 12, 13, 14, 15 or 16.

What do these terms mean?

Duty holder -In terms of the Electricity Regulations is clearly defined.

The legislation states that where an EMPLOYEE is in CONTROL of electrical danger, the duties imposed on the INDIVIDUAL are equivalent to the duties placed upon the employer and the self-employed. This means you are as guilty as your employer if a mistake is made.

Regulation 16 states that no person shall engage in work that requires technical knowledge or experience to prevent danger or injury, unless he/she has that knowledge or experience, or is under appropriate supervision.

Reasonable -Would a professional acting under the same circumstances, with the knowledge available to the field at the time, have concluded that the given response/action was reasonable?

Due diligence or due care -in civil law is the effort made by a reasonable person to avoid harm to another party. Failure to make this effort may be considered negligence.

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Regulation 134.2.1 requires any installation, or indeed part of an installation such as a circuit, to be inspected and tested before it is put into service.

Chapter 61 deals with Initial verification

Requirement 610.1

'Every installation shall during erection and on completion before being put into service, be inspected and tested to verify, so far as reasonable practicable, that the requirements of the regulation have been met'.

610.3 'The verification shall include comparison of results with relevant criteria to confirm the requirements of the regulations have been met'.

610.4 'For an addition or alteration to an existing installation, it shall be verified that the addition or alteration complies with the Regulations and does not impair the safety of the existing installation'.

610.5 'The verification shall be made by a competent person'

IET Guidance Note 3

The IET produce a series of guidance notes for electricians and those working in the construction industry. Guidance note 3 is concerned with part six of the BS 7671 - Inspection and Testing. They explain and enlarge upon the requirements.

Section 2.6.2 states the general procedure for Initial inspection

"Inspection and, where appropriate, testing should be carried out and recorded on suitable schedules progressively throughout the different stages of erection and before the installation is certified and put into service".

Section 3.1 states the purpose of periodic inspection and testing

Section 3.5 gives guidance on routine checks. Electrical installation should be checked on a regular basis, domestic installations rely on the occupier arranging repairs to breakages or worn equipment replaced.

Commercial and industrial installation come under the EWR and formal arrangements are required for maintenance and routine checks. These will vary depending on the use of the premises.

Section 3.7 deals with the frequency of Periodic inspection and table 3.2 lists the recommended times between the inspections.

HSE

The HSE produce a guidance leaflet **Safety in Electrical Testing (**INDG354) Which provides basic guidance on safe electrical testing and is intended for anyone who runs or manages a workplace where electrical testing is carried out, and for those people doing the actual testing. It is complemented by information sheets which give more detailed information about specific types of testing. The guidance contains recommendations to help you prevent or reduce electrical danger.

Prior information

Certain information is required before we start to make sure that we can make right judgements. The inspector must know the extent of the installation to be inspected and tested and any criteria relating to the limits placed on his/her inspection, such as access, switching off circuits etc.

It is a requirement of BS 7671 that the following should be available to aid the safety of the inspection

- diagrams and charts
- design criteria
- The type of the circuit, including points of utilisation, number and size of conductors and type of cable. The installation method.
- The method for compliance with the requirements for basic and fault protection and , where appropriate the conditions required for automatic disconnection.
- The information necessary for the identification of each device performing the function of protection, isolation and switching and its location
- Any circuit vulnerable to a specific test

To be able to carry out the inspecting and testing, the inspector must also have the following information to assess the general characteristics. These details are needed for the documentation that must accompany ever new installation. More about this later.

Regulation 311.1

- The maximum demand expressed in amperes, kW or kVA per phase (after diversity has been taken into account).

Regulation 312.1

- The number and type of live conductors of the source(s) of energy and of the circuits used in the installation.

Regulation 312.2

- The type of earthing arrangement used by the installation and any facilities provided by the distributor for the user

Regulation 313.1

- The nominal voltage(s) and its characteristics including harmonic distortion
- The nature of the current and supply frequency
- The prospective short-circuit current at the origin of the installation
- The earth fault loop impedance (Z_e) of that part of the system external to the installation
- The type and rating of the overcurrent protective device acting at the origin of the installation

These should be available for all sources of supply

- The presence of any sensitive electronic devices which may be susceptible to damage when carrying out insulation resistance tests which put 500 V dc in to the system.

The Health and Safety at Work Act requires as an aid to inspection and testing that charts, diagrams and tables are available

Exercise 3

1. Regulation 114 of *BS 7671* details the relationship between *BS 7671* and statutory regulations. What is that relationship?

2. Name two specific statutory regulations that specifically relate to the electrical industry.

3. Regulation 4(4) of the EWR requires that electrical equipment shall be suitable for the use for which it is provided, be maintained in a condition suitable for that use, and be properly used.
   When considering test equipment, how will this regulation apply?

4. In the light of your answer to q.4, how will this regulation apply to an electrical installation?

5. What does the terms ‘technical knowledge’ or ‘experience’ include?

6. What information must a distributor supply?

7. Regulation 29 provides a defence for a duty holder who can establish that he took all reasonable steps and exercised all due diligence to avoid committing an offence under regulations 4(4), 5, 8, 9, 10, 11, 12, 13, 14, 15 or 16. Who is a duty holder and what do you understand by the terms ‘reasonable’ and ‘due diligence’?

8. What sort of prior information would be useful to the electrician carrying out the inspection and test of an installation?

4: Inspection

In this session the student will:

- Select appropriate items to be checked during the inspection process
- Identify the human senses appropriate for initial verification
- State how the senses can be used during the inspection
- State the items that should be inspected in accordance in Guidance Note 3
- Specify the requirements of the inspection of the following
  - Earthing conductor
  - Circuit protective conductor
  - Protective bonding conductors
    - Main bonding conductors
    - Supplementary bonding conductors
  - Isolation
  - Type and rating of overcurrent protective devices

We have already learnt that requirement 610.1 states;
'It is ***essential*** that a detailed inspection be carried out both during installation and immediately prior to testing'.

Requirement 611 .1 states;
'Inspection shall precede testing and shall normally be done with that part of the installation under inspection disconnected from the supply'.
This is obvious in a way, as there is no point in testing something which has not been visually checked for faults first.

Before any inspection can take place, there is an absolute necessity to guarantee the safety of anyone who is checking the installation.

Inspection must not be carried out live. With switch and socket fronts taken off and distribution boards being poked around in, it would be extremely unwise to do anything when the installation is turned on.
It also breaks the requirements of the EWR.

> "No person shall be engaged in any work activity on or so near a live conductor (other than one suitable covered with an insulating material so as to prevent danger) that danger may arise unless:
>
> a). It is unreasonable in all circumstances for it to be dead; **and**
>
> b). It is reasonable in all circumstances for him to be at work on or near it while it is live; **and**
>
> c). Suitable precautions (including where necessary the provision of suitable protective equipment) are taken to prevent injury."

Regulation 16 of EWR states:
The task must have been planned in such a way that no live working takes place. The risks to injury must be limited.

Inspecting an installation
To inspect an installation we don't need a whole range of instruments, we are relying on our own senses.
With inspection we make particular use of:

- **Sight** – identify conductors, use of diagrams and charts, presence of earth conductors, Presence of fire barriers
- **Sound** – to check if a bearing is running badly, sparking in an enclosure
- **Smell** – to check if a winding is burning out
- **Touch** – if it is safe to do so, then we are able to check connections of conductors, no sharp edges in containment systems, signs of overheating, barriers and enclosures.

Items to be checked during the inspection
The On- Site- Guide, Guidance Note 3 and BS 7671 give extensive lists of items to be checked during the inspection. It is highly recommended that you refer to these when carrying out an inspection.
All these items should be noted on the inspection schedule. Copies of these are in Appendix 6 of BS 7671

Regulation 611.3 states that the inspection should include the following, where relevant and should include special installations (which we will look at later).

(i) *Connection of conductors*

Any connection between conductors and equipment/other conductor must be electrically and mechanically sound

(ii) *Identification of conductors*

Any bare conductors should be identified as necessary.

(iii) *Routing of cables in safe Zones or protection against mechanical damage , in compliance with section 522*

Cables and management systems should be designed and installed taking into account the use of the installation and any stresses that might incur. Refer to 522.6 for the requirement of cables installation.

(iv) *Selection of conductor's for current carrying capacity and voltage drop, in accordance with the design.*

The cable should be assessed against the protective arrangements where practical , based on the design specification and referring to Appendix 4

(v) *Connection of single pole devices for protection or switching in line conductors only.*

It must be verified that protection for single pole devices or switching are installed in line conductors only

(vi) *Correct connection of accessories and equipment.*

Check that the connections or correct in regard to polarity, environment, suitability and the female couplings are fitted on the end remote from the supply

Refer to table 55.1 for types of socket-outlets, plugs, rating to British standards

(vii) *Presence of fire barriers, suitable seals and protection against thermal effects.*

Fire barriers, seals and or protection against thermal effects should be checked during the erection stage.

viii *Methods of protection against electric shock*

The most common measure is basic protection by insulation or enclosures together with fault protection by automatic disconnection of supply

(a) Both basic and fault protection

- SELV see 414.3 and 414.4
- PELV see 414.3 and 414.4
- Double insulation see 412
- Reinforced insulation see 412

(b)	**Basic protection (including measurement of distances, where appropriate)** - **protection by insulation of live parts** - cable insulation and or enclosures **protection by barrier or enclosure** This deals with consumer units, distribution boards etc. Has the correct IP protection been applied? Have the correct IP numbering of equipment been used. Have the distances for touch been checked? **protection by obstacles** This provided protection against unintentional contact in areas only accessible to skilled or instructed persons. Not to be used in areas of increased shock risk (part 7) **protection by placing out of reach** This also provides basic protection. Care needs to be taken in areas where long or bulky objects might be handled
(c)	**fault protection:** When there is a fault it can reasonably be expected that metalwork will become live. The next few items detail some of the areas that should be considered. - **automatic disconnection of supply** For each circuit ADS is required, verification needs to be considered on **earthing conductor** Earthing conductors link the distributor's means of earthing to the installation. The sizing requirements of the cable are defined in Section 543 of BS 7671. **presence of circuit protective conductors** These are the circuit protective conductors that connect the Main Earthing Terminal (MET) to the exposed-conductive-part on the piece of equipment. **presence of main equipotential bonding conductors** These connect the MET to extraneous-conductive-parts. **presence of supplementary bonding conductors** These are commonly found in bathrooms, but can also be seen connecting exposed-conductive-parts to exposed-conductive-parts, exposed-conductive-parts to extraneous-conductive-parts and extraneous-conductive-parts to extraneous-conductive-parts at relevant points. Check Section 544 and Regulation 411.3.1.2

	presence of earthing arrangements for combined protective and functional purposes. Check Regulation 543.5.1 of *BS 7671*. Sometimes equipment relies on an earth to function properly. This may be the case for certain measuring instruments' etc. the protective conductor is not there merely to perform a protective function, it is also required to make the equipment work. presence of adequate arrangements for alternative source(s), where applicable Due consideration must be given to the earthing arrangements for generators, UPS etc. **FELV** FELV exists where the requirements of SELV and PELV do not. Check 411.7. choice and setting of protective and monitoring devices (for fault and/or overcurrent protection) Are the protective devices appropriate to ensure that they disconnect the supply under fault conditions? **-non-conducting location (including measurement of distances, where appropriate)** This is a rare arrangement where a room is providing fault protection by removing all means of earthing. Socket-outlets will have no earth pin etc. Check Section 418. **-earth-free local equipotential bonding** This is a rare arrangement where a room is providing fault protection by removing all means of earthing. However, the exposed-conductive-parts are connected together using earth-free equipotential bonding conductors. Check Section 418. -**electrical separation** Electrical separation is a protective measure where basic protection is provided by insulation of live parts or by barriers/ enclosures in accordance with section 416 and fault protection is provided by separation of the separated circuit from other circuit and from earth. If it is intended to supply more than one item of equipment using electrical separation, it is necessary to meet the requirements of 481
ix	**Prevention of mutual detrimental influence** The requirements state that the electrical installation and its equipment shall not cause detriment to other electrical and non electrical installation. Here you will have to investigate other systems during the inspection to make sure there is no interference with each other. Check voltage bands etc

x	**Presence of appropriate devices for isolation and switching correctly located** BS7671 requires that effective, suitably positioned means of isolation and switching are provided so that all voltages maybe cut off from every installation, every circuit within the installation and from each piece of equipment so as to prevent or remove danger.
xi	**Presence of undervoltage protective devices** Normally this requirement only covers motor circuits. Suitable precautions should be put in place where reduction in voltage or loss and subsequent restarting of equipment could cause danger
xii	**Labelling of protective devices, switches and terminals** Each protective device must be arranged and labelled so that the circuit protected can be easily identified. A diagram or chart showing the function of each circuit and size of conductor is required. The inspector should have this information in order to carry out the inspection
xiii	**Selection of equipment and protective measures appropriate to external influences** Equipment must be selected appropriate to the conditions it is going to used in. This should take into account ambient temperature, heat, water, foreign bodies, corrosion, impact, vibration, flora, fauna, radiation, building use and structure.
xiv	**Adequacy of access to switchgear and equipment** Every piece of equipment that requires operation or attention by a person must be installed so that there is adequate and safe access as well as safe working space. This must be checked.
xv	**Presence of danger notices and other warning signs** Suitable notices are required to be installed giving information on voltage, isolation, testing, RCDs, and earthing and bonding connections
xvi	**Presence of diagrams, instructions and similar information** Each distribution board should have a distribution board schedule which provides information on the types of circuits, number and size of conductors, types of wiring etc. This should be attached within or adjacent to each distribution board
xvii	**Erection methods** Fixing of switchgear, cables, conduit fittings etc must be adequate for the environment. A detailed visual inspection is required during the erection stage as well as on completion.

Every installation you come across will be different. There are more variations in Guidance Note 3

Requirements for inspection

Below is a list of items that you are required to consider in your inspection. As stated before, every installation will be different and some of these items will not apply.

- Earthing conductors

  Is there one present?

  Is it of the correct cross-sectional area? This can be easily checked using Table 4.4(i) in the OSG.

  For a TT system does the csa match the sizes given in Table 4.4(ii) in the OSG?

  Is it of the correct material?

  Is it suitably protected?

  Is labelling present?
- Circuit protective conductors

  Are they sized correctly in relation to the line conductor?

  Are they bonded to the exposed conductive parts of the electrical installation?

  Are they sleeved properly?

  Have they been installed in the correct terminals in the MET to match the line conductor?
- Main and supplementary protective bonding conductors

  Is the main protective bonding conductor of correct csa, see Table 4.4(i) of the OSG.

  Is the supplementary protective bonding conductor of correct csa, see Table 4.6 of the OSG.

  Are the connections electrically and mechanically sound?

  Is labelling present?
- Devices for isolation and switching

  Are the devices appropriate for the tasks?

  Can they be secured in the OFF position?

  Are they in the correct location for their function?

  Is appropriate labelling present?
- Type and rating of overcurrent protective devices

  Has the correct rating of overcurrent device been installed for the circuit it is to protect?

  Are the fuse holders and carriers undamaged?
- Type and rating of RCDs and RCBOs

  Has the correct type of circuit breaker been selected for the circuit they are to protect?

  Have they been installed correctly?

  Have the earth and neutral leads of the RCBO been installed correctly into the neutral and earth bars?

Exercise 4

1. State three human senses that may be used during the inspection of an installation and give an example of each.

2. What information is required before inspection is carried out?

3. What threefold purpose does inspection have?

4. During an inspection of the following installations, what particular areas would you need to concentrate on checking?
   - Agricultural
   - Domestic
   - Commercial
   - Industrial

5. A luminaire is to be replaced in a bathroom. What should you check for prior to commencing any work?

6. Regulation 15 of the EWR requires that for the purposes of enabling injury to be prevented, adequate working space, adequate means of access, and adequate lighting shall be provided at all electrical equipment on which or near which work is being done in circumstances which may give rise to danger.
   What equipment will you need prior to inspection and testing being carried out?

7. What precautions will you need to consider should you need to gain access to a consumer unit situated in an understairs cupboard?

5: Safe testing

In this session the student will:

- State the tests to be carried out on an electrical installation in accordance with BS 7671 and IET Guidance note 3
- Identify the appropriate instrument for each test to be carried out in terms of
  - The instrument is fit for purpose
  - Identifying the correct scale or setting
- Specify the requirements for the safe use of instruments to be used for testing and commissioning, to include
  - Checks required to prove the test instruments are safe functioning correctly
  - The requirements for test leads and probes must comply with HSE Guidance GS38
  - The need for instruments to be regularly checked and calibrated
- Explain why it is necessary for test results to comply with standard values
- State the actions to be taken in the event of unsatisfactory results being obtained
- Explain why testing is carried out in the sequence specified in BS7671 and IET Guidance note 3.

Testing

Regulation 612.2 to 13 states;
'Where relevant, testing shall be carried out and the results compared with relevant data'.
Measuring instruments and methods shall be chosen in accordance with the relevant parts of BS EN 61557.
Test of Regulation 612.2 to 6 shall be carried out in that order before the installation is energised. Where the installation incorporates an earth electrode, the test of regulation 612.7 shall also be carried out before the system is energised.
These tests results should be recorded on the schedule of test results.

Sequence of tests

The Guidance Note 3 and BS 7671 state that the tests should be carried out in the following order.

- Continuity of protective conductors, including main and supplementary bonding. (612.2.1)
- Continuity of ring final circuits (612.2.2)
- Insulation resistance (612.3)
- Protection by SELV, PELV or by electrical separation (612.4.1-3)
- Functional extra low voltage (612.4.4)
- Protection by barrier or enclosure provided during erection (612.4.5)
- Insulation resistance of non-conducting floors and walls (612.5)
- Polarity (612.6)
- Earth electrode resistance (612.7)
- Protection by automatic disconnection of supply (612.8)
- Earth fault loop impedance (612.9)
- Additional protection (612.10)
- Prospective fault current (612.11)
- Phase sequence (612.12)
- Functional testing (612.13)
- Voltage drop (612.14)

These test results should be recorded on the Installation test schedule and compared with the design criteria.

Why do we test in this sequence?

The tests are carried out in the sequence stated because testing any installation is dangerous not only to yourself but to any others in the area.

For example;

- The safety of the inspector and others could be at risk if the continuity was not done first. Undiscovered faults could lead to fatal consequences when carrying out live testing
- The results of one test can have an effect on the others

If any test indicates a failure, the cause must be rectified and then re-tested from before the point of failure or where the test could have been influenced by the fault, before going any further.

For a new installation you would not want to be handing over to the client circuits that were not working correctly.

For an Electrical Condition Report, you would simply mark on the Schedule of Test Results your findings. You may not have the authority to carry out corrections.

Test results

It is necessary for test results to comply with industry values because we need to satisfy that the installation meets the criteria for protection against electric shock.

Considering Regulation 410.3.3 of BS 7671, the most commonly used protective measure is automatic disconnection of supply (ADS). This is made up of two parts;

- basic protection
- fault protection

What do these terms mean?

Basic protection; Basic insulation of live parts, or by barriers etc, this is verified by inspection and by performing insulation resistance checks and the results compared with Table 61 of BS 7671

Fault protection; Basically, this deals with the earthing and bonding of all metalwork to the earthing system of the installation. The integrity of this provision is verified by continuity checks and by EFLI measurements.

The results are compared with the appropriate tables for the disconnection times. These tables are found in Appendix B of the OSG, or Tables 41.2, 41.3 and 41.4 of BS 7671.

Test instruments

Before using any test instruments you must:

- Understand the equipment you are using, its rating and the characteristics of the installation you are intending testing
- Check that the instrument you are going to use conforms with BS EN 61557 this is a requirement of BS 7671
- The safety measures set out in GS 38 must be observed for all instruments, leads, probes and accessories. Some manufactures advise that their instruments be used in conjunction with fused test leads and probes.

There are two main types of instrument, analogue which has a needle that gives a direct reading on a fixed scale or digital, where the instrument gives a numeric display of the actual measurement taken. Insulation and continuity tester can be obtained in either format. RCD and earth fault loop impedance tester are usually digital only.

Any digital instrument that you use should have a basic accuracy of 5%, analogue instruments should have a full scale accuracy of 2%.

Point to remember

Basic instrument accuracy will only be achieved in ideal conditions. The actual reading will be affected by:

- the operator's ability
- the state of the battery
- the ambient temperature
- the position of the instrument
- loss of calibration
- deterioration of leads etc
- external influences
- poor probe contact
- poorly nulled test leads
- weak crocodile clips
- leads used other than those supplied with the instrument.

Low resistance ohmmeter (Continuity test instrument)

The instrument used for low-resistance tests maybe either a specialised low-resistance ohmmeter or the continuity range of an insulation and continuity tester or multi-function tester.
The test current may be dc or ac. It is recommended that it uses a no-load voltage source between 4 V and 24 V, and a short circuit current not less than 200 mA.
The measuring range should cover the span 0.2 Ω to 2Ω, with a resolution of a least 0.01Ω for digital instruments.
Errors in the reading obtained can be introduced by contact resistance or by lead resistance.
Contact resistance cannot be eliminated entirely and can introduce errors of 0.01 Ω. Lead resistance can be eliminated by either, clipping the leads together and zeroing the instrument before use or measuring the resistance and subtracting this from the reading obtained

Insulation resistance test instrument

The instrument must be able to develop the test voltage required across a load.

The test voltage required is

1. 250 V dc for SELV and PELV circuits
2. 500 V dc for all circuits rated up to and including 500 V, but excluding extra-low voltage circuit mentioned above
3. 1000 V dc circuits rated above 500 V up to 1000 V.

Instruments conforming to BS EN 61557-1 will be able to do the above tests. This type of instrument will be able to lock the instrument into the 'ON' position so that it can be used 'hands free'. An automatic nulling device will take into account the resistance of the test leads.

The accuracy of the readings include the 50 Hz currents induced into the cables under test. These errors cannot be eliminated by the test procedure. The instrument should have an automatic discharge facility capable of discharging a capacitance which can be as high as 5 µF. The instrument should be left connected after an insulation resistance test to fully discharge the capacitance.

Earth fault loop impedance tester

These instruments will raise the potential of the protective earth system. They operate by circulating a current from the line of the conductor into the protective earth. To minimize the hazard of electric shocks for the potential of the protective conductor, the test duration has to be within safe limits. The test instrument should cut off the test current after 40 ms.

Instrument accuracy decreases as the scale reading reduces. To allow for the effect of the variation on mains voltage, this test should be repeated at least twice.

For circuits rated up to 50 A, a line-earth loop tester with a resolution of 0.01Ω should be adequate.

Earth electrode resistance testers

There are three general methods of testing;

Megger DET4TC2

1. Using a dedicated earth electrode tester (three or four terminal type) care should be taken to ensure the spikes are positioned with reasonable accuracy.
2. Using a dedicated earth electrode tester (stakeless or probe type)
3. Using an earth fault loop impedance tester.

The most accurate is method 1

Method 2 cannot be used to measure the resistance of a single earth electrode.

The accuracy of the readings can be affected by the temporary spike resistance, interference currents and the layout of the test electrode.

The Megger DET4TC2 offers the full range of earth electrode testing in one instrument.

The instrument should have some facility to check that the resistance to earth of the temporary potential, and current spikes, are within the operating limits of the instrument. Care should be taken to make sure that the temporary spikes are positioned reasonably accurately.

RCD testers

Test instruments should be capable of applying the full range of test current to an in service accuracy as given in BS EN 61557-6. This accuracy will include the effects of voltage variations around the nominal voltage of the tester.

To check the RCD operation and to minimize the danger during the test, the test current should be applied for no more than 2 s.

Phase rotation instruments

BS EN 61557-7 gives the requirements for measuring equipment for testing phase sequence in three phase distribution systems where indication is given by mechanical, visual or audible means. The requirements are:

- Indication should be unambiguous between 85% and 110% of the nominal system voltage or within the range of the nominal voltage and between 95% and 105% of the nominal voltage frequency.
- The measuring equipment should be suitable for continuous operation

- The measuring equipment should be designed so that when either one or two measuring leads are connect to earth and the remaining measuring lead(s) remain connected to their corresponding line conductors, the resulting total current to earth should not exceed 3.5 mA rms.
- The measuring equipment should not be damaged nor should the user be exposed to danger in situations where the measuring equipment is connected to 120 % of the rated system voltage or to 120 % of its rated maximum voltage.
- Portable measuring equipment should be provided with permanently attached leads or with a plug device with live parts not accessible, whether plugged or unplugged.

Multimeters

These do not figure prominently in inspection and testing, other than they could be used for fault finding or measuring voltages and currents.

Checking of test instruments

The Electricity at Work Regulations 1989 requires electrical test equipment for use by electrically competent people to be as follows:

Equipment should be, so far as reasonably practicable:

- constructed;
- maintained; AND
- used in a way to prevent danger.

The various test instruments should be checked for their accuracy and checked that the way and used appropriate.

The accuracy of as test instrument is judged in two ways:

- regular checks of the accuracy of the test instruments using resistors etc.
- regular (at least annual) calibration of the test instrument.

Instrument	Checks
Low resistance ohmmeter	Have a range of low value resistors or a check box with known values. These can be measured on a monthly basis and a record kept of the resistance value
Insulation resistance test instrument	Have a range of high value resistors or a check box with known values. These can be measured on a monthly basis and a record kept of the results.
Earth loop impedance test instrument.	Treat a socket outlet in your home or place of business as a check point. This will give you a constant value of impedance. Keep a record of the value.
RCD test instrument	Treat a socket outlet in your home or place of business as a check point. This will give you a constant value of time. Keep a record of the value.

Calibration

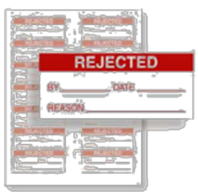
There are three main reasons for having instruments calibrated:

1. To ensure readings from an instrument are consistent with other measurements.
2. To determine the accuracy of the instrument readings.
3. To establish the reliability of the instrument i.e. that it can be trusted.

To make sure the reading taken is fairly accurate, all instruments should have an accuracy of at least 5%. To maintain this all instruments should be calibrated regularly, this would depend on the usage, but not exceed 12 months.

The instruments have to be calibrated in laboratory conditions, which mean sending the instrument to a specialist test laboratory. Once calibrated, the instrument will have a label attached to it stating the date and place of calibration, plus the date of the next calibration. A certificate will be issued detailing the tests carried out and a reference to instrument. These certificates should be retained.

Before using an instrument the information on the certificate should be checked.



Any instrument that is found to be faulty will have a rejection label and should not be used.

Other checks to be carried out:

- Batteries.
  - Is there any sign of corrosion?
  - When where they last changed?
- Outer casing
  - Is it cracked?
  - Is the screen clean?
  - Can you read the gauges?
- Leads
  - Are the clips or probes in good order?
  - Are they clean?
  - Is there any cracking or broken insulation?
  - Do they meet the requirements of GS 38?

GS 38 requirements

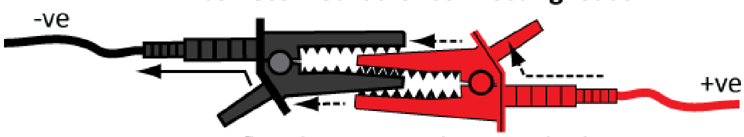
GS 38 states the equipment must have:

- Adequate insulation
- Have coloured leads to distinguish one lead from another.
- Have finger barriers to stop accidental slipping of hand.
- Be insulated so that the tip of the probe shows no more than 4 mm of bare metal; it is strongly recommended that this is kept to less than 2 mm.
- Be flexible and robust enough for their use.
- Be sheathed to prevent mechanical damage.
- Be long enough for their purpose.
- No part accessible to fingers, even if a lead becomes loose.
- Have fused leads

The person carrying out the tests should also be aware that the accuracy of any results will depend on the way in which a particular test instrument is used. You should check that:

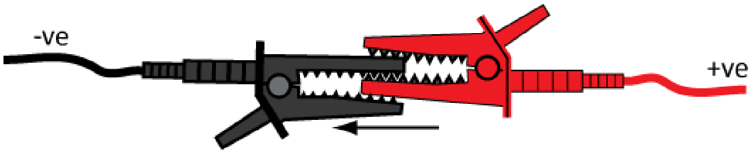
- you know how to 'null' or 'zero' , where necessary, the test instrument
- Where necessary the crocodile clips are connected the right way round.

Incorrect method of connecting leads



Current flow has to travel across the hinges

Correct method of connecting leads



Current flow is straight from clip to clip

Exercise 5

1. State the meaning of the terms;
   a) ADS
   b) Basic protection
   c) Fault protection

2. List the order of tests to be carried out on a new installation. Ignore the specialist tests.

3. Why are the test for a new installation done in the order stated in BS 7671 and GN3? Give an example of your reasoning.

4. State the test voltages to be applied and the minimum values of insulation resistance allowed, when carrying out an insulation resistance test on EACH of the followings circuits.
   a) A 25 V circuit supplied from an isolating transformer to BS EN 60742
   b) A 400 V motor circuit
   c) A 750 V discharge lighting circuit

5. State whether a good quality general purpose multimeter could be used for the following tests. Give reasons for or against using such an instrument.
   a) Continuity testing
   b) Insulation resistance testing
   c) Verification of voltage drop in accordance with Appendix 4 of BS 7671

6. State five requirements of GS 38.

6: Requirements for testing 1

In this session the student will:

- State why it is necessary to verify continuity to include
  - Protective bonding conductors
  - Circuit protective conductors
  - Ring final circuits
- State the methods for verifying continuity to include
  - Protective conductors
  - Ring final circuit conductors

We have looked at the information that is needed before we can start testing. In this session we will look at two test that need to be carried out, continuity and polarity.
The first one that has to be carried out is the continuity of conductors.

What does continuity mean?
'Staying the same, of being consistent throughout, or of not stopping or being interrupted'.
This is what we are testing for in the 'continuity test', to make sure the conductors are connected properly; there are no breaks or interruptions. There is no point in carrying out any of the other tests; in fact it would be dangerous to do so, until we have established the cables are correctly installed and connected.

Regulation 612.2.2 tells us that:
'A test shall be carried out to verify the continuity of each conductor, including the protective conductor, of every ring final circuit'.

Regulation 411.3.1.1 requires that;
'Installations which provide protection against electric shock using automatic disconnection of supply must have a circuit protective conductor run to and terminated at each point in the wiring and at each accessory.
An exception is made for a lamp holder having no exposed conductive parts and suspended from such a point.'

This means every protective conductor, including circuit protective conductors; the earthing conductor and the main and supplementary equipotential bonding conductors should be tested to verify that the conductors are electrically sound.
The test instrument used is a **Low resistance ohmmeter.**

Regulation 612.2.1states:
A continuity test shall be made. It is recommended that the test be carried out with a supply having a no-load voltage between 4 V and 24 V dc or ac, and a short-circuit current of not less than 200 mA
The test results should be recorded on the installation schedule and compared with design criteria.

Verifying continuity

Protective bonding conductors

It is necessary to verify these to ensure;

- They are present
- The connections are electrical and mechanically sound
- Where required the bonding is in place

Circuit protective conductors

It is necessary to verify these to ensure;

- The connections are electrical and mechanically sound, especially where steel containment systems have been used.
- Circuit cables that are SY, SWA, MI and rely on special terminations are sound.

Ring final circuit conductors

It is necessary to verify these to ensure;

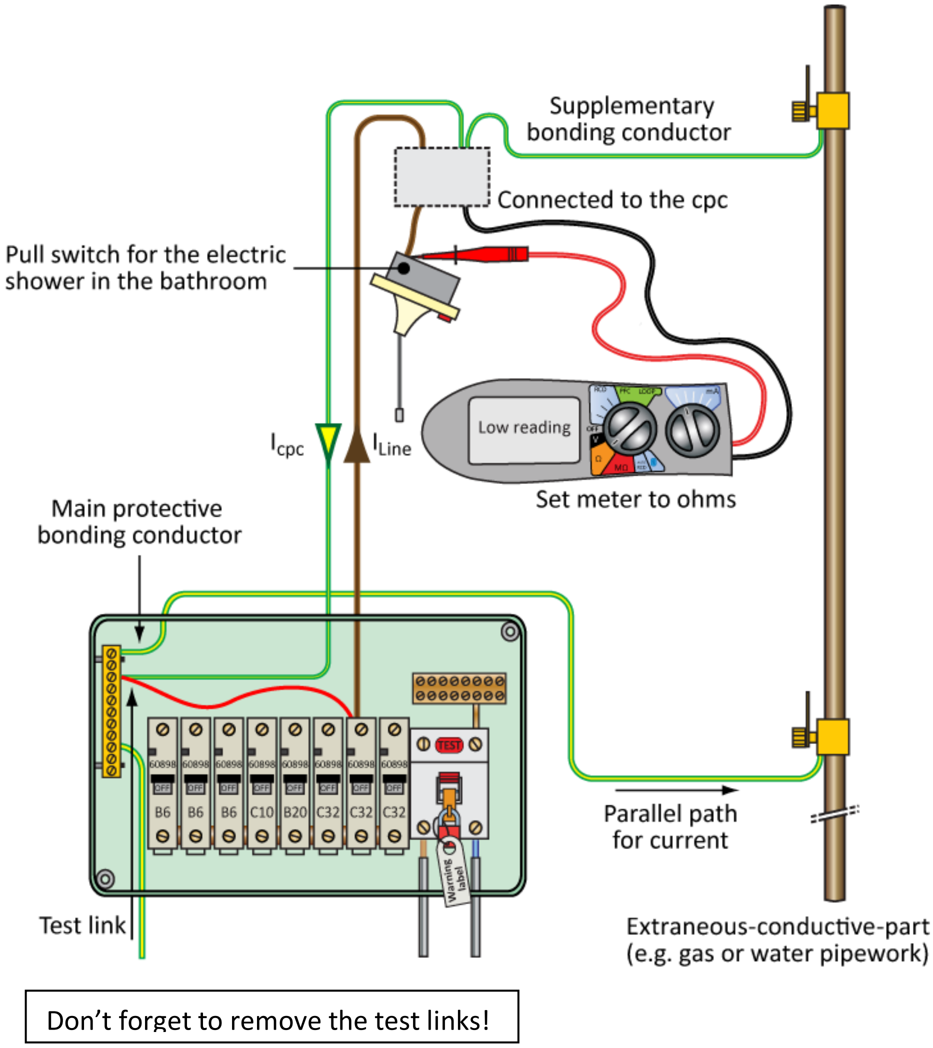
- That it is a complete ring
- It is not made up of spurs.

The problem of parallel paths

Before testing it is necessary to consider parallel paths.

The continuity test(s) test must be carried out prior to the connection of any supplementary bonding conductor or main bonding conductors.

If there are either supplementary protective bonding conductors or main protective bonding conductors connected then you may not be testing just the circuit protective conductor, you may also be testing a parallel combination of earthing and bonding conductors. The resistance readings of which will be very different if only the circuit protective conductor was being considered.



Notice the potential parallel earth paths.

These may occur where there is a connection, between one part of the circuit, such as might exist in the bathroom, and the pipework and a second connection, usually made at the consumer unit.

Before testing

Prior to the testing of continuity in either radial circuits or ring final circuits, you must check three things:

- That the instrument has batteries that are adequate for the task. They must be replaced regularly to maintain the current we require.
- The connecting leads and the instrument must be 'zeroed'. This is a process in which the instruments needle is set at a known start point so that any results are accurate.
- A current calibration certificate or a current record of the accuracy of the test instrument.

As well as checking the continuity of the continuity of the protective conductor, the meter will measure $R_1 + R_2$ which when corrected for temperature and added to the value of Z_e will help verify the earth loop impedance Z_s.

Testing the continuity of protective conductors

There are two methods for testing the continuity of protective conductors. These are called 'Method 1' and 'Method 2'.

Generally, Method 1 uses the circuit cable shorted out and Method 2 uses a supplementary length of test cable and is commonly known as the 'wandering lead method'.

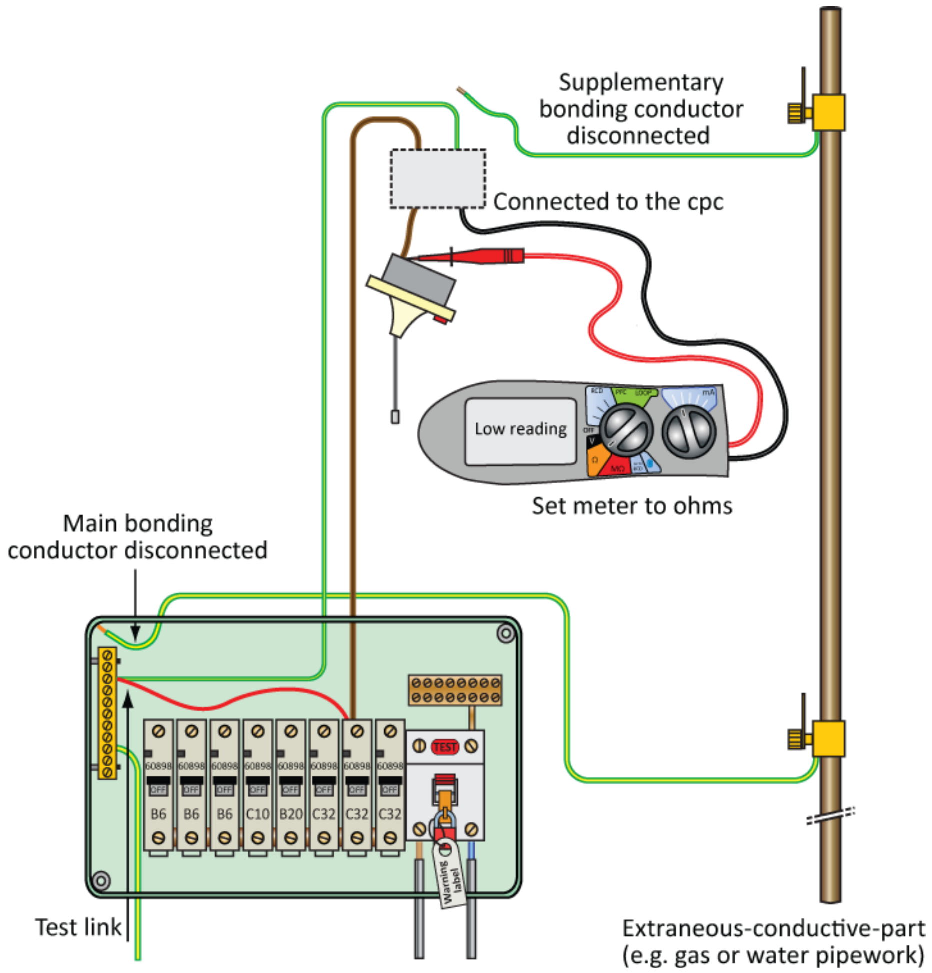
Care should be taken when testing any protective conductors, such as the Earthing conductor or main and supplementary bonding conductors in an installation that is live. The installation relies on these conductors for the safety of the installation. The loss of the Earthing conductor, for example, whilst testing might lead to a situation where a fault exists but does not clear sufficiently quickly. Such a situation would be hazardous both for the inspector and the users of the installation.

Because of these concerns the inspector should only test the continuity of protective conductors after undertaking a suitable assessment of risk to satisfy him/her self that it is safe to do so.

Method 1

Now for the test itself.

- As this is a 'DEAD' test. Where necessary, prove that the installation or circuit is dead first.
- Connect the line conductor to the protective conductor at the distribution switchboard. This can be done with a link, a connector block, or by connecting the circuit protective conductors with the line conductor in the top of the fuse holder.
- Test between the line and circuit protective conductor at the remote appliance. This records the combined value of the line conductor and the circuit protective conductor - $R_1 + R_2$
- The measurement of $R_1 + R_2$ should be recorded in Ohms (Ω). You don't need to test **EVERY** point, just the furthest points. If the results are acceptable at the farthest points then they must be acceptable everywhere on that circuit.



The resistance data for copper conductors can be found in Appendix B of BS 7671 and the expected values can be approximated and compared with the test values.

If Method 1 is used, the resistance value of the circuit protective conductor is combined with the resistance value of the line conductor. In most circumstances, as long as this is what has been recorded, then everything is acceptable.
However, there may be an instance where you are requires to know what the actual resistance of the line conductor or the resistance of the circuit protective conductor is. This might be necessary where we want to assess the voltage drop.

If there is a need, however remote, to determine the resistance of the circuit protective conductor as a value on its own then:

$$R_2 = R_R \times \frac{A_1}{A_1 + A_2}$$

Where:
R_2 is the resistance of the circuit protective conductor
R_R is the measured resistance reading of the circuit
A_1 is the cross-sectional area of the line conductor
A_2 is the cross-sectional area of the circuit protective conductor

Look at the example below.

1) The continuity of a lighting circuit protective conductor (cpc) is tested using Method 1 and shows a reading of 0.2 Ω. If the line conductor has a cross-sectional area (csa) of 1.5 mm^2 and the cpc has a csa of 1.0 mm^2 what will be the value of resistance of the cpc?

$$R_2 = R_R \times \frac{A_1}{A_1 + A_2} = 0.2 \times \frac{1.5}{1.5 \times 1.0} = 0.2 \times 0.6 = 0.12\Omega$$

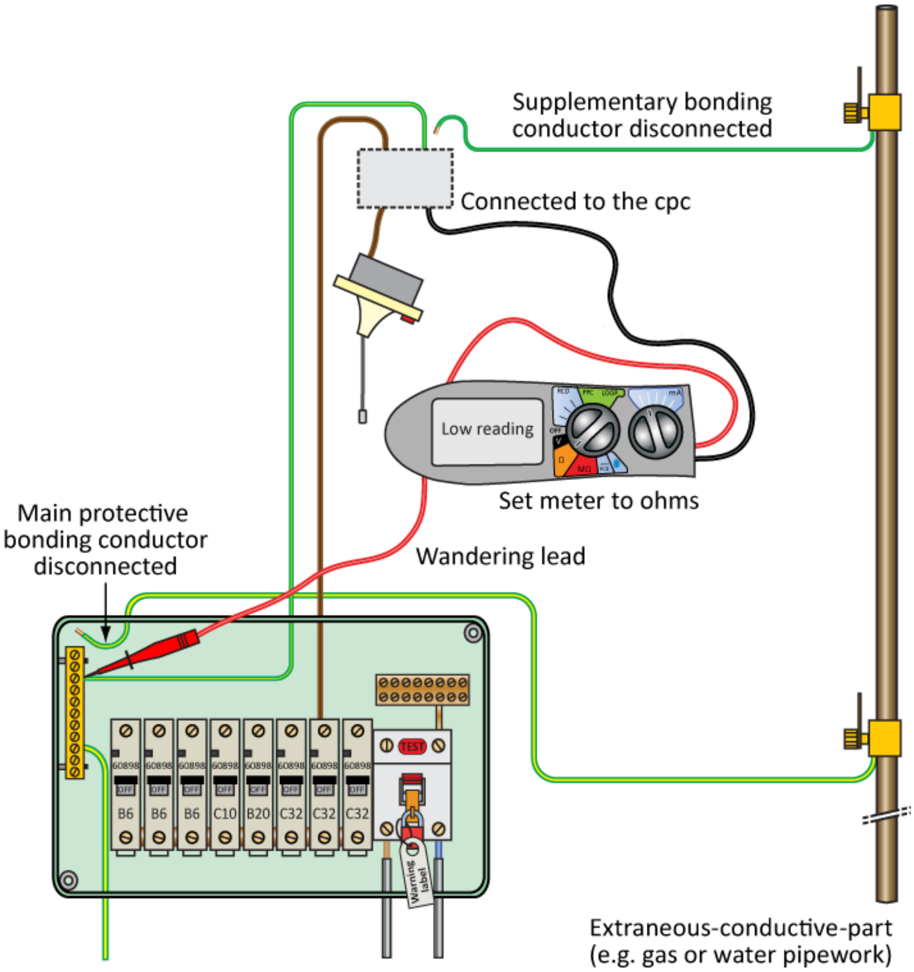
Notice that the share of the resistance of the circuit protective conductor is greater than that of the line conductor. This is as it should be: after all, the line conductor has a greater csa and so it must have a lower resistance value.
This particular test is particularly useful when you don't want to be wandering about with a trailing test lead. It also allows one person to do the test without having to rely on a second pair of hands.

When verifying this test you should be looking for a reading somewhere between 0.8 and 1.2 ohms. If the circuit has several outlets a slightly higher measurement might by recorded because of the resistance in the screw terminals.

Method 2

After checking, where possible and where safe to do so, that there are no parallel paths:

- Zero or null the leads prior to the test, or measure the resistance and subtract from the readings.
- Connect one lead of the low resistance ohmmeter to the conductor at the consumer unit or distribution board.
- Connect the other lead (wandering lead) of the low resistance ohmmeter to the other end of the conductor under test and record the results.



This method of testing only measures the resistance of a single conductor, such as the circuit protective conductor of a circuit or a bonding conductor.

Testing of all the bonding and earthing conductors should be done using Method 2 and the value should be lower than 0.05 Ω.

However, where doubt exists about the effectiveness of supplementary bonding, the resistance between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts shall fulfil the following conditions;

for a.c. systems: $R \le \frac{50}{I_a}$ and for d.c. systems: $R \le \frac{120}{I_a}$

Where:

I_a is the operating current in amperes of the protective device. For RCDs replace I_a with $I_{\Delta n}$.

Any continuity test, whether a.c. or d.c., must be carried out, not only on circuit protective conductors but also on bonding conductors and on earthing conductors. There are no short cuts, and you must test every circuit.

Verifying the results

As a reminder, if you are going to test a circuit that is connected to a distribution board, which is supplying a number of other circuits that are still turned on, you, should avoid carrying out this test.

If a fault occurs on any of the other circuits, then an earth fault current would flow and a potential difference would appear across the circuit that you are testing. If you are not permitted to isolate the supply then it would be better to stick to an earth fault loop impedance test.

A further thing we have to consider when looking at continuity tests is, “What is an acceptable value?” Remember that Regulation 612.1 requires that we compare our results with ‘***relevant criteria***’.

Guidance note 3 Table 1B gives us a series of values of resistance per meter set at 20 ^{0}C for differing sizes of cpc. These values must be compared with your readings and then you must decide if they are reasonable.

What sort of reading should we expect from our test instruments? It is unacceptable to simply record a result, we must judge whether that result is reasonable.

Let us consider this with the aid of an example.

2) A radial circuit wired in 4.0/2.5 mm^2 thermoplastic insulated and sheathed twin and earth cable has a length of 36 m and is protected by a 32 A Type B *BS EN 60898* circuit-breaker. What should the approximate measured reading of the circuit be?

There are two possible ways in which we can approach this problem. We can use the data from GN3, GN1 or the On-Site Guide for resistance and we get:

1. Resistance per metre is: $R_1 + R_2 = 12.02\,m\Omega/\text{m}$ @ 20°C

   Total resistance is calculated using $R_1 + R_2 = \dfrac{m\Omega/\text{m} \times \text{l}}{1000}$

   Total resistance at 20°C is $R_1 + R_2 = \dfrac{12.02 \times 36}{1000} = 0.43\Omega$

2. Alternatively, we can use the data found in Appendix 4 of *BS 7671*, where the voltage drop is given in terms of mV/A/m which is the same as the resistance per metre.

Care should be taken with this next method as the quoted figures of mV/A/m are for the combined line and neutral conductors.
The figures found in the tables therefore want halving to get to the data we require. Consider Table 4D5A for our thermoplastic cable and a voltage drop per ampere per metre for 4.0 mm^2 of 11 mV/A/m and for 2.5 mm^2 of 18 mV/A/m.

Add the two values of mV/A/m together: $R_1 + R_2 = \dfrac{11 \times 18}{2} = 14.5\,mV/A/m$

This figure had to be halved as the quoted figures are for a two-core cable. This combined figure is stated at the operating temperature of the cable, which in this case is 70°C. To get a more accurate figure we would have to derate by a factor of 1.2 to align the values at 20°C, or recognise that no correction factor up to 70°C would be applied as it so often is when considering earth fault loop impedance. In this case therefore:

Resistance at 70°C would be: $R_1 + R_2 = \dfrac{mV/A/m}{1000} \times \dfrac{14.5 \times 36}{1000} = 0.522\Omega$

If we wanted to check that figure align we simply divide the value of 0.522 Ω by 1.2 and we get 0.43 Ω, which is very close to our original value using data from the On-Site Guide.

We can see that a reading either under or over this value would point to one of a number of possibilities:

i) temperature is greater or smaller than 20 °C
ii) parallel paths exist
iii) there is a loose connection.

When the 14th Edition of the IEE Wiring Regulations was in force, there used to be set figures for both copper (0.5 Ω) and steel (1 Ω) conductors. Today there isn't! There are maximum figures given for differing circumstances (Tables 41.2, 41.3 and 41.4), but what we need to guarantee is what value of fault current will operate the protective device, and will my cpc deliver this fault current in the required time?

I know that you are going to get a more accurate value when you carry out the earth loop impedance test, but to carry out that test you need to turn the circuit on. This means that it must be safe before it is powered up, not after you have had a '***fiddle***' with it after it has been turned on.

Think this through carefully with me.

- In differing circumstances protective devices (fuses etc.) must operate within set times. (The maximum disconnection times may be found in Table 41.1 with common values of 0.2 s, 0.4 s and 5 s. These times reflect the level of shock risk associated with a particular circuit)
- It will require a higher fault current to make a protective device operate in 0.2 s as opposed to 5 s
- A cpc must be capable of withstanding the rise in temperature, due to the fault current for the set time.
- Current increase=Temperature increase. However, the increase in temperature is limited by a faster disconnection time and therefore it is likely that cables will overheat when there is a slow disconnection time and a low value of fault current.
- Will the resistance reading of the continuity test enable a reasonable judgement to be made in accordance with BS 7671, about the time it takes to clear the fault? Can it be guaranteed that the cpc will not open-circuit before the protective device operates?

If this last question can be answered with a **YES**, then the results will be acceptable.

The final thing to consider with continuity testing is, "What happens if the test is unsatisfactory?" Firstly, we have to ask ourselves, "What type of fault could it be?"

Unsatisfactory test results

The final thing to consider with continuity testing is, “What happens if the test is unsatisfactory?” Firstly, we have to ask ourselves, “What type of fault could it be?”

1) **Open circuit on a cpc**
   - i) A cable could have been cut by another person
   - ii) A nail could have split the cpc
   - iii) The connections are not tightened up adequately and the cpc could have worked free.

2) **‘Borrowed’ cpc**

   This could happen if the electrician has used a cpc from another circuit to provide an ‘earth’ for a circuit. This is not acceptable! The csa of the cpc may not have been designed for that circuit and therefore may not be capable of withstanding the heat generated within it during fault conditions.

3) **‘Borrowed’ neutral**

   This is an all too common fault when electricians take a neutral from one circuit to give to another circuit. As you are no doubt aware, this goes against Regulation 314.4!

It is not the role of the inspector to carry out remedial work. It is the role of the inspector to determine whether the installation is safe for continued use. He/she should report on what exists not on what might exist unless it is very clear what the problem is. Fault finding is not part of the role of the inspector.

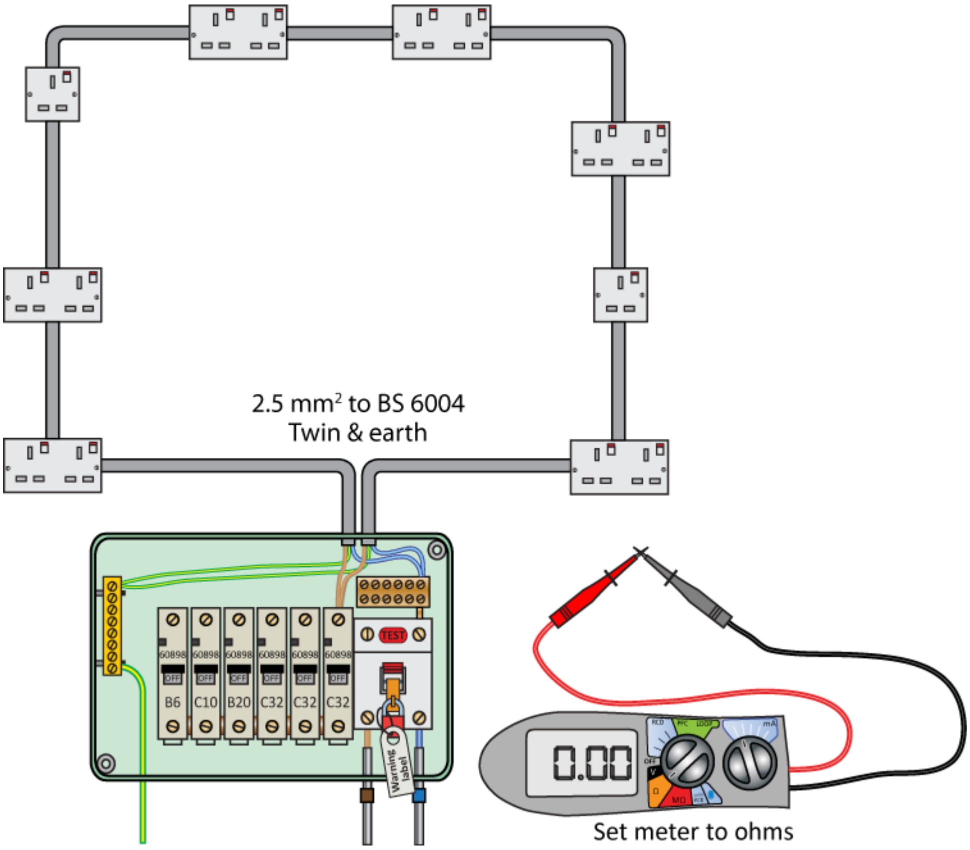
Ring final circuit testing

The instrument to be used for this test is a low-resistance ohmmeter.

You must 'zero' the low-resistance ohmmeter in exactly the same way as you would for the continuity test, or any other test that you may need to carry out using an ohmmeter.

This test is required to verify the continuity of each conductor, including the cpc in every ring final circuit. It is also to ensure that no multiple loops appear in the ring circuit.

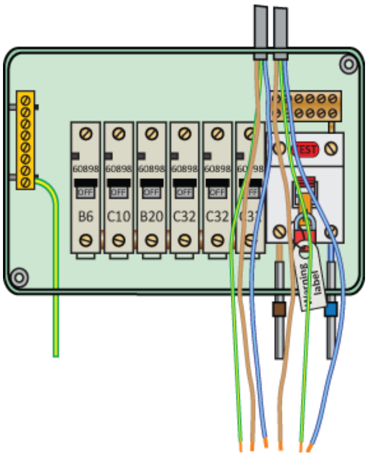
As with the continuity test, there is no explanation of how the test should be carried out. All we have to make sure is that the test meets the requirement of BS 7671.



Here we see a typical ring final circuit containing no spurs.

The above consumer unit shows the typical arrangement of the connections of the line, neutral and circuit protective conductors.

A true ring final circuit has two line, two neutral, and two circuit protective conductors. As you start this test, disconnect the line, neutral and cpc conductors from their respective terminals, and open them all out as per the diagram below.



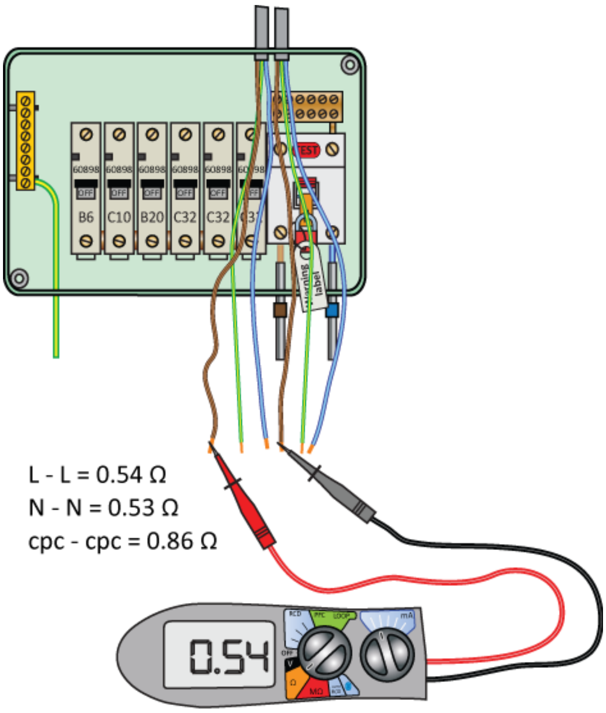
You should now have six conductors. This test **must** have the board isolated to carry it out safely, as with the continuity of the protective conductor test.

Remember to follow the process below very carefully.

- Isolate and prove that the circuit is dead
- Connect the low resistance ohmmeter to the end of each line conductor and record the result

Repeat the above step for both the neutral conductors and the protective conductors.

The measured reading of the line and neutral conductors should be similar. Where the circuit protective conductor has a smaller cross-sectional area this value will be slightly higher. About 1.67 times the line conductor values.



The result of this process will provide us with an accurate measure of the continuity of the ring final circuit.

To gain the value of continuity that we need to record, we must add together the line and protective conductor values and quarter the results.

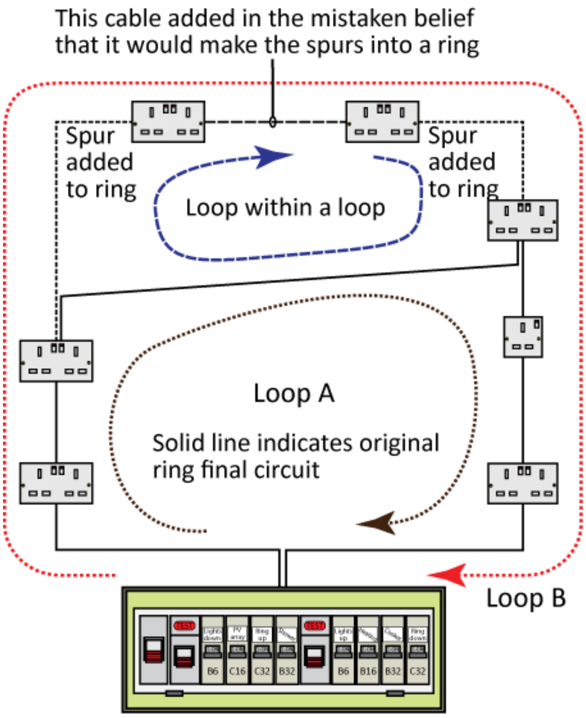
$$R_1 + R_2 = \frac{R_1\text{(end to end measured)} + R_2\text{(end to end measured)}}{4}$$

The readings are quartered because you have halved the length and doubled the cross-sectional area.

Think about the expression $R = \frac{\rho l}{a}$, if the length is halved and the csa doubled, this becomes;

$R = \frac{l}{2} \times \frac{1}{2 \times a} = \frac{l}{4 \times a}$ the resistance is quartered.

Now move onto the next stage of the test.

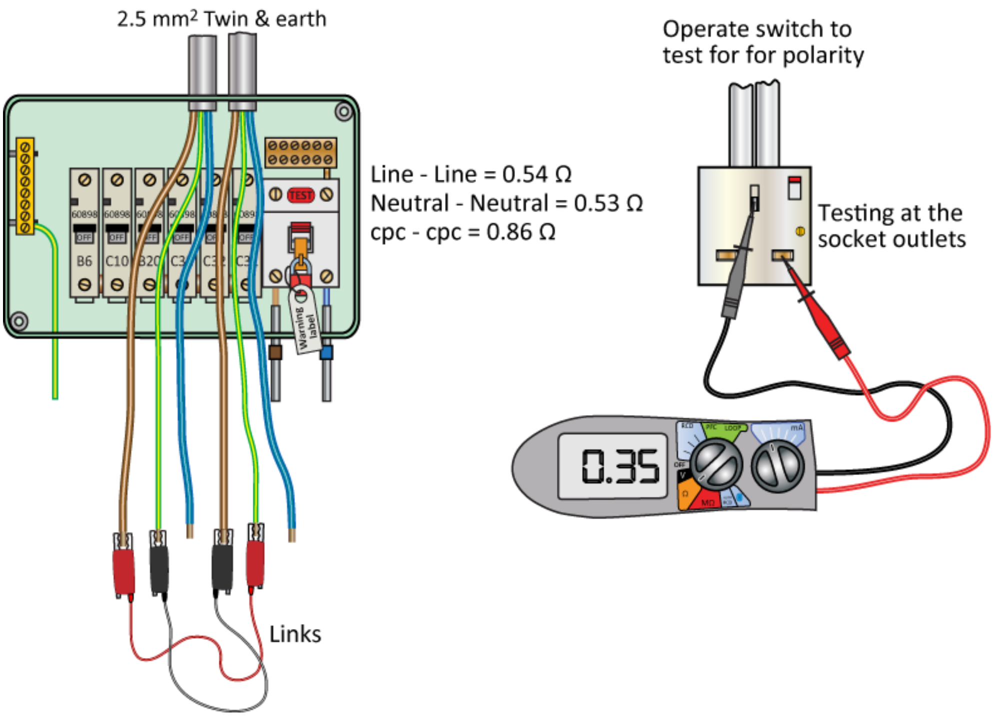


This stage requires you to check that a true ring circuit exists at all parts of the circuit and that there are no multiple loops in the circuit.

A multiple loop is where you have a loop within a loop making in effect a figure of eight. This can occur where people have added sockets on to a ring final circuit at a later date.

You should now:

- interconnect (short) the line and circuit protective conductors together at the consumer unit/distribution board.

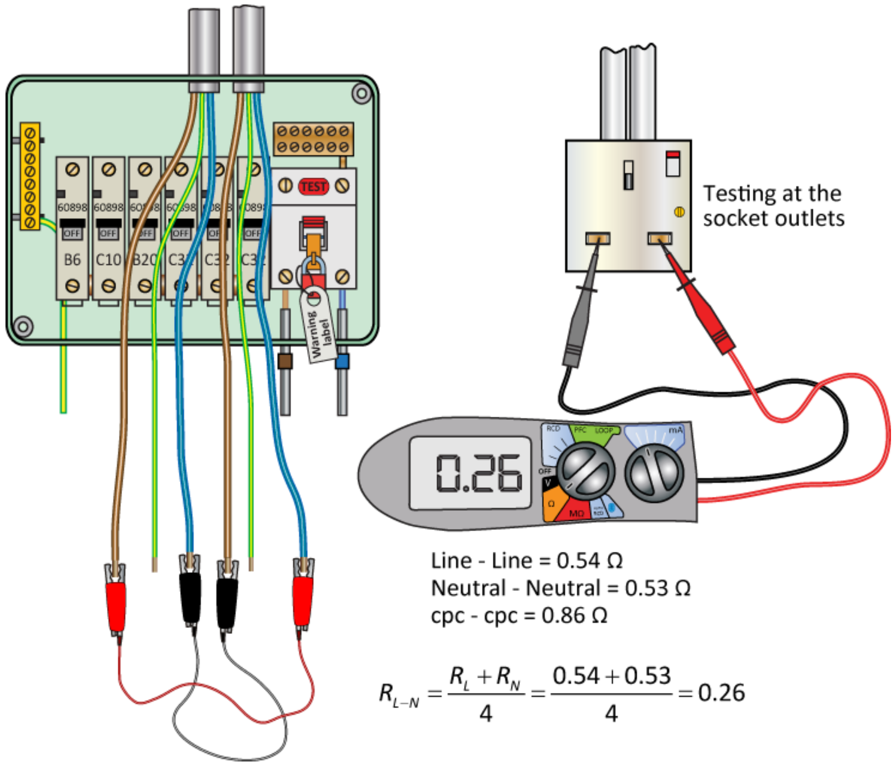


- test the resistance between line and circuit protective conductors at each socket-outlet. (The best way to test at the socket-outlet, particularly where the socket-outlets have shutters that are difficult to access, is to use a proprietary plug top that allows the leads to safely connect to the socket-outlet without having to take the front cover off.

The readings should be substantially (within 0.05 Ω) the same at each socket-outlet, and be approximately the same as your quartered initial test result.
This process will confirm that no multiple loops or breaks in the ring circuit exist. A multiple would show a series of varying readings at each socket-outlet.

Continuity of line and neutral

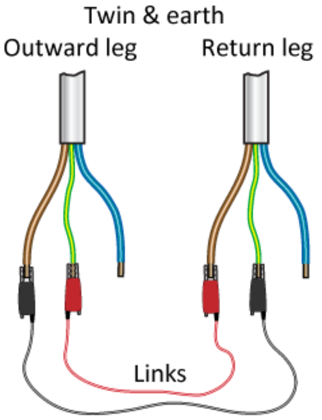
It is also necessary to verify the continuity of the neutral conductor as well. The process is very similar to that used for testing the continuity of the line and cpc conductors, only this time the line and neutral conductors are used.
Having tested between the line and cpc, the process is repeated for the neutral and line. This process will be a check on the polarity of the circuit.



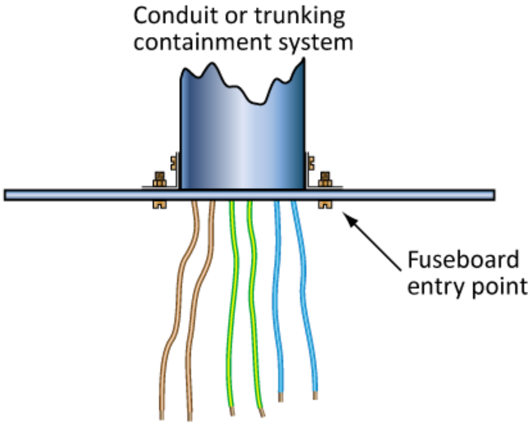
Notice the link, and the conductors that you are testing. The reason for choosing the line and neutral is that we have to determine that we have continuity on the neutral, but we also want to check the polarity. Some socket-outlets are double-pole devices, and as such, we need to check the switching of the neutral as well as the line conductor.
You have now performed two sets of tests on the ring circuit. Both line to earth and line to neutral connections have been checked with each socket-outlet being checked as well.

Ring circuits in conduit or trunking systems

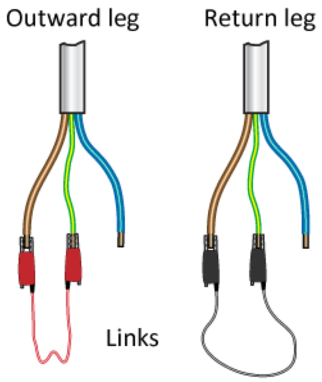
The other possible reason for a change in readings is usually based on ring final circuits in conduit or trunking systems. In such systems, it can be difficult to know which are the related legs of the ring; who's to know which is the outward leg or the inward leg? In these situations if the line conductor of the outward leg is connected to the cpc of the outward leg and the same occurs with the return leg, then when you test at the socket-outlets, the results will increase as you move away from the distribution board. To rectify this, just change over the connections at the distribution board.



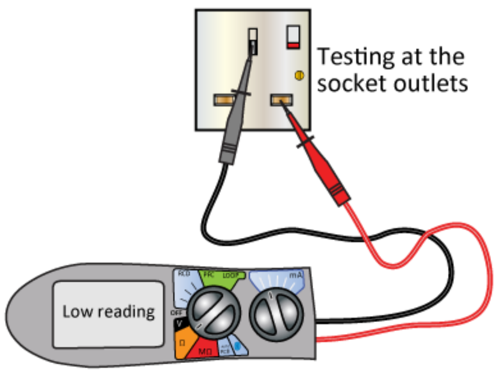
This arrangement would give **correct** readings when testing at the sockets



Which are the outward legs, and which are the return legs of the ring?



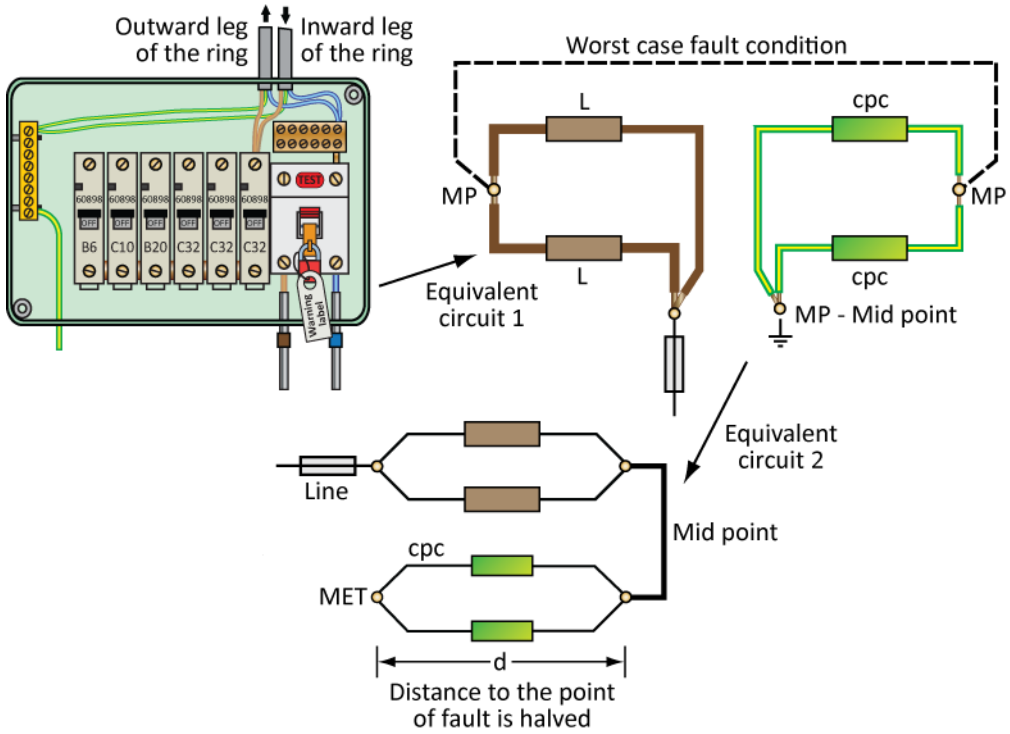
This arrangement would give **incorrect** readings when testing at the sockets



Set meter to ohms

Minimum fault current

The worst-case fault current (the lowest value for operating the protective device) will occur at the mid-point of the ring final circuit. What we now have is a type of series/parallel circuit. This means that we have halved the length of the conductors to the point of the fault, but because the conductors both start and finish at the same point, we have also doubled their cross sectional area.



When the length of a conductor decreases then so does the resistance (resistivity). Similarly, when the cross-sectional area increases then the resistance will also decrease. Therefore, we've decreased the resistance twice.

Consider an example.

1) A ring final circuit containing seven single socket-outlets has been tested and the following results have been obtained.

At the distribution board the end-to-end resistance values measured are:

Line – line Ω	Neutral – neutral Ω	Cpc to cpc Ω
0.8	0.8	1.28

The following results are measured at each of the socket-outlets:

Socket	Line-cpc Ω	Line-neutral Ω
A	0.52	0.4
B	0.48	No reading
C	0.55	0.44
D	No reading	0.38
E	0.78	0.5
F	0.53	0.43
G	0.53	0.39

The second table describes the readings that have been obtained for the two tests when the line and cpc and the line and neutral have been interconnected at the main board with each socket-outlet then being tested. The table shows the two sets of results that would be generated when the polarity and ring circuit check is being made.

To get an idea of what results we should expect at each socket-outlet we need to add together either the line to cpc or the line to neutral values and then divide them by four. Therefore:

Line to cpc

$$R_1 + R_2 = \frac{\text{measured test result}}{4} = \frac{0.8 + 1.28}{4} = \frac{2.08}{4} = 0.52\,\Omega$$

Line to neutral

$$R_1 + R_n = \frac{\text{measured test result}}{4} = \frac{0.8 + 0.8}{4} = \frac{1.6}{4} = 0.4\,\Omega$$

This means that at each socket-outlet measured values should be 0.05 Ω either side of 0.52 Ω when testing between line and cpc and, 0.05 Ω either side of 0.4 Ω when testing between line and neutral. Therefore, for line to cpc readings results between 0.47 Ω and 0.57 Ω are acceptable, whilst for line to neutral readings results between 0.35 Ω and 0.45 Ω are considered acceptable.

Socket	Line-cpc Ω	Line-neutral Ω	Comment
A	0.52	0.4	Good reading
B	0.48	No reading	Line to cpc probably swapped in socket outlet
C	0.55	0.44	Good reading
D	No reading	0.38	Line to neutral probably swapped in socket outlet
E	0.78	0.5	Possible loose connection or 'slack' socket pins. Can also be a spur
F	0.53	0.43	Good reading
G	0.53	0.39	Good reading

This can appear confusing. However, all I have done is consider the inter-linked conditions at the socket-outlets.

- Socket-outlet B. The line and cpc must be swapped over. When we get an acceptable reading between line and cpc it must be assumed that it is either the line or the cpc that is being switched. When the line to neutral test is being made at the socket-outlet shows that it must have been the cpc that was being switched

- Socket-outlet D. The line to neutral result shows that either the line or the neutral is being switched and it is the line to cpc interconnection that tells us that the neutral is the switched conductor

- Socket-outlet E. Is correctly connected but the readings are too high and out of the permitted tolerance range. This may be due to a variety of reasons, the most common being loose terminal connections or an old socket-outlet whose pins have become ‘slack’ due to use. It can also be however, that the socket-outlet is a spur.

Exercise 6

1. What type of test instrument should be used for testing continuity, and what properties must it have?

2. What two things must be checked before commencing a continuity test?

3. Which regulations cover both continuity tests?

4. Why should supplementary bonding conductors be removed from a distribution board prior to testing a cpc?

5. Which method of test would you use on a single main equipotential bonding conductor?

6. How should a continuity test be carried out on a length of steel trunking?

7. Describe how a ring circuit test is performed.

8. A ring circuit containing seven single socket-outlets has been tested and the following results have been obtained. At the distribution board on an open loop:

Line-cpc Ω	Line-neutral Ω
2.2	1.65

At each of the socket-outlets

Socket	Line-cpc Ω	Line-neutral Ω	Answers
A	0.52	0.42	
B	0.55	No reading	
C	No reading	0.44	
D	No reading	No reading	
E	0.5	0.38	
F	0.6	0.45	
G	0.65	0.48	

State whether all socket-outlets are functioning properly giving reasons for your decisions.

9. The following values are provided for a ring final circuit.

Cross-sectional area mm^2	Resistance/metre mΩ/m
1.5	12.10
2.5	7.41

If the total length of run of each conductor is 84 m determine the expected values of resistance between line and cpc, and between line and neutral at each socket-outlet.

7: Requirements for testing 2

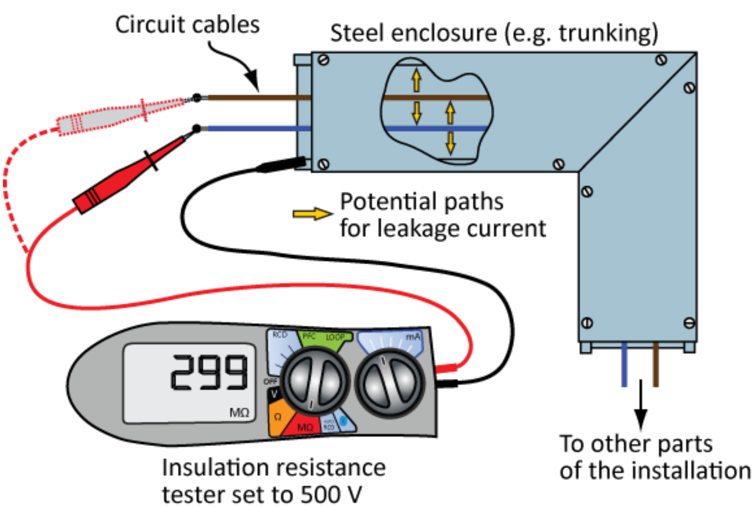
In this session the student will:

- Specify the procedures for completing insulation resistance testing
- State the effects of insulation resistance values that the following can have
  - Cables connected in parallel
  - Variations in cable length
- Explain why it is necessary to verify polarity
- State the procedures for verifying polarity.

In this session we will look at the last two dead test that need to be carried out, insulation resistance and polarity.

Insulation resistance testing

The insulation resistance test is the electrician's pressure test. Rather than look for leaks of water, we pressurise the system using a voltage and we see where the current leaks rather than where the water leaks out.



Precautions prior to insulation resistance testing

We are now going to consider the precautions to be taken prior to an insulation resistance test being carried out; the way in which the tests should be performed and what we should do with the results.

The insulation resistance test is a straightforward test to do, and is much less involved than many of the other tests. The insulation resistance test instrument needs to be checked that it functions correctly, it doesn't require 'zeroing' or 'nulling' in the same way as the continuity test instrument because the readings are so large in comparison to the test leads.

This test is used to verify that the insulation of conductors, accessories and equipment is acceptable (has a high resistance).

The testing engineer should not carry out this test whilst the mains electricity supply is still live. The consumer unit or distribution board must be isolated for the test to be carried out safely. Poor isolation may lead to a significant increase in shock risk.

Before testing can commence it is essential that:

- All pilot and indicator lamps are disconnected from circuits. For example, neon indicators have a resistance of 200 kΩ and will lead to inaccurate readings
- Disconnect capacitors and/or inductors as they will also give inaccurate readings
- Disconnect or switch off all loads that are connected, or you will be testing the winding of the loads not the insulation resistance
- All voltage sensitive devices, such as dimmer switches and electronic starters must be disconnected. If they are not disconnected, damage to sensitive components may occur
- There is no electrical connection between any live conductor and earth.
- The Earthing conductor must be connected. Simple installations, such as houses, that contain no distribution circuits need to be tested as a whole. The tests should be carried out with:
- The main switch **ON**
- **All** fuses in place
- **All** switches and circuit breakers closed
- **All** lamps removed and other equipment disconnected.

Where it is impracticable to remove lamps, such as fluorescent tubes, the local switches controlling the lamps may be opened. However, you should be aware that you then would not be testing the whole circuit.

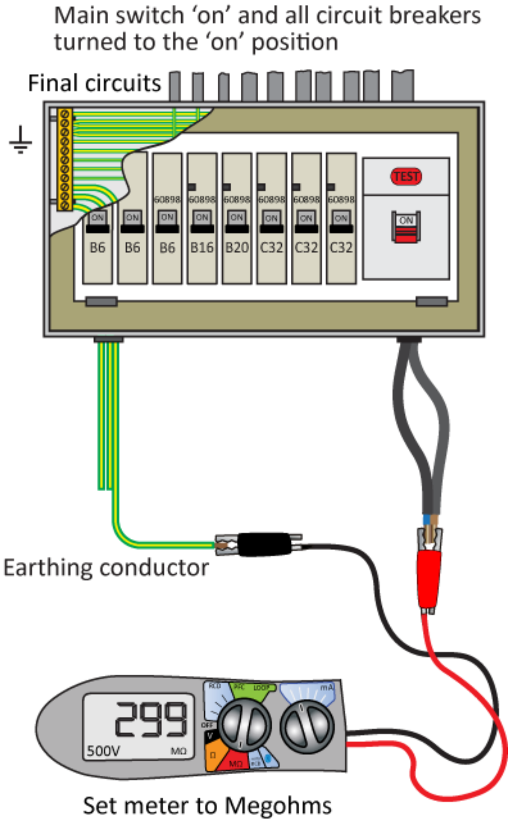
Single-phase IR testing

Now let's look at the process. Remember that all fuses are in and all switches are on. We can now test the mains tails before they are connected to the energy meter.

Insulation resistance live conductor to earth

This part of the test determines whether there is sufficient insulation resistance between live conductors to earth.

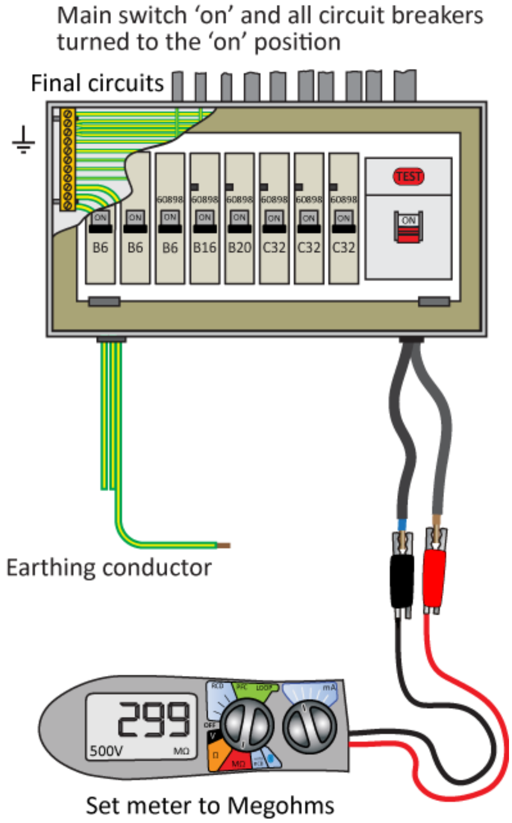
- Connect one lead to the line and neutral conductors
- Connect the other test lead to the earth conductor
- Take a reading and record your result.



Insulation resistance between live conductors

This part of the test determines whether there is sufficient insulation resistance between live conductors.

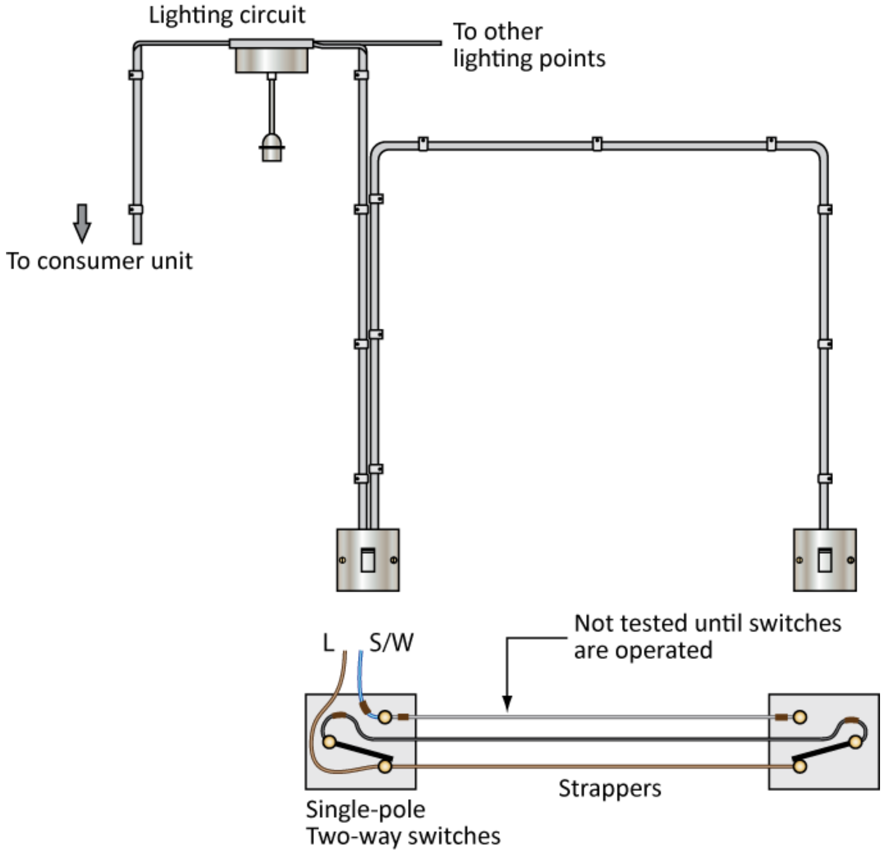
- Connect one test lead to the line conductor
- Connect the other test lead to the neutral conductor
- Take a reading and record your result.



If there are RCBO devices fitted the earth lead needs to be removed from the MET otherwise they can be destroyed by these tests.

In practice, it may be likely that you will have to test each of the live conductors to earth separately. However, for those circuits where you are unable to, or not permitted to, disconnect the electronic items of equipment, you must connect the live conductors together and test them as a combined value to earth. You must not test the separate live conductors to earth! This may require individual circuits to be tested in turn.

However, if you have any circuits that involve two-way or intermediate switching, such as lighting circuits, then, while the test is taking place, you should try the switches to see if any changes take place in the readings.



The reason for this is that we want to test all the conductors and if the switching arrangements involve strappers, then they are not always necessarily connected.
Notice that in a certain switch position, there is a conductor not being tested. This is what we are trying to eliminate.

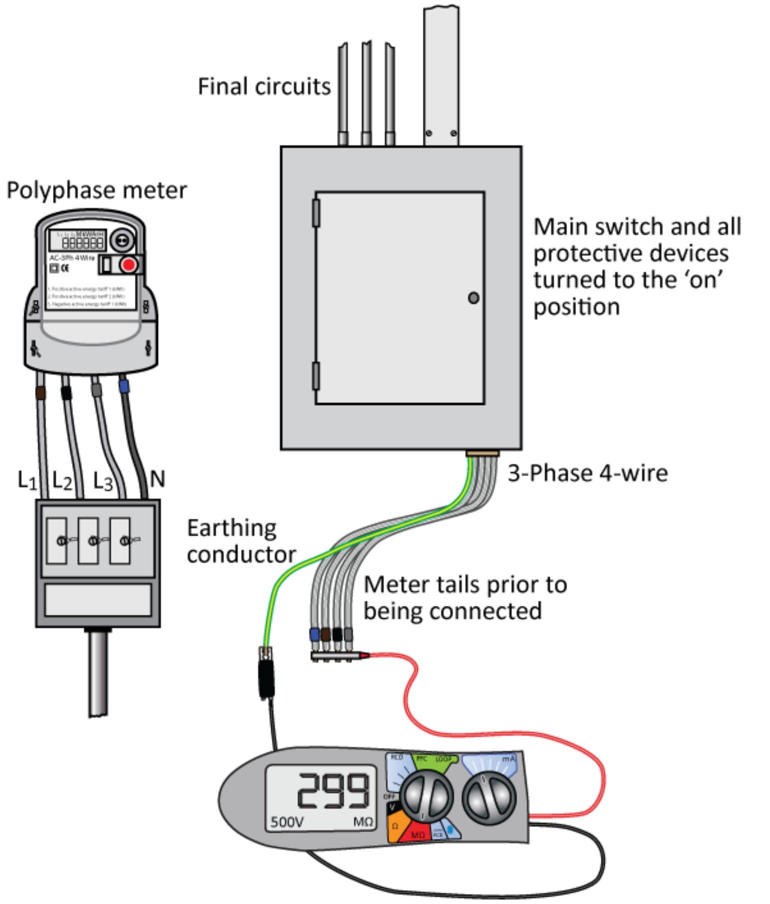
In large installations, it may be necessary to sub-divide the installation into its component parts. This is because as the length of run increases, then the insulation resistance value falls. This has nothing to do with how well the installation has been wired; it is just a feature of running long cables. When testing a large installation, we are allowed to split the installation into smaller parts for testing purposes.

Three-phase IR testing

The testing of three-phase systems is not very much more complicated than for a single-phase system.

Insulation resistance between live conductors and earth

- Connect one lead to the three-line conductors and the neutral conductor
- Connect the other test lead to the earth conductor
- Take a reading and record your result.



Insulation resistance between live conductors

The process is slightly more involved in that each live conductor must be checked against every other live conductor.

- Connect one lead to the line conductors and the other lead to the neutral and test.
- Connect one lead to two of the line conductors and the other test lead to the third line conductor. Test and record your result.
- Connect your test lead between the two remaining line conductors. Test and record.

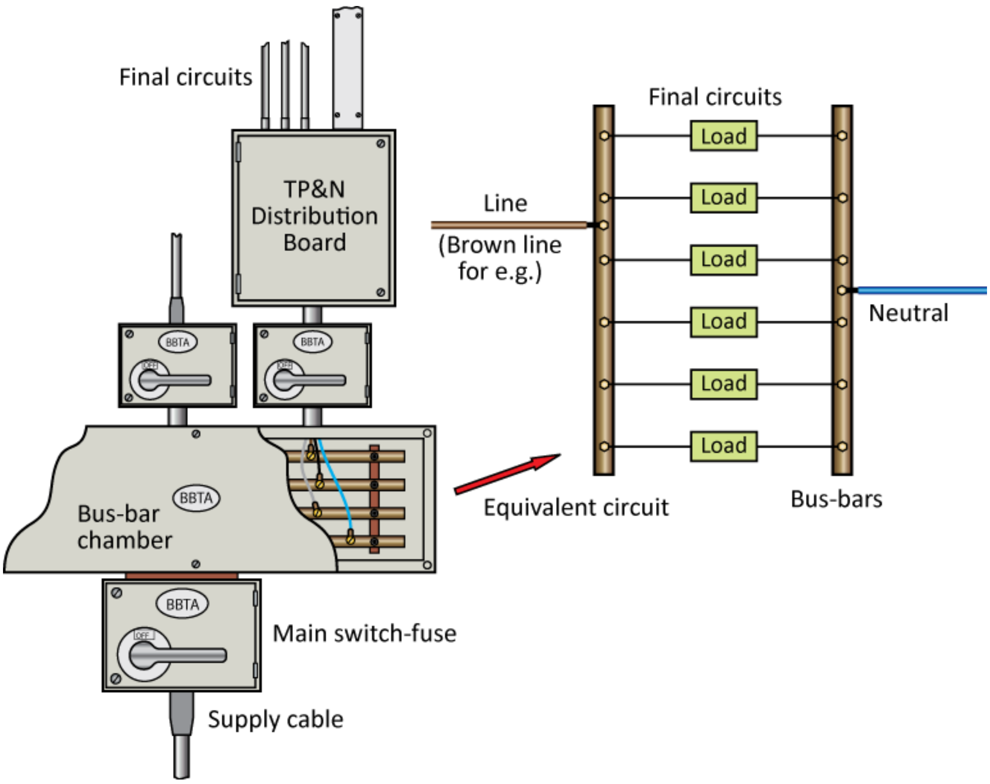
Effectively we need to carry out a total of ten (10) tests between the following:

L_1 - L_2	L_1 - L_3	L_1 - N	L_1 - E
L_2 - L_3	L_2 - N	L_2 - E	
L_3 - N	L_3 - E		
N - E			

It takes slightly longer but is still straightforward. Let's consider why we need to be concerned before we investigate what may be causing the problem.

Understanding of insulation resistance values

Insulation resistance tests give a value for the total installation. The results are a combination of all the individual resistance values of all the circuits. Now, these circuits are all connected in parallel with each other. That is, they all have the same start point and the same end.



As far as the total insulation resistance value is concerned, we have a series of parallel resistors.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \ldots + \frac{1}{R_n}$$

Now think about an example.

1) A six-way distribution board has six individual circuits. Four of them show a reading of 299 MΩ with the other two results being measured at 5 MΩ and 2.8 MΩ respectively. What would be the approximate total insulation resistance?

The key to this type of question is to recognise that the large values of insulation have very little effect on the overall result. This means that we can simply deal with the two smallest values. It is Regulation 612.3.2 that requires that more than individual circuits are measured and that the minimum value is for distribution circuits along with their associated final circuits.

- Determine each value and for two circuits in parallel use 'product over sum':

$$R_{T1} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{5 \times 2.8}{5 + 2.8} = 1.8M\Omega$$

You can see that two poor readings will lead to a significant reduction in the overall value of insulation resistance, and it is the overall value that we are concerned about! Consider another example.

2) An eight-way distribution board has just had an insulation resistance test carried out on each of the individual circuits. The readings obtained were:

Circuit	1	2	3	4	5	6	7	8
Reading MΩ	600	600	600	45	600	20	10	3

Again, in this example we will only consider the value that we would get when we only take into account those values that are less than 600 MΩ.

- Determine each value and invert the sub-total calculated:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{45} + \frac{1}{20} + \frac{1}{10} + \frac{1}{3}$$

$$\frac{1}{R_T} = 0.022 + 0.05 + 0.1 + 0.33 = 0.505$$

$$R_T = \frac{1}{0.505} = 1.98M\Omega$$

So, what can cause low readings?

Here is a list, although it is not a complete list of all the faults that can occur.

- Cable has been crushed or bent too tight.
- MI cable may have a faulty seal allowing in water.
- MI cable might be old and has deteriorated slightly.
- Conductors crushed by a screw.
- Too many cables in a box. When the lid is put on the cables can get crushed.
- Nail pierces a cable in a wall or under a floor or behind capping.

There are just six here, however there will be others.

It is also worth noting that low insulation resistance readings may occur where no fault exists. These might include:

- Damp or wet insulation
- Busbars and switchgear that have been stored in very damp or cold conditions
- Damp buildings
- Installations having high humidity where seals are not fitted correctly
- New plaster 'sweating' when the heating is first turned on

Again, this is not an exhaustive list but simply an indicator of possible issues.

Factors that affect conductor resistance values

Conductor resistance is effected by;

- Cables connected in parallel
- Variations in cable length
- Variation in conductor cross sectional area.

Cables connected in parallel

We have already mentioned the need to be aware of parallel paths affecting the readings. Parallel paths may be caused by steel conduit, steel trunking, MICC, SWA , any metal sheathed cables, equipment, accessory boxes fitted to metal stud walls, lights fitted to metal grid systems. They can occur in domestic, industrial or commercial installations.

The effect can be to make the measured value head towards 'zero'. It is not always possible to disconnect all the parallel paths.

The formula for calculating resistance in parallel is:

$$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}.......+\frac{1}{R_n}$$

Remember the more paths in parallel, the lower the overall resistance will be.

Variation on cable length.

Do not think that just because the conductors in the cable have the same length they automatically have the same resistance. This is an application of ***resistivity***.

If you remember from your studies with resistivity; if the length of the conductor doubles then the resistance doubles.

This comes from: $R=\frac{pl}{A}$

Where:

R is the resistance of the conductor

ρ (rho) is the specific resistance of the material that the conductor is made from

l is the length of the conductor

A is the csa of the conductor.

As cable length increases, insulation resistance decreases proportionally. Therefore, if the length of a circuit is doubled, the insulation resistance must half. If a number of circuits are tested together, in effect the quantity of cable being tested increases and therefore the insulation resistance decreases.

Whilst low insulation resistance values when testing may indicate a breakdown in insulation, the low reading also may be due to the fact that a large number of circuits are being tested at the same time or the circuits may be of a long length.

Variation in conductor cross sectional area.

The resistance is also dependant on the cross sectional areas (csa), the greater the csa the lower the resistance, and the smaller the csa the greater the resistance.

We can use the mnemonic MALT to help us remember the factors which affect resistance.

- **M** Material, what the conductor is made out of, i.e. copper or aluminium
- **A** Area, cross-sectional area of the conductor
- **L** Length, how long the conductor is
- **T** Temperature, all metals have a positive temperature coefficient, as they get hot their resistance increases. This has an effect under fault conditions.

The tables for correcting temperature are found in Table B2 of Guidance note 3

Protection by SELV, PELV and electrical separation

Where it is necessary for the following tests to be carried out, the same level of care should be used as you would use for more typical test processes.

Protection by SELV, PELV or electrical separation is dealt with in BS 7671 starting at Regulation 612.4. Regulation 612.4 details the primary requirements for each condition that may arise when considering separation of circuits. These are:

SELV in Regulation 612.4.1

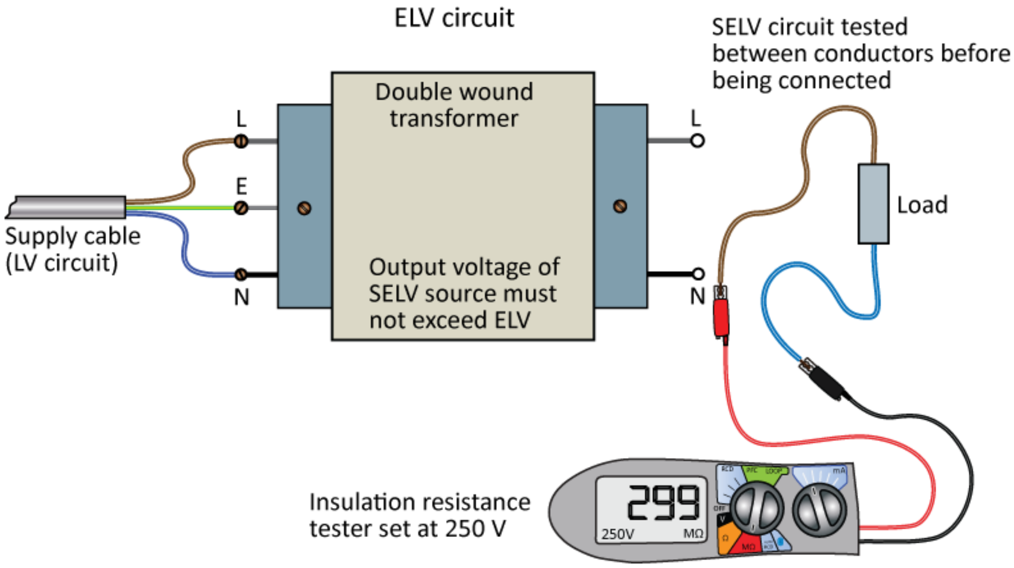
PELV in Regulation 612.4.2

Protection by electrical separation in Regulation 612.4.3.

SELV

A SELV (Separated Extra-Low Voltage) system can be obtained from four possible processes; the most common of these is via a double wound transformer that has a secondary voltage of no more than 50 V a.c. with no connection to earth on the secondary. This test is used to ensure that this distinction is guaranteed.

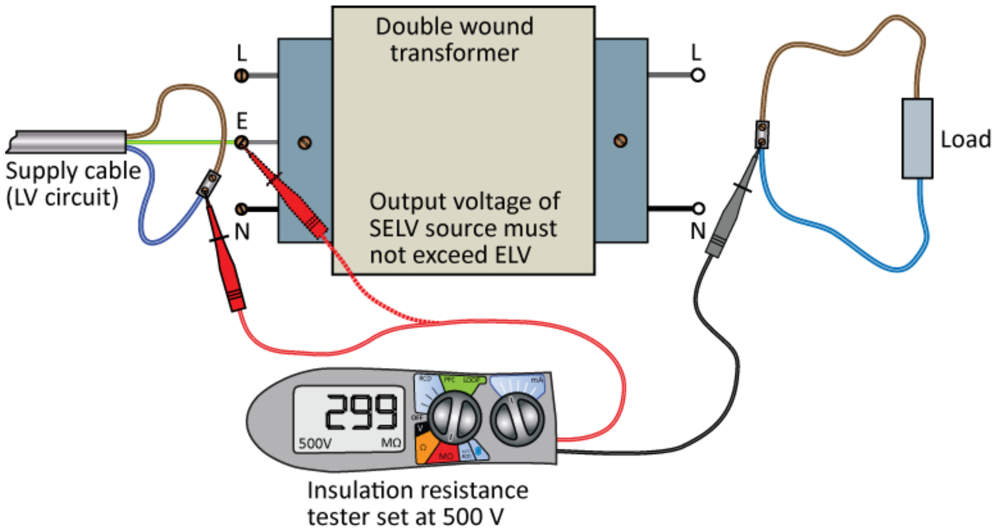
The first test takes place on the extra-low voltage side with the insulation resistance test instrument set at 250 V d.c.



The values obtained from the insulation resistance test will vary depending upon the level of extra low voltage.

The actual test voltages would normally be in accordance with Table 61 of *BS 7671*, although to demonstrate compliance with *BS 7671* an additional insulation resistance test should be applied at 500 V d.c. between the live conductors of the SELV circuit and those of other circuits and the protective conductor of the higher voltage circuit present.

The insulation resistance must not be less than 0.5 MΩ and in practice any reading less than 5 MΩ would want to be investigated in more detail.
The second test should take place between the low-voltage side and the extra-low voltage side of the supply. The insulation resistance test instrument voltage should be set at 500V d.c. and the insulation resistance value should be not less than 5 MΩ.



PELV

With a PELV system there is the same double wound transformer and voltage levels as for a SELV system. However there is a protective earth on the secondary side and the primary side. The tests should be carried out in the same way as for SELV circuits.

Functional Extra Low Voltage (FELV)

A functional extra low voltage circuit is neither a PELV or SELV circuit and the normal insulation resistance tests should be carried out. Take a look at Regulation 612.4.4.

Protection by separation of circuits

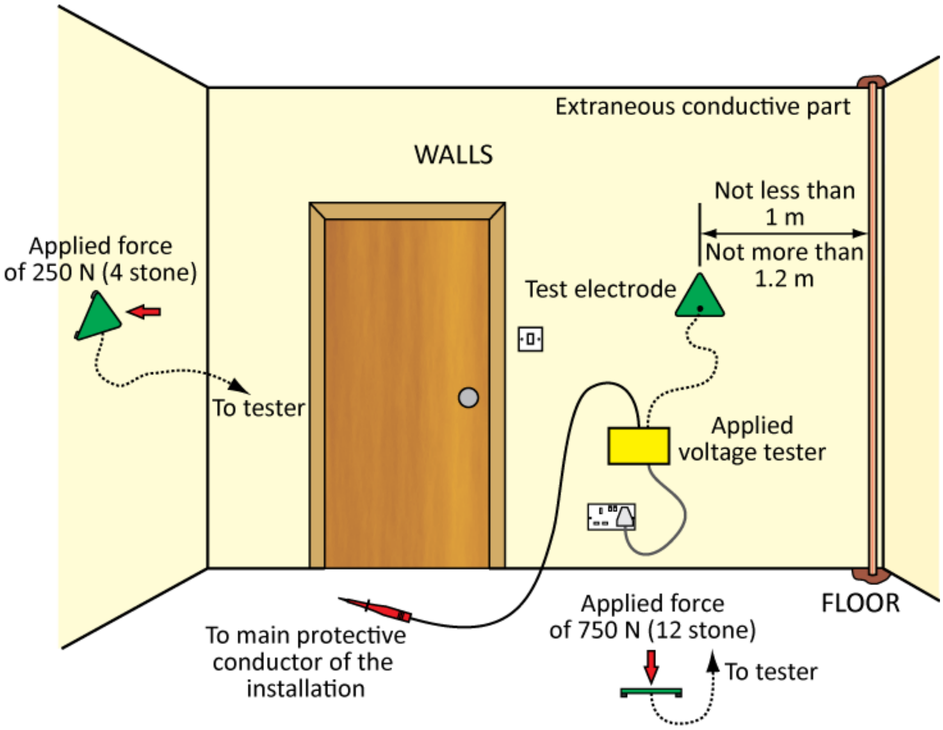
As with the SELV (see page 112) system so it is for Protection by Separation of Circuits, with one exception. With Protection by Separation of Circuits, there is the same double wound transformer and lack of earth, but this time the voltage levels can rise to 500 V a.c. on the secondary.
The test process is exactly the same as with a SELV circuit with one minor alteration: the voltage levels must be set at 500 V d.c.

Additionally, Regulation 612.4.3 requires that where there is electrical separation with more than one item of current-using equipment, it must be verified (by measurement or calculation) that where there are two coincidental faults with negligible impedance (short circuits) between line conductors and either the protective bonding conductor or exposed-conductive-parts connected to it, at least one of the faulty circuits shall be disconnected.

Non-conducting floors and walls

The application of Protection by non-conducting floors and walls is not looked on favourably. The technique is more common on the continent and may be applied in areas where there is an increased risk caused by a fault to earth.

The test that must be applied is listed in Appendix 13 of *BS 7671* and requires a test electrode to be placed on the floor with a weight of at least 750 N (approximately 75 kg) applied, or on a wall with a force of 250 N (25 kg). The second electrode has an area of 900 mm2 and is triangular. As with the first electrode, a force of 750 N is applied and the test carried out.



This test is usually carried out by those specialising in this type of work. In areas of increased risk it can be sensible to avoid the presence of any means of earthing.

Polarity

It is **not** acceptable to wait until you turn the power on and then run around with a socket-outlet tester to see if the installation is safe for the client to use. There have been cases where ‘even’ the distributor gets its polarity wrong! You are in effect, putting people and the installation at risk by trusting in the connections made: testing is necessary!

Regulation 612.6 states;

A test for polarity shall be made and it shall be verified that:

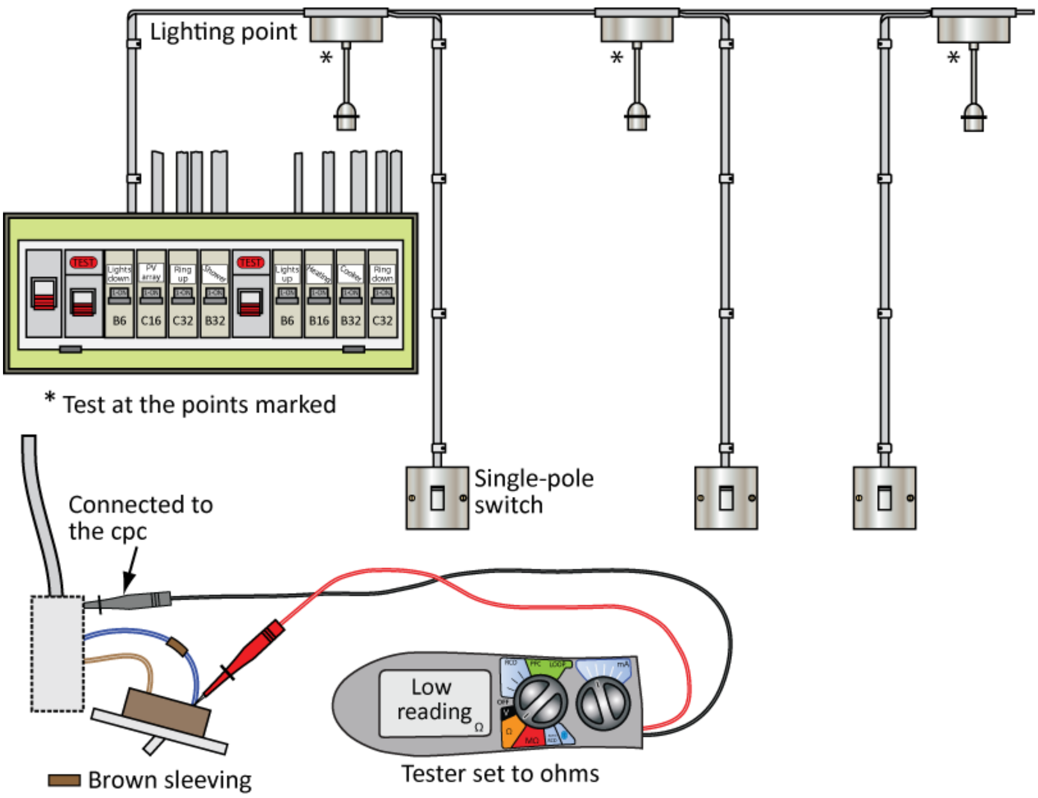
i) every fuse and single-pole control and protective device is connected in the line conductor only, and
ii) except for E14 and E27 lampholders to BS EN 60238, in circuits having an earthed neutral conductor, centre contact bayonet and Edison screw lampholders have the outer or screwed contacts connected to the neutral conductor, and
iii) wiring has been correctly connected

The test instrument to be used for the polarity test is a low resistance ohmmeter.

For radial circuits, including lighting circuits, the same test used when shorting out the line and cpc at the distribution board is a partial polarity test.

The only extra part is that you are required to test at each point where there is a load connected. This will include every light point, although not every switch. However, every switch must perform its function. Notice that you must test at all the light points or at the switch on the switch wire (all marked with an asterisk *).

No resistance reading is necessary; usually a tick in a box is adequate as a test result. You are after all, only confirming the correct operation of the circuit.



Results that show that any switching of the neutral takes place should lead you to further investigation.

It is necessary to check that all fuses and single pole control and protective devices are connected in the line conductor. The centre contact of screw type lampholders must be connected to the line conductor (except E14 and E27 to BS EN 60238).

Exercise 7

1. a) The resistance of a 50 m length of conductor is 0.2 Ω. What would be the resistance of 100 m of the same conductor?
   b) The insulation resistance of 1000 m of twin cable is 50 MΩ. What would be the insulation resistance of 2000 m of the same cable?
   c) The resistance of a length of 1.0 mm^2 conductor is 0.8 Ω. What would be the resistance of a 4.0 mm^2 conductor of the same length?

2. Before an insulation resistance test is carried out what should checked?

3. When doing an insulation resistance test what should be switched on or removed?

4. In terms of insulation resistance what occurs in the following events:
   a) An extra circuit is installed?
   b) A circuit is removed?
   c) A circuit is wired having its cable reduced in size from 4.0 mm^2 to 2.5 mm^2?
   d) A circuit is extended?
   e) A large installation is to be tested?

5. Why should the continuity test be carried out prior to the insulation resistance test?

6. In terms of insulation resistance what occurs in the following events:
   a) An extra circuit is installed?
   b) A circuit is removed?
   c) A circuit is wired having its cable reduced in size from 4.0 mm^2 to 2.5 mm^2?
   d) A circuit is extended?
   e) A large installation is to be tested?

7. What are you guaranteeing when carrying out a polarity test?

8. What instrument is used to carry out a polarity test?

9. Where would you carry out a polarity test?

10. What sort of results do you expect from a polarity test?

8: Live testing 1

In this session the student will:

- State the procedure for confirming polarity at the incoming supply
- Specify the methods for measuring earth electrode resistance to include;
  - Installations forming part of a TT system
  - Generators and transformers
- Describe common earth fault loop paths
- State the method of verifying protection by automatic disconnection of supply

Confirming polarity at the incoming supply

The polarity needs to be checked at the incoming supply because the distributor can sometimes get the neutral and line conductors the wrong way round.

This check is very simple and only requires a suitable voltage indicator such as the Martindale test lamp you use for proving dead.

Measure the line voltage to neutral and to earth, the result should be 230 V +10%, -6%. For a three-phase system you will need to measure each line to neutral and earth, and between phases.

Once completed, tick the confirmation of supply polarity box, on the schedule of test results form.

Earth electrode test

Metal pipes of the water mains used to be used as earth electrodes, but this cannot be relied on any more as plastic pipes are becoming more common.

Accepted earth rods are;

- Earth rods or pipes
- Earth tapes or wires
- Earth plates
- Underground structural metal work which is embedded in the foundations
- Lead sheaths or other metallic covering of cables
- Metal pipes

BS 7671 requires that earth electrode testing is carried out.
Regulation 612.7.
'Where the earthing system incorporates an earth electrode as part of the installation; the electrode resistance to Earth shall be measured'.

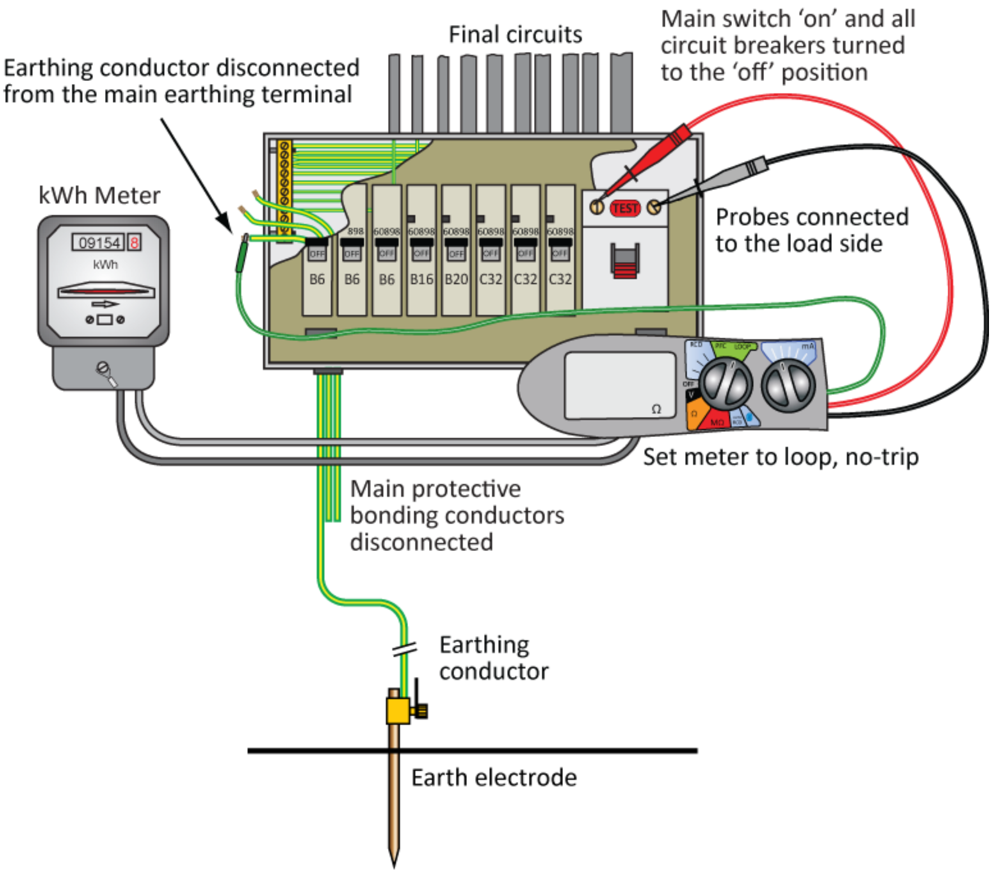
What we measure when testing the earth electrode is the resistance of the area that is affected by that electrode.
There are two possible ways of testing for this:

- using an earth loop impedance test instrument (this is carried out live and is therefore a more dangerous test)
- using an earth electrode tester.

Using an earth loop impedance test instrument

If the installation is part of a TT system and has an RCD protecting it, then an earth loop impedance test instrument can be used.
The tester should be connected to the live conductors at the source of the installation and the earthing conductor. The resistance of the Earth conductor is very small compared to that of the Earth, and therefore the resistance of the general mass of Earth and the Earthing conductor can be assumed to be the earth electrode resistance value.
If this method is used, it is essential that all supplementary and main equipotential bonding conductors be disconnected so that parallel paths are not measured. If you do not remove the extra parallel paths you will get an unrealistically low value of resistance.

While you are carrying out this test you must be aware of the increased risk to others.

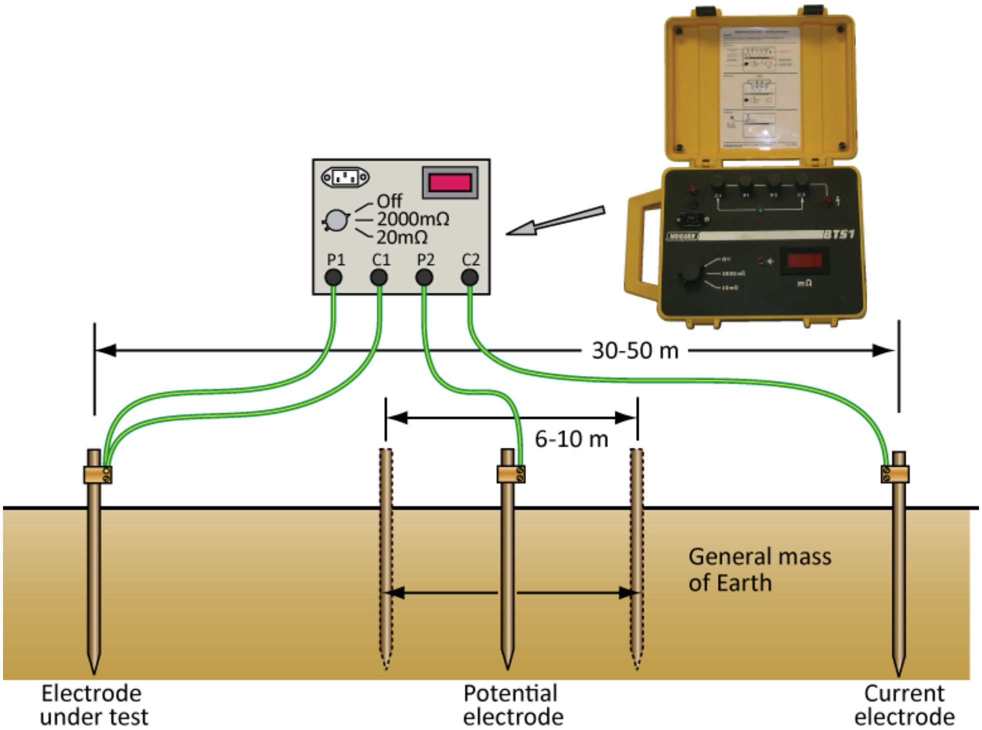


Using an earth electrode test instrument (second method)

The second way of testing is a little bit more involved but is less dangerous, and involves the use of an 'earth megger'.

This method is called the 'fall of potential' method.

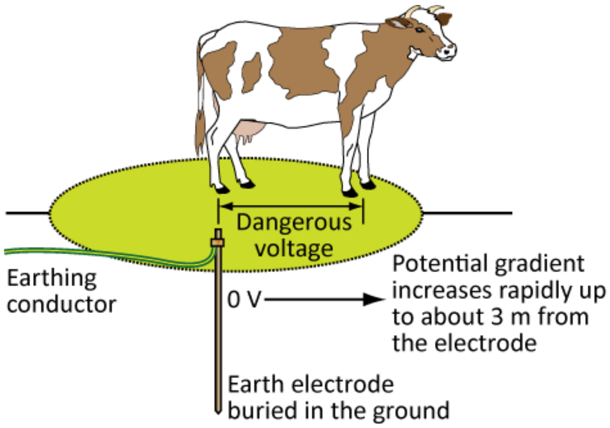
- Disconnect any earthing conductor on the electrode.
- Hammer a temporary rod (current spike) into the ground between 30 m -50 m away from the earth electrode under test.
- Hammer a second temporary rod (potential spike) into the ground at a distance halfway between the earth electrode under test and the current spike.
- Connect terminals C1 and P1 to the electrode under test.
- Connect P2 to the potential spike.
- Connect C2 to the current spike.
- Take a reading.



- Move the potential spike 3 m - 5 m towards the earth electrode under test and take a reading
- Move the potential spike back towards the current spike by the same distance and take a reading.
- You should get three readings that are similar in value. An average should be taken of these three readings, and this figure compared to each of the readings taken.

A maximum deviation can be calculated and the overall value should be accurate to 5 %. The average reading should be the one recorded. If there is any significant variation in results then you should re-do the test with the current spike moved further away from the earth electrode under test. Any variations might mean that the resistance areas have begun to overlap.

If an animal were to stand within the resistance area a voltage would appear between the front and rear legs of the animal. Therefore, for an animal, such as a cow, with a distance between their legs of 1.2 m (approx.), it could be possible under fault conditions for a voltage of 100 V to appear between the front and rear legs of the animal. This could lead to the death of the animal.



The earth electrode test must be carried out when the electrode is connected to anything other than TT systems. You'll remember that with a TT system you are allowed to use an earth loop impedance test instrument.

Example

1) An earth electrode test is carried out and readings of 58 Ω, 55 Ω and 59 Ω are generated. Assuming that a 5 % accuracy is required state whether the readings are appropriate.

- Average the resistance readings:

$$R_A = \frac{R_1 + R_2 + R_3}{3} = \frac{58 + 55 + 59}{3} = \frac{172}{3} = 57.3\ \Omega$$

The deviation percentage will be greatest when there is the greatest difference between the average reading and a measured reading. In this example that would be between the 55 Ω reading and the 57.3 Ω average.

- Determine the percentage deviance; $\% \text{ deviance} = \frac{57.3 - 55}{57.3} \times 100 = 4\ \%$

The area affected by the earth electrode is usually no more than 3 m. After this point, the resistance of the soil does not rise very much and so the risk of shock falls. You should also be aware that the distributor will commonly require that any earth electrode should be placed at least 9 m away from their electrode.

The maximum value of the earth electrode resistance depends on two key factors.
These are:

- the rated residual operating current rating *($I_{\Delta n}$)* of the RCD
- the permitted reference voltage (Regulation 411.5.3).

In a TT system Regulation 411.5.3 requires that:

i) the disconnection time shall comply with the requirements of Regulation 411.3.2.2 or Regulation 411.3.2.4 and,

ii) $I_n \times R_A \leq 50$ V

The disconnection times will be limited to 0.2 s for a 230 V nominal voltage, and not more than 1 s for a distribution circuit.
This is another of those requirements where you need to verify that the test results will cause the circuit to comply with BS 7671.
For different types of RCD the earth electrode resistance can be allowed to vary as long as the reference voltage is kept within the stated values. We are merely using a variation on Ohm's law.
The table below shows the maximum calculated figures for a range of RCDs.

RCD trip ratings (mA)	Maximum value of earth electrode resistance Ω at 230 V
10	5 000*
30	1 667*
100	500*
300	167*
500	100

Most of these values are of no use to us however, as they exceed the recommended maximum figure of 200 Ω given in a note to Table 41.5 of BS 7671.
The reason for this is that once the earth electrode resistance rises to these figures then the values are too open to fluctuation caused by varying weather and soil conditions. Drying out, freezing etc. all have an effect on the resistance of the electrode.

The electrode resistance can be improved in a variety of ways. These are:

- increase the depth of the electrode
- increase the number of electrodes [connect them in parallel]
- alter the mineral content of the soil.

What is not permitted is to wet the ground before carrying out the test and then hoping that the result is OK for that day. Tests should ideally be carried out over a 13-month or 11-month cycle so that every condition of soil is allowed for.

Transformers and generators

Making reference to BS 7430, three main types of generating set are considered:

a) small sets having ratings below 10 kW that are not earthed and not operated in parallel with the electricity supply;
b) sets having ratings usually in excess of 10 kW that are normally 3-phase and require earthing; and
c) small-scale embedded generators (up to 16 A/phase) for operation in parallel with public low-voltage distribution networks.

It is recommended that that where an unearthed generator is to supply an installation, one pole of the generator is connected to the MET and an earth electrode is installed.
The installation should be protected by RCDs. The method of protection is to be ADS.
For independent earth electrodes associated with the local earthing of the star point of generating plant, the earth resistance should not exceed 20 Ω

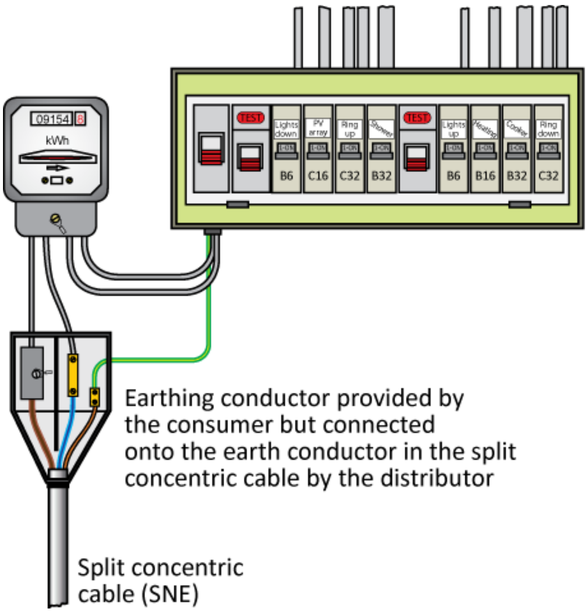
Therefore, with such equipment as transformers and generators the earth loop impedance test instrument is not adequate.
The testing of the earth electrode resistance must be carried out using the earth electrode test instrument as described above.

Earth fault loop impedance tests

What do we mean by impedance?
Impedance is something that delays or prevents progress, or the preventing of progress. So in this test we are looking for something that stops or delays path of an earth fault.

Regulation 612.8.1 requires that the effectiveness of the measures for fault protection by automatic disconnection of supply is verified for TN systems, TT systems and IT systems. For the majority of systems (TN and TT) this verification can be determined by measuring or calculating the earth fault loop impedance of the circuits within an installation.

TN-S Supply system



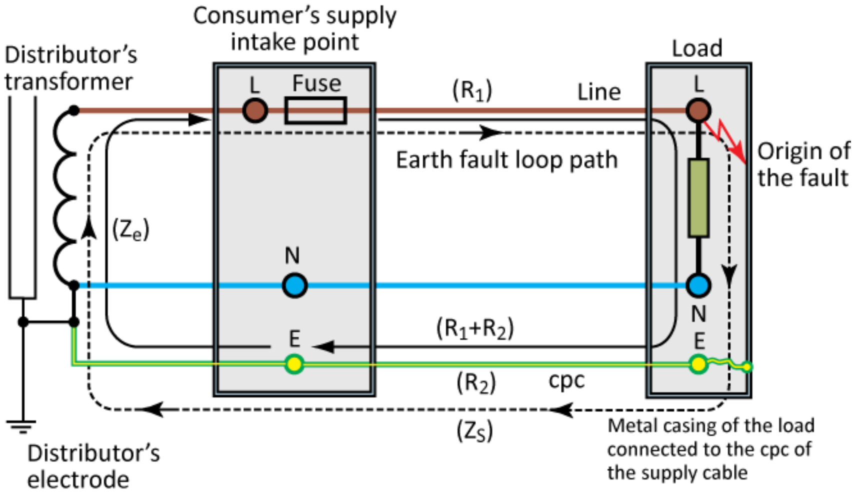
TN-S supply via a split concentric cable

T meaning the supply is directly connected to the earth at one or more points

N meaning that the exposed metal work of the installation is connected directly to the earthing point of the supply

S meaning that separate neural and protective conductors are being used throughout the system

A TN-S system usually has an external earth fault loop impedance of around 0.8 Ω quoted by the distributor for both single-phase supplies and three-phase supplies.



The internal earth fault loop depends on many factors such as the length and the cross-sectional area (csa) of the cable.

The external earth fault loop is labelled Z_e and the internal earth fault loop is labelled (R_1+R_2).

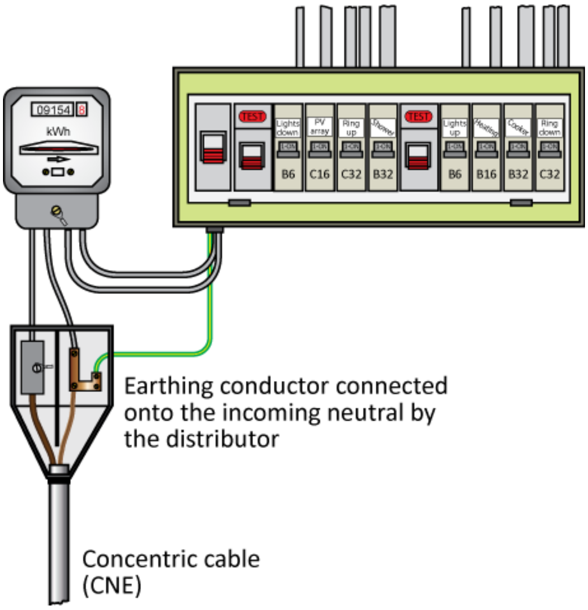
These figures, when combined, give the overall impedance of the earth fault current path.

$$Z_S = Z_e + (R_1 + R_2)$$

Notice that the earth fault loop path includes the protective conductor, the star point of the transformer, and the windings of the distributor's transformer, the supply line conductor and the line conductor of the circuit supplying the fault.

TN-C-S Supply system

The TN-C-S system is the most common found in new installations today



TNC-S supply via a concentric cable

T meaning the supply is directly connected to the earth at one or more points

N meaning that the exposed metal work of the installation is connected directly to the earthing point of the supply

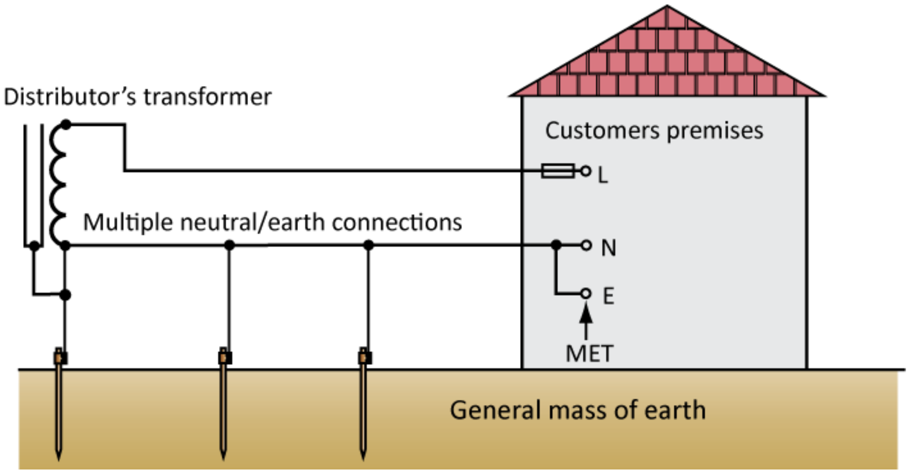
C the neutral and prospective functions are combined in a single conductor (PEN conductor)

S meaning that separate neural and protective conductors are being used throughout the system

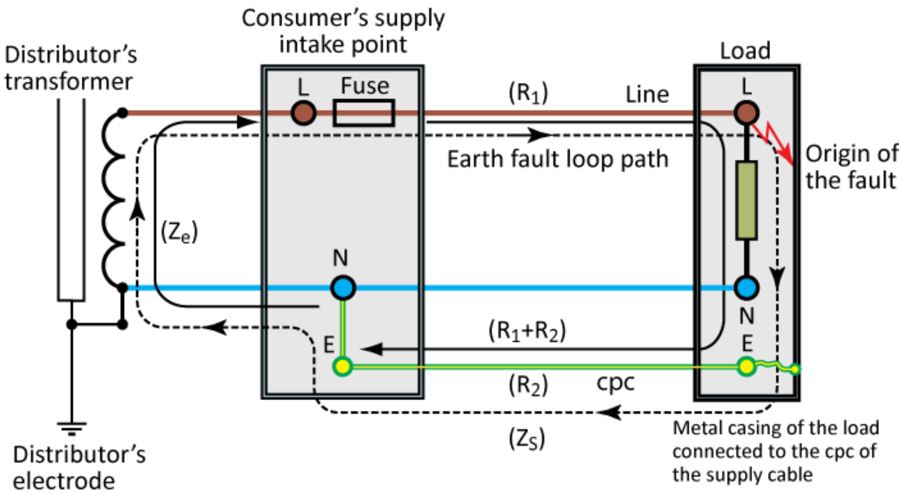
This system has a combined neutral and earth in the supply cable but at the consumer's installation they separate, and are separate throughout the rest of the installation.
An example of this type of supply arrangement would be PME (Protective Multiple Earthing) or PNB (Protective Neutral Bonding).

Protective Neutral Bonding is available where there is a dedicated transformer used by only one consumer. With PNB the PEN (CNE) conductor is connected to the general mass of Earth at one point only, generally close to the distributor's transformer. There are no further connections to the general mass of Earth.
The advantage of it is that if there is a break in the distributor's neutral conductor there is less chance of a touch voltage appearing between wet floors and the exposed metalwork that has been bonded together.

PME (Protective Multiple Earthing) is an arrangement where the neutral is connected to the star point of the transformer (usually at the substation) and, additionally, is connected to a number of earth electrodes along its length, usually every 30 m.
The neutral/earth combined cable sheath is connected regularly to Earth via earth electrodes.



The TN-C-S system is the most commonly installed today, and is used to supply houses etc. unless the customer asks for something different.
The main problem with this system is that should the neutral in the supply cable open circuit then the supply voltage may appear on the exposed-conductive-parts and the extraneous-conductive-parts leading to a shock risk where someone is in contact with the general mass of Earth.

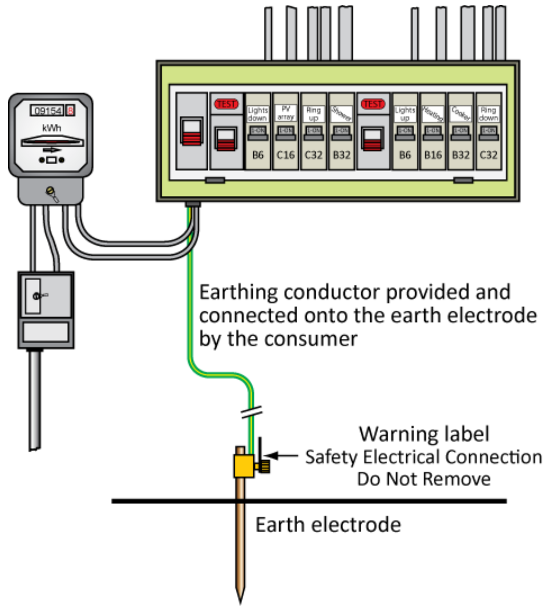


A typical value of external earth loop impedance would be a maximum of 0.35 Ω for single-phase supplies. For three-phase supplies, the figures vary slightly.

- Up to 200 A $Z_e = 0.35\ \Omega$
- 200 A - 300 A $Z_e = 0.20\ \Omega$
- Over 300 A $Z_e = 0.15\ \Omega$

These are all maximum values and impedance values may be significantly lower. Indeed, there are times when these values might be exceeded.

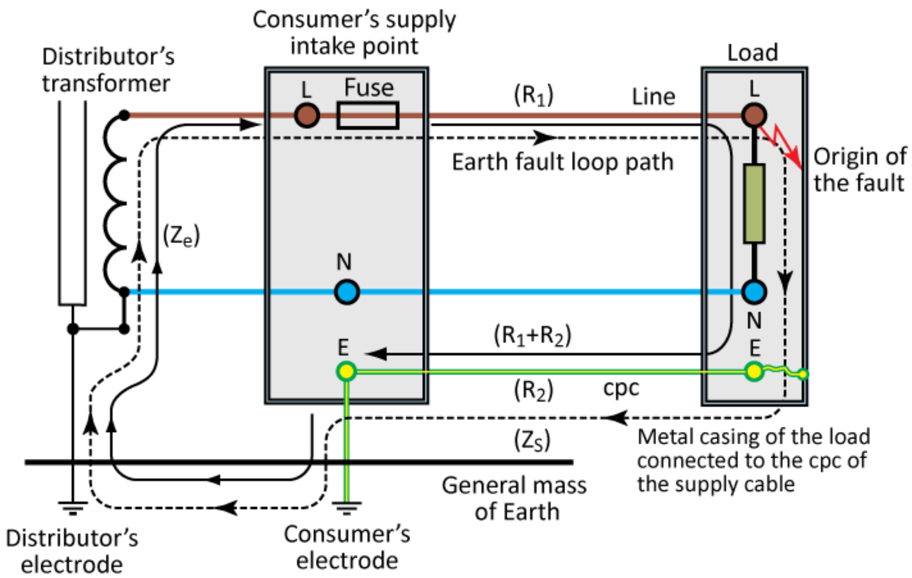
TT Supply system



T meaning the supply is directly connected to the earth at one or more points

T the second T meaning that the exposed metal work of the installation is connected to the earth by a separate earth electrode. The only connection between these two points is the earth mass.

This system has no earth provided by the distributor; just the normal current-carrying conductors. The consumer must provide his/her own Earth via an earth electrode.
There must also be an RCD installed to comply with the requirements of Regulation 411.5.3. This is both to limit the time that a fault exists for and to make sure that the voltage appearing between bonded metalwork and wet floors etc. does not give rise to risk of shock.



A typical figure for the external earth loop would be 21 Ω. This value covers the resistance of the neutral to earth, the impedance of the transformer winding and the line conductor.
This type of system is most commonly fed from an overhead supply system; the type that is commonly found in farms etc.

Even though the TT system is most commonly provided for installations such as farms and villages, it can also be found in installation such as petrol station forecourts, caravan and camping sites, marinas etc.
The loop on the supply authority side passes via the general mass of earth.

Means of testing the earth loop impedance
The most common form of testing for the earth fault loop impedance is using an earth fault loop impedance test instrument. You are also allowed to determine the earth fault loop impedance by calculation.

The earth fault loop test is necessary when we want to make sure that our protective devices will operate within the required time. This time may be anything from 0.05 s to 5 s depending on where we are, what we are testing and the levels of voltage that are available.

There are a number of ways in which the earth fault loop impedance can be determined. These are:

- The measurement of the earth loop impedance (Zs) and external impedance (Ze)
- Establish Ze from enquiry
- Calculate the value of Zs from given information
- Compare Zs and the maximum tabulated figures as specified in BS 7671

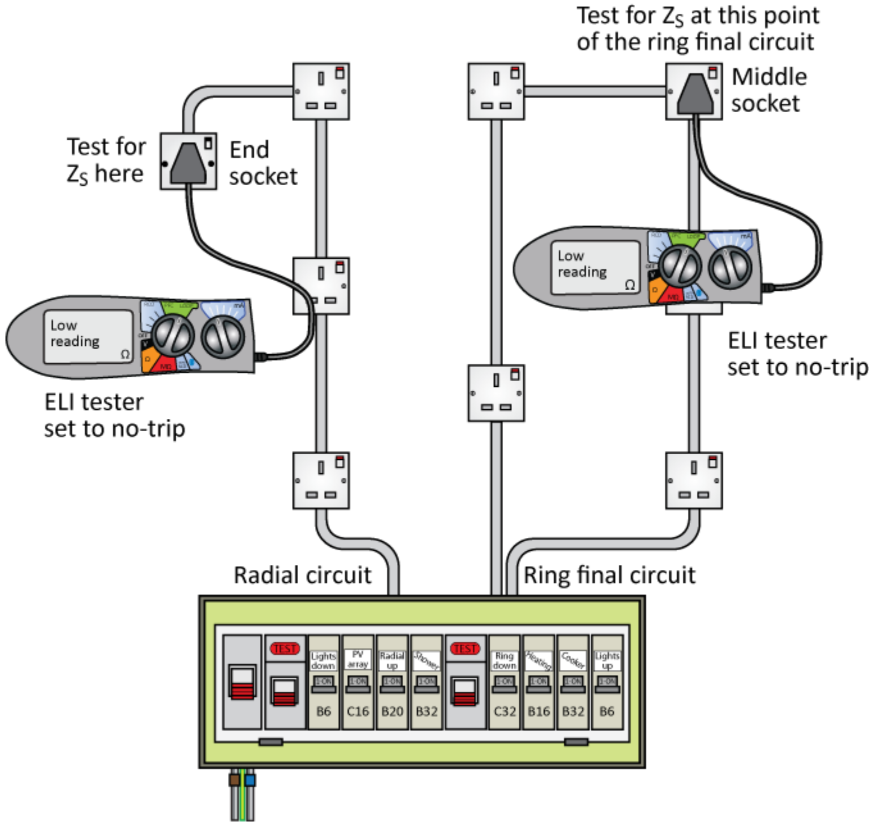
The use of a test instrument for determining the level of impedance is reasonable and yet you need to be aware;

- If you are testing sockets-outlets, it may be wise to test all the socket-outlets as well as recording the worst-case result; the worst-case result being the largest figure that you obtained. In a ring final circuit, this is most commonly the mid-point of the circuit.
- When you are testing lighting circuits, the end-point of the circuit should be tested and the results recorded, although it may be wise to also test all the lights on the circuit.

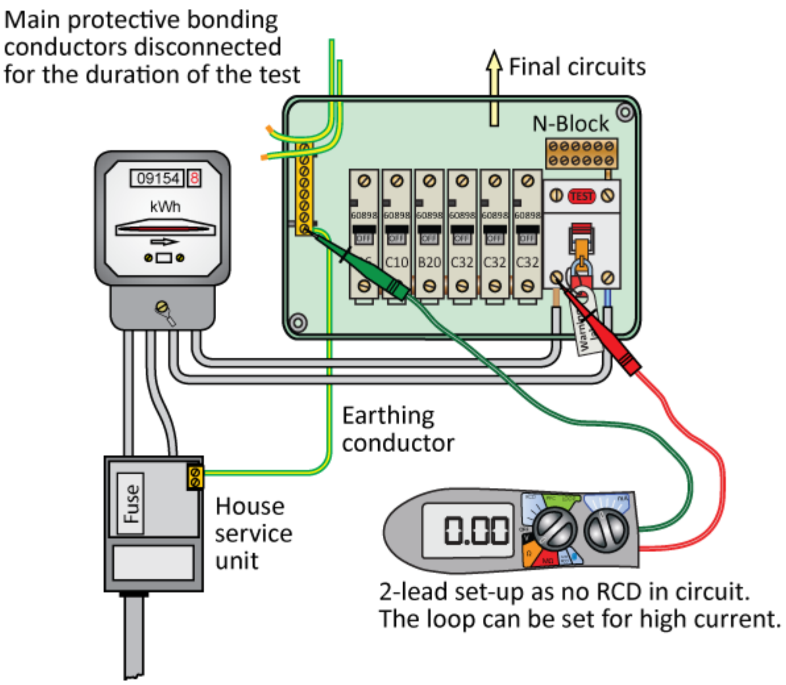
For all testing however you should remember the requirements of Regulation 14 of the Electricity at Work Regulations. Carrying out an earth fault loop impedance test is a live test and as such care should be taken in the preparation and practice of carrying out the test(s). Be careful to be able to recognise what is required and what is desirable though.
If you aren't careful, you may end up spending more time testing than is strictly reasonable. Be aware also that the test by its very nature injects a fault on to the system. The level of fault current is greater than 20 A and can be up to 25 A, and it is necessary for you to be

aware of the increased risk to others.

Testing at the end-point gives you the total loop impedance (Z_s) of that circuit. Additionally, you will need to test at the intake position and at each subsequent distribution board.



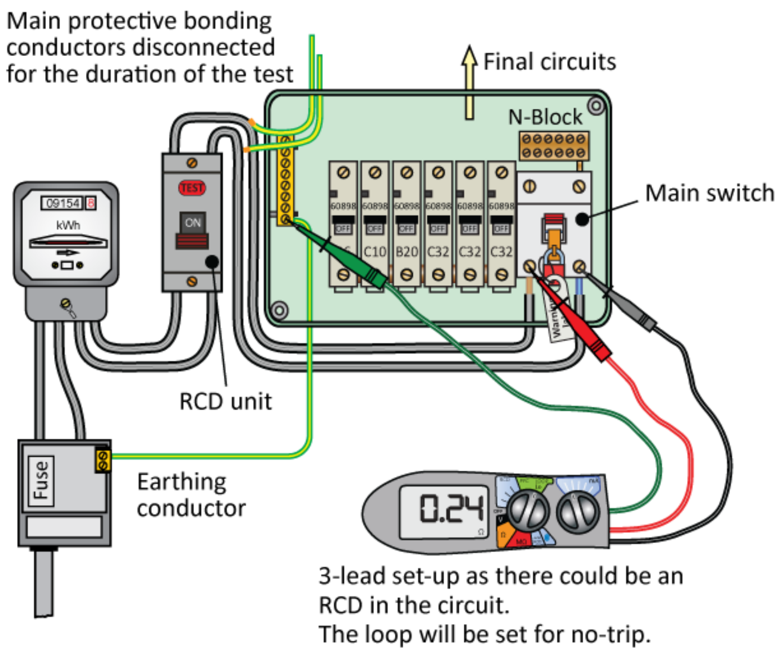
Earth loop impedance test using two-lead instrument



In this arrangement the line lead connects to the incoming line meter tail whilst the second lead connects to the main earthing terminal MET. Testing at this point gives you the external impedance of the supply. This is labelled Z_e.

You will also need to test at each subsequent distribution board where fitted.

Earth loop impedance test using a three-lead instrument

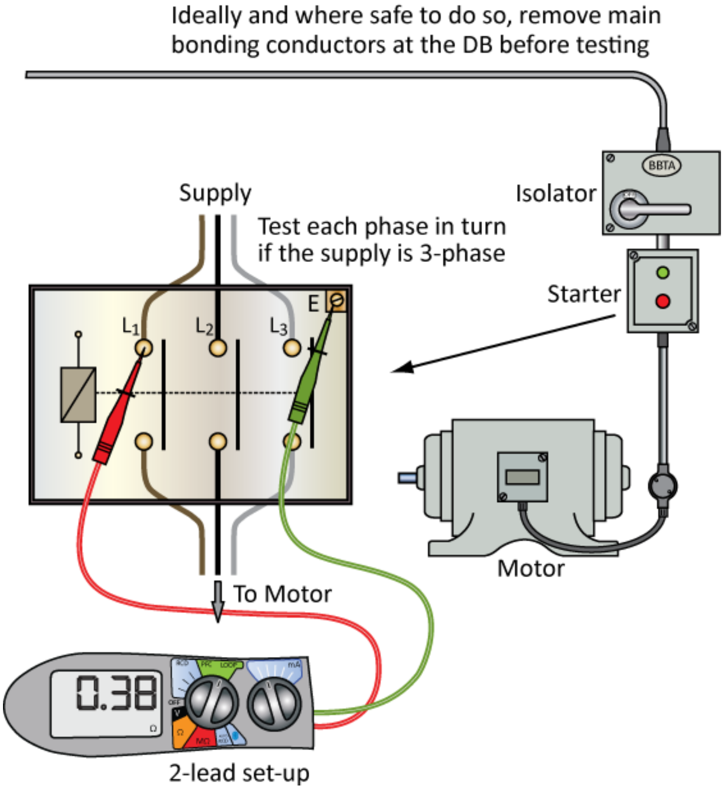


To test using a three-lead instrument.

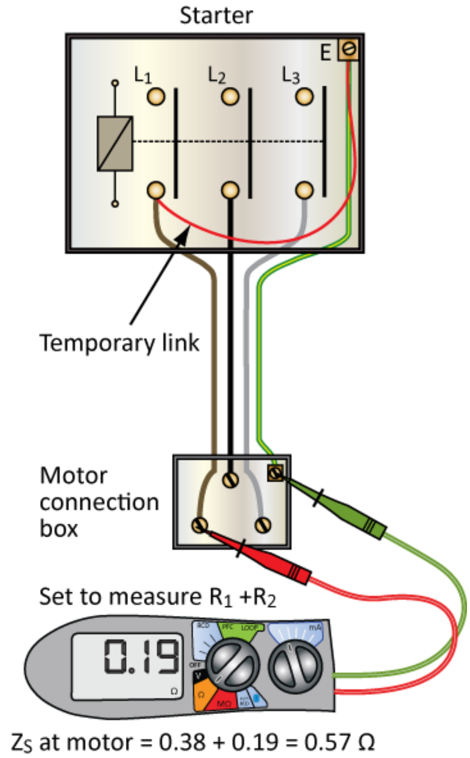
With this arrangement the line and neutral leads are connected to the incoming meter tails with the third lead connected to the MET.

Testing a motor circuit

As far as Guidance Note 3 is concerned, you are not permitted to test at the terminals of the motor. Depending on whether you have a two-lead instrument or a three-lead instrument, will vary how you perform the test, but you must test on the supply side of the motor control gear.



Test at the incoming terminals of the starter



Test at the motor terminals

The total earth fault loop impedance will have to be a combination of impedance readings and from when you performed your continuity test. $Z_s = Z_{int} + (R_1 + R_2)$

A couple of points do need making:

- Make sure that you are taking the power for the meter from the circuit that you are testing. It is not appropriate to plug your meter into the nearest socket-outlet and then wander about with the earth lead 'prodding' it onto a particular lighting circuit for eg.
- Remove the main equipotential bonding conductors. This removes the help that parallel paths will give you and ensures that you are only testing the circuit. However, when carrying out a periodic inspection and test it might not be safe to remove bonding conductors and these then should be remain connected with account taken of the reduction that is likely to occur in the overall earth loop impedance value.

Confirming measured test results

You should be aware that when you carry out your test you are usually doing it when the circuit is not loaded. This means that the cable temperature hasn't risen very much. Under earth fault conditions as well as normal operating conditions the temperature can and will be much higher.

Once measured the earth fault loop impedance should be checked. This is the case for both TN systems and TT systems. For TN systems a circuit rated at not more than 32 A must disconnect within 0.4 s for a 230 V supply. For TT systems a circuit rated at not more than 32 A must disconnect within 0.2 s.

Where the circuit in a TN system is a distribution circuit or has a current rating in excess of 32 A, a 5 s disconnection time is permitted irrespective of the supply voltage. Similarly, where the circuit in a TT system is a distribution circuit or has a current rating in excess of 32 A, a 1 s disconnection time is permitted, irrespective of the supply voltage.
Generally, a TT system will overcome the requirements of Regulation 411.3.2.2 and Regulation 411.3.2.4 by means of the use of an RCD.
A fault current significantly in excess of the rated residual operating current of the RCD ($I_{\Delta n}$) will cause the RCD to operate faster than the 0.3 s (300 ms) permitted maximum for modern RCDs to BS EN 61008 or RCOs to BS EN 61009.
More thought, however, will need to be given to the use of time delay RCDs, where disconnection times will exceed 300 ms.
Further information should be sought from the manufacturer.

For TN systems, there are a number of options currently found in GN3, including:

1) For standard thermoplastic circuits the values found in Appendix I of the On-Site Guide and Appendix B of Guidance Notes 3 can be used.
2) The designer's own calculated figures.
3) Table 41.2, 41.3 and 41.4 of *BS 7671* after being corrected for temperature.
4) Using a 'rule-of-thumb' value.

Option 4 is the one most commonly used.

Rule of thumb

If you are unwilling to work through all the factors, the IEE Guidance Notes (GN3), provide you with a 'rule of thumb' against which you can operate.

The value that is attached to this 'rule of thumb' in Appendix 14 of *BS 7671* is 80 %.

You can operate with this in two possible ways. The first option I will show you is the preferred method:

- determine a new maximum tabulated value and then compare with the measured value
- determine the relationship between the measured and tabulate values and see whether the overall result is less than 80 %.

Let's consider a couple of examples using both methods.

1) Z_S from the table is 1.09 Ω.
   Z_S *measured* is 0.8 Ω.

2) Z_S from the table is 0.8 Ω
   Z_S measured is 0.68 Ω.

We'll consider each in turn.

Answer 1) New maximum; $Z_S = Z_{S_{max}} \times 0.8 = 1.09 \times 0.8 = 0.872\,\Omega$

This is acceptable as the measured value of 0.8 Ω is less than the new adjusted maximum value of 0.872 Ω.

Answer 2) New maximum; $Z_S = Z_{S_{max}} \times 0.8 = 0.8 \times 0.8 = 0.64\,\Omega$

This is not acceptable as the new adjusted maximum value of 0.64Ω is less than the measured value of 0.68 Ω.

The problem with applying the 'rule of thumb'

In some instances, you may end up rejecting what is perfectly acceptable which might have been avoided with the application of a little more thought.

Problems with the earth loop test

An earth fault loop test instrument may cause an RCD or a 6 A type B circuit-breaker to BS EN 60898 to trip when they are being tested.

For an RCD this is not surprising as they operate on an earth fault basis and the test instrument introduces an earth fault.

For a 6 A type B circuit-breaker the earth fault loop test instrument introduces an earth fault of between 20 A and 25 A onto the circuit. Because a 6 A type B circuit-breaker may operate instantaneously between 18 A and 30 A $(3I_n\text{-}5I_n)$ nuisance tripping may occur.

For an RCD, there are a number of solutions to this problem:

- replace the RCD for the duration of the test (not a preferred option) with a circuit-breaker
- use a meter that has D-Lok or some other arrangement
- measure the external impedance (Z_e) and add this value to the measured value of (R_1+R_2). The use of something akin to D-Lok enables the test to be carried out very quickly and effectively 'tricks' the RCD into not seeing the imbalance (most of the time!). The D-Lok type meter is not fool-proof, and you should be very conscious of the type of circuit that you are testing before you use this meter.

You must NOT short out the RCD!

Similar solutions can be put in place to reduce the tripping of a 6 A BS EN 60898 circuit-breaker.

There are certain other makes of test instrument that will measure the value of earth loop impedance before they trip the RCD and will record the result. Still other makes use other variants of D-Lok that are less unstable.

Exercise 8 Live testing 1

1. What instrument is used to carry out an earth electrode test?

2. Where would an earth loop impedance test instrument be connected when carrying out an earth electrode test?

3. The earth electrode resistance has been measured at 18 Ω. If the system is protected by a 300 mA RCD will this comply with the requirements of Regulation 411.5.3?

4. Why is an earth fault loop impedance test carried out?

5. What are the three most common types of earthing systems, and what are their common external earth fault loop impedance values?

6. How would you carry out an earth loop impedance test using a two-lead test instrument and a three-lead test instrument?

7. You are to test the earth loop impedance at a compressor which has been wired in XPLESWA. Explain how you would perform the test.

8. A series of earth loop impedance tests are carried out on the following circuits:

Circuit No.	Protection device	Maximum Z_s (Ω)	Measured Z_s (Ω)	Answers
1	32A Type B circuit-breaker	1.5	1.2	
2	32A Type C circuit-breaker	0.75	0.55	
3	16A Type B circuit-breaker	3	2.2	
4	16A Type C circuit-breaker	1.5	1.25	
5	6A Type B circuit-breaker	8	4	
6	6A Type D circuit-breaker	2	1.5	

State whether each of the circuits comply.

9: Live testing 2

In this session the student will:

- Identify the requirements for measurement of prospective fault current
- Specify the methods for determining prospective fault current
- Verify the suitability of protective devices for prospective fault currents
- Specify methods for testing the correct operation of residual current devices
- State the reasons for verifying phase sequence
- State the need for functional testing

Prospective fault current

The prospective fault current (pfc) tests enable us to judge whether the breaking capacity of switchgear and protective devices are appropriate and the tests carried out on RCDs enable us to judge whether the disconnection time is appropriate for the setting of the device.

The prospective fault current is classified as a live test and is done with the power on.

The prospective fault current is a single name given to cover two specific tests. These are:

- Prospective short circuit test - this takes place between live conductors
- Prospective earth fault test - this takes place to earth.

Regulation 612.11 requires that the prospective fault current under both short-circuit and earth fault conditions be measured, calculated or determined by another method at the origin and at other relevant points.

Regulation 434.1 gives further information on the relavant points.
434.2 states 'a device providing protection against fault current shall be installed at a point where a reduction in the cross sectional area or any other change in current carrying capacity of the conductors, except where regulation 424.2.2 or 424.2.3 apply'.

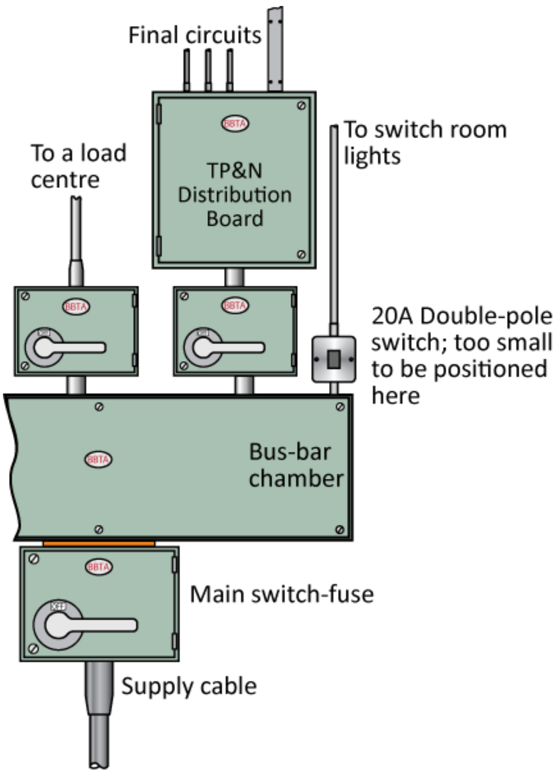
Regulation 434.5.1 states 'the breaking capacity rating of each prospective device shall not be less than the PFC at its point of installation'.
More critically, it is important that the inspector recognises that a distribution board may contain a range of protective devices having a range of breaking capacities.

For example, a circuit-breaker can have a rated breaking capacity of 6 kA, 10 kA or 16 kA. A distribution board, therefore, which might be tested at 8 kA might be inadequate for certain protective devices rated at 6 kA. Generally, the nearer the distributor's transformer(s), then the higher the fault current will become. It is normal for distributors to quote 16 kA (16 000 A) and even 25 kA (25 000 A) for the prospective fault currents.

These figures usually fall as cable length increases and there is a move away from the transformer. However, values may exceed this in certain circumstances and it is essential that the greatest of care is taken when considering whether, or not, to carry out this test, rather than calculate the maximum value.

When this amount of current flows explosions can occur, this test process is dangerous Regulation 14 applies. Do not put yours or anyone else's life in danger.

All switchgear has a breaking capacity figure quoted on it.
Often the figure for the prospective fault current quoted by the distributor is considered inadequate because it is set at what is, for any particular installation, too high a value. The value the distributor quotes is a figure based on the fault current at their cable rather than after a length of run to the installation.



With this in mind a prospective fault current test should be carried out at the terminals of the installation.
The instrument used is an earth fault loop impedance tester set at the prospective fault current range. Failure to do so could damage the instrument and lead to false readings.

The prospective fault current test is a live test and due care should be taken to make sure that the level of risk is reduced. A risk assessment should be carried out with a 'Permit to Work' etc required.

It is because of this need to determine the pfc at relevant parts of an installation, that it would become apparent that the placing of a 20 A switch placed on top of a busbar chamber is not appropriate. The reality is that the breaking capacity of the metal-clad switchgear will be very large and that of the small 20 A switch will be tiny in comparison. Under fault conditions what is reasonable for the heavy duty switchgear won't be for the 20 A one.

You should be aware that where necessary you may need to carry out the test at both the intake position and at subsequent distribution boards.

Prospective fault current testing

The OSG recommends that Pfc tests are carried out with all main bonding in place.

There are a number of results to be determined;

Single-phase

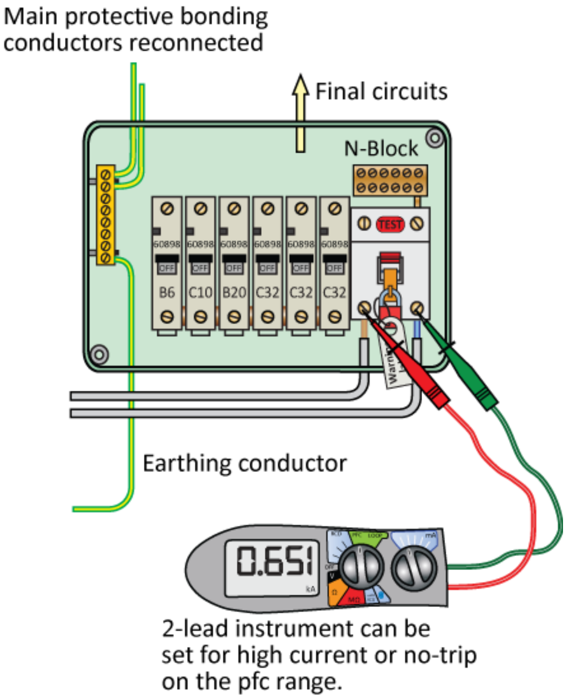
- Line to neutral
- Line to earth.

Three-phase

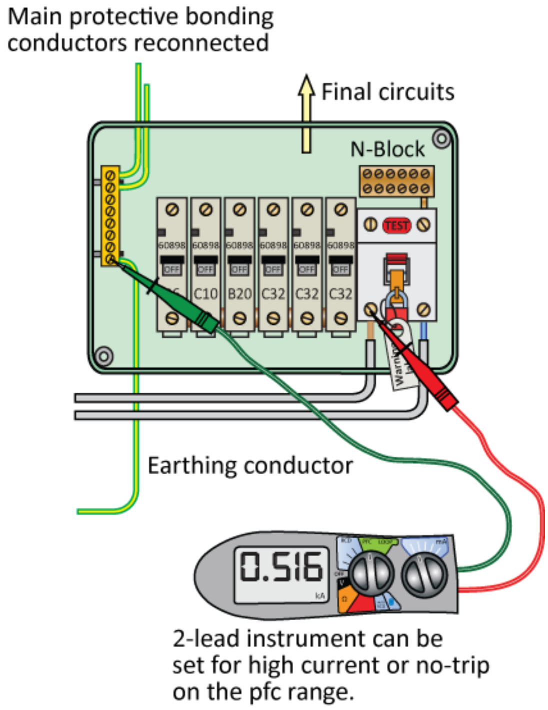
- Each line to neutral
- Each line to Earth
- Between each line (Only on two-lead instruments).

Two-lead test instrument

The main switch at the fuse board can still be locked off. The test is on the live side at the incoming terminals.

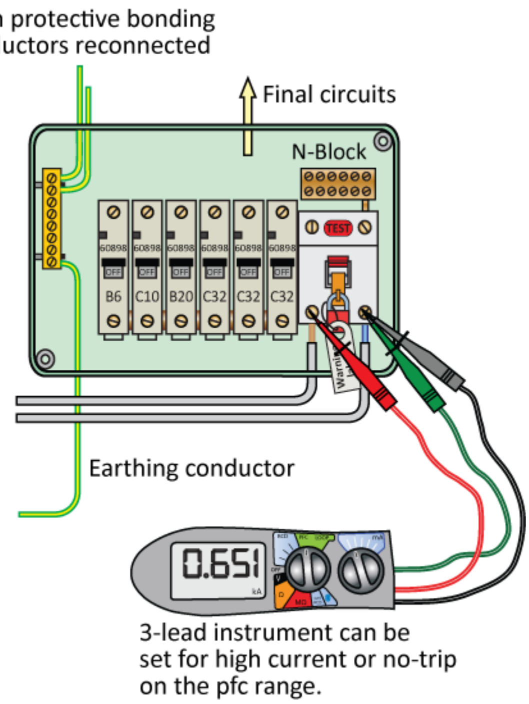


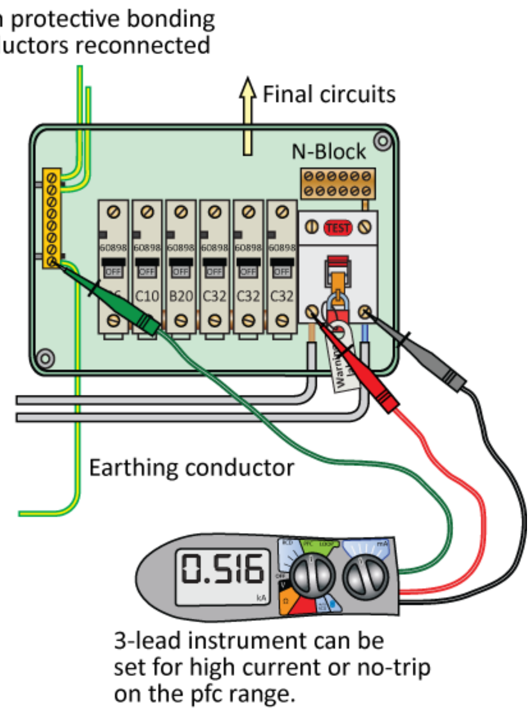
The prospective short-circuit current test should be made between the supply intake line and the neutral.



The prospective earth fault current should be made between the intake line and the main earthing terminal (MET).

Three-lead test instrument





For a single-phase supply the prospective short-circuit current test using a three-lead instrument, the neutral lead and the protective earth (PE) lead should both be connected to the neutral.

The prospective earth fault current using a three-lead test instrument shows that for a single-phase supply each of the three leads must be connected to the main earth terminal, the neutral and the intake line.

Three-phase supplies

For three-phase supplies we must check the worst case condition and this is a short-circuit across all three lines. If you use a single-phase test instrument then a test between line and neutral should be performed and the worst-case value of prospective fault current should be doubled. This is an approximation and is always too large, but will be accurate enough for testing purposes and will err on the safe side.

If you have already measured the earth fault loop impedance, then the prospective earth fault current can be calculated using Ohm's law

The earth fault current can be calculated using; $I_{pefc} = \frac{U_0}{Z_e}$

Example 1

The external earth fault loop impedance (Z_e) value for a TN-S system has been measured at 0.14 Ω for a 230 V supply voltage. Determine the prospective earth fault current.

$$I_{pefc} = \frac{U_0}{Z_e} = \frac{230}{0.14} = 1643\ A$$

For a TN-C-S system the prospective earth fault current and the prospective short circuit current values are the same.

Example 2

The prospective short circuit current has been measured using a two-lead test instrument at a value of 3.6 kA. The prospective earth fault current has been measured at a value of 3.75 kA. The installation has a 400 V three-phase supply.

Determine what the recorded prospective fault current should be on the Electrical Installation Certificate.

In this instance it is the prospective earth fault current that is the greater figure, however the greatest fault current will be a three phase short-circuit across all three lines, and therefore it is necessary to double the prospective short-circuit value.

$$I_{pfc} = 2 \times I_{pscc} = 2\ x\ 3.6\ =\ 7.2\ A$$

Things become a little more complex with instruments that can be connected across two lines. Patently, we get a two-line fault measured, but this is not quite accurate as it is the three-line fault that concerns us. We need therefore to apply a multiplier other than simply doubling the single-line result.

When converting between a two-line measuring instrument to a three-line fault a multiplier of 1.15 may be used. Using a multiplier of 1.2 provides a margin for safety and will provide a more accurate figure than simply doubling the single-phase test.

To show why the multiplier works

If we assume that the impedance of the line and neutral conductors are the same value, such as 1 Ω each and we can ignore the reactance of the transformer, and that the nominal voltage is 230 V single-phase and 400 V three-phase.

The working out for each situation is shown below.

Single-phase fault current $$I_{pfc} = \frac{U_L}{Z_{L\text{-}L}} = \frac{400}{1+1} = 200\ A$$

Two-phase fault current $$I_{pfc} = \frac{U_0}{Z_L} = \frac{230}{1} = 230\ A$$

Three-phase fault current $$I_{pfc} = \frac{U_0}{Z_{L\text{-}N}} = \frac{230}{1+1} = 115\ A$$

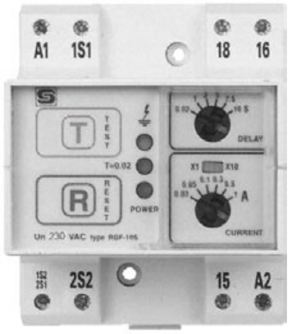
We can see that the jump between a single-line fault and a fault across two lines is in the order of 1.73. The jump between a single-line fault and a fault across all three-lines is in the order of 2. However, the jump between a fault across two lines and across all three lines is in the order of 1.15.

The results are recorded in the box headed the Nature of supply Parameters, which require the PFC at the origin to be recorded. The value that should be recorded is the greater of either the Short Circuit Current (between the live conductors) or the earth fault current (between the line conductor(s) and the MET). Any other necessary recorded values can be recorded on the Schedule of Test Results.

Residual current device (RCD) test

An RCD is unlike any other type of protective device.

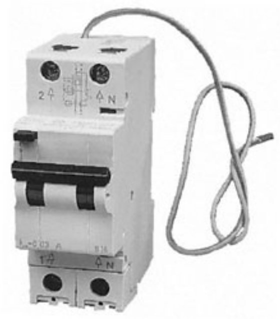
An RCD will only operate on an imbalance and will therefore only operate under earth fault conditions. It will not operate on overload conditions, unless it happens to be a combined RCD and CB (RCBO).



Time delay type

RCDs

Single pole RCBO



Double pole RCBO

All RCDs come equipped with a test button. This test button does not measure the time it takes for the RCD to operate, however the use of the test button does two things:

- it helps to maintain the function of the RCD and helps to reduce the failure rate of the device
- it ascertains whether the RCD will actually operate.

The test button should be checked (tested) quarterly

RCD test instruments to BS EN 61557-6 come equipped with a variety of ranges and test currents. These will include as a minimum:

- x½ the trip rating of the RCD
- x1 the trip rating of the RCD
- x5 the trip rating of the RCD.

There are various types of RCD tester.

For use as an RCD tester, use the blue range

Dedicated RCD tester

Regulation 612.10

Where RCDs are required for additional protection, the effectiveness of automatic disconnection of supply by RCDs shall be verified using suitable test equipment according to BS EN 61557-6 to confirm the relevant requirement of chapter 41 are kept.

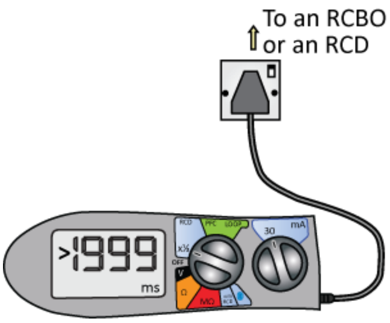
Regulation 612.13 states 'where fault protection and/or additional protection are to be provided by an RCD, the effectiveness of any test facility incorporated in the device shall be verified'.

You should ensure that the earth loop impedance test is performed prior to the RCD test. This is for safety reasons as the RCD test itself inserts a fault current to earth.

You have to use a test instrument! The test must be made on the load side of the RCD between the line conductor and the earth. Whilst the test is being carried out, the load should be disconnected.

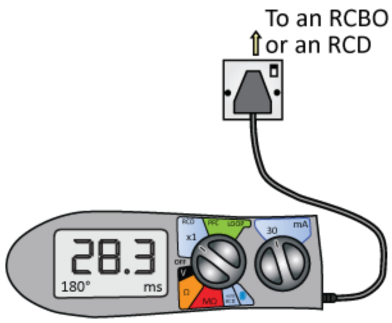
When a three-phase RCD is being tested, the neutral should be connected to the earth, although this may cause the RCD to operate even under the 50 % test and you should always make sure that manufacturer's data is checked before failing anything.

The following procedure should be followed when testing:



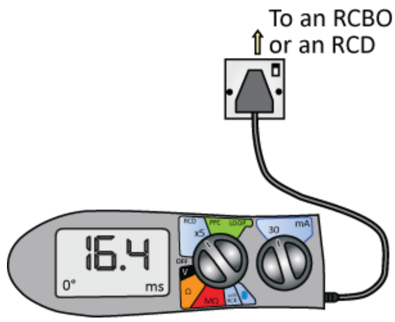
Test at 50 % of rated residual operating current for 2 000 ms (2 s)

The RCD should not operate



Test at 100 % of rated residual operating current.

The RCD must operate within 200 ms (0.2 s) if it is to BS 4293, or 300 ms (0.3 s) if it is to BS EN 61008/61009



If the RCD is providing additional protection then it should be tested at $5I_{\Delta n}$.

It must operate within 40 ms or 0.04 s

Each part of the test must be performed on both the positive and negative half cycles of the a.c. waveform. This is done by switching the instrument between either 0° and 180° or between + and -.

Where a time delay RCD is incorporated to BS 4293, then the device should trip within a time range of 50-100 % of the rated time delay plus 200 ms. This effectively means that an RCD at its rated tripping current must operate within 300-400 ms. For RCDs to BS EN 61008 or BS EN 61009 then the device with a time delay should trip within a range of 130-500 ms.

The problem with a time delay device is that it is not always possible to meet the requirements of Regulation 411.3.2.2, where for a 230 V TT system supplying circuits rated at not more than 32 A, the maximum disconnection time permitted is 0.2 s.

In each of the tests, the test voltage must not rise above 50 V rms. The accuracy of the instrument must be ± 10 % to allow for voltage variations and a timing accuracy of ± 5 %, and should allow for positive and negative half-cycles to be tested, as well as allowing for the time delay of the RCD.

The d.c. switch is used to take into account the effect that d.c. transients may have on certain RCDs. As solid-state (electronic) devices are increasingly connected to an installation, there is more chance that the RCD could be affected.

You should also know that some of the older RCDs are unable to ‘see’ the negative half cycle of the supply.

Phase sequence or phase rotation

Regulation 612.12 requires that the phase sequence of a multiphase circuit is maintained.

In practice this is a comparison test. The check on phase rotation should be made at the incoming supply at then at each position where it is necessary to assess whether there has been any alteration in the phase sequence. This may occur where, for example, a colour-coded steel wire armoured cable feeds a motor control centre (mcc) and single colour single-core cables then connect the motor control centre to a motor. The single-core cables may all have the same colour and it would be necessary to assess the phase sequence under such circumstances.

The test process involves the use of a test instrument that has a specific phase sequence test range on it - not all do!

The three leads from the test instrument should be connected to each of the lines on the supply side and the test performed. A second test should then be carries out after there has been any colour change etc. to assess whether any change of sequence has occurred.

The test instrument is likely to show up either a rotation of 123 or of 321. This simply tells you whether the rotation is different. This is sufficient as if there is a difference all we need to do is change over any two phases.

Verification of voltage drop

Appendix 4 of BS 7671:2008 Table 4b - Voltage drop			
		Lighting	Other use
(i)	Low voltage installations supplied directly from a public low voltage distribution system	3 %	5 %
(ii)	Low voltage installation supplied from private low voltage supply	6%	8%

The verification of voltage drop is not required during initial verification but is important. Regulation 525.1 requires that in the absence of other considerations, under normal service conditions the voltage at the terminals of any fixed current-using equipment shall be greater than the lower limit corresponding to the product standard relevant to the equipment.
Appendix 4 of BS 7671 details in Table 4Ab the permitted maximum recommended voltage drops, expressed as a percentage of the nominal voltage.
For a new installation the verification of the voltage drop should have taken place during the design stage. With this data to hand there is no reason why any other test or calculation is performed.

Functional testing

Regulation 612.13.1 requires that where fault protection is provided by an RCD, the effectiveness of any test facility incorporated in the device shall be verified.
Regulation 612.13.2 requires equipment such as switchgear and control assemblies, drives, controls and interlocks shall be subjected to a functional test to show that it is properly mounted, adjusted and installed in accordance with the relevant requirements of these regulations.
Functional testing is one of the last checks to do. There is no point in handing the installation over to the client with the light switches for example switching on instead of off.
We have already considered the requirements for the testing of RCDs. However, it is important, as part of the commissioning process for the person carrying out the testing to ensure that switchgear and control gear functions correctly.
The inspector should check, amongst other things, that:

- circuit-breakers open and close the circuit that they protect
- isolators open and close a circuit
- overloads are set correctly
- switches control the correct circuits
- emergency stop buttons work correctly.

There are no doubt many other items that you can think of.

Practical approach to testing

The order of tests as laid down in *BS 7671* gives a clear route through the tests, and there are indeed clear reasons why certain tests are carried out in a set order. However, it will soon become apparent to the practitioner that certain tests are very similar and can be performed at the same time. The two examples are that of testing the continuity of protective conductors using Method 1 and polarity, and testing ring final circuits and polarity.

It is important however that continuity is assessed prior to insulation resistance as this ensures that any breaks in the protective conductors are found. Without this order a fault might exist on the cable and it would not show up as the protective conductor is broken.

Additionally, it is important that the earth loop impedance is found to be acceptable prior to the RCD tests being performed as the RCD test places a fault on the protective conductor which can be dangerous where there is a break in the earth fault loop.

I will provide a route through the testing process. It is not a recommendation for action, but it does give a practical approach.

The list below is one possible option:

- Continuity of protective conductors and polarity using Method 1. Test every radial circuit for each distribution board and record your results. In addition use Method 2 to test the bonding and earthing conductors.
- Continuity of ring final circuit conductors and polarity. Tests every ring circuit for each distribution board and record results.
- Insulation resistance test. Turn every circuit-breaker on; disconnect every electronic device; make every switch; make sure every fuse is in. Test from the main intake position. This will make sure that every part of the installation is tested without having to carry out the same test at each board. Done once at the right place and this test should take no longer than 5 minutes. As long as the overall insulation resistance value is acceptable then this value can be recorded for each separate circuit.
- Turn all switches off and make the system live. This will ensure that when the system is energised only part will become live and you will have control.
- Test for live polarity. This ensures that the distributor has connected the main supply the right way round.
- Test for external earth loop impedance. Record the results.
- Test for prospective short circuit current and earth fault current. It is the higher of the two that is to be recorded.
- Turn each subsequent distribution board on and test for earth loop impedance and short circuit current at each board. Record the results.
- Turn each circuit on in turn and test earth loop impedance for each circuit. Record the results.
- Test each RCD and record the disconnection times where relevant.
- Check each circuit works appropriately, phase rotation is correct, each isolator functions appropriately etc. Give this list consideration, but recognise that it is only one option providing a possible route through the testing process.

Exercise 9 Live testing 2

1. What is the function of the test button on an RCD?

2. Why is it necessary to carry out a prospective fault current test?

3. An RCD is used to provide additional protection. What is the maximum residual operating current and what are the correct disconnection times?

4. What tests must be carried out on an RCD having a rated residual operating current of 300 mA?

5. What rating RCD is required to be installed in a farm?

6. Why are disconnection times for time delay RCDs a problem?

7. Describe how a prospective fault current test should be performed using a three-lead instrument on a single-phase consumer unit

8. A single-phase instrument is used to measure the prospective fault current on a TP&N distribution board. How is the test to be performed and what must be done to the result?

9. Why is the assessment of phase rotation important?

10. You are carrying out the functional test and a motor has a full load current of 12.1 A. What would you set the overloads at?

11. Why should a live polarity check be made after the supply to an installation is turned on?

12. Under what circumstance might it be more acceptable to determine the prospective fault current by means other than measurement?

10: Periodic inspection and testing

In this session the student will:

- Identify the requirements for periodic inspection
- The routine checks to be carries out
- The frequency of inspections
- Sampling
- Periodic inspection
- Periodic testing

Periodic testing and inspection is different to an initial inspection, because with periodic testing and inspecting we are looking at an **existing** installation and have to decide whether it is still in a satisfactory condition to continue to be used.

The inspection and testing is carried out, so far as is reasonably practicable for;

- The safety of persons and livestock against electric shock and burns
- Protection against damage to property by fire and heat arising from an installation defect
- Confirmation that the installation is not damaged or deteriorated so as to impair safety
- The identification of installation defects and departures from the requirements of the regulations that might arise

Periodic inspection and inspection is required:

- To confirm that there is compliance with BS 7671
- To make sure the electrical installation is maintained in a safe condition
- When there is a change of use of the building
- Change of tenancy of the building
- On completion of alterations or additions to an original installation
- Where significant increase of loading to the installation has occurred
- When there has been significant damage to the installation

Organisations such as mortgage lenders, insurance companies and licensing authorities may require testing and inspection to be carried out.

Regulation 621.1 tells us that 'where required periodic inspection and testing of every electrical installation shall be carried out in accordance with regulations 621.2-5 in order to determined, so far as reasonable practicable, whether the installation is in a satisfactory condition for continued service. Where possible, the documentation arising from the initial certification and any previous periodic inspection and testing shall be taken into account. Where no previous documentation is available, investigation of the electrical installation shall be undertaken prior to carrying out the periodic inspection and testing'.

Regulation 622.2 allows installations which are under constant supervision by a skilled person competent in that work, that periodic testing and inspection be replaced by a scheme of continuous monitoring and maintenance of the installation and all its parts. Appropriate records of this must be kept.

The Electricity at Work Regulations 1989 requires:

' that as maybe necessary to prevent danger, all systems shall be maintained so as to prevent danger, so far as is reasonable practicable, such danger'.

Regular inspection is part of the preventative maintenance; this can be done with or without dismantling the equipment. If dismantling is required the extra danger must be considered.

All persons carrying out inspection and testing must be competent to do so.

Routine checks

In domestic premises it is assumed that the occupier will arrange for any defect or faults to be put right as they occur. In commercial or industrial installations, which fall under the EWR 1989, formal arrangements need to be made for maintenance and routine checks; these will depend on the use of the premises and will be set by the electrical duty holder.

List of things to look for when carrying routine checks.

Activity	Check
Inspection	Breakages Wear and tear Overheating Missing screws/covers Loose fittings Switchgear accessible enclosures secure labelling in place
Operation	Operate switchgear Operate equipment where possible Test RCD test buttons

Required information

As with initial verification a certain amount of information is required before any testing can take place.

The extent of the installation to be tested must be decide on first and recorded. Technical information for the electrical installation should be obtained from the person responsible. This needs to include any relevant diagrams, design specifications, type of electricity supply, plus any alternative supplies and earthing arrangements. There need to be means to identify types of circuits, identification of protective devices for shock protection, isolation and switching and the method used for fault protection.

Frequency of periodic inspections

Regulation 622.1

In deciding the frequency of the periodic test account needs to be taken of:

- The use of the building
- The type of installation
- External influences
- The equipment
- Maintenance
- Recommendation of other reports if any

The inspector should apply their judgement on the interval between tests. Guidance Note 3 gives lists of recommended frequencies of inspection of electrical inspections.

The table below gives examples of the frequencies given.

Type of installation	Routine check	Maximum period between I&T
General domestic accommodation	-	Change of occupancy/10yrs
Domestic accommodation (rented)	1 year	Change of occupancy/5yrs
Schools	6 months	5 years
Hospitals	1 year	5 years
Cinemas	1 year	1-3 years
Churches	1 year	5 years
Pubs	1 year	5 years
Construction site installations	3 months	3 months
Caravans	1 year	3 years

General procedure

A visual inspection should be carried out first to look for areas which might be identified as dangerous during the testing. These locations should be noted and safety precautions taken. Areas where sampling can take place can be identified at this point.

Where diagrams and charts are not available, it will be necessary to investigate the installation to identify switchgear, control gear, and the circuits they control.

Included in the inspection should be a check on the environmental conditions, any changes in use or condition of the building.

Enquiries need to be made as to whether there is any equipment on the site that might be damages by the high voltage tests. The client needs to be informed as to when the power will be disconnected so they can arrange for the computer data to be backed up, and any other steps that need to be taken during the testing.

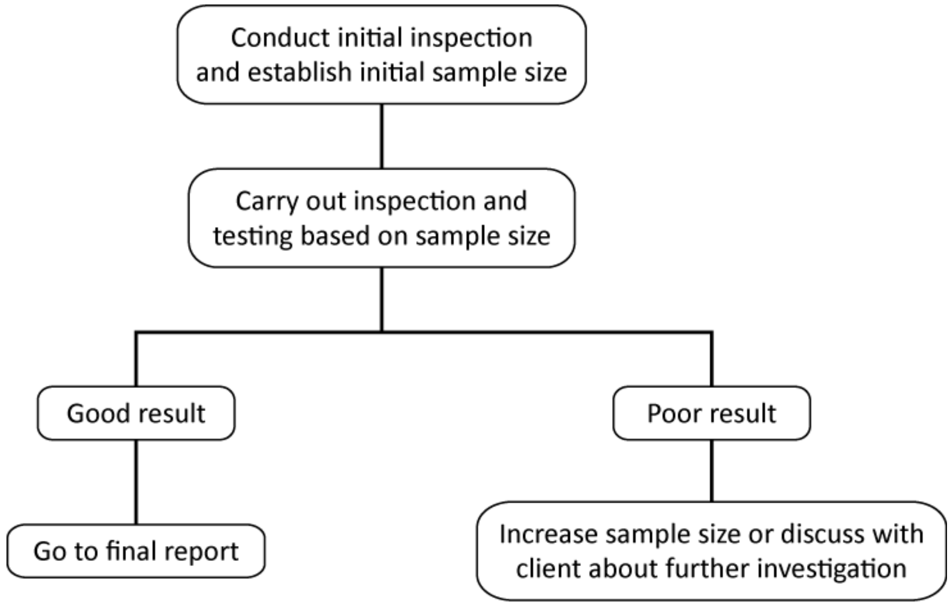
Emergency backup systems need to be investigated to make sure the power is not energised when the mains is disconnected.

Sampling

It might be unrealistic to test the whole of an electrical installation. During the visual inspection the condition of the installation will give an indication of the amount of testing that is needed.

Sampling will be judged on

- Age and condition of the electrical installation
- Type and use of the installation
- Environmental conditions
- The effectiveness of any maintenance schedules
- Time since last inspection/testing
- The size of the installation
- The clients wishes
- The quality and availability of any previous records/reports/data



If a relatively small sample size is chosen it is important that these are representative of the complete installation.

Suggested range of sample sizes as given in Guidance note 3

Item	Suggested minimum sample size	Typical checks
Main switch gear (external examination)	100%	Signs of overheating, damage or aging
Main switch gear (internal sections and cable terminations)	Ideally 100% but not less than 10%	Signs of overheating, or aging, check tightness of cable connections
Main switch gear (internal inspection of circuit-breaker connections and control sections)	Ideally 100% but not less than 10%	Signs of overheating, or aging, check tightness of cable connections
Final circuit distribution boards	Ideally 100% but not less than 25%	Signs of overheating, or aging, check tightness of cable connections
Final circuit	Between 10% to 100%	Damage, signs of overheating
Earthing and protective bonding conductors	100%	Presence and tightness

Where the sample gets poor results, this would suggest that there are problems elsewhere in the uninspected items. The choice would then be to increase the size of the sampling or to consult with the client as what to do next.

Periodic inspection

A list of items in various location which need inspecting is listed Guidance Note 3 and in Appendix 6 of BS 7671.

The inspection and testing should not take place unless the inspector has enough information to process safely. A visual inspection should be carried out with the supply, where possible, de-energised.

A thorough inspection should be made of all electrical equipment that is not concealed, damaged or where deterioration has occurred. This should be recorded on the inspection schedule.

The periodic inspection should include all the equipment and materials used in the installation including; (full list is in Appendix 6 BS 7671)

- Electrical intake equipment
- Presence of adequate arrangements for parallel paths
- Automatic disconnection of supply
- Other methods of protection
- Distribution equipment
- Isolation and switching
- Current using equipment (permanently connected)
- Part 7 Special installations

Periodic testing

Periodic testing is not necessarily done to the same level and range as initial testing. Installations that have been previously tested or are under a maintenance program will not need as much as an installation that has no records. This is where sampling can be applied.

Tests to be made

The inspector needs to decide which tests are to be applied.

Test	Recommendations
Protective conductors continuity	Assessable exposed conductive parts of current using equipment and accessories
Bonding conductor continuity	Main bonding conductors to extraneous conductive parts Supplementary bonding conductors
Ring circuit continuity	Where there are previous records, this test may not be necessary unless there have been changes to the ring final circuit
Polarity	Origin of the installation Distribution boards Accessible socket outlets Extremities of radial circuits
Earth fault loop impedance	Origin of the installation Distribution boards Accessible socket outlets Extremities of radial circuits
Insulation resistance	Between live conductors and Earth at main and final distribution boards
Earth electrode resistance	Test each earth rod or group of rods separately with the test links removed and with the installation isolated from the supply source
Functional tests RCDs. Functional tests of circuit breakers. isolators and switching devices.	Test as required by regulation 612.13.1, followed by the operation of the test button Manual operation to confirm that the devices disconnect

Continuity of protective conductors and equipotential bonding conductors and earth loop impedance testing.

If an electrical installation **is isolated** from the supply guidance note 3 states that it is permissible to disconnect protective and equipotential bonding conductors from the main earthing terminal in order to determine their continuity.

Where an electrical installation **cannot be** isolated from the supply protective and equipotential bonding conductors **should not** be disconnected as under fault conditions they could be raised to a dangerous level above earth potential.

Measurement of earth fault loop impedance at various parts of the installation is to be carried out with the protective and equipotential bonding conductors connected.

Motor circuits

Loop impedance tests on motors can only be carried out on the supply side of the isolated motor control gear. A continuity test between the cpc and the motor is then necessary.

Insulation resistance

Insulation test should be made on electrically isolated circuits with all electronic equipment that might be damaged switched off. Warnings should be placed on circuits and equipment when the testing is taking place.

Operation of overcurrent devices

Where protection is provided by circuit breakers, the manual operation of **each** circuit breaker should be operated to verify that the device operates satisfactorily.

Operation of devices for isolation and switching

Where means are provided in accordance with the regulations for isolation and switching, the devices should be operated to verify their effectiveness and correct labelling. Easy access of the devices must be maintained. The access must be labelled to make sure that they are not obstructed. Devices used for isolating must be externally visible.

Any switches that have lockable or detachable handles must be checked to make sure that cannot be used for any other device and are not interchangeable.

Mechanical switching devices must be verified that they cannot be unintentional activated.

On completion of Periodic inspecting and testing the results should be recorded on the Electrical Installation Condition report, the schedule of inspection and the schedule of test results.

Any damage deterioration, defects, dangerous condition as well as non compliance with BS7671 should be recorded in the report.

Classification codes

If appropriate the codes C1, C2 or C3 should be entered in Section K.

Classification of danger or non compliance	Description	Notes
C1	Danger present. Risk of injury. Immediate remedial action required	To be used in situations which cannot be left.
C2	Potentially dangerous urgent remedial action required	To be used in situations which whilst urgent do not require immediate remedial action
C3	Improvement required	To be used where C1 and C2 do not apply

Exercise 10 Periodic inspection & testing

1. What information is required before an inspection is carried out?

2. Which law are you breaking if you don't inspect and test?

3. What two regulations found in *BS 7671* are a specific concern as they relate to inspection and testing?

4. A bathroom has no supplementary bonding installed. You are required to replace a light fitting. Are you able to change the luminaire without any additional work being done?

5. State the four reasons for carrying out a periodic inspection and test.

11: Completing documentation

In this session the student will:

- Appropriate procedures for dealing with customers and clients
- The purpose and information of the documentation associated electrical inspecting and testing
- The responsibilities of clients and inspectors in the completion of the certification

The last session in this unit deals with the documentation and certification process. This is in some ways the most important because there is no point in carrying out the process if there is no evidence to back it up.

As has been stated before, the documentation you complete and hand to the customer is lawfully binding, and you as the inspector, have to be very sure that you have done everything you can to make sure the installation or the part tested is safe. The consequences of getting it wrong could lead to fires, burns, electric shock or in the worst case death.

Part of your job of an inspector is to keep your customers/ client's safe, happy and informed. The testing and inspecting can be carried out in a home, shop commercial premises, in fact anywhere where there might be other people. Before and during the inspection process their safety is of great importance. Information, signs, barriers and labelling must be considered at all stages of the process. The timing of the inspection and testing should be discussed with the client beforehand so that it can be done with the minimum disruption to their normal activities. Labels should be clearly placed near, or attached to, any part of the electrical circuit/s that has yet to be commissioned.

Documentation

There are three general forms recognised by BS 7671. These are:

- Electrical Installation Condition Report (EICR).
- Electrical Installation Certificate (EIC)
  - Schedule of inspections
  - Schedule of test results
- Minor Electrical Installation Works Certificate (MEIWC)

Electrical Installation Certificate

The Electrical Installation Certificate (EIC) is a form based on that detailed in Appendix 6 of BS 7671 used, together with a Schedule of Inspection and Schedule of Test Results, to record the condition of the electrical installation at handover and should show that the installation complies with the current Standard.

It should not be made or authenticated by anyone other than a competent person in inspection and testing of electrical installations. It is only to be used for the **Initial Certification** of a new installation or for an addition or alteration to an existing installation where new circuits have been added to.

Regulation 632.1 requires that following an initial verification required by Chapter 61, an Electrical Installation Certificate (EIC), together with a Schedule of Test Results and a Schedule of Inspection is issued to the person who ordered the work.

It should be well noted that the EIC contains a box for the extent of the inspection and testing and the limitations placed on the person carrying out the inspection and testing. It is absolutely essential that this box is filled out (ideally prior to any work being carried out) as it is a record of what has been agreed between the person ordering the work and the person carrying the work out.
Over the next few pages we will address the information that should be recorded on an EIC. The EIC may be produced in either written or electronic form, but it must be a durable medium (Regulation 631.5 refers).

Client details

DETAILS OF THE CLIENT ....
INSTALLATION ADDRESS ....

This box should contain the details of the person who ordered the work and not necessarily the details of the person either living in the house or running the establishment. The client may for example be a national company running a pub chain. The pub in question is not the client, the pub chain is. The address of the installation should also be included here.

Description and extent of the installation

This box details the nature of the installation and whether it is complete or limited. Care should be used to describe clearly how much is covered by the certificate. There are three further checkboxes listed to highlight whether we are dealing with a new installation, additions to an existing installation, or alterations to an existing installation such as adding socket-outlets to an existing ring final circuit.

DESCRIPTION AND EXTENT OF THE INSTALLATION Tick boxes as appropriate Description of installation:	New installation ☐
Extent of installation covered by this Certificate:	Addition to an existing installation ☐
(Use continuation sheet if necessary) see continuation sheet No:	Alteration to an existing installation ☐

Signatures for design, installation and inspection and testing

This section details those who should be signing the certificate, whether there have been any departures and a mention of the extent this certificate covers.

FOR DESIGN I/We being the person(s) responsible for the design of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the design hereby CERTIFY that the design work for which I/we have been responsible is to the best of my/our knowledge and belief in accordance with BS 7671:2008, amended to .... (date) except for the departures, if any detailed as follows:
Details of departures from BS 7671 (Regulations 120.3 and 120.4):
The extent and liability of the signatory of the signatories is limited to the work described above as the subject of this Certificate. For the DESIGN of the installation: ** (Where there is mutual responsibility for the design) Signature: .... Date: .... Name (IN BLOCK LETTERS): .... Designer No 1 Signature: .... Date: .... Name (IN BLOCK LETTERS): .... Designer No 2**
FOR CONSTRUCTION I/We being the person(s) responsible for the construction of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the construction hereby CERTIFY that the construction work for which I/we have been responsible is to the best of my/our knowledge and belief in accordance with BS 7671:2008, amended to.......... (date) except for the departures, if any detailed as follows:
Details of departures from BS 7671 (Regulations 120.3 and 120.4):
The extent and liability of the signatory is limited to the work described above as the subject of this Certificate. For CONSTRUCTION of the installation: Signature: .... Date: .... Name (IN BLOCK LETTERS): .... Constructor
FOR INSPECTION & TESTING I/We being the person(s) responsible for the inspection & testing of the electrical installation (as indicated by my/our signatures below), particulars of which are described above, having exercised reasonable skill and care when carrying out the inspection & testing hereby CERTIFY that the work for which I/we have been responsible is to the best of my/our knowledge and belief in accordance with BS 7671:2008, amended to ....(date) except for the departures, if any detailed as follows:
Details of departures from BS 7671 (Regulations 120.3 and 120.4):
The extent and liability of the signatory is limited to the work described above as the subject of this Certificate. For INSPECTION & TESTING of the installation: Signature: .... Date: .... Name (IN BLOCK LETTERS): .... Inspector

Date to the first periodic inspection

This section requires the inspector to state when the first periodic inspection and test should be carried out. This is usually a judgement issue and will depend on a number of factors. For example, where a completely new installation exists then the period of time to the first periodic inspection and test might be, say, ten years for a domestic dwelling. However, where a circuit is added to an existing installation, the judgement might be that it would be better to set a shorter period of time before a periodic inspection and test is called for.

NEXT INSPECTION
I/We the designer(s), recommend that this installation is further inspected and tested after an interval of not more than .... years/months.

Particulars of signatories to the EIC

This section is the first section on the second page of the EIC and requires each of the signatories to state their name, the company they work for, their address (the companys) and a telephone number.

PARTICULARS OF SIGNATORIES TO THE ELECTRICAL INSTALLATION CERTIFICATE	
Designer (No 1)	Name: .... Company: .... Address: .... Postcode: .... Tel No: ....
Designer (No 2) (if applicable)	Name: .... Company: .... Address: .... Postcode: .... Tel No: ....
Constructor	Name: .... Company: .... Address: .... Postcode: .... Tel No: ....
Inspector	Name: .... Company: .... Address: .... Postcode: .... Tel No: ....

Supply characteristics and earthing arrangements

This section is very similar to that required for the EICR and requires the person carrying out the inspection and testing to ascertain the nature of the supply and earthing arrangements. This might be provided by the designer where the designer is different from the person carrying out the inspection and testing.

SUPPLY CHARACTERISTICS AND EARTHING ARRANGEMENTS Tick boxes and enter details, as appropriate

Earthing arrangements	Number and Type of Live Conductors		Nature of Supply Parameters	Supply Protective Device Characteristics
TN-C ☐	a.c. ☐	d.c. ☐	Nominal voltage, U/U_0 (1) V	Type: ....
TN-S ☐	1-phase, 2-wire ☐	2-pole ☐	Nominal frequency, f (1) .... Hz	
TN-C-S ☐	2-phase, 3-wire ☐	3-pole ☐	Prospective fault current, I_{pf} (2) .... kA	Rated current .... A
TT ☐	3-phase, 3-wire ☐	other ☐	External loop impedance, Z_e (2) .... Ω	
IT ☐	3-phase, 4-wire ☐		*(Note: (1) by enquiry, (2) by enquiry or by measurement*	
Alternative source of supply (to be detailed on attached schedule) ☐				

Particulars of installation at the origin

This section is very similar to that required for the EICR. Here the required data should be provided by the designer. It is important that correct values are quoted and correct standards referred to. Where there is doubt make sure it is noted.

PARTICULARS OF INSTALLATION REFERRED TO IN THE CERTIFICATE Tick boxes and enter details, as appropriate

Means of Earthing	**Maximum demand**
Distributor's facility ☐	Maximum demand (load) .... kVA / Amps Delete as appropriate
Installation earth electrode ☐	**Details of Installation Earth Electrode** *(where applicable)* Type (e.g rod(s), tape etc) .... Location .... Electrode resistance to Earth .... Ω

Main Protective Conductors

Earthing conductor: material .... csa .... connection verified ☐

Main protective bonding conductors material .... csa .... connection verified ☐

To incoming water and/or gas service ☐ To other elements: ....

Main Switch or Circuit -breaker

Voltage rating V

BS, Type and No. of poles .... Current rating ....A

Location .... Fuse rating or setting ....A

Rated residual operating current $I_{\Delta n}$ =.......... mA, and operating time of .... ms (at $I_{\Delta n}$) (applicable only where an RCD is suitable and is used as a main circuit-breaker)

Comments on existing installation

This section requires the inspector to assess and report on an existing installation where there has been either an alteration or an addition, or both. This is not a requirement to carry out a complete periodic inspection and test, however, where there are obvious issues these should be brought to the attention of the client.

There is also a place to record the number of sheets used for the Schedules of Inspections and Results. Each sheet must be clearly numbered.

COMMENTS ON EXISTING INSTALLATION (in the case of an addition or alteration see Section 633):

....

....

....

....

SCHEDULES

The attached Schedules are part of this document and this Certificate is valid only when they are attached to it.

.... Schedules of Inspections and .... Schedules of Test Results are attached.

(Enter quantities of schedules attached).

Opinion should not be recorded and neither should solutions. A Best Practice Guide has been published by the Electrical Safety Council detailing the recommendation codes accepted by most of the major players within the industry.

Test result schedules

An EIC is not complete without schedules of inspections and test results attached.

These forms can be found in Appendix 6 of BS 7671:2008 Amd No. 1.

Minor Electrical Installation Works Certificate

A MEIWC is a single sheet document and is only to be issued where an existing circuit has been altered or added to. It should not be used for new circuits added to an existing installation or to the installation of a consumer unit.

It should not be made or authenticated by anyone other than a competent person in inspection and testing of electrical installations

The MEIWC is divided into four parts:

- Description of minor works
- Installation details
- Essential tests
- Declaration.

Description of minor works

The first part requires the general details of the installation to be recorded, including a description of the work, the address where the work was carried out, the date on which the work was completed, including the certification, and the details of any departures from the current Standard.

PART 1:Description of minor works

1. Description of the minor works
2. Location/address
3. Date minor works completed
4. Details of departures, if any, from BS 7671:2008

Installation details

Here the specific technical detail of the installation should be recorded. This will include the earthing arrangements, the method of fault protection (usually ADS), the nature of the protective device for the circuit amended and any comments worth mentioning.

PART 2:Installation details

1. System earthing arrangement TN-C-S☐ TN-S☐ TT☐
2. Method of fault protection
3. Protective device for the modified circuit Type .... Rating .... A

Comments on existing installation, including adequacy of earthing and bonding arrangements (see Regulation 131.8):

Essential tests

The essential tests for a circuit include continuity, insulation resistance, earth fault loop impedance, polarity and, where necessary, RCD test.

PART 3:Essential Tests

Earth continuity satisfactory ☐

Insulation resistance:

Line/neutral .... MΩ

Line/earth .... MΩ

Neutral/earth.. MΩ

Earth fault loop impedance .... Ω

Polarity satisfactory ☐

RCD operation (if applicable). Rated residual operating current $I_{\Delta n}$ .... mA and operating time of .... ms (at $I_{\Delta n}$)

Declaration

Someone has to take responsibility for the work that has been carried out. The declaration places that individual in the frame. The declaration requires someone to state that the work has been carried out on an existing circuit and that the additional work does not make the installation worse than it was before the work was carried out. The inspector (usually the installer) will then state the client's details and his/her own details, sign it and date it.

PART 4:Declaration

I/We CERTIFY that the said works do not impair the safety of the existing installation, that the said works have been designed, constructed, inspected and tested in accordance with BS 7671:2008 (IEE Wiring Regulations), amended to .... (date) and that the said works, to the best of my/our knowledge and belief, at the time of my/our inspection, complied with BS 7671:2008 except as detailed in Part 1 above.

Name:	Signature: ....
For and on behalf of:	Position: ....
Address:..	
....	Date:..
....	

Completion of the commissioning process

Electrical Installation Certificate

Regulation 631.1 tells us that on completion of the verification of a new installation or changes to an existing installation an Electrical Installation Certificate shall be provided to the client/customer.

Regulation 631.4 tells us that the certificate can only be compiled and signed by an electrically competent person/s.

Regulation 631.5 tells us that the certificates can be produced in any format including written and electronic media as long as it is durable. The media used must be reliable and be able to show that it is a true copy of the original.

The Electrical Installation Certificate will contain the recorded test results and a recommended interval until the first periodic inspection takes place. Appendix 6 of BS 7671 has model certificates. Schedules of inspection and schedules of test results should be issued with the Electrical Installation Certificate.

The original certificate is to be given to the person ordering the work and a duplicate should be retained by the contractor. If the person ordering the work is not the owner, then the certificate or a copy of it should be passed to the owner. This certificate is only valid if it is accompanied by the relevant schedules of inspection and testing.

The client needs to be aware that the 'original' certificate should be retained in a safe place, so that it can be used as a reference for anyone undertaking further work. It can also be used to demonstrate to potential buyer of the property that the building complied with the current British Electrical Standards at the time the certificate was issued.

Minor Electrical Installation Works Certificate

The same rules apply to the Minor Electrical Installation Works Certificate which should only be used for alteration or additions to an installation which does not include new circuit/s (Regulation 631.3).

This certificate can also be used for the replacement of equipment such as lights or accessories, but not for distribution boards and similar items.

A separate certificate should be produced for each existing circuit on which 'minor work' has been carried out.

The Electrical Installation Condition Report

This report should only be used for reporting the condition of an existing installation and should include the testing and inspection schedules.

Any items classed as (C1) danger present should be rectified immediately or the owner notified by writing as a matter of urgency.

The 'original report' should be retained in a safe place by the client, the purpose of the certificate should be explained and any defects pointed out. The need for quarterly testing of RCDs needs explaining. The date for the next recommend inspection should be discussed with the client and a label containing this information placed on or near the consumer unit or distribution board.

Exercise 11

1. A domestic installation has been rewired. What certification must be provided and who should receive it?

2. Which Regulation states the requirement for the extent of a periodic inspection of an electrical installation?

3. What are the key requirements for someone who is going to inspect and test?

4. Considering your answer to Q3, why does this matter?

5. Why is it so important that results are compared with relevant criteria?

6. A property has had some electrical work carried out within it. The electrician that carried out the work has left and not issued any documentation. You have been called out by the homeowner and asked to supply a certificate. What should you do?

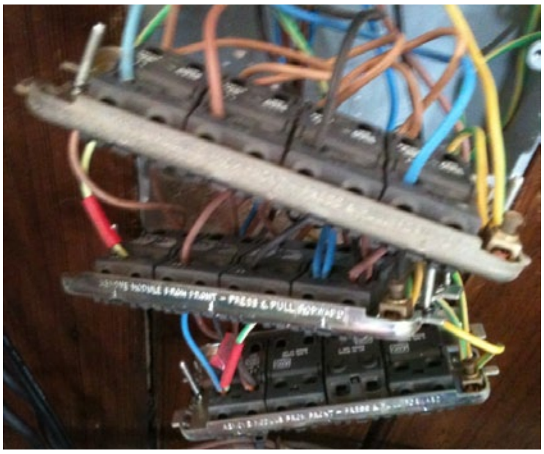
End of unit questions

1. You enter an installation to add a new circuit for a shower. The earthing system appears to be a TN-C-S system. What size main equipotential bonding conductors do you expect to find?

2. A TT system has an RCD having a rated residual operating current of 100 mA and a measured earth electrode resistance of 120 Ω. The nominal voltage is 230 V. Does this meet the requirements of Regulation 411.5.3? Give reasons for your answer.

3. During the inspection, what sort of things would the inspector be looking out for?

4. What is wrong with this picture (besides it being slightly out of focus)?



5. Which law are you breaking if you do not inspect and test

6. Name the instruments necessary to carry out the typical tests on an electrical installation.

7. Why is it necessary to maintain your test instruments?

8. You are to test a SELV circuit. What voltage/s would you use and what are the minimum values of insulation resistance?

