WiringMatters

Your insight into BS 7671

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User and maintenance instructions for modern domestic electrical installations

By: **EUR ING Graham Kenyon CEng MIET**

This article explores the changing needs in instructions for users, and information that is required to be available for maintainers, of domestic electrical installations, and is based on Section 8 of the newly-published IET *Electrician's Guide to Domestic Electrical Energy Storage Systems*.

The changing face of electrical installations

Fifty years ago, it was not uncommon to see new houses with as few as four or six final circuits, perhaps comprising, for example:

- a shower (or cooker)
- downstairs socket-outlets
- upstairs socket-outlets
- upstairs lighting
- downstairs lighting
- a spare (or outbuilding).

As time progressed, new and less expensive protective devices entered the market, and installations began to include far more circuits. Simple domestic installations began to include circuits for:

- an intruder alarm
- a fire detection and alarm system (where not connected via a lighting circuit)
- a garage (which itself might have had multiple circuits)
- outside lighting (and possibly garden socket-outlets).

It was also more cost-effective to include residual current device (RCD) protection on individual circuits by selecting appropriate combined residual current breakers with over-current protection (RCBOs).

Today's new domestic electrical installations are becoming more complex. Supported by developments in BS 7671 and relevant legislation, they may cater for:

- solar photovoltaic (PV) renewable generation sources (Section 712 was included in BS 7671:2008)
- electric vehicle (EV) charging (Section 722 was introduced in Amendment 2:2013 to BS 7671:2008)
- coordinated energy management and overall considerations for prosumer's electrical installations, or PEIs (Chapter 82 was introduced in BS 7671:2018+A2:2022)
- battery storage (a new Chapter 57 of BS 7671 was proposed in the Draft for Public Consultation of Amendment 4 to BS 7671:2018).

Installations now include automatic functions and controls, managed by system software. Not every installation will be configured to operate in the same way.

User instructions

Traditionally, installation work will be provided with relevant electrical installation certification, along with, where relevant, manufacturer's manuals for equipment.

Since modern installations may differ between configurations and options selected, and operation may be complex, provision of traditional information alone is not likely to be suitable. Users will typically require brief operational and emergency procedures for basic functions of the key systems in the electrical installation (energy management, solar PV, battery storage, etc.). These might include:

- step-by step user start-up and shutdown procedures
- procedure for emergency shutdown by users
- safety precautions and procedures in the event of an incident
- meaning of main indications, alarms and fault codes
- contact details for help, repair, maintenance and warranty.

The above information should be compiled into clear, succinct information, and should not rely on the users searching through lengthy product information. However, some information may be suited to being provided on instruction notices in prominent positions near relevant equipment. An alternative may be to provide non-emergency information via a two-dimensional barcode URL link, or on any smartphone or web app used to manage the system.

Where relevant, specific information will also be provided by the installer for internet connectivity and system security. That might include:

- information on which equipment is required to be connected to a home Wi-Fi network, and details of how to change the network connection, connect to a new Wi-Fi network and enter Wi-Fi network passwords
- requirements for password complexity and security
- details of how to report security issues with products
- information on how security updates are to be provided, and how frequently
- download details and helpdesk details for smartphone or web apps used to control and/or monitor parts of the electrical installation.

Maintenance instructions

The Construction (Design and Management) Regulations 2015 require designers to eliminate, so far as reasonably practicable, foreseeable risks to the health and safety of anyone maintaining the structure, which includes the electrical installation. The requirement applies to all electrical installations, including domestic installations. The person maintaining some or all of the domestic PEI may not always be the original installer. It is recommended that electrical work is carried out only by those competent to do so; however, it is reasonably foreseeable that some electrical maintenance work might be carried out, or attempted, by homeowners themselves.

As with user instructions, the information in product and system manufacturer's manuals is extensive, and it might be difficult to locate information that is key to the safety of the installation. In addition, the manuals often contain different options for configuration of the system, and it is imperative that relevant information on the actual configuration is available.

Sufficient, clear information should therefore be provided with the installation in respect to the principal hazards.

Where information is provided in the form of diagrams or charts, these should be durable (for example, laminated) and provided in an accessible place such as a technical document holder adjacent to relevant electrical equipment. Alternatively, diagrams or charts might be provided in an accessible electronic form such as portable document format (PDF), accessible from a maintained website, for example, via a two-dimensional barcoded URL that the maintainer can freely and readily access.

Functionality for PEIs might include:

- remote or automatic switching of energy to circuits or electrical equipment
- remote or automatic control of supply transfer arrangements when switching to island mode (where the installation ceases to be connected to the grid, and is supplied from local generation sources such as energy storage systems and solar PV (see Figure 1)).

Figure 1 Domestic loads powered in island mode

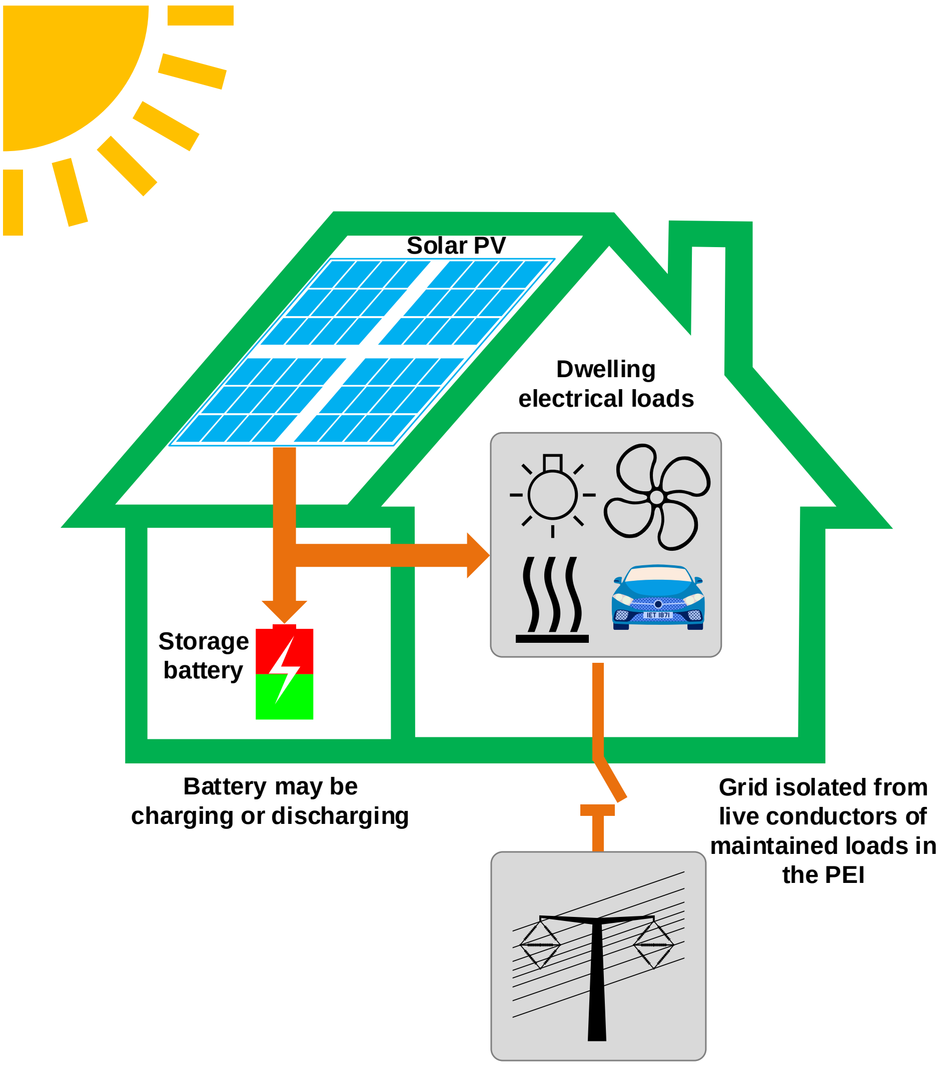


Table 1 provides examples of hazards that can be present in domestic PEIs, and the information that could be provided for maintainers working on the installation.

Table 1 Examples of provision of information for safe maintenance of prosumer's electrical installations

Example hazards	Examples of reasons for additional consideration	Examples of maintenance information relevant to the hazards
Safe isolation	Automatic switching and sources of supply vary between installations	• Warning notices for alternative or additional supplies according to Regulation 514.15 of BS 7671, at relevant distribution boards and points of isolation • Clear marking of functional switching devices, isolators and protective devices used for isolation to indicate what they serve • Warning notices on distribution boards for maintained loads, indicating that the

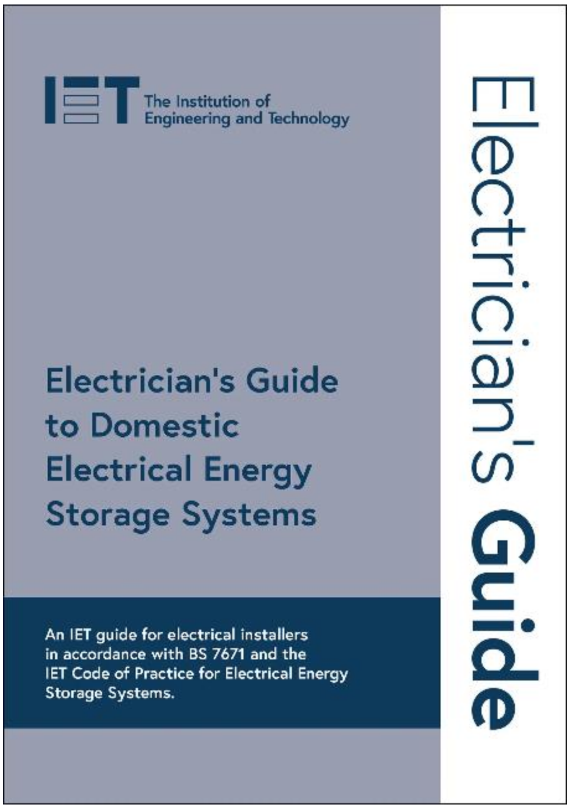
		supply might be energized when the grid power is lost • System diagrams highlighting the location of functional switching devices that might operate remotely or automatically • 'Solar PV in installation' and other notices as required by Regulation 712.514 of BS 7671
Battery hazards	Varies with battery chemistry and between different manufacturer's products	• Suitable warning and instruction notices that might include (as relevant): o 'Battery in premises' notices as required by Clause 8.2.2 of PAS 63100 o Warning notice of accessible battery voltage (particularly where this exceeds 60 V DC (see Clause 11.1 in both BS EN IEC 62485-2:2018 and BS EN IEC 62485-5:2021)) o Instruction notice to use insulated tools o Instruction to wear suitable arc flash protective equipment o Warnings of relevant chemical hazards o Other notices recommended by the battery manufacturer • Suitable information on arrangements for ventilation of the battery system
Location, arrangement and operation of automatic/remote switching arrangements	Varies between installations and manufacturers' products	Include information on appropriate system diagrams

Conclusion

As electrical installations become more complex, more information is necessary for their users and maintainers. Because manufacturer's instructions are often extensive and relate to various options of configuration of an installation, suitable, relevant information should be compiled by the installer and made available to the users and maintainers of an installation. This will assist the installer and designer of the modifications to the installation in fulfilling their duties under the Construction (Design and Management) Regulations 2015.

Post-scriptum or call-out

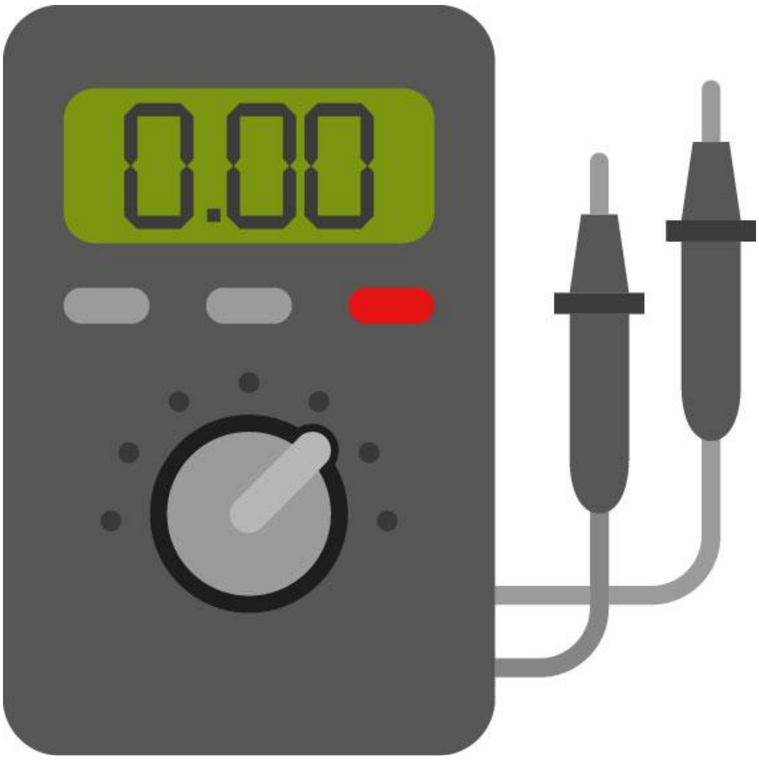
The IET *Electrician's Guide to Domestic Electrical Energy Storage Systems* launched on 2 April 2025 and is now available from the IET Bookshop.



The publication provides practical, hands-on guidance on the installation of domestic electrical energy storage systems, specifically looking at:

- benefits and limitations of domestic electrical energy storage systems
- planning permissions and consents
- electrical design, system arrangements and schematics
- fire safety and electrical safety, specifically in relation to domestic battery installations
- data communications, control and monitoring, and information security
- inspection, testing and commissioning
- user and maintenance instructions.

The guide accompanies BS 7671:2018+A3:2024 and the IET *Code of Practice for Electrical Energy Storage Systems, 3rd Edition,* and is intended to be used by training providers, certification and awarding bodies, electrical contractors, electrical installers and new entrants into the industry. It might also be useful for international manufacturers seeking an overview of legislation, installation practices and safety requirements for the UK domestic electrical energy storage market. Presented in a way that is easily understandable by practitioners, it is packed full of practical illustrations and example calculations, as well as appendices with useful information.



Minimizing unnecessary live testing for initial verification

By: **Michael Peace CEng MIET**

Initial verification is the process of inspection, testing and certification. This is an important process that is carried out before putting an electrical installation into service. This article focuses on the testing aspect of this important process and looks at the minimum level of live testing required to verify the protective measure, automatic disconnection of supply (ADS), in the event of a fault in an electrical installation, in accordance with BS 7671:2018+A3:2024 (referred to as BS 7671 hereafter).

What is initial verification?

Regulation 641.1 of BS 7671 requires every installation, during erection and on completion, to be inspected and tested before being put into service to verify, so far as is reasonably practicable, that the requirements of BS 7671 have been met.

Regulation 641.4 states that “precautions shall be taken to avoid danger to persons and livestock, and to avoid damage to property and installed equipment, during inspection and testing.”

What are common working practices?

It is often the case that people do things a certain way because they have been taught that way and never questioned it. Many inspectors and testers carry out earth fault loop impedance testing for all circuits, which is not necessary and can be potentially dangerous. The information required for initial verification can often be obtained using dead testing. To be safe and to keep on the right side of the law, live working needs to be minimized. It is important to ask yourself; could some testing be done dead?

What is required by the law?

The Electricity at Work Regulations (EAWR) 1989 apply to all employed and self-employed persons. Every work activity, including operation, use and maintenance of a system, and work near a system, shall be carried out in such a manner as not to give rise, so far as is reasonably practicable, to danger.

Regulation 14 of the EAWR states:

Work on or near live conductors

> ***14.*** *No person shall be engaged in any work activity on or so near any live conductor (other than one suitably covered with insulating material so as to prevent danger) that danger may arise unless–*
>
> > *(a) it is unreasonable in all the circumstances for it to be dead; and*
> > *(b) it is reasonable in all the 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.*

If an accident occurred when carrying out live testing, the question that would be asked in a court of law would be; was it necessary to carry out live testing? For some aspects of initial verification, it is clearly necessary to carry out live tests but not in all instances.

What tests are required to be carried out by BS 7671?

Regulation 643.1 of BS 7671 states that the tests of Regulation 643.2 to 643.11, *where relevant***,** shall be carried out and the results compared with relevant criteria. The words “where relevant” are important as they mean exactly that.

The sequence of tests for initial verification in Figure 1 is extracted from IET *Guidance Note 3: Inspection & Testing, 9th Edition*. The tests are described in Regulations 643.2 to 643.11 of BS 7671.

Figure 1 Sequence of tests for initial verification

Regulation Group	Test description	Section in this Guidance Note	Safety considerations
643.2	Continuity of protective conductors, including main earthing conductor, and main and supplementary protective bonding conductors	2.6.5	Regulation 643.1 requires the tests in Regulations 643.2 to 643.6 inclusive tests to be conducted (where relevant for the particular installation) in the order shown, prior to the installation being energized. It is strongly recommended to address any unsatisfactory conditions discovered during a test, before proceeding with any subsequent tests.
643.2	Continuity of ring final circuit conductors	2.6.6	
643.3	Insulation resistance	2.6.7	
643.4	Protection by SELV, PELV or electrical separation	2.6.8 2.8.9	
643.5	Insulation resistance of non-conducting floors and walls (*rarely required*)	2.6.11	
643.6	Polarity	2.6.12	
643.7	Protection by automatic disconnection of supply. Test as relevant: • *Earth electrode resistance** • *Earth fault loop impedance* • *Operation of RCDs*	2.6.14 *2.6.13* *2.6.15* *2.6.18*	*Where present, Regulation 643.1 requires earth electrode resistance to be measured prior to energization. These tests may involve parts of the installation being energized, depending on the test method adopted.
	Prospective fault current	2.6.16	
643.8	Additional protection. *A test is required to verify the operation of RCDs used for additional protection*	2.6.18	
643.9	Check of phase sequence	2.6.17	
643.10	Functional testing	2.6.18 2.6.19	
643.11	Verification of voltage drop	2.6.20	

How to determine the characteristics of available supply or supplies?

Regulation 132.2 of BS 7671 states that “information on the characteristics of the available supply or supplies shall be determined by calculation, measurement, enquiry or inspection.” Therefore, it is permitted to determine the external earth fault loop impedance (Z_e) and prospective fault current (PFC) by enquiry to the distribution network operator (DNO). However, an enquiry to the DNO is likely to result in being quoted the maximum PFC for a single-phase supply of 16 kA and the typical declared maximum Z_e values for supplies up to 100 A, as in Table 1:

Table 1 Typical maximum external earth fault loop impedance values

System	Z_e
TN-C-S	0.35 Ω
TN-S	0.8 Ω
TT	21 Ω

NOTE 1: In ENA ER P23/1:1991, this value was quoted for both protective multiple earthing (PME) and protective neutral bonding (PNB) earthing arrangements. Higher values may apply where the consumer was supplied from small capacity pole-mounted transformers and/or long lengths of low voltage overhead line.

NOTE 2: The external earth fault loop impedance for TT systems consists of the resistance of the neutral to earth plus the impedance of the transformer winding and line conductor, but does not include the resistance of the consumer's earth electrode.

The DNO, distribution system operator (DSO) or independent distribution network operator (IDNO) are required to provide this information in writing, according to Regulation 27 and Regulation 28 of the Electricity Safety, Quality and Continuity Regulations 2002, as amended (ESQCR), or Regulations 28 and 29 of ESQCR (NI).

In some cases, this is not helpful because the maximum earth fault loop impedance for a device could be lower than the Z_e value stated. For example, according to Table 41.3 of BS 7671, the maximum earth fault loop impedance for an 80 A Type C circuit-breaker to BS EN 60898 is 0.27 Ω. This is not helpful as it could lead to designers specifying residual current devices (RCDs) for fault protection unnecessarily.

The other issue with determining Z_e by enquiry is that it doesn't verify that the installation is earthed. The safest way to determine earth fault loop impedance is to measure external earth fault loop impedance once and calculate the earth fault loop impedance values using measured $R_1 + R_2$ values.

Regulation 643.7.3.201 of BS 7671 requires the PFC to be measured, calculated or determined by another method, at the origin and at other relevant points in the installation. However, in domestic (household) premises, where a consumer unit that conforms to BS EN 61439-3 is used and the maximum PFC declared by the distributor is 16 kA, it is not necessary to measure or calculate PFC at the origin of the supply. Appendix 14 of BS 7671 provides further information.

For installations other than domestic (household) premises, the PFC can be measured at the same time as carrying out external earth fault loop impedance testing.

What is required to determine earth fault loop impedance?

The most common live test carried out unnecessarily is earth fault loop impedance testing. A value of Z_s is required to verify ADS in accordance with Section 411 of BS 7671. Regulation 643.7.3.1 states that "Where protective measures are used which require a knowledge of earth fault loop impedance, the relevant impedances shall be measured, or determined by an alternative method."

An alternative method of determining Z_s is by calculation. To determine the earth fault loop impedance, it is simply a case of adding the measured $R_1 + R_2$ value for the circuit to the Z_e value. The $R_1 + R_2$ value is the resistance of the line conductor (R_1) and circuit protective conductor (R_2), which are determined by dead testing. This reduces the need to access live terminals multiple times unnecessarily. $R_1 + R_2$ testing can also aid in verifying polarity. It would not be considered acceptable to measure the Z_s and subtract the Z_e value to calculate the $R_1 + R_2$ values. This is because the Z_e is measured excluding any parallel paths, whereas Z_s includes parallel paths and therefore, usually results in lower measured Z_s values.

Where overcurrent protective devices such as fuses or circuit-breakers are used, Z_s shall be measured or determined by an alternative method, such as calculation as described previously. The results are compared with maximum earth fault loop impedance values from manufacturers' data or from Table 41.2, Table 41.3 and Table 41.4 of BS 7671. It is important to note that the maximum values listed will need to be adjusted to allow for temperature correction. This is explained in further detail in this IET *Wiring Matters* article by Craig O' Neill.

This is to verify that the Z_s value is sufficiently low to create an earth fault current high enough to operate the protective device within the maximum disconnection times stated in Table 41.1 of BS 7671.

How to verify automatic disconnection of supply for residual current device protected circuits

Where the protective measure ADS is used, the method of verification depends on the protective device. Where RCDs are used for fault protection, knowledge of earth fault loop impedance is not as important because RCDs to BS EN 61008/61009 are designed to operate within 300 ms at the rated residual current. So, the value of earth fault loop impedance doesn't affect the disconnection time, but it is important to ensure that the value is low enough to provide an earth fault current sufficient to operate the RCD. For example, the maximum earth fault loop impedance for a 30 mA RCD to conform to Regulation 411.4.4 of BS 7671 for TN systems is 7283 Ω (see the calculation below).

$$Z_s \times I_a \leq U_0 \times C_{min}$$

Rearranged to determine the maximum permitted Z_s:

$$Z_s \leq \frac{U_0 \times C_{min}}{I_a}$$
$$Z_s \leq \frac{230\,V \times 0.95}{0.03\,A}$$
$$Z_s \leq 7283\,\Omega$$

where:

Z_s is the impedance in ohms (Ω) of the fault loop comprising:

- the source
- the line conductor up to the point of the fault
- the protective conductor between the point of the fault and the source.

I_a is the current in amperes (A) causing the automatic operation of the protective device within the time specified in Regulation 411.3.2.2, or Regulation 411.3.2.3, of BS 7671. When an RCD is used, this current is the residual operating current providing disconnection in the time specified in Regulation 411.3.2.2, or Regulation 411.3.2.3

U_0 is nominal AC RMS or ripple-free DC line voltage to Earth.

C_{min} is the minimum voltage factor to take account of voltage variations depending on time and place, changing of transformer taps and other considerations.

NOTE: For a low voltage supply given in accordance with the ESQCR, C_{min} is given the value 0.95.

Where RCDs are used for TN systems, Regulation 411.4.204 of BS 7671 states that Table 41.5 may be applied. However, it is important to note that the maximum earth fault loop impedances are derived from a touch voltage of 50 V, not 230 V.

Where RCDs are used for TT systems, Regulation 411.5.3 of BS 7671 applies, which refers to Table 41.5, therefore, $R_A \times I_{\Delta n} \leq 50$ V.

Figure 2 Maximum earth loop impedance values for TT systems

TABLE 41.5 –
Maximum earth fault loop impedance (Z_S) for non-delayed and time delayed 'S' Type RCDs to BS EN 61008-1 and BS EN 61009-1 for U_0 of 230 V (see Regulation 411.5.3)

Rated residual operating current (mA)	Maximum earth fault loop impedance Z_s (ohms)
30	1667*
100	500*
300	167
500	100

Disconnection shall be within the times stated in Table 41.1.

NOTE 1: Figures for Z_S result from the application of Regulation 411.5.3(i) and (ii).

NOTE 2: * The resistance of the installation earth electrode should be as low as practicable. A value exceeding 200 ohms may not be stable. Refer to Regulation 542.2.4.

Where RCDs are used for fault protection, Regulation 643.7 of BS 7671 states that verification shall be made by visual inspection and testing. Visual inspection is required to confirm the RCD is the correct type and rating. Testing is required to verify that the RCD operates within the time stated by the product standard, for example, BS EN 61008 and BS EN 61009.

It is often argued that RCDs are products and should not require testing if they conform to the product standard. After all, BS 7671 does not require testing of other protective devices, such as circuit-breakers, surge protective devices (SPDs) and arc fault detection devices (AFDDs).

However, Regulation 643.7.1 of BS 7671 requires RCD testing where RCDs are used for fault protection or additional protection. Regardless of RCD type, effectiveness is deemed to have been verified where an RCD disconnects within 300 ms for general non-delay type RCDs with an alternating current test at rated residual operating current ($I_{\Delta n}$).

Regulation 643.7 also states that:

> "Where the effectiveness of the protective measure has been confirmed at a point located downstream of an RCD, the protection of the installation downstream from this point may be proved by confirmation of the continuity of the protective conductors."

This means that earth fault loop impedance testing is not required downstream of an RCD. Continuity of protective conductors is deemed sufficient to confirm the effectiveness of ADS.

What testing is required?

Each electrical installation is different, and appropriate testing needs to be selected according to the protective measures. For example, it is common for a residual current operated circuit-breaker with integral overcurrent protection (RCBO) to be used on each circuit for a domestic installation. In such cases, the minimum testing to be carried out is:

- continuity of protective conductor
- continuity of live conductors for ring final circuits
- insulation resistance
- polarity
- external earth fault impedance
- polarity of the supply at the origin of the installation
- RCD testing.

In this case, the only live testing required to be applied is external earth fault loop impedance, polarity of the supply at the origin of the installation and RCD testing. This requires only one live test at source and one RCD test for each RCD. If Z_s testing was carried out, this could increase the amount of live testing needed.

RCD testing should be carried out at the outgoing terminals of the RCD. This is to prevent the wiring or connected equipment from influencing the test results. However, it is often argued that it is safer to carry out the testing with a plug-in test lead at a socket-outlet with no other equipment connected in the circuit. This would remove the need for being exposed to live parts.

Regulation 643.6 of BS 7671 requires the polarity of the supply at the origin of the installation to be verified before the installation is energized. This is a test that can only be carried out live. This test can be carried out at the same time as measuring external earth fault loop impedance. The indicators on a multi-function test instrument will verify polarity at the same time as carrying out an earth fault loop impedance test, so it doesn't need to be a separate test.

What other testing is required in BS 7671?

Regulation 643.9 provides requirements for 'check of phase sequence'. It states that "for polyphase circuits, it shall be verified that the phase sequence is maintained at all relevant points throughout the installation." Checking phase sequence is carried out by visual inspection by checking that the line conductors are connected to the appropriate terminals throughout the installation. Phase sequence is a dead test and is often confused with phase rotation which is a live test. BS 7671 does not provide requirements for phase rotation testing. Phase rotation testing may be required in some circumstances, for example, to determine whether a motor will rotate in the correct direction.

Summary

Initial verification can be carried out in a number of ways. It should not be the case of doing it a particular way because that's the way it has always been done.

Regulation 14 of the EAWR states that no work shall be carried out on or near live conductors unless it is unreasonable for them to be dead. For initial verification, it would be difficult to argue that it is unreasonable for the installation to be dead for certain tests.

Periodic inspection and testing may pose different challenges to initial verification. Either for initial verification or periodic inspection, it is important that a risk assessment is carried out to determine what live testing is to be undertaken. Where live testing is required, suitable precautions shall be taken as required by Regulation 14 of the EAWR.

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Guide to Temporary Electrical Systems, 2nd Edition

By: **James Eade**

The IET's *Guide to Temporary Electrical Systems* has finally arrived after undergoing a long-awaited update. As regular readers of *Wiring Matters* will appreciate, the field of electrical safety constantly evolves, with standards, equipment, tools and techniques all improving and changing over time. Since the first edition in 2012, the world of temporary power has changed considerably, though not necessarily in how it is used; after all, the need for a temporary supply and associated distribution is a requirement as old as the need for electrical installations in buildings.

The use of temporary power is very widespread, from railways, military services, construction, festivals, street markets, temporary funfairs, exhibitions and more. While the underlying theme of the book is temporary power for events, the advice and guidance covering generators to cable selection, and design methodologies to hybrid system deployment, are universal and apply to any other sector using temporary electrical systems because the design requirements are drawn from BS 7671.

Compared to the first edition, two significant changes are noteworthy. Firstly, much work is underway, both nationally and internationally, regarding generator use and their earthing arrangements; the understanding of system topologies and protection is now much advanced. While much of the standards development is still underway and yet to be published, the *Guide to Temporary Electrical Systems* gives guidance based on the latest knowledge in this area and is unique in the UK.

The second significant progression has been in renewable energy. Clearly, the days of the combustion engine are waning and hydrogen and solar are becoming more established as energy sources, though they are still limited in capacity at a practical level. Renewable fuels for diesel engines are popular, but the veracity of the environmental credentials for vegetable oil-based diesel has recently come under the spotlight, with some companies refusing to use it.

Rather than the energy sources, perhaps the biggest benefit has been the development of large-scale battery storage, with capacities in the region of up to 400-500 kVA available in transportable formats. The use of such systems allows hybridization of generator packages which is important in the move to Stage V emissions compliant diesel engines. Running such generators on low loads often results in unexpected shutdowns as the exhaust temperatures do not get hot enough for the emissions filters to work effectively; hybridizing a system with energy storage allows the generator to work hard for shorter durations, bringing the exhaust temperature up and alleviating the problem. As the generator will usually operate in parallel with the battery unit, it is important to consider earthing arrangements and the effects of circulating currents. Another key aspect with battery systems is their performance under fault conditions – many inverters will not deliver the current required to operate the protective devices in a distribution, so managing protection for faults requires more diligence on the part of the designer.

Along with these issues, the updated guide looks at the considerations around energy storage capacities, as well as how battery units can integrate into generation systems, such as working in a simple hybrid mode or as a mini-grid with other generators operating in a load-on-demand configuration, for example.

On the subject of generators, information on generator control and operation has been updated and now includes guidance on parallel operation of sets, leading power factors and the stability of generator sets powering capacitive loads, such as switched-mode power supplies, as commonly found in most modern equipment and lighting. The (often vexed) question over generator earthing – or lack of – has been significantly revised to take into account the previous work published in the IET *Practitioner's Guide to Temporary Power Systems*. Importantly, the requirements for specifying appropriate earth electrode resistances are explained, along with the typical failure modes experienced with temporary systems.

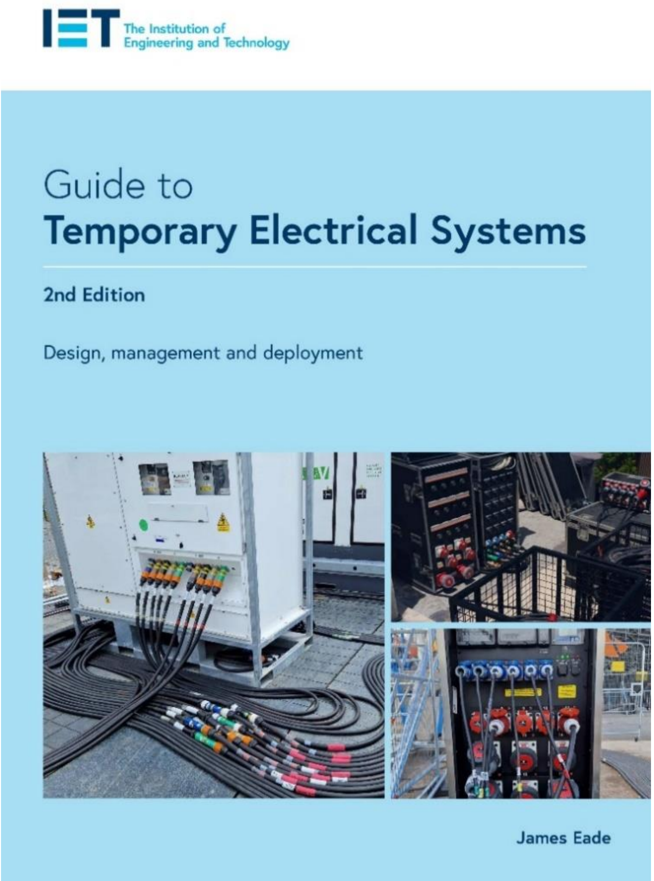
Another section to receive a makeover is "Mobile and transportable units", which range from temporary site huts and office cabins through to complex broadcast vehicles. In general, the requirements relating to equipment selection detailed in Part 717 of BS 7671 are quite straightforward, but the design is sometimes less so. There are diagrams in Part 717 which give examples of how the supply and earthing arrangements to a unit may be configured but understanding the benefits and drawbacks of each can be a challenge. These are all explained in the revised section, in particular, the benefits of transformer-based designs with respect to mitigating shock risks in the event of supply neutral (PEN) conductor failure where units are connected to the public distribution.

"Protective earthing" has been revised to provide more guidance on determining extraneous-conductive-parts in and around temporary structures and the appropriate requirements for protective bonding. In a similar vein, the need to join electrical environments (in essence, separate electrical sources and distributions) is often necessary where multiple supplies are operating in proximity to each other. This has been considered in more detail (including fault current paths), building on the guidance in BS 7909.

Supply resilience is increasingly important in installations as well as with temporary systems. The section on uninterruptible power supplies has been expanded and updated and now includes information on the hazards associated with neutral switching on uninterruptible power supply (UPS) inputs for example, as well as looking at how inverters behave when faults occur on the output, which can vary between designs. Supply resilience in the event of emergencies is important for events where there may be large numbers of the public present. Systems may have to be kept operational for crowd control purposes and this is very important for outdoor events where thunderstorms can roll in. The guide has a completely revised section on management of the temporary systems when lightning is forecast, taking into account recent industry guidance on the subject.

While these are headline changes, there are of course a significant number of updates arising from the revisions to BS 7671 and BS 7909, and other relevant guidance. The former has undergone a range of changes since the first edition of the book, with salient topics including cables in escape routes, the use of arc fault detection devices, surge protective devices and the application of 30 mA residual current devices (RCDs) on socket-outlets rated at 32 A or less. BS 7909:2023+A1:2024 is the first major revision of the standard since the last one in 2011. Many of the changes reflect those in BS 7671, whereas others relate to generator operation, earthing and renewables, for example, which are explored in more detail in this guide.

The IET *Guide to Temporary Electrical Systems, 2nd Edition* is now available to purchase from the IET Bookshop.



Neutral current diversion (NCD) – industry research update

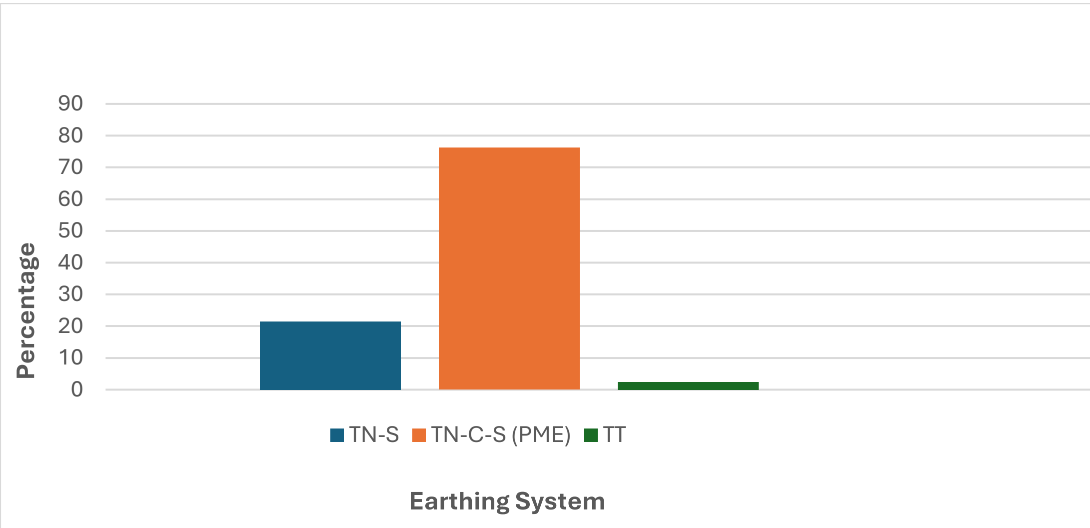
By: **Calum Mansell IEng MIET**

Last year, the IET set out to gain information on 'neutral current diversion', working with industry partners NICEIC, ECA, Electrical Safety First, NAPIT, and SELECT. To support our research, we asked electrical installers and inspectors to answer a series of questions upon discovery of 'neutral current diversion'. This article presents the information received from the industry, along with a commentary on the results.

What was the most common earthing system reported?

The TN-C-S protective multiple earthing system (PME) was the most common form of system recorded approximately 76 % of the time, followed by the TN-S system at 22 %, and the remaining 2 % being TT systems (see Figure 1).

Figure 1 Most common earthing systems reported



It is widely accepted that the TN-C-S (PME) system is provided for new installations. A cable which contains phase conductor(s) and a combined protective earth and neutral conductor is used within the distributor's network. This combined conductor is used for the protective earthing and neutral functions and is known as the protective earthed neutral (PEN) conductor.

Whilst BS 7671, *Requirements for Electrical Installations*[1], "Part 2 Definitions", refers to the term 'PEN conductor', it is common for Distribution Network Operators (DNOs) to use the term combined neutral and earth (CNE) cable. Neutral current diversion (NCD) occurs where the PEN conductor is broken.

Prior to the introduction of PME, the network cable of choice was the separate neutral earth (SNE) cable. However, SNE cables in the network have become increasingly rare due to modifications, fault repair and the increase of CNE cables installed within sections of the network. The Energy Networks Association (ENA) provides guidance on PME networks in the form of the *Engineering Recommendation G12, Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks, Issue 5, 2023*[2] and references the term 'hybrid network' where SNE (TN-S) cables were originally installed and, over time, CNE cables have been inserted. The TN-S system requires a continuous earth connection all the way back to the supply transformer; however, with the rise in the number of hybrid networks, it could be argued that very few TN-S systems exist in the public distribution network.

Recognizing this, the IET *Code of Practice for Electric Vehicle Charging Equipment Installations, 5th Edition*[3], has advised designers to treat TN-S systems as TN-C-S (PME) unless it can be guaranteed that the TN-S system extends back to the supply transformer and will not be modified in the future. An example of this could be where a TN-S system is supplied by a private transformer.

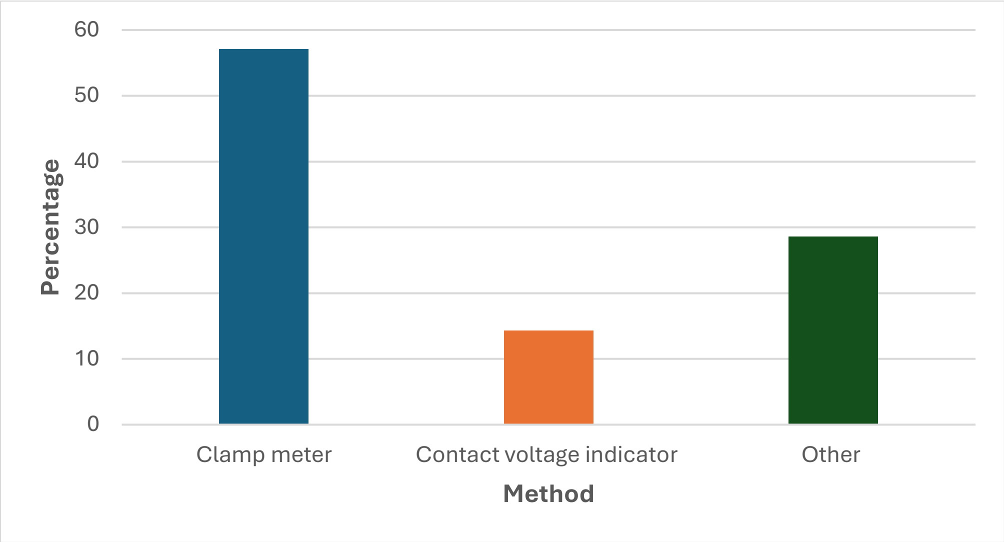
Where older installations may have been converted from a TN-S to TN-C-S (PME) system, the cross-sectional area of any main protective bonding conductors should be verified as suitable for continued use. This is due to older installations often having smaller main protective bonding conductors in situ; this, coupled with the risk of open PEN conditions in TN-C-S (PME) systems, may increase the risk of thermal damage to conductors.

While the amount of TT systems recorded was low, it is important to consider that in the event of an open PEN conductor, voltage could appear on a TT system. Designers are therefore required to maintain separation below ground between earth electrodes and buried conductive parts connected to TN-C-S (PME) systems. Local DNOs may have specific requirements for maintaining separation, which should be confirmed before installation. For additional guidance, see BS 7340:2011+A1:2015 *Code of practice for protective earthing of electrical installations*[4], which contains information on potentials around earth electrodes.

What method was used to determine neutral current diversion?

The application of a clamp meter, both before and after isolation of the installation, provides a useful check of any current flowing in the earthing conductor and the main protective bonding conductor(s) while identifying changes in load. Approximately 57 % of those who responded utilized a clamp meter to determine NCD, a method identified in Table D1 of the IET's *Guidance Note 3: Inspection & Testing, 9th Edition*[5], followed by 14 % who used a contact voltage indicator. Other methods included the use of multimeters, data loggers and visual signs of arcing, making up the remaining 29 % (see Figure 2).

Figure 2 Method used to determine neutral current diversion



One respondent reported they were first alerted to the possibility of current diversion due to sparks on the gas service installation pipework when verifying the continuity of conductors (test method 2) with the installation isolated.

Within older electrical installations, extraneous-conductive-parts often take the form of metallic water and gas installation pipework, as opposed to the modern-day preference of plastic. In the case of an open PEN conductor, the path the current takes is effectively determined by the load and impedance on the network. Extraneous-conductive-parts offer low impedance paths for neutral current to flow, potentially resulting in a significant heat build-up that can lead to fires and gas explosions.

Another respondent reported that the current recorded at the installation they were working at was subsequently found to have originated from an adjoining installation. This is a general theme of the comments and highlights that NCD can affect multiple installations at a time.

What was the average voltage/current measured?

In 67 % of cases, respondents found an unexpected voltage that first highlighted NCD. The average current measured through the earthing conductor and/or extraneous-conductive-parts was 12 A, while the highest current recorded was 67 A.

As mentioned earlier in the article, the path taken by the current is effectively determined by the impedance of each available path and the load on the network at a given time. This is validated by the comments provided by a respondent, in which they report there was little to no current at the point of beginning the work. However, as the work progressed, a load was added to the installation next door, which resulted in 43 A being recorded at the installation being worked upon.

Precautions should be taken when disconnecting any earthing and protective bonding conductors. Where an open PEN conductor exists, the removal of the earthing conductor or protective bonding conductors can cause hazardous touch voltages to appear on extraneous-conductive-parts and exposed-conductive-parts.

Table D1 of the IET's *Guidance Note 3: Inspection & Testing, 9th Edition*, confirms that a non-contact voltage indicator, commonly referred to as a volt-stick, can be utilized to check for voltage at extraneous-conductive-parts, as well as the main earth terminal, the earthing conductor and the main protective bonding conductors. It is important to remember that a non-contact voltage indicator is a proximity device and should not be used for proving equipment as dead; however, it can be useful in identifying live equipment.

It is not just electricians who are noticing the effects of NCD. Information provided by another respondent attending an emergency call-out following a gas engineer reporting "sparks on the gas installation pipework when a nut was undone" recorded 3.9 A present. The gas industry has produced information and guidance relating to safe-to-touch and safe isolation for gas engineers when carrying out gas work – The Gas Safe Register, Technical Bulletin (TB) 118a, ***Safe to touch and/or safe isolation and proving electrically dead on low voltage single-phase supplies (below 1000 volts)*****, Feb 2023**[6]. The process of 'safe-to-touch' is a custom practice within the gas industry, where a non-contact voltage indicator is used to ensure a hazardous touch voltage is not present due to a fault condition by touching appliance casings, gas and water installation pipework. Additionally, Network Rail has provided all electrically and non-electrically trained members of staff with non-contact voltage indicators to check for any potentially dangerous voltages.

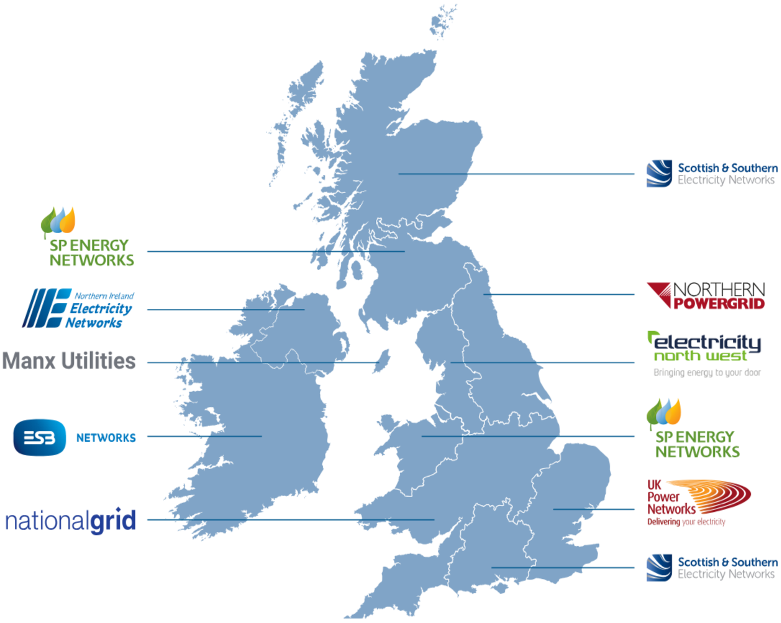
Did all respondents contact the DNO following the identification of neutral current diversion?

The percentage of respondents who reported the incident to the respective DNO was around 49 %, with the DNO attending in all but one of those cases.

Regulation 114.1 of BS 7671 states that for a supply provided in accordance with the Electricity Safety, Quality and Continuity Regulations (ESQCR), "it shall be deemed that the connection with Earth of the neutral of the supply is permanent." DNOs have responsibilities under the ESQCR, which is a statutory document.

It should be remembered that NCD can cause hazardous touch voltages to appear on the extraneous-conductive-parts and exposed-conductive-parts of the installation, as well as fire, explosion and damage to electrical equipment. Therefore, the IET and our industry partners strongly advise anyone who suspects NCD is present to report without delay to their local DNO by calling 105 (see Figure 3).

Figure 3 Map of the UK and Ireland's distribution network operators
https://www.energynetworks.org/energy-networks-explained[7]



Where was neutral current diversion reported?

The results have highlighted parts of the UK with significantly higher occurrences of NCD, for example, the Midlands and the South East of England; however, no significant volumes of NCD were reported in Wales, Northern Ireland and the North of England (see Figure 4). The rationale behind obtaining the location of NCD is to identify patterns of occurrence, be that in a specific part of the UK, DNO or several incidents within the same postcode region.

Figure 4 Map of the UK indicating where neutral current diversion was reported

While we have received a great deal of information regarding NCD incidents from industry, we feel that additional information would only benefit our research; therefore, we have decided to leave the survey open at this point to continue our investigation.

How do I report neutral current diversion?

Should NCD be detected, we ask that you submit your findings.

Please use the QRCode or visit **https://response.questback.com/theiet/wipzxj3tay** where you will be presented with a number of simple questions.

Acknowledgments

- Craig O'Neill
- Frank Bertie
- Leon Markwell
- Luke Osborne
- Michael Peace

Further information

- **IET Bookshop: *IET Guidance Note 3: Inspection & Testing, 9th Edition***
- **IET *Wiring Matters* "Broken PEN" (Issue 84, March 2021)**
- **IET *Wiring Matters* "Neutral current diversion (NCD) - industry research" (Issue 101, July 2024)**

References

1. BS 7671 *Requirements for Electrical Installations, IET Wiring Regulations, Eighteenth Edition*
2. ENA *Engineering Recommendation G12, Requirements for the Application of Protective Multiple Earthing to Low Voltage Networks, Issue 5, 2023*
3. IET *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition*
4. BS 7340:2011+A1:2015 *Code of practice for protective earthing of electrical installations*
5. IET *Guidance Note 3: Inspection & Testing, 9th Edition*
6. Technical Bulletin 118a *Safe to touch and/or safe isolation and proving electrically dead on low-voltage single-phase supplies (below 1000 volts)*
7. Who's my electricity network operator? – Energy Networks Association (ENA)