WiringMatters

Your insight into BS 7671

theiet.org/wm

Buried conduits and ducts

Which ones offer equivalent mechanical protection to armoured cables when buried in the ground?

Mythbuster! "Event distribution boards with socket-outlets are not permitted for use on construction sites"

Challenging this misconception with information from industry standards

Competency in the electrical installation industry

Exploring the background of competency and what it means

The Institution of Engineering and Technology

In partnership with CEF Your Electrical Experts

CEF

YOUR ELECTRICAL EXPERTS

products available online with next day delivery

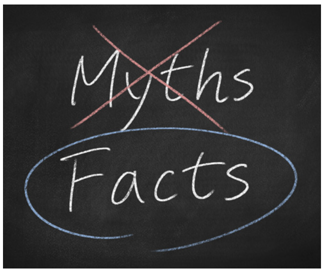
Branch | App | Catalogue | Online

cef.co.uk

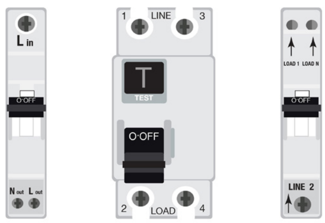
Contents

6

11



14



Welcome to the Wiring Matters 2025 Annual

@IET_WM

We are pleased to bring you this year's annual which collects some of the most popular Wiring Matters articles from 2024.

Here in the Codes and Guidance Team at the IET, the last year saw the publication of several titles including the *Code of Practice for Electrical Energy Storage Systems, 3rd Edition,* the *Guide to Depot Charging of Electric Heavy Goods Vehicles*, the *Guide to Electric Vehicle Charging Infrastructure for Local Authorities* and the IET's first standard, *Open combined protective and neutral (PEN) conductor detection devices (OPDDs), IET 01:2024.*

These titles and many more can be found at:
https://electrical.theiet.org/guidance-and-codes-of-practice/

We also published Amendment 3 (2024) to BS 7671:2018 IET Wiring Regulations, which is available to download as a free PDF 'bolt-on' and is an addition to Amendment 2 (2022) - the brown book. Amendment 3 introduces a new regulation (530.3.201) for the use of bidirectional and unidirectional devices, and two new definitions. It can be downloaded at: **https://www.theiet.org/updates**

Last year, and into 2025, our national technical committee (JPEL/64), BSI and the IET are working hard to revise and amend BS 7671 to make way for Amendment 4. This amendment will address the need for essential industry requirements for electrical installations, to keep pace with rapidly emerging technologies coming on to the market, and is expected to publish in 2026.

Looking ahead to 2025, there are several new publications in the pipeline. Those coming soon include *Temporary Electrical Systems - A guide to the application of BS 7671 and BS 7909 for events, 2nd Edition,* the *Guide to Prosumer Electrical Installations, Electric Vehicle Charging Installations at Filling Stations, 2nd Edition* and the *Electrician's Guide to Domestic Electrical Energy Storage Systems*. Keep an eye out for further news on these titles as they become available.

We are very grateful for the continued support of you, our readers, and as always, we would be keen to hear from you with suggestions for future articles, or any feedback you'd like to share with us. Please don't hesitate to get in touch by emailing us at **wiringmatters@theiet.org.**

I very much hope you enjoy the Wiring Matters 2025 Annual and will see you in March for the first digital newsletter of the year.

Susannah Girt
Editor, Wiring Matters

Figure 1 Cable marker tape

Buried conduits and ducts

Which conduits and ducts offer equivalent mechanical protection to armoured cables when buried in the ground?

By: Michael Peace CEng MIET MCIBSE

The use of unarmoured cables, such as HO7RN-F rubber flexible cables or unarmoured XLPE cables buried in the ground, is becoming more popular, especially for DC string wiring of photovoltaic (PV) systems and for certain interconnections in electric vehicle (EV) charging installations.

For such installations, it is necessary for the cables to have sufficient mechanical protection. This article looks at the use of such cables and the type of conduit and ducting that should be used where these cables are buried in the ground.

What are the requirements for cables buried in the ground?

Regulation 14(2) of the Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002 and Regulation 15(2) of the ESQCR (Northern Ireland) 2012, require that all buried cables shall be installed at a sufficient depth, or otherwise protected, to avoid damage or danger.

For public and private electrical installations, Regulation 522.8.10 of BS 7671:2018+A2:2022+A3:2024 (referred to as BS 7671 thereafter) provides requirements for cables buried in the ground. Generally, a cable buried in the ground is required to incorporate an earthed armour or metallic sheath or both, suitable for use as a protective conductor.

The location of a buried cable is also required to be marked by cable covers (see Figure 2) or a suitable marker tape (see Figure 1).

Alternatively, Regulation 522.8.10 of BS 7671 permits an unarmoured cable to be buried in the ground that is installed in a conduit or duct that provides equivalent protection against mechanical damage.

Which conduit and ducts offer equivalent mechanical protection to armoured cables?

The note to Regulation 522.8.10 of BS 7671 cites BS EN 61386-24 as the standard for underground conduits. BS EN 61386 is titled, *Conduit systems for cable management, Part 24: Particular requirements – Conduit systems buried underground*. The word duct is not included in the standard. However, BS EN 61386-24 provides requirements for nominal sizes of ducts or conduits from 25 mm to 250 mm in diameter.

BS EN 61386-24 requires the conduit or duct to be marked to indicate the impact rating as detailed in Clause 6 of BS EN 61836-24:2010. Code L is used to identify light resistance to impact, whereas code N is used for normal resistance to impact. Following the resistance to impact rating, the resistance to compression code rating is required, '250', '450' or '750', according to the resistance to compression.

Type N450 and Type N750 are intended to be directly buried in the ground without additional precautions. Whilst many N750-rated ducting solutions comprise rigid ducting, N750-rated flexible duct solutions are available.

What is the minimum impact and compression rating for conduit and ducts?

The minimum impact rating of N450 should be used for an unarmoured cable. The required impact and compression rating of duct will depend on the ground above and its intended use. For example, where heavy traffic is expected, a higher rating will be required but this becomes a matter for a civil engineer.

Section 5.10.3 of the IET *Code of Practice for Grid-connected Solar Photovoltaic Systems, 2nd Edition* recommends a buried conduit or duct should meet the classification of N750. This is the same specification for a duct required by distribution network operators (DNOs) and distribution system operators (DSOs) for public distribution network cables.

What does 'suitably identified' mean?

Regulation 522.8.10 of BS 7671 states that buried conduits and ducts shall be suitably identified. Ducts are usually identified by colour according to the service, for example, black is used for low-voltage electricity, red is used for high-voltage electricity, yellow for gas and blue for water.

The Streetworks UK publication, *Guidelines on the Positioning and Colour Coding of Underground Utilities' Apparatus*, is aimed at contractors working on public highways, such as work for a DNO's network, but there is nothing to prevent the publication being used for general electrical installations.

What is suitable marking for buried cables?

Regulation 522.8.10 of BS 7671 requires the location of buried cables to be marked by cable covers or a suitable marker tape. Cable covers or marker tape is laid above the buried duct or cables to provide an early warning that electric cables are present (see Figure 1 and Figure 2). Some marker tapes include a metallic strip which can be detected using a cable detection tool.

To offer additional mechanical protection, cable covers can be installed above ducts to provide an early indication there are electric ducts present (see Figure 2).

> Buried cables, conduits and ducts shall be at a sufficient depth to avoid being damaged by any reasonably foreseeable disturbance of the ground.

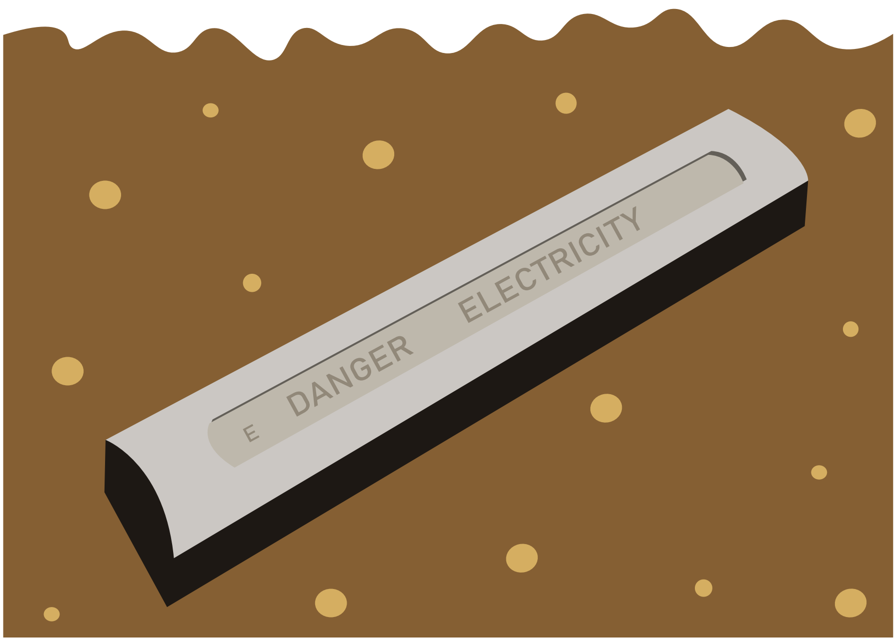


Figure 2 Illustration of a concrete cable cover for buried cables

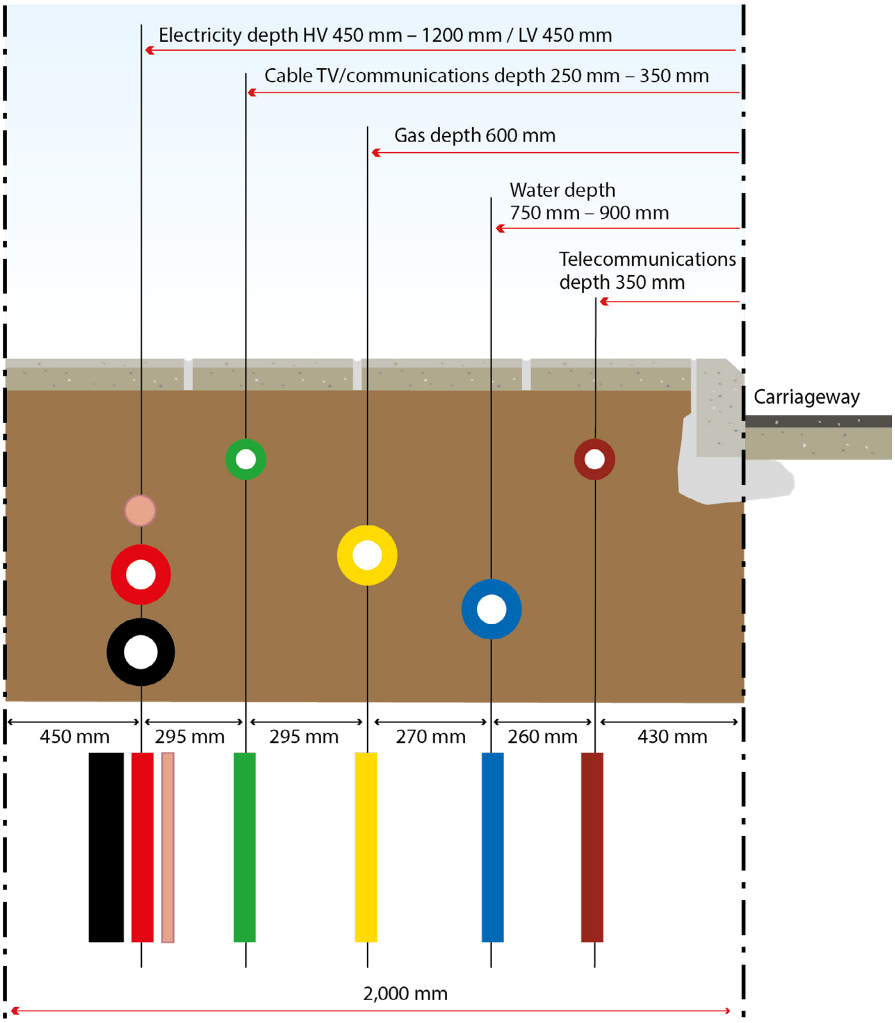


Figure 3 Recommended minimum cable depths for footways

What are the sufficient depths for buried cables, conduits and ducts?

Buried cables, conduits and ducts shall be at a sufficient depth to avoid being damaged by any reasonably foreseeable disturbance of the ground. This may seem ambiguous but there are so many variables that it would be difficult to cover all situations. Essentially, it is an engineering judgment made by the designer of the electrical installation.

In some cases, particularly undeveloped land, land where a major construction redevelopment is taking place, or where the conditions are otherwise unknown, it may be necessary to commission a ground survey and/or take the advice of a civil engineering groundworks specialist.

The Streetworks UK publication also provides guidelines on recommended minimum depths for buried services in a 2 m footway (see Figure 3).

For low-voltage cables, a minimum depth of 450 mm is recommended. As with identification, there is nothing to prevent installers choosing to use these depths for general electrical installations; however, this is not a requirement called for in BS 7671.

For installations where the ground preparation does not meet highway constructional standards, IET *Guidance Note 1: Selection & Erection* recommends a minimum depth of 500 mm to protect the cable from damage from ground movement and frost heave.

A summary of the various requirements and recommendations surrounding cable depth is provided in Appendix K to the IET *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition* (see Table 1), and Appendix E to the IET *Code of Practice for Grid-connected Solar Photovoltaic Systems, 2nd Edition*.

In some special installations or locations, such as those detailed in Part 7 of BS 7671, minimum depths of burial are specified. It should be noted that these are minimum depths, not targets, and deeper burial may be necessary in some cases to prevent damage by reasonably foreseeable disturbance of the ground. Such locations include:

- In Section 705 Agricultural and Horticultural Premises, Regulation 705.522 specifies a minimum depth of burial of 0.6 m, increasing to a minimum depth of 1.0 m for arable or cultivated ground.
- In Sections 708 Electrical Installations in Caravan / Camping Parks and Similar Locations, and 730 Onshore Units Of Electrical Shore Connections For Inland Navigation Vessels, a minimum depth of 0.6 m is required (see Regulations 708.521.7.2 and 730.521.101.3.2).
- In Section 709 Marinas and Similar Locations, Regulation 709.521.1.7 requires a minimum depth of 0.5 m.

Where cables or ducts are buried in soft ground, account should be taken of ground compression from vehicle or machinery movement over wet or damp ground, frost heave, and sinking of soft back-fill where trenches are dug.

Where armoured cables are not earthed

Earthed armoured cables are typically associated with the protective measure automatic disconnection of supply (ADS). If any of the live conductors come into contact with the earthed armour, the associated protective device disconnects the supply in accordance with Section 411 of BS 7671. There would be no advantage providing earthed armouring for unearthed DC systems such as EV charging and the DC side of PV systems - in fact, doing so could create a hazardous situation.

Table 1 Minimum depth or burial of low and extra-low-voltage cables from Appendix K to the IET *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition*

Area classification of ground under which cable is buried (NOTE 1)	Minimum depth of burial (NOTES 2 and 3)	References to requirements and guidance
General minimum depth (unless within ducts encased in concrete)	0.5 m	Regulation 522.8.10 of BS 7671. Section 5.6 of IET Guidance Note 1: *Selection & Erection*
Agricultural (general, and including areas where livestock graze)	0.6 m	Regulation 705.522 of BS 7671
Agricultural (arable or cultivated ground)	1.0 m	
Caravan sites	0.6 m	Regulation 708.521.7.2 of BS 7671
Marinas	0.5 m	Regulation 709.521.1.7 of BS 7671
Shore connection points for inland navigation vessels	0.6 m	Regulation 730.521.101.3.2 of BS 7671
Highway – footway, verge or bridleway (NOTE 4)	0.5 m	Regulation 522.8.10 of BS 7671. Section 5.6 of IET Guidance Note 1: *Selection & Erection* Street Works UK Publication Volume 1 – Street Works UK Guidelines on the Positioning and Colour Coding of Underground Utilities' Apparatus
Highway – carriageway (NOTE 4)	0.6 m	

NOTE 1: Where an area under which cables are buried may come under two classifications, the most onerous (deepest) minimum depth applies.
NOTE 2: Depth is to top of duct (or top of cable if cables with earthed metallic armour are directly buried).
NOTE 3: Where cables or ducts are buried in soft ground, the depths should be increased by 400 mm to account for ground compression from vehicle or machinery movement over wet or damp ground, frost heave, and sinking of soft ground back-fill.
NOTE 4: See also Table K.2 and Figure K.1.

For example, take a PV system and consider, if the armour was earthed to the AC system and it came into contact with a DC conductor, effectively it creates an earthed DC system. Regulation 712.312.2 permits earthing of one of the live conductors where there is simple separation between the AC and DC side. However, most inverters are transformerless inverters without simple separation.

The armouring of a cable is considered an exposed-conductive-part and therefore, it must be earthed. If the armour is unearthed and a live DC conductor from a PV string came into contact with the unearthed armouring, the armour would be live during daylight, at a voltage up to 1,500 V DC. With no method of disconnecting the supply, this is potentially a very dangerous situation.

The protective measure used for the DC side of PV systems is typically double or reinforced insulation in accordance with Section 412 of BS 7671. The principle of this protective measure is that the insulation prevents live conductors coming into contact with each other and with metallic parts, reducing the possibility of short-circuit or earth faults occurring.

The requirements in Regulation 712.521.101 of BS 7671 and Section 412 are therefore clear, in that cables should have a non-metallic sheath, or be installed in insulated conduit or trunking and the risk of contact with earth minimized.

Are there any other considerations when using ducts?

It is important to seal the ends of conduits and cable ducts using an approved method for a number of reasons, such as, to prevent foreign objects or rodents entering the duct. Another issue that is often overlooked is natural gas and water can accumulate in underground ducts. Where there is a risk of gas entering a duct, a suitable gas proof seal should be used.

Where a cable is installed in a duct, it is possible that the duct will become waterlogged. Depending on the ground conditions, for example, where the soil has a high clay content, or where the depth of burial will place the cable or duct below the water table for long periods, consideration should be given to the suitability of the cables for continuous submersion. Where there is any doubt, the manufacturers of the cable and duct are best placed to advise.

On completion of any buried cable installation, it is important to record the details of the cable route, depth and method of protection. This is useful for any future works to prevent danger or damage to the buried services.

Safety

Before any excavation is undertaken for cable, ducting or other works, HSE guidance booklet HSG47 *Avoiding danger from underground services* should be followed, as it provides valuable advice on safety aspects. In many cases, it is advisable to commission or undertake an underground services survey according to PAS 128:2022 *Underground utility detection, verification and location – Specification.*

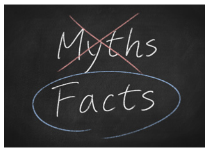
Summary

A cable installed in a duct should be installed at a depth where mechanical damage is unlikely to occur. The minimum rating of the conduit or duct that should be considered to offer the equivalent protection to armoured cables is Type N450 duct to BS EN 61386-24. However, some applications and standards require Type N750 ducts.

The rating and depth of ducting will depend on the ground conditions and the expected use. Where doubt exists, a civil engineer should be consulted. Consideration should be given to the suitability of cables installed in ducts which may become waterlogged. Ducts should be sealed at both ends to prevent mechanical damage, ingress of water or solids, gas accumulated in the ground from entering the building, or damage from fauna such as rodents or rabbits. Armoured cables are not suitable for the DC side of unearthed PV systems where the protective measure is double or reinforced insulation.

Acknowledgements

- Bob Cairney
- Craig O'Neill
- Darren Crannis
- Frank Bertie
- Gary Gundry
- Graham Kenyon
- John Peckham
- Leon Markwell
- Mark Coles
- Peter Monfort (Arena Training)
- Roberts Lapsevskis



Mythbuster #10

"Event distribution boards with socket-outlets are not permitted for use on construction sites."

By: James Eade BEng (Hons) CEng MIET

This myth stemmed from a query from a colleague and, having discussed it with a distribution board manufacturer, it appears it is not an unusual issue. The concern is that distribution boards which are fitted with connectors (exampled in Figure 1) are not as suitable for use in a typical construction environment, unlike typical steel framed boards to which incoming and outgoing circuits are manually terminated (as illustrated in Figure 2).

Many rental companies are moving over to preassembled extension leads and distribution boards as the equipment can be reused time and again without waste. It also saves time on-site, allowing functional systems to be erected and commissioned quickly using pre-terminated and pre-tested equipment.

There are three standards of relevance for this application. Firstly, BS 7671:2018+A2:2022+A3:2024 (referred to as BS 7671 thereafter) has, as well as the general rules, additional requirements for construction and demolition sites in Section 704. The second standard is BS EN 61439 *Low-voltage switchgear and controlgear assemblies* and particularly Part 4 of that standard, BS EN 61439-4 *Low-voltage switchgear and controlgear assemblies. Particular requirements for assemblies for construction sites (ACS).* The final one is BS 7375 *Distribution of electricity on construction and demolition sites. Code of practice.*

As always, it pays to start at the beginning to trace the requirements. Part 1 of BS 7671 (Scope, Object and Fundamental Principles) requires the designer to consider the environmental conditions to which the electrical installation will be subjected to (Regulation 132.5.1) and equipment should be selected, taking into consideration the conditions of the installation (Regulation 133.3), and to ensure that equipment complies with appropriate standards (Regulation 133.1).

Figure 1 Distribution board fitted with plug and socket connectors

Moving through BS 7671, Regulations 511 and 512.2 reinforce the requirements for compliance with standards and equipment selection according to external influences respectively. Notably, Regulation 512.2.2 does state that:

"If the equipment does not, by its construction, have the characteristics relevant to the external influences of the location, it may nevertheless be used on condition that it is provided with appropriate additional protection in the erection of the installation."

These requirements are expanded on in Section 704. In respect of Regulation 511, Regulation 704.511.1 details which standards as follows:

"All assemblies on construction and demolition sites for the distribution of electricity shall be in compliance with the requirements of BS EN 61439-4. Plugs and socket-outlets with a rated current

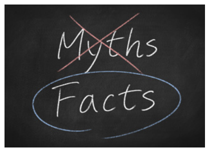


Figure 2 Rewireable metal-cased distribution unit

of 16 A up to 125 A shall comply with the requirements of BS EN 60309-2. Plugs and socket-outlets with a rated current exceeding 125 A up to 800 A and where interchangeability is not required shall comply with BS EN 60309-1."

Regulation 704.512.2 expands on the types of environmental factors to which equipment may be subject as follows:

"Consideration shall be given to the risk of damage to electrical equipment by corrosive substances, movement of structures and vehicles, wear and tear, tension, flexing, impact, abrasion, severing and ingress of liquids or solids."

Note that Regulation 704.511.1 refers to BS EN 60309-2 connectors ('Commando' or 'Ceeform' types) which is of course a characteristic of the distribution boards shown in Figure 1. Regulation group 704.522.8 goes on to state requirements for cable, noting that H07-RNF types should be used for low-voltage supplies which are commonly used with BS EN 60309 connectors in this application. The common single-pole connectors used for supplies over 125 A (often referred to by the brand name 'powerlock') are also catered for in Regulation 704.511.1.

With these requirements in mind, it can be seen that BS 7671 does not preclude the use of such distribution boards if they comply with BS EN 61439-4 and where connections are made by plug and socket, that the connections use BS EN 60309-2 connectors as depicted in Figure 1.

In respect of compliance with standards, distribution boards should be manufactured to BS EN 61439-1 and additional specific requirements for assemblies for construction sites (ACS) are given in BS EN 61439-4. This has requirements for service conditions such as ambient air temperatures, humidity and pollution levels. Part 4 also has specific requirements for labelling, handles, accessible parts and terminals for external conductors. Notably, this has requirements for terminals for external conductors, stating "All connections shall be rewireable or shall be socket-outlets."

Assuming the distribution unit is constructed to comply with Part 1 of BS EN 61439, suitably IP rated and complies with the additional mechanical, impact and corrosion requirements of Part 4, there are no particular requirements that would preclude the use of the distribution boards exampled in Figure 1.

Finally, there is the *Distribution of electricity on construction and demolition sites, Code of practice,* BS 7375. The current version is dated 2010 and is in need of revision in places, not least to review the out-of-date references. As well as general requirements for robustness, it does state inter alia that:

"Distribution equipment in site installations should embody the following features: a) flexibility in application for repeated use on contract work, i.e. to allow easy substitution of components for specific duty as might be required from site to site; b) suitability for transport and storage."

The distribution boards exampled in Figure 1 fulfill both these requirements admirably. They have long been in used in events and entertainment where such portability and robustness are key factors as they are often used in different locations on a daily basis and in quite arduous conditions.

Assuming a distribution board complies with BS EN 61439, there is no reason why it cannot be used on construction sites whether fitted with connectors or other terminations. Even if the mechanical or IP rating requirements cannot be complied with, BS 7671 does allow for additional measures to be put in place to achieve an equivalent level of protection.

The Institution of Engineering and Technology

Electrical Safety Management technical course

11 - 12 March 2025 | IET Stevenage

13 - 15 May 2025 | Live Virtual

25 - 26 November 2025 | IET Stevenage

electricalsafety.theiet.org

Bidirectional protective devices

By: Michael Peace CEng MIET MCIBSE

With the advent of alternative supplies such as solar photovoltaic (PV) and energy storage systems, power flows in both directions and bidirectional power flow is something that needs to be considered with respect to certain protective devices.

This article looks at the selection and erection of protective devices for other sources, such as PV and electrical energy storage systems, as highlighted in the *BEAMA Technical Bulletin - Connection of Unidirectional and Bidirectional Protective Devices*.

What is a unidirectional protective device?

Unidirectional protective devices are marked to indicate the line and load terminals and are designed to work when the power can only flow in one direction, i.e., from supply to load. It is vital to observe the connection details.

Single-module sized residual current breakers with over-current protection (RCBOs) have been available for several decades and utilize electronic circuits to provide residual current protection. These compact RCBOs contain electronic components and are typically unidirectional. Arc fault detection devices (AFDDs) are also typically unidirectional.

The product standard for RCBOs states that if it is necessary to distinguish between the supply and load terminals, they shall be clearly marked, for example, by line and load placed near the corresponding terminals or by arrows indicating the direction of power flow. Therefore, if a device is marked line, load, with arrows etc, it is indicating that it is necessary to distinguish between the supply and the load terminals. Not all compact RCBOs are unidirectional. Some RCBOs employ technology/solutions that ensure that the RCBO is not damaged when supplied in either direction and these are bidirectional.

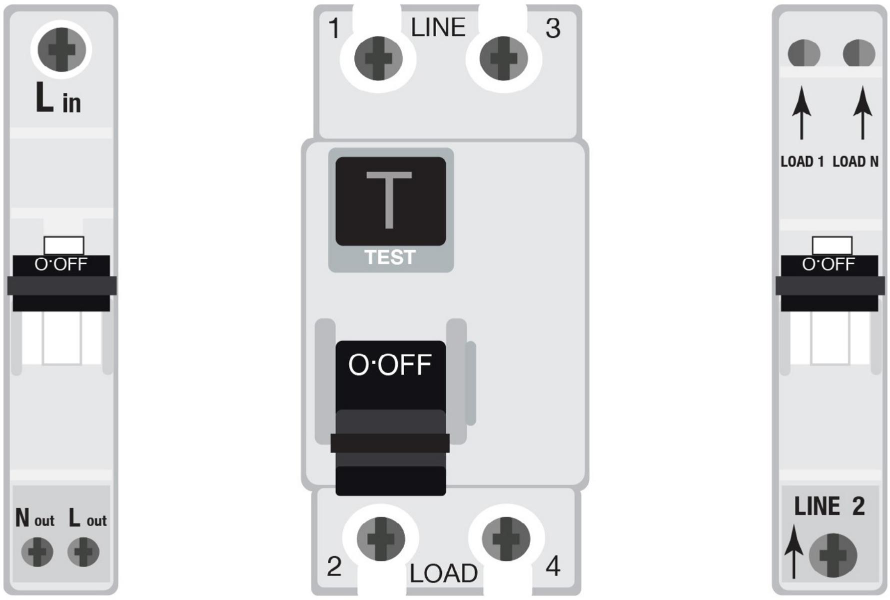


Figure 1 Protective device connection details

What is a bidirectional protective device?

A protective device that does not have markings to indicate line and load terminals is a bidirectional device, where power flow in either direction will not cause damage.

The 'typical' residual current circuit-breaker (RCCB) is an electromechanical device, however, electronic RCCBs also exist. RCCBs for consumer units are in the form of a two module-sized device. These devices are not usually marked in and out, and therefore are bidirectional. In some cases, RCCBs are marked to indicate the terminals to which the neutral or line should be connected.

Single-phase RCBOs are available in a single module, known as 'compact', and two module sizes. Two module RCBOs are not usually marked as with circuit-breakers (CBs), and thus are also bidirectional.

How are unidirectional protective devices marked?

Where required, protective devices such as CBs, RCCBs, RCBOs and AFDDs feature a marking on the device to distinguish between the supply and load terminals. This can be marked in a number of ways such as, line and load, in and out, or by using directional arrows to indicate the power flow. The connection details are shown in Figure 1.

Can unidirectional protective devices be used for other sources, such as PV systems?

In addition to Section 712 of BS 7671:2018+A2:2022+A3:2024 (referred to as BS 7671 thereafter), PV systems are also covered in Part 8 of BS 7671 which covers prosumer's electrical installations.

Regulation 826.1.2.2 states current flow and polarity should be taken into account. As with all electrical equipment, it is important to take account of manufacturer's instructions, Regulation 134.1.1 and 510.3 of BS 7671 refers.

Where an additional source in parallel to the low-voltage (LV) electrical supply is present, such as a PV generator in, the installer is faced with a dilemma. The issue is that it is not possible to follow the line and load convention where two supplies are present.

Unidirectional protective devices should not be used for such power sources as the power flow could be in either direction. Applying a power source to the load terminals of a unidirectional RCCB/ AFDD will, under certain circumstances, result in damage to the electronics, rendering the residual current protection inoperable.

Doesn't the inverter shut down automatically in the event of a short circuit or loss of mains?

The power electronic converter system (PECS), or more commonly known as the inverter, is designed to shut down, very quickly, typically milliseconds, in the event of a fault or loss of supply. The maximum trip time for loss of mains for modern PV inverters, according to EREC G98, is up to 0.5 seconds, however, some older PV inverters may have a trip time of up to 2.5 seconds.

The concern highlighted by BEAMA is that a voltage present on the outgoing terminals of the protective device, either due to the device operating in the event of an earth fault or by use of the functional test button, could cause irreparable damage.

Are residual current devices (RCDs) required for PV systems?

RCDs are not required for PV systems per se, but they may be required for other reasons, such as fault protection in TT systems or for additional protection where the AC PV inverter supply cable is buried in a wall.

The majority of PV systems are likely to be retrofit, where the cable used for the AC PV inverter supply circuit is installed surface mounted using steel wire armoured (SWA) cable. Therefore, RCD protection would not be required for additional protection in this case.

Some manufacturers discourage the use of RCDs for inverters due to leakage currents. Where possible, it is best to design it out and provide other methods of protection where required.

Where RCDs are required for generators intended to be used in parallel with the distribution network, it is important to ensure they are bidirectional.

How does this affect existing installations?

When considering existing installations, such as when carrying out an electrical installation condition report (EICR), it is important to keep things in perspective. If the electronic circuit within a RCBO was damaged by voltage on the outgoing terminals, the thermal/ magnetic part of the device would still operate, providing overload and short-circuit protection.

For TT systems, RCDs are installed to provide fault protection for the protective measure with automatic disconnection of supply (ADS). Failure of the RCD could be a serious safety issue and would require urgent remedial action.

In a situation where an RCD has been installed for additional protection, such as for cables buried in a wall, if the RCD were to fail, it would be a no more dangerous situation than an electrical installation from BS 7671:1992, the Sixteenth Edition of the IEE Wiring Regulations, when additional protection was not included in the standard at that point.

It's important to remember that the requirements of the latest version of BS 7671 are not retrospective. The Electrical Safety First (ESF) Best Practice Guide (BPG) 4 guidance states that a recommendation for improvement is appropriate for the absence of an RCD for cables buried in a wall. However, the inspector must make an engineering judgement based on the situation.

The guidance in the BEAMA Technical Bulletin is that "proportionate action" is required and it is recommended to contact the protective device manufacturer, seeking their advice as to the correct course of action.

Other considerations for RCD selection for generators

It can be easy to think only of Section 712 when considering PV systems. It sometimes gets overlooked that PV systems are in fact generators, which are covered in Section 551 of BS 7671, and it is important to remember that the general requirements also apply.

Regulation 551.7.1 of BS 7671 provides requirements where a generating set may operate in parallel with the distribution network, such as a PV system. It states that where an RCD is providing additional protection in accordance with Regulation 415.1 for a circuit connecting the generator set to the installation, the RCD shall disconnect all live conductors, including the neutral conductor. This can be in the form of a double-pole or single-pole with switched neutral protective device. It is important to check as some compact RCBOs are only available as single-pole devices. This requirement has been included in BS 7671:2008.

It is important to select the correct type of RCD according to DC residual current to prevent the RCD being blinded. Regulation 712.531.3.5.1 of BS 7671 provides requirements for RCDs for solar photovoltaic (PV) power supply systems. It states that where an RCD is used for protection of the PV AC supply circuit, the RCD shall be of Type B according to BS EN 62423 or BS EN 60947-2, unless the inverter or installation provides at least simple separation between the AC and DC side or the inverter does not require a Type B RCD as stated by the manufacturer, based on their instructions.

Summary

Bidirectional power flow of generators or energy storage systems must be considered when selecting protective devices. Unidirectional protective devices are not suitable for other sources, such as PV and battery storage systems.

There is no requirement for RCDs for PV systems as such, however, this is dependent upon the installation characteristics. To avoid unwanted tripping due to leakage currents, design the circuit in such a way that RCD protection is not required.

Where RCDs are required for PV systems, they must switch all live conductors, including the neutral. It is important to select the correct type of RCD according to the expected level of DC residual current to prevent blinding, where a Type B would be most suitable. It is important to take account of manufacturer's instructions.

The product standard for RCBOs states that if it is necessary to distinguish between the supply and load terminals, they shall be clearly marked, for example, by line and load placed near the corresponding terminals or by arrows indicating the direction of power flow. It is important to check with the manufacturer of the protective devices to confirm their suitability for bidirectional power flow.

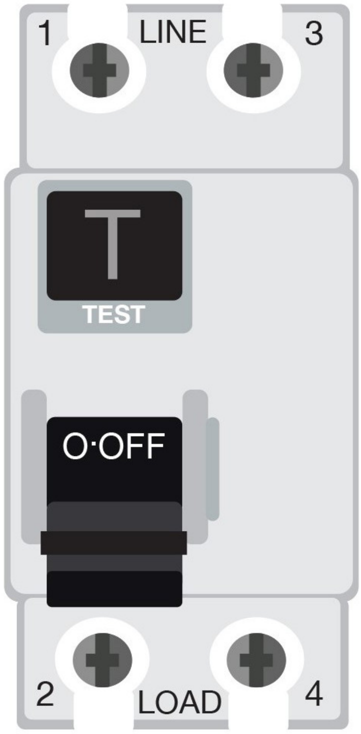
Acknowledgments

I would like to thank the following individuals for their contributions to this article:

- BEAMA
- Frank Bertie (NAPIT)
- Neil Bridgeman (RIA)
- Mark Coles (IET)
- Darren Crannis (ECA)
- Jon Elliot (Certsure)
- Leon Markwell (IET)
- Craig O'Neill (IET)
- Gary Parker (ECA)
- SELECT

Further reading

BEAMA Technical Bulletin - Connection of Unidirectional and Bidirectional Protective Devices.



Resistance and heat

Why are the values of maximum earth fault loop impedance different in BS 7671 to the IET's *On-Site Guide* and *Guidance Note 3: Inspection & Testing*?

By: Craig O' Neill BEng (Hons) MIET

The effect heat has on electrical circuits is an important concept for electricians to understand.

An increase in heat affects all aspects of a circuit. Temperature limits of the insulation, protective devices, switchgear, accessories, etc., can be compromised and the resistance of the conductors can increase.

Rating factors are published in BS 7671:2018+A2:2022+A3:2024 (referred to as BS 7671 thereafter) which enable the designer to keep temperature limits in check. Theses can be found in Tables 4A1-4C6 and Tables 4D1-4J4 of BS 7671.

This article, however, is focussing on the effect heat has on the resistivity of conductors and therefore, their resistance.

Heat and resistance theory

The effect heat can have on resistance of conductors can be seen in a simple experiment.

Using a low ohm resistance meter, a resistance of approximately 70 Ω would be displayed for a 60 W @240 V tungsten lamp at around 20 °C, if measured across the element.

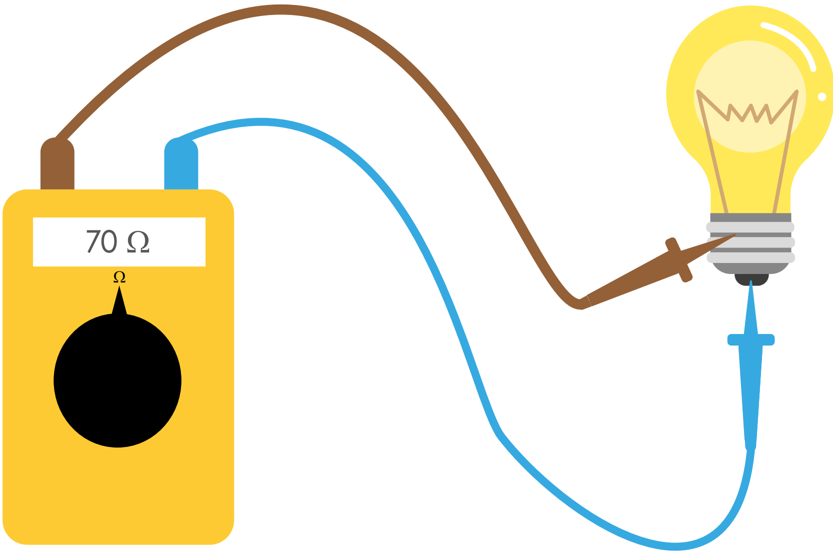


Figure 1 A low ohm resistance meter measuring the resistance of the lamp's element

Using Ohm's law, we can see that we could expect a current of:

$$V = IR \therefore I = \frac{V}{R} \therefore \frac{240}{70} = 3.43\ Amps$$

However, the manufacturer has stated the voltage and output wattage of the lamp for a reason. This is to enable a simple calculation of the expected current when the lamp is energized to the stated voltage.

$$P = VI \ \therefore I = \frac{P}{V}$$

We can see we get a different result of:

$$\frac{60}{240} = 0.25\ Amps$$

Where:
V = Voltage in volts.
I = Current in amperes.
R = Resistance in ohms (Ω).
P = Power in watts.

NOTE: *The reason for using 240 V in these calculations instead of Uo of 230 V is because most of these older lamps are rated at 240 V rather than 230 V.*

If 230 V was applied, the power output would be 55.2 W and draw a current of approximately 0.24 A based on element measuring 70 Ω at 20 °C.

The reason for the difference is that the temperature change was not considered in the first calculation. The resistance was measured at 20 °C but, when the lamp is energized with 240 V, the high resistance element gets hot – very hot! In fact, some types of elements could reach a temperature of up to 3,000 °C.

It is possible to alter the 20 °C resistance measurement and predict the approximate resistance value when the lamp is operating using the following equation:

$$R_{final} = R_o + \left(R_o\ \beta\ (\Delta t)\right)$$

(Equation 1)

Where:
R_{final} = Predicted final resistance.
R_o = Original resistance at 20 °C.
β = The temperature coefficient of resistance in ohms per degree centigrade increase. (For copper, the temperature coefficient of resistance is approx. 0.00393 Ω/°C. BS 7671 uses a value of 0.004 Ω/°C, whilst tungsten is 0.0044 Ω/°C.)
Δt = Change in temperature.

Substituting the values, we obtain a more realistic resistance reading:

$$R_{final} = 70 + (70\ \times 0.0044\ \times 2{,}980)$$
$$R_{final} = 988\ \Omega$$

And then applying Ohm's law, we get:

$$I = \frac{V}{R}$$

$$\frac{240}{988} = 0.243\ Amps$$

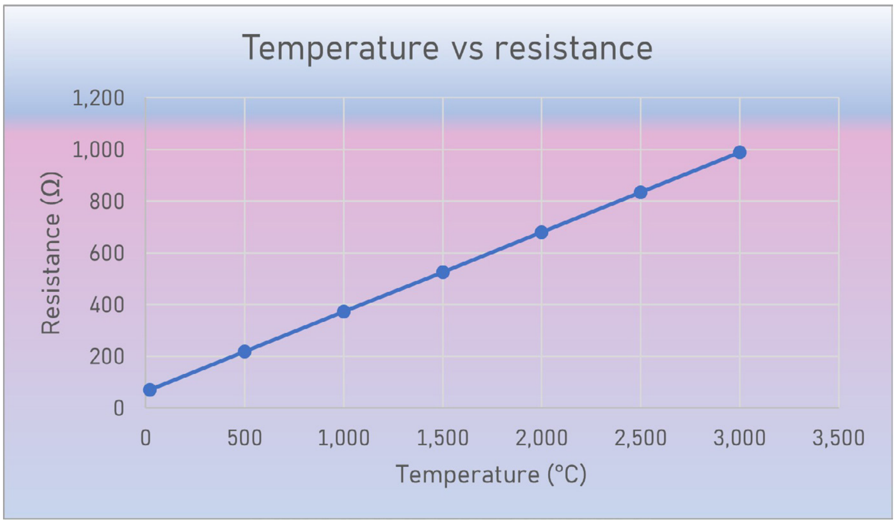


Figure 2 The linear relationship between heat and resistance

This is much closer to reality. This simple experiment shows how temperature needs to be considered with any resistance measurements.

If we calculate a few other temperatures along the way and create a quick graph, we can see a very linear relationship between an increase of heat and an increase of resistance.

Why are the values of maximum earth fault loop impedance (max Z_s) different depending on which publication you read?

You may now be able to answer this but let's look in a bit more detail about those differences.

Designing a circuit and calculating earth fault loop impedance (Z_s)

BS 7671 has tables in Chapter 41 stating max Z_s values for some of the most common protective devices. Tables 41.2-41.4 refer to values of impedance when the circuit is running at full capacity. This is commonly 70 °C however, some cables can run higher in certain circumstances, so it is important to understand Notes 2 and 3 below Tables 41.2-41.4 (see Figure 3).

These maximum Z_s values in Tables 41.2-41.4 of BS 7671 are useful when designing a circuit. The current carrying capacity tables, rating factors and volt drop values in BS 7671 are all comparative in keeping safely, yet economically, within the declared maximum permitted operating temperatures of any cable or equipment. Therefore, it makes sense to list the same values assuming similar conditions in BS 7671 for comparing max Z_s.

Guidance on how to calculate the max Z_s of a circuit is not provided within BS 7671. However, Section 7.3 of The IET's *Electrical Installation Design Guide, 5th Edition* shows how this can be calculated and confirmed to comply with BS 7671. The IET's *Electrical Installation Design Guide, 5th Edition* states:

"Circuits are designed to meet the shock protection requirements by limiting the earth fault loop impedances to the end of the circuit (Z_s) to the maximum values given in Tables 41.2 to 41.4 of BS 7671 (Z_{41})."

$$Z_{41} \geq Z_e + Z_1 + Z_2.$$

(Equation 2)

NOTE 2: The circuit loop impedances given in the table should not be exceeded when:

(i) the line conductors are at the appropriate maximum permitted operating temperature, as given in Table 52.1, and

(ii) the circuit protective conductors are at the appropriate assumed initial temperature, as given in Tables 54.2 to 54.5.

If the conductors are at a different temperature when tested, the reading should be adjusted accordingly. See Appendix 3.

NOTE 3: Where the line conductor insulation is of a type for which Table 52.1 gives a maximum permitted operating temperature exceeding 70 °C, such as thermosetting, but the conductor has been sized in accordance with Regulation 512.1.5:

(i) the maximum permitted operating temperature for the purpose of Note 2(i) is 70 °C, and

(ii) the assumed initial temperature for the purpose of Note 2(i) is that given in Tables 54.2 to 54.4 corresponding to an insulation material of 70 °C thermoplastic.

Figure 3 The Notes found below Tables 41.2-41.4 in BS 7671

Where:
Z_{41} = The max Z_s as listed in Tables 41.2-41.4 of BS 7671.
Z_e = The external part of the earth fault loop path (usually controlled by the DNO/DSO).
Z_1 = The impedance of the line conductor of the installation.
Z_2 = The impedance of the circuit protective conductor (cpc) of the installation. These are all measured in ohms (Ω).

It then shows how to calculate the earth fault loop impedance and the Z_1 and Z_2. The Z_e is usually out of the control of the designer.

The equation is shown arithmetically as:

$$Z_e + \sqrt{\left[\left(R_1'' + R_2''\right)^2 \times C_r^2 \times L^2\right] + \left[\left(X_1'' + X_2''\right)^2 \times L^2\right]} \leq Z_{41}$$

(Equation 3)

Where:
Z_{41} = The max Z_s as listed in Tables 41.2-41.4 of BS 7671 (Ω).
Z_e = The external part of the earth fault loop path (Ω) (usually controlled by the DNO/DSO).
R''_1 = The resistance per metre of the line conductor (Ω/m) (see Tables F.1 and F.7 of the *Electrical Installation Design Guide*, I1 of the *On-Site Guide* and B1 of *Guidance Note 3*).
$R_{2''}$ = The resistance per metre of the protective conductor (Ω/m) (see Tables F.1 and F.7 of the *Electrical Installation Design Guide*, I1 of the *On-Site Guide* and B1 of *Guidance Note 3*).
C_r = The correction factor for temperature (see Table F.3 of the *Electrical Installation Design Guide*, I3 the *On-Site Guide* and B3 of *Guidance Note 3*).
L = The length of cable in circuit (m).
X''_1 = The reactance per metre of the line conductor (Ω/m) (see Table F.7 of the *Electrical Installation Design Guide* and Tables 4d1-4J4 of Appendix 4, BS 7671).
X''_2 = The reactance per metre of the protective conductor (Ω/m) (see Table F.7 of the *Electrical Installation Design Guide* and Tables 4d1-4J4 of Appendix 4, BS 7671).

Note that the temperature correction factor is only applied to the resistive part of the conductor and not the reactive component.

The heat of a conductor will have no effect on reactance. Cables under 16 mm² will have negligible reactance, so for the purposes of simplicity in this article, the equation below will be used for examples:

$$Z_e + \left[\left(R_1'' + R_2''\right) \times C_r \times L\right] = Z_s$$

(Equation 4)

Example

Consider a theoretical **77 m** circuit consisting of **1.5 mm² line** and neutral conductors and a **1.0 mm²** cpc. **Z_e = 0.35 Ω, $R''_1 + R''_2$ = 0.0302 (Ω/m)** (found in Table I1 of the *On-Site Guide* or Appendix B of *Guidance Note 3*), **C_r = 1.2** (found in Table I3 of the *On-Site Guide* or B3 of *Guidance Note 3*).

With temperature correction = 0.35 + [(0.0302) × 1.2 × 77] = 3.14 Ω.

Without temperature correction = 0.35 + [(0.0302) × 77] = 2.68 Ω.

If our protective device had a max Z_{41} of 2.73 Ω and we didn't adjust for temperature in our calculations for our circuit Z_s, then we could wrongly consider the result compliant when it may not be.

Confirming a circuit max Z_s after installation

When circuits are tested, the circuit will rarely be at the max operating temperature. For initial verification, a common method is to calculate the actual Z_s value of the circuit based on the R_1+R_2 reading and a measured Z_e reading. This is sensible because it proves the circuit will likely be compliant before energizing and removes any possibilities of parallel paths such as metallic services or structural framework of a building which could skew the results and have a reduction effect on the Z_s. In this case, the conductors would have never been energized so the possibility of being at max operating temperature is unlikely to say the least!

We are therefore required to alter these values to the temperature we are testing at to ensure we are comparing the actual measurement value with the max Z_s of that temperature. Otherwise, we could pass an unsatisfactory circuit.

Some engineers like to do an additional live Z_s measurement after initial verification. This can highlight any high impedance parts of the busbar, protective devices or switchgear assemblies which may not get highlighted using a calculation method of obtaining the Z_s value. There are always safety precautions to consider with any live working and appropriate risk assessments and methods of operating are essential.

Example

The max Z_s of a 32 A B-type circuit-breaker to BS EN 60898 is listed in Table 41.3 of BS 7671 as 1.37 Ω.

If the measured Z_s on the circuit was recorded as 1.25 Ω then you could assume, possibly incorrectly, that was a pass. However, the temperature at the time of measurement was not likely to be the maximum permitted operating temperature, so we would need to find the maximum Z_s for the temperature we measured the Z_s.

Using guidance in Appendix 3 of BS 7671

Appendix 3 of BS 7671 simplifies this by taking into account the increase of the conductor resistance with increase of temperature due to load current which may be used to verify compliance with the requirements of Regulation 411.4 for TN systems (TT systems generally wouldn't comply with this without the use of residual current devices (RCDs)).

It displays an equation:

Z_{41} values

$$Z_S(m) \leq 0.8 \times \frac{U_O \times C_{min}}{I_a} \qquad \text{Equation 5}$$

Simple multiplier to reduce Z_{41} values

Where:
Z_{41} = The max Z_s as listed in Tables 41.2-41.4 of BS 7671.
$Z_s(m)$ = The measured impedance of the earth fault current loop up to the most distant point of the relevant circuit from the origin of the installation (Ω).
U_0 = The nominal AC rms line voltage to Earth (V).
I_a = The current in amps (A) causing operation of the protective device within the time stated in Table 41.1 of BS 7671 or within 5 s according to the conditions stated in Regulation 411.3.2.3.
C_{min} = The minimum voltage factor to take account of voltage variations depending on time and place, change of transformer taps and other considerations.
0.8 = The factor to take into account the increase of resistance of the conductors with the increase of temperature due to load current.

NOTE: *For a low-voltage supply given in accordance with the Electricity Safety, Quality and Continuity Regulations (ESQCR) as amended,* C_{min} *is given the value of 0.95.*

For the example above of a 32 A Type B circuit-breaker to BS EN 60898, applying the equation in Appendix 3 of BS 7671 would give a max Z_s of:

1.37 Ω x 0.8 = 1.096 Ω

Therefore, the measured Z_s of 1.25 Ω would indicate a non-compliant circuit.

This method, incidentally, provides the same values you will find in the *On-Site Guide* and *Guidance Note 3* as these publications are designed to be used in the field so publishing design values makes little sense.

Adjusting max Z_s for various conductor temperatures based on ambient temperatures using *Guidance Note 3*

Alternatively, guidance is provided in Appendix A of *Guidance Note 3* to help calculate the max Z_s at a variety of temperatures.

The simplest method is shown at the end of Section A1 which explains that the correction factors in Table A7 can be multiplied by the max Z_s values from Tables A1-A5 in *Guidance Note 3* or B2-B6 of the *On-Site Guide* to alter the max Z_s for a given ambient temperature.

Under the notes, it shows an example for a 32 A circuit-breaker to BS EN 60898 and how to adjust the 10 °C value to 25 °C. By applying the same method as the example shown for other values of ambient temperature, a similar graph can be created which shows the same heat and resistance relationship demonstrated at the start of this article.

▼ **Table A5** Circuit-breakers. Maximum measured EFLI (in Ω) at ambient temperature where the overcurrent device is a circuit-breaker to BS 3871 or BS EN 60898 or RCBO to BS EN 61009

For 0.1 to 5 s disconnection times (includes 0.4 s disconnection time)

Circuit-breaker type	Circuit-breaker rating (amps)														
	3	5	6	10	15	16	20	25	30	32	40	45	50	63	100
1	14.57	8.74	7.29	4.37	2.92	2.74	2.19	1.75	1.46	1.37	1.10	0.98	0.88	0.70	0.44
2	8.33	5.00	4.17	2.50	1.67	1.57	1.25	1.00	0.84	0.79	0.63	0.56	0.50	0.40	0.25
B	11.66	7.00	5.83	3.50	2.34	2.19	1.75	1.40	1.17	1.10	0.88	0.78	0.70	0.56	0.35
C and 3	5.83	3.50	2.92	1.75	1.17	1.10	0.88	0.70	0.59	0.55	0.44	0.39	0.35	0.28	0.18
D (0.4 s)			1.46	0.88		0.55	0.44	0.35		0.28	-	-	-	-	-
D (5 s)			2.92	1.75		1.10	0.88	0.70		0.55	0.44		0.35	0.28	0.18

Regulation 434.5.2 of BS 7671:2018 requires that the protective conductor csa meets the requirements of BS EN 60898-1-2 or BS EN 61009-1, or the minimum quoted by the manufacturer. The sizes given in Table A6 are for energy-limiting Class 3, Types B and C devices only.

▼ **Table B6** Circuit-breakers. Maximum measured earth fault loop impedance (in Ω) at ambient temperature where the overcurrent device is a circuit-breaker to BS 3871 or BS EN 60898 or RCBO to BS EN 61009

0.1 to 5 second disconnection times

Circuit-breaker type	Circuit-breaker rating (amperes)														
	3	5	6	10	15	16	20	25	30	32	40	45	50	63	100
1	14.57	8.74	7.29	4.37	2.92	2.74	2.19	1.75	1.46	1.37	1.10	0.98	0.88	0.70	0.44
2	8.33	5.00	4.17	2.50	1.67	1.57	1.25	1.00	0.84	0.79	0.63	0.56	0.50	0.40	0.25
B	11.66	7.00	5.83	3.50	2.34	2.19	1.75	1.40	1.17	1.10	0.88	0.78	0.70	0.56	0.35
C and 3	5.83	3.50	2.92	1.75	1.17	1.10	0.88	0.70	0.59	0.55	0.44	0.39	0.35	0.28	0.18
D (0.4 s)			1.46	0.88		0.55	0.44	0.35		0.28	-	-	-	-	-
D (5 s)			2.92	1.75		1.10	0.88	0.70		0.55	0.44		0.35	0.28	0.18

Regulation 434.5.2 of BS 7671 requires that the protective conductor csa meets the requirements of BS EN 60898-1, -2 or BS EN 61009-1, or the minimum quoted by the manufacturer. The sizes given in Table B7 are for energy limiting class 3, Types B and C devices only.

Figure 4 Max Z_s values for various circuit-breakers at ambient temp (10 °C). *Guidance Note 3* (Table A5) and the *On-Site Guide* (B6)

▼ **Table A7** Ambient temperature correction factors

Ambient temperature (°C)	Correction factor (from 10 °C) (Notes 1 and 2)
0	0.96
5	0.98
10	1.00
20	1.04
25	1.06
30	1.08

Notes:

1 The correction factor is given by: {1 + 0.004 (ambient temp – 20)}/{1 + 0.004 (10 - 20)} where 0.004 is the simplified resistance coefficient per °C at 20 °C given by BS EN 60228 for both copper and aluminium conductors. (Alternatively, the correction factor is given by (ambient temp + 230)/(10 + 230)).

2 The factors are different from those of Table B.2 because Table A7 corrects from 10 °C and Table B.2 from 20 °C.

The ambient correction factor of Table A7 is applied to the EFLI of Tables A1 to A5 if the ambient temperature is other than 10 °C.

For example, if the ambient temperature is 25 °C, the measured EFLI of a circuit protected by a 32 A Type B circuit-breaker to BS EN 60898 should not exceed 1.1 × 1.06 = 1.17 Ω.

Figure 5 Table A7 of *Guidance Note 3* to correct 10 values of max Z_s to other temperatures

> Some engineers like to do an additional live Z_s measurement after initial verification. This can highlight any high impedance parts of the busbar, protective devices or switchgear assemblies which may not get highlighted using a calculation method of obtaining the Z_s value.

Ambient temperature (°C)	Correction factor	Calculation	Adjusted max Z_s (Ω)
0	0.96	1.1 X 0.96	1.06
5	0.98	1.1 X 0.98	1.08
10	1	1.1 X 1	1.1
15	1.02	1.1 X 1.02	1.12
20	1.04	1.1 X 1.04	1.14
25	1.06	1.1 X 1.06	1.17
30	1.08	1.1 X 1.08	1.19

Figure 6 Table of adjusted maximum values of measured Z_s in ohms (Ω) using simplified correcting method from Appendix A of *Guidance Note 3*

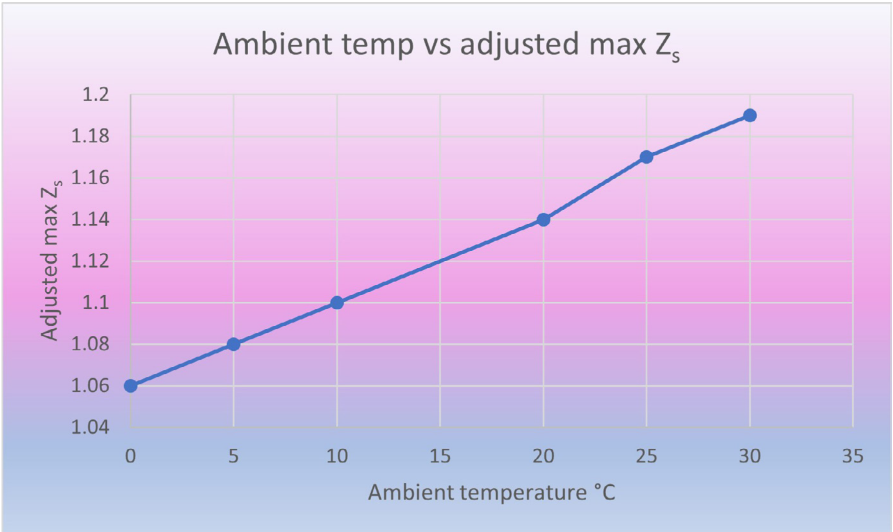


Figure 7 Graph using simplified method of ambient temperature adjustment to maximum Z_s in (Ω) from *Guidance Note 3* Appendix A

The graph in Figure 7 shows a little wobble through the line. This is because there has been rounding in the process here, so the accuracy is reduced.

Appendix A continues to show a more accurate method which either uses the correction factors in table A7 of *Guidance Note 3* or the correction factors in Table B2. Each table requires a different F factor as they are adjusting from different temperatures.

It displays an equation to use:

$$Z_{test} \leq Z_e + \frac{\alpha}{F}(Z_{41} - Z_e)$$

(Equation 6)

Where:
Z_{41} = The max Z_s as listed in Tables 41.2-41.4 of BS 7671.
Z_{test} = Max Z_s after temperature adjustment (Ω).
F = Temperature correction factor found in Table B3 Appendix B of *Guidance Note 3* (also known as Cr in the *Electrical Installation Design Guide*), Table I3 in *On-Site Guide, Guidance Note 1.*
α = Ambient temperature correction factor Table B2 Appendix B of *Guidance Note 3* or Table A7 Appendix A of *Guidance Note 3, Guidance Note 1.*
Z_e = External earth fault loop impedance (Ω).

Example

A 32 A Type B circuit-breaker to BS EN 60898 using Table A7 of *Guidance Note 3* for α and a correction factor (F) of 1.25 and assuming a Z_e of 0.35. The graph in Figure 9 now shows a better linear relationship.

Which values need to be recorded on the schedule of circuit details of the model forms?

The model form schedule of circuit details has a column number 12 labelled "Maximum permitted Z_s (Ω)§". In the notes at the bottom of the schedule, it explains what value to input in the column.

"§ Where the maximum permitted earth fault loop impedance value stated in column 12 is taken from a source other than the tabulated values given in Chapter 41 of BS 7671, state the source of the data in the appropriate cell for the circuit in the 'Remarks', column 31, of the Schedule of Test Results."

So, by default, it is expecting the values from Tables 41.2-41.4 of BS 7671 and would expect the testing engineer to adjust and compare their actual readings accordingly. Alternatively, you could use the values stated in *Guidance Note 3*/the *On-Site Guide* but you must clearly state which publication other than BS 7671 you have used in the remarks column.

Ambient temperature (°C)	Correction factor	Calculation	Adjusted max Z_s (Ω)
0	0.96	$Z_{test} = 0.35 + \frac{0.96}{1.25}(1.37 - 0.35)$	1.132
5	0.98	$Z_{test} = 0.35 + \frac{0.98}{1.25}(1.37 - 0.35)$	1.149
10	1	$Z_{test} = 0.35 + \frac{1}{1.25}(1.37 - 0.35)$	1.166
15	1.02	$Z_{test} = 0.35 + \frac{1.02}{1.25}(1.37 - 0.35)$	1.183
20	1.04	$Z_{test} = 0.35 + \frac{1.04}{1.25}(1.37 - 0.35)$	1.2
25	1.06	$Z_{test} = 0.35 + \frac{1.06}{1.25}(1.37 - 0.35)$	1.217
30	1.08	$Z_{test} = 0.35 + \frac{1.08}{1.25}(1.37 - 0.35)$	1.234

Figure 8 The table of adjusted maximum values of measured Z_s in ohms (Ω) using a more accurate correcting method given in Appendix A of *Guidance Note 3*

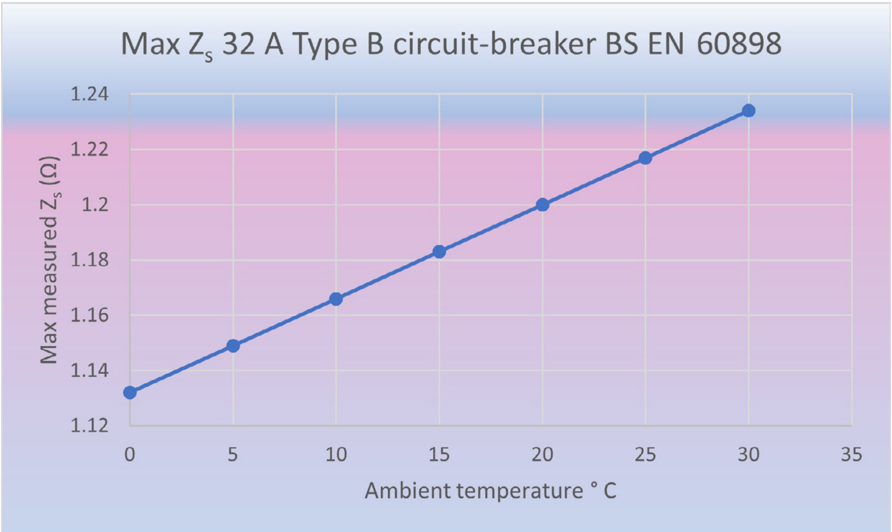
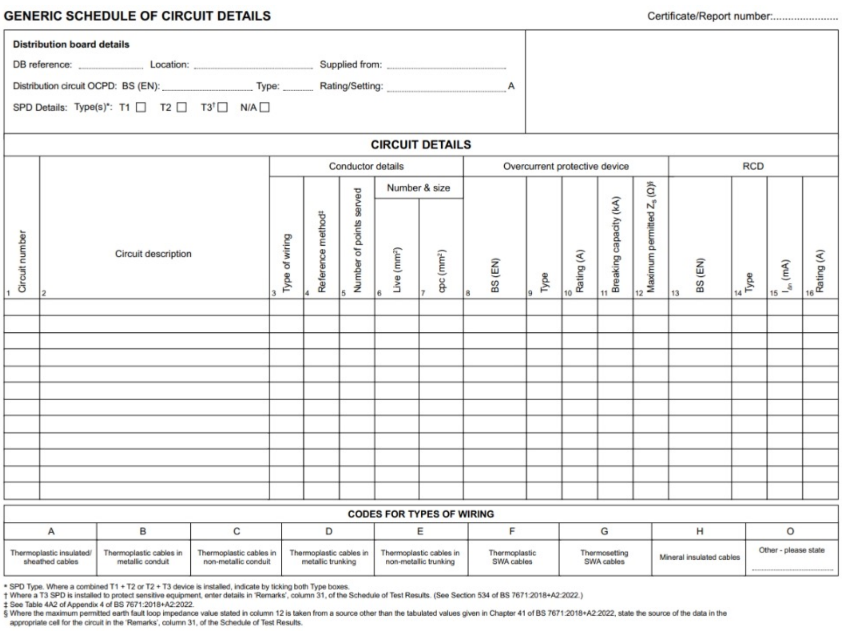


Figure 9 Graph using the more accurate method of ambient temperature adjustment to maximum Z_s in (Ω) from Appendix A of *Guidance Note 3*



GENERIC SCHEDULE OF CIRCUIT DETAILS Certificate/Report number:......................

Distribution board details

DB reference: .... Location: .... Supplied from: ....

Distribution circuit OCPD: BS (EN): .... Type: ...... Rating/Setting: .... A

SPD Details: Type(s)*: T1 ☐ T2 ☐ T3† ☐ N/A ☐

CIRCUIT DETAILS

		Conductor details					Overcurrent protective device					RCD			
					Number & size										
1 Circuit number	2 Circuit description	3 Type of wiring	4 Reference method‡	5 Number of points served	6 Live (mm²)	7 cpc (mm²)	8 BS (EN)	9 Type	10 Rating (A)	11 Breaking capacity (kA)	12 Maximum permitted Z_s (Ω)§	13 BS (EN)	14 Type	15 $I_{\Delta n}$ (mA)	16 Rating (A)

CODES FOR TYPES OF WIRING

A	B	C	D	E	F	G	H	O
Thermoplastic insulated/ sheathed cables	Thermoplastic cables in metallic conduit	Thermoplastic cables in non-metallic conduit	Thermoplastic cables in metallic trunking	Thermoplastic cables in non-metallic trunking	Thermoplastic SWA cables	Thermosetting SWA cables	Mineral insulated cables	Other - please state ....

* SPD Type. Where a combined T1 + T2 or T2 + T3 device is installed, indicate by ticking both Type boxes.
† Where a T3 SPD is installed to protect sensitive equipment, enter details in 'Remarks', column 31, of the Schedule of Test Results. (See Section 534 of BS 7671:2018+A2:2022.)
‡ See Table 4A2 of Appendix 4 of BS 7671:2018+A2:2022.
§ Where the maximum permitted earth fault loop impedance value stated in column 12 is taken from a source other than the tabulated values given in Chapter 41 of BS 7671:2018+A2:2022, state the source of the data in the appropriate cell for the circuit in the 'Remarks', column 31, of the Schedule of Test Results.

Figure 10 Model form generic schedule of circuit details from BS 7671

So, in summary:

- Increased heat in the conductor, either due to current flow or external heat application, will increase the resistance in the conductor. Designers need to be mindful of applying temperature correction in their calculations.
- Inspectors and testers need to be mindful of actual temperatures and apply the required factors to compensate and compare results with max permitted values carefully.
- The model form is expecting values published in Tables 41.2-41.4 of BS 7671 and the inspector can adjust accordingly as default but does not preclude using other publications if it is clearly cited in column 31 (Remarks) on the schedule of results sheet.

The 'C' word (competency in the electrical installation industry)

By: Eur Ing Leon Markwell MSc BSc (Hons) CEng MIET MCIBSE LCGI

It's quite surprising how many words relevant to electrical installation and electrical safety begin with the letter C. Words such as 'cable', 'current', 'contractor', 'cost', 'construction', 'certification', 'compliance', and of course the big one, 'competence'!

Since the tragic Grenfell Tower fire incident, a light has been shining on competence and it has been looked at in a way it perhaps never has been before. We are seeing new proposals for competence and competence management, but what really is competence or being competent? It is a specific requirement of Regulation 16 of the Electricity at Work Regulations 1989, which requires persons to be competent to prevent danger and injury, but there is no specific legal definition of 'competent' or 'competence'. Various non-legal attempts at defining it have been made, but in every case that goes to law, a court will decide the circumstances and competence (or a lack of it!).

A definition of 'competent person' was introduced in Part 2 of BS 7671:2008:

"**Competent person.** A person who possesses sufficient technical knowledge, relevant practical skills and experience for the nature of the electrical work undertaken and is able at all times to prevent danger and, where appropriate, injury to him/herself and others."

However, this was removed from BS 7671:2008+A3:2015 and replaced by the definition 'Skilled person (electrically)':

"**Skilled person (electrically).** Person who possesses, as appropriate to the nature of the electrical work to be undertaken, adequate education, training and practical skills, and who is able to perceive risks and avoid hazards which electricity can create."

(This is understood not to require a person to be qualified with electrical craft skills, only to have knowledge to avoid danger.)

And 'Instructed person (electrically)':

"**Instructed person (electrically).** Person adequately advised or supervised by a skilled person (as defined) to enable that person to perceive risks and to avoid hazards which electricity can create."

Unfortunately, this just provided further definitions on the same competence theme for people to understand. The 'instructed person' definition also has the 'circular' note that Regulation 16 of the Electricity at Work Regulations 1989 requires persons to be 'competent' to prevent danger and injury. However, nowhere is there any mention of experience, attitude or management processes to confirm that the required work has been correctly completed and documented.

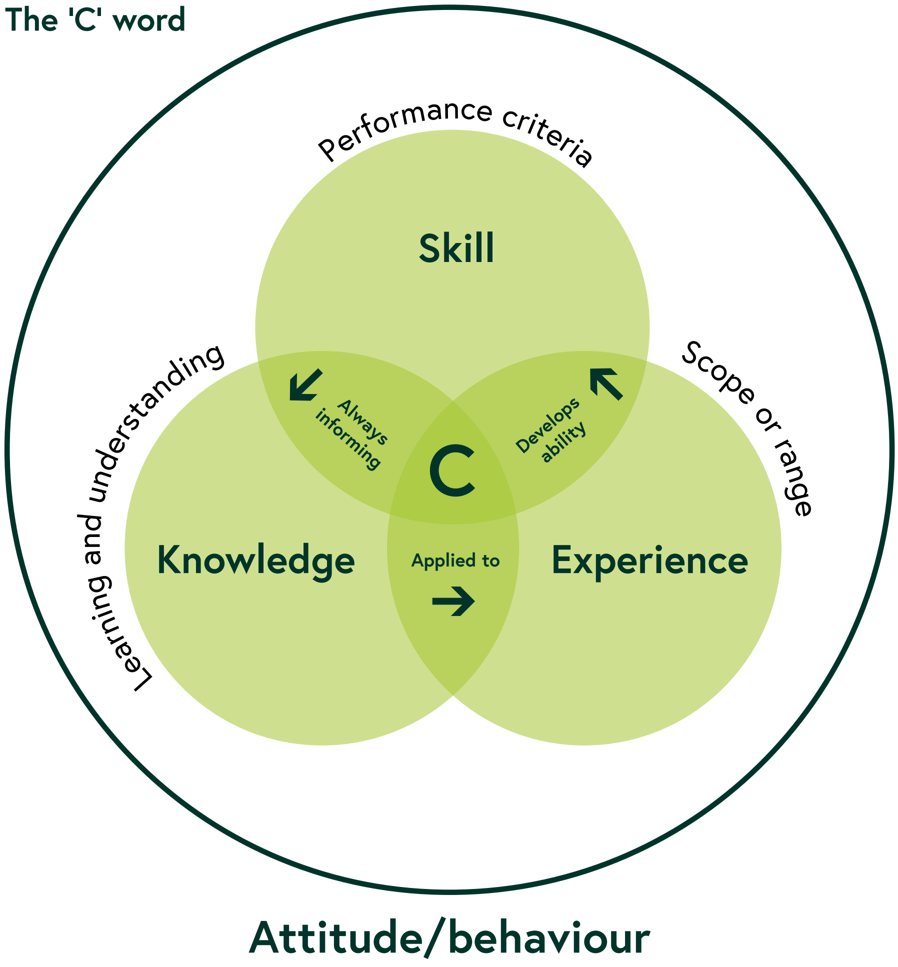
What is competence?

The term 'competency' was believed to have been created in 1973 by the American psychologist, David McClelland, to indicate the human factors by which competence depends. Initially, competencies were related to effective performance and were task and organization specific. Nowadays in education, vocational training and career guidance, the term competency indicates each personal characteristic generally utilizable in the workplace, in school or in ordinary life, regardless of the nature of the work or level of performance achievable through its use.

Almost 50 years ago, McClelland (1973) wrote his seminal article on competencies, beginning the competency movement. Competencies have since grown into a useful input for human resource (HR) tools. Input is the key word in the last sentence. A competency model in and of itself is not useful – it is just a bunch of words. Only when it is incorporated into HR practices does the model become useful, and a consequence of being used is that it becomes part of an employment decision. If that HR practice is later questioned, then the underlying competency model that serves as a foundation is open to detailed scrutiny.

Whatever the requirement, to be 'competent' is not new, and on 11 May 1882, the Society of Telegraph Engineers and of Electricians (now the IET) decided to appoint a committee to consider rules for the prevention of fire risks from electricity. Those first rules are sound general advice rather than a wiring specification. They differ in intent, as well as in content, from the 18th Edition of BS 7671. The first rules were expressly "for the guidance and instruction of those who have...electric lighting apparatus installed in their premises". The preamble to the rules makes the point that the

The 'C' word



chief dangers of electricity arise from ignorance and the chief element of safety is the employment of skilled and experienced electricians to supervise the work. (I don't believe that this advice has changed since then!)

In *How competent are you?*, a blog post on the Construction Industry Council website posted on 27 October 2020, Construction Industry Council Chief Executive Officer, Graham Watts OBE, writes:

Much more recently, evidence that was given to the Grenfell Tower Inquiry has revealed an industry that was complacent and seemingly unaware of crucial safety issues. It has also typified the industry's broken business model, which has encouraged a careless race to the bottom in terms of winning work and one that has gone unchecked by a building regulatory regime that stops well short of control. The Grenfell Tower fire has brought all of this into the sharpest focus.

While the industry must take responsibility for its own failings, recent governments are also culpable. The rampant pursuit of deregulation has progressively emasculated the building control profession. In my dealings with the Ministry of Housing, Communities and Local Government prior to the Grenfell Tower fire, the officials responsible for building regulations were metaphorically side-lined to a broom cupboard somewhere in the basement. Building safety was never discussed in meetings. Complacency ruled everywhere.

The Department for Levelling Up, Housing and Communities (DLUHC) operates the Building Regulation's 'competent person scheme' under which, companies (enterprises) deemed suitable through initial and regular third-party assessment are able to self-certify that their own completed work complies with the requirements of the Building Regulations (where these apply to the work being done) rather than receive an independent Local Authority Building Control inspection and approval. Unfortunately, the self-certification is usually carried out by supervisors who may not have actually carried out the specific work.

Since 2002, on behalf of the electrical installation industry, the IET has accommodated and supported the Electrotechnical Assessment Specification Management Committee (an independent industry committee and not a part of the IET) which publishes the Electrotechnical Assessment Specification document, the base document covering the minimum requirements necessary to determine the competence of a company (enterprise) undertaking electrical work to carry out electrical design, construction, maintenance, and/or inspection and testing work in compliance with BS 7671 and self-certify their work.

Competence now

The Building Safety Act was introduced in 2022, coming into effect in parts in 2022 and 2023, and has considerably changed the way building regulations requirements, and the competence to apply them correctly and safely, are reviewed.

There are specific competence requirements built into the Act (such as the requirement for architects to undertake continuing professional development (CPD)), specific requirements to present a design at certain 'gateways' and the requirement to provide a completed building with documentation for inspection before occupation handover.

BSI have now published BS 8670-1:2024. This is a set of core competence criteria covering the knowledge, skills, experience and behaviours required to work on buildings of all types and scales. The goal is to help raise levels of individual professional competence across the built environment in support of the new Building Safety Regime. Based on experiential feedback from the industry, BS 8670-1:2024 provides a benchmark framework that will help professional institutions and other organizations develop sector-specific competence frameworks for technical and non-technical roles, raising professional competency across the sector.

Conclusion

So, what has gone wrong with our industry when we already have many competence, training and skills requirements to work to and with? Perhaps construction time pressures, competitive tendering and required profitability etc. should be reconsidered?

The IET certainly supports individual competence for any work being carried out, relevant training and continuing professional development.