

# WiringMatters

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## IET Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition

What's new in the latest edition of this popular title

## Mythbuster! "Flexible cables are not permitted in fixed installations"

A look into where this concept first came from and a report on its validity

## Surge Protective Devices

What are transient overvoltages and how do they occur?

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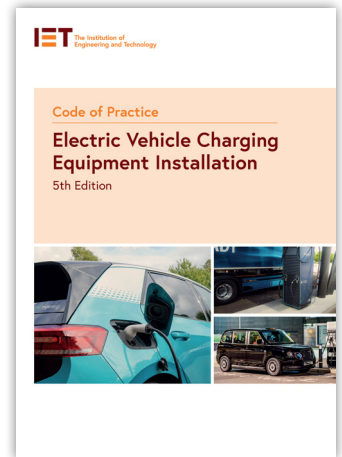
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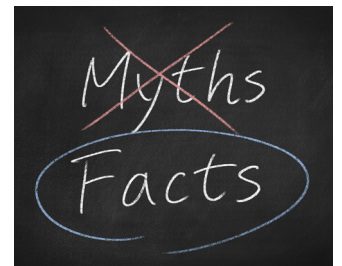
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## Welcome to the Wiring Matters 2024 Annual

We are delighted to bring you this year's Annual which collects some of the most popular articles from the previous year. 2023 was a busy year for the Codes and Guidance Team at the IET, with several books published and the development of many others well under way and scheduled to be published later in 2024.

The first book to be published in 2023 was the eagerly anticipated fifth edition of the Code of Practice for Electric Vehicle Charging Equipment Installation, which was updated to reflect changes in this rapidly developing area and provides a clear explanation of, and highly practical guidance for, the safe installation of electric vehicle charging equipment. As an accompaniment to this book, a purchasable PDF document containing the relevant checklists and risk assessments is also available.

Later in the year, we saw the publication of the second edition of two books in the Exam Preparation series - Exam Preparation: Requirements for Electrical Installations (2382) and Exam Preparation: Initial and Periodic Electrical Inspection and Testing (2391). These books are essential study guides for learners taking the relevant City & Guilds qualifications and contain practice questions with model answers, as well as guidance and advice about sitting the exams.

The year ended with the publication of the On-Board Guide: Electrical Safety for Small Craft. This book is aimed at people who are responsible for the design, installation, testing, commissioning and maintenance of electrical installations on small recreational or commercial craft. These titles and many more can be purchased from the IET bookshop here: [shop.theiet.org](https://shop.theiet.org).

Within this Wiring Matters 2024 Annual, we cover some of our most informative and comprehensive articles from last year. Graham Kenyon, author of the Code of Practice for Electric Vehicle Charging Equipment Installation, provides details of the changes made to this latest edition which were prompted by calls from industry, James Eade shares an instalment of his popular 'Mythbusters' series in which he seeks to debunk the idea that flexible cables are not permitted in fixed installations and Craig O' Neill, Senior Engineer at the IET, offers updated information on Surge Protective Devices (SPDs) and how they link to BS 7671.

Joseph Cannon from Cannon Electrical Services wrote his first article for Wiring Matters in March 2023, which has been included in this Annual. It focuses on the developing area of earth fault loop impedance and standardization and how this links to BS 7671:2018+A2:2022, BS EN 60898 and BS EN 60947-2, to name just a few.

The Annual concludes with an article from IET Senior Engineer, Michael Peace, who discusses the important issue of isolation and switching when it pertains to mechanical maintenance. Informed by questions Michael frequently gets asked, as well as discussions he has had in his professional career, this article has a lot to offer.

As we look ahead to 2024, there are lots of publications on the way. The latest version of the Model Form on Contract MF/1 2024 (Revision 7) was published at the beginning of the year, with its accompanying PDF of fillable forms to follow shortly.

Also due to publish this year are the Temporary Guide to Electrical Systems (which was first published under the title of Temporary Power Systems in 2013), Electrical Energy Storage Systems, 3rd Edition, the new IET Standard, Open combined protective and neutral (PEN) conductor detection devices (OPDDs) and the online publication, The Application of Artificial Intelligence in Functional Safety, amongst others - so watch this space!

We are very grateful for the continued support of our readers and would love to hear from you with suggestions for future articles you would like to read, or any feedback you would like to share. Please don't hesitate to get in touch by emailing us at [wiringmatters@theiet.org](mailto:wiringmatters@theiet.org).

I really hope you enjoy the Wiring Matters 2024 Annual and I look forward to bringing you more interesting and informative articles via our Wiring Matters e-newsletter throughout the rest of this year.

**Susannah Girt**  
Editor, Wiring Matters



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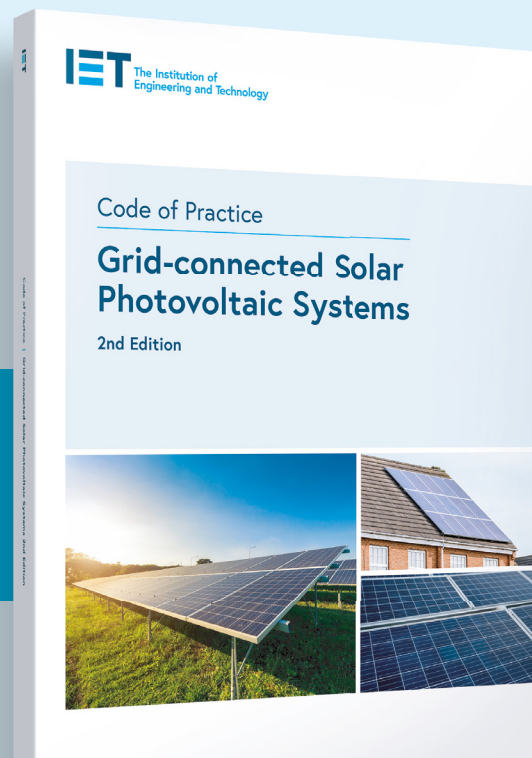
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# Fifth Edition of the IET Code of Practice for Electric Vehicle Charging Equipment Installation

By: EUR ING Graham Kenyon BEng (Hons) CEng MIET TechIOSH

There have been a number of changes in the electric vehicle (EV) charging installation sector since the publication of the Fourth Edition of the IET Code of Practice for Electric Vehicle Charging Equipment Installation in 2020, which have prompted calls from the industry for updates to the publication. The guidance has been updated and expanded primarily as a result of:

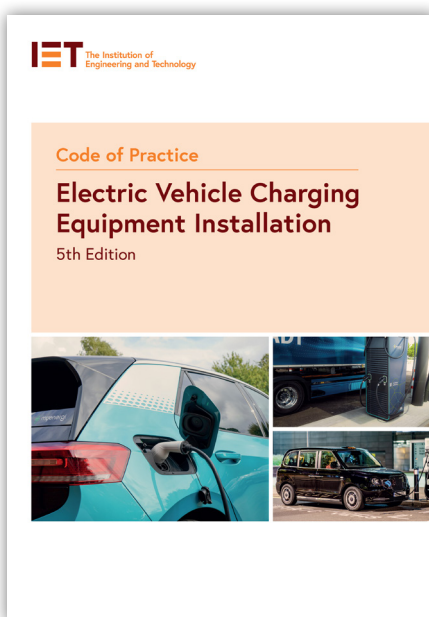
- introduction of new legislation;
- availability of new guidance on fire safety and accessibility of charging points;
- increased roll-out of Mode 4 (rapid charging) points;
- removal of indent (i) to Regulation 722.411.4.1 in BS 7671:2018+A2:2022;
- change of focus of related industry vocational qualifications; and
- completion of vehicle-to-grid (V2G) trials, along with innovations making vehicle-to-home (V2H) applications more likely.

The Fifth Edition of the IET Code of Practice for Electric Vehicle Charging Equipment Installation is now available. Technical Author Graham Kenyon provides some insight into what we can expect from the new publication.

## The Electric Vehicles (Smart Charge Points) Regulations 2021

The Electric Vehicles (Smart Charge Points) Regulations 2021 came into force in Great Britain in June 2022 and apply to private charging points rated at not more than 50 kW, installed after 30 June 2022. The legislation requires charging points to include:

- inter-operable smart functionality to enable integration of the charging



- equipment to integrate with the smart grid for load curtailment (dropping maximum output of the charger) and demand side response services;
- pre-set default charging times for off-peak usage (with a suitable user-override);
- cyber-security; and
- minimum safety provisions.

Further guidance on the Regulations can be found on the Office for Product Safety and Standards website: [www.gov.uk/guidance/regulations-electric-vehicle-smart-charge-points](http://www.gov.uk/guidance/regulations-electric-vehicle-smart-charge-points).

## Part S of the Building Regulations in England

Part S of the Building Regulations came into force in England on 15 June 2022 and relates to EV charging point provision associated with dwellings and residential buildings and certain non-residential premises. The legislation mandates

charging equipment to be at least Mode 3, with a power capability of at least 7 kW, with a universal outlet supplied by a dedicated circuit, and mandates the equipment to be installed according to BS 7671 and the IET Code of Practice for Electric Vehicle Charging Equipment Installation.

## Installation of telecommunications and auxiliary cabling

One impact of the Electric Vehicles (Smart Charge Points) Regulations 2021 for installers is the increased requirement for communications interfaces and, where applicable, control and monitoring. As a result, guidance on communications and integration has been expanded in the Fifth Edition of the Code of Practice, and now includes guidance on telecommunications and auxiliary (control and monitoring) cabling installation according to BS 7671, BS 6701 and BS EN 50174 series. Cabling for Ethernet, ANSI/TIA/EIC-485-A (commonly known as 'RS 485') and control and monitoring auxiliary purposes are considered.

Guidance is provided on selection of appropriate cabling and installation practices for telecommunications cabling inside and outside buildings.

## Location and accessibility of charging points

The guidance on location and accessibility of charging points has been updated to take account of new standard PAS 1899:2022 Electric vehicles - Accessible EV charging points - Specification and the requirements of the Scotland Building Standards Division technical handbooks that came into force in June 2023.

Installers are also advised to consider RISC Authority RC59 Recommendations for fire safety when charging electric vehicles when considering the location of charging points.

### Vehicle as storage

Section 10 of the Code of Practice, which looks at vehicle as storage, has been updated to reflect guidance on the latest BS 7671 requirements for prosumer's electrical installations and includes guidance on V2H integration for installations operating in island mode when the grid supply is disconnected.

### Inspection and testing

Section 9 on inspection and testing has additional guidance for:

- earth electrode resistance measurement;
- RCD testing; and
- use of vehicle simulators for carrying out tests at socket-outlets or tethered cable vehicle connectors on the vehicle side of charging equipment.

The Code of Practice also provides advice on testing of RCD-DDs to BS IEC 62955. BS 7671 does not require tests of RDC-DDs to be conducted, however, tests could be carried out for fault-finding purposes, or functional testing if recommended by the manufacturer of the RDC-DD or electric vehicle charging equipment. Although, it should be noted that the test parameters in RCD test instruments or multifunction testers to BS EN IEC 61557 series "Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. Equipment for testing, measuring or monitoring of protective measures" are not always suitable for RDC-DDs.

### Installation of earth electrodes

Clearer guidance is provided for good practice in the installation of earth electrodes in accordance with BS 7671 and BS 7430.

### Calculations for steel wire armoured (SWA) cables where the armour is used as the circuit protective conductor (cpc)

A new appendix has been included to help designers consider the reactance of steel wire armoured cables on the earth fault loop impedance calculations where

the armour is used as a cpc (with or without an additional copper conductor in parallel). This can also be used by those carrying out inspection and testing in cases where loop impedances are to be determined at least in part by calculation.

Appendix 4 to BS 7671 tells us that reactive effects need not be considered where the cross-sectional area (csa) of cables does not exceed 16 mm<sup>2</sup>. However, where SWA cables are used, the csa of the armour usually exceeds 16 mm<sup>2</sup>. For example, with BS 5467 cables, the gross csa of the armour exceeds 16 mm<sup>2</sup> for all:

- three-, four- and five-core multicore cables with conductor csa at least 1.5 mm<sup>2</sup>; and
- two-core cables with conductor csa of at least 2.5 mm<sup>2</sup>.

What is the effect of not taking cable reactance into account for SWA cables? As we can see from Table 1, ( $Z_1+Z_2$ ), taking into account reactance, is between 4 % and 9 % greater than ( $R_1+R_2$ ), and this might be significant for long runs where overcurrent protective devices provide automatic disconnection of supply. In addition, with larger supplies required for commercial sites and Mode 4 (DC rapid charging) electric vehicle charging equipment installations, it may be necessary to take into account the reactance of the loop impedance at the feeder pillar or distribution board, which will have a further impact.

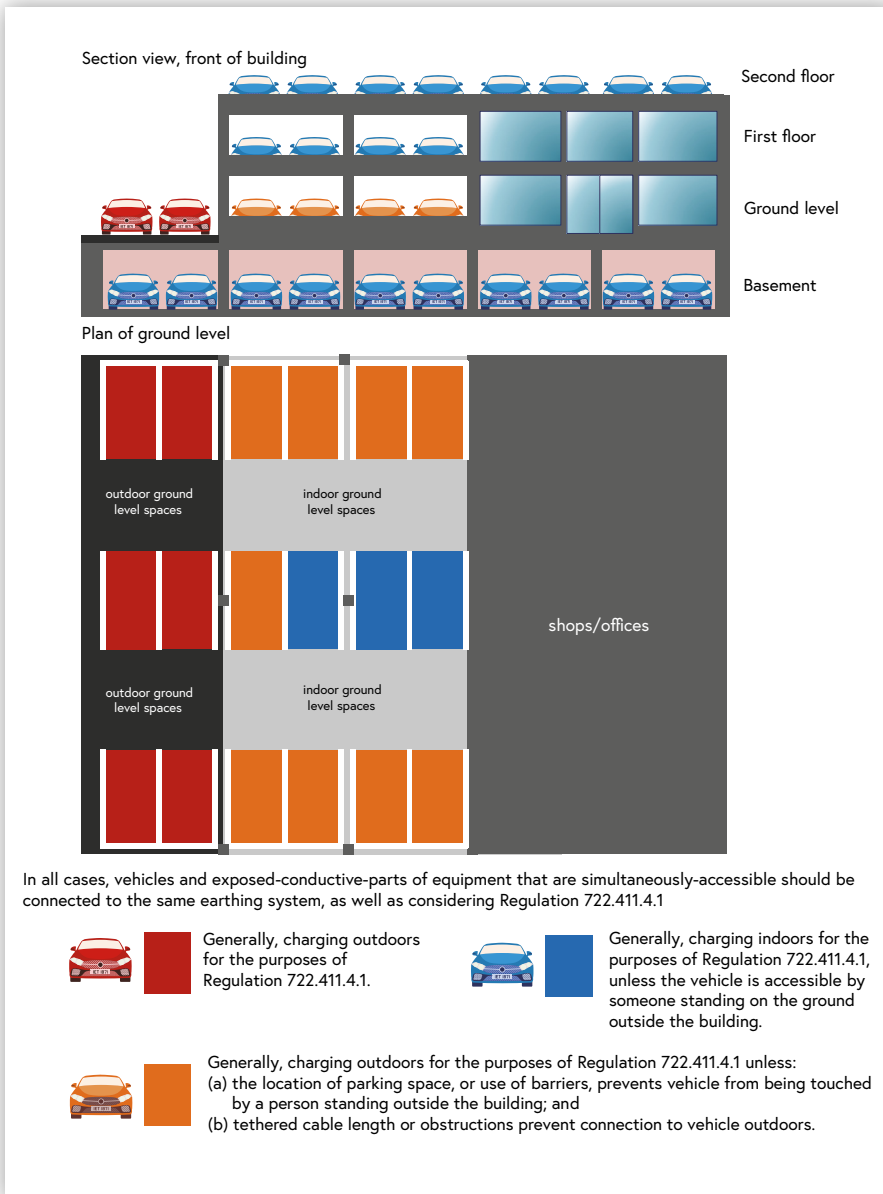
**Table 1 Comparison of loop impedance contribution of SWA cables to BS 5467, where the armour is used as cpc, with and without consideration of reactance**

Conductor csa (mm <sup>2</sup> )	Loop impedance contribution per metre at 70 °C (mΩ/m)							
	2-core		3-core		4-core		5-core	
	( $Z_1+Z_2$ )	( $R_1+R_2$ )	( $Z_1+Z_2$ )	( $R_1+R_2$ )	( $Z_1+Z_2$ )	( $R_1+R_2$ )	( $Z_1+Z_2$ )	( $R_1+R_2$ )
1.5	28.3	27.0	27.3	26.2	26.4	25.3	25.6	24.6
2.5	20.8	19.7	19.9	18.9	19.2	18.3	18.1	17.2
4.0	16.2	15.2	15.6	14.7	14.7	13.9	13.9	13.1
6.0	13.1	12.3	12.7	11.9	9.50	8.96	8.96	8.47
10	10.3	9.55	7.59	7.10	7.19	6.73	6.78	6.36
16	6.37	5.91	6.10	5.67	5.57	5.18	4.35	4.08
25	5.19	4.79	3.98	3.69	3.71	3.45	3.31	3.08
35	3.61	3.32	3.47	3.20	3.20	2.96	2.80	2.59
50	3.17	2.91	2.91	2.67	2.24	2.06	1.97	1.81

**NOTE:** ( $Z_1+Z_2$ ) is the loop impedance taking into account reactance. ( $R_1+R_2$ ) is the loop impedance not taking into account reactance.

Guidance is provided on selection of appropriate cabling and installation practices for telecommunications cabling inside and outside buildings.

**Figure 1 Examples of vehicle spaces considered to be indoors or outdoors for the purposes of Regulation 722.411.4.1 (from the 5th Edition of the IET Code of Practice for Electric Vehicle Charging Equipment Installation)**



## Depth of buried cables and height of overhead cables

With the exception of the Streetworks UK guidelines relating to cabling buried under the highway, there is currently no easy-use reference for the minimum depth of buried cables and minimum height of overhead cables. It has been recognized that EV charging equipment is now starting to be installed in a variety of different types of premises, some having more onerous requirements. Appendix K to the Fifth Edition of the Code of Practice provides a 'one-stop-

shop' for designers and installers to easily see how minimum depth and height requirements may change when providing charging points in, say, agricultural premises or caravan sites.

## Other guidance for designers

For each of the use-case classifications (domestic, on-street, and commercial and industrial) there is updated guidance on determining adequacy of supply and maximum demand. The guidance takes into account load curtailment (where used) and also helps designers

understand the difference between the maximum demand values required for:

- the maximum demand required by the electricity supplier (DNO);
- sizing switchgear assemblies and distribution arrangements; and
- selection of final circuit wiring systems and suitable conductor cross-sectional area.

There is also guidance on determining whether vehicles on charge are considered indoors or outdoors for the purposes of Regulation 722.411.4.1 in commercial and industrial applications. This is not always straightforward in buildings with parking on multiple levels (see Figure 1).

## Conclusion

The Fifth Edition of the IET Code of Practice for Electric Vehicle Charging Equipment Installation contains a number of timely updates so that industry can be kept up-to-speed with the rapidly changing landscape in this field, which is of key importance to the UK Government's approach to reducing the UK's carbon emissions. The Fifth Edition includes updates to cover technological developments, industry practices and legislative frameworks, since the previous edition.

## About the author

Graham Kenyon is a Chartered Engineer, and Managing Director of consultancy G Kenyon Technology Ltd. Graham chairs:

- the joint IET/BSI Committee JPCL/64, responsible for BS 7671;
- the IET Wiring Regulations Policy Committee; and
- the IET Committee that developed the IET Standard for open-PEN detection devices (OPDDs).

He is the technical author of a number of IET guidance publications including the IET Code of Practice for Electric Vehicle Charging Equipment Installations, the Second Edition of the IET Code of Practice for Grid-connected Solar PV Installations (2022), and the latest editions of IET Guidance Notes 3, 5 and 6.

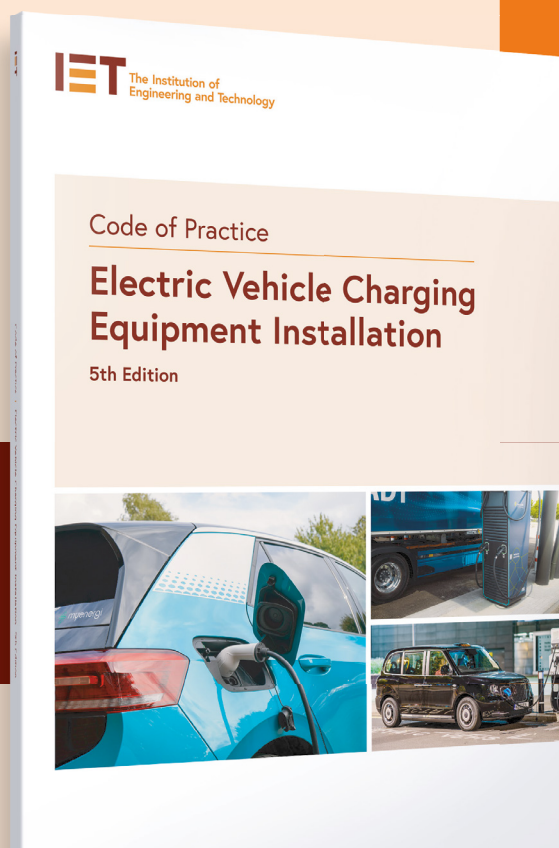
# Order your copy of the Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition from the IET Bookshop

This newly updated Code of Practice is a well-established and authoritative guidance document providing a clear explanation of this subject area. It sets out the considerations and planning needed prior to installation and covers the necessary physical and electrical requirements during the installation process.

Significant changes include:

- full alignment with BS 7671:2018+A2:2022
- requirements of The Electric Vehicles (Smart Charge Points) Regulations 2021
- guidance to meet the requirements of Building Regulations of the devolved nations and PAS 1899 on accessibility
- a substantial update on 'vehicle as storage'
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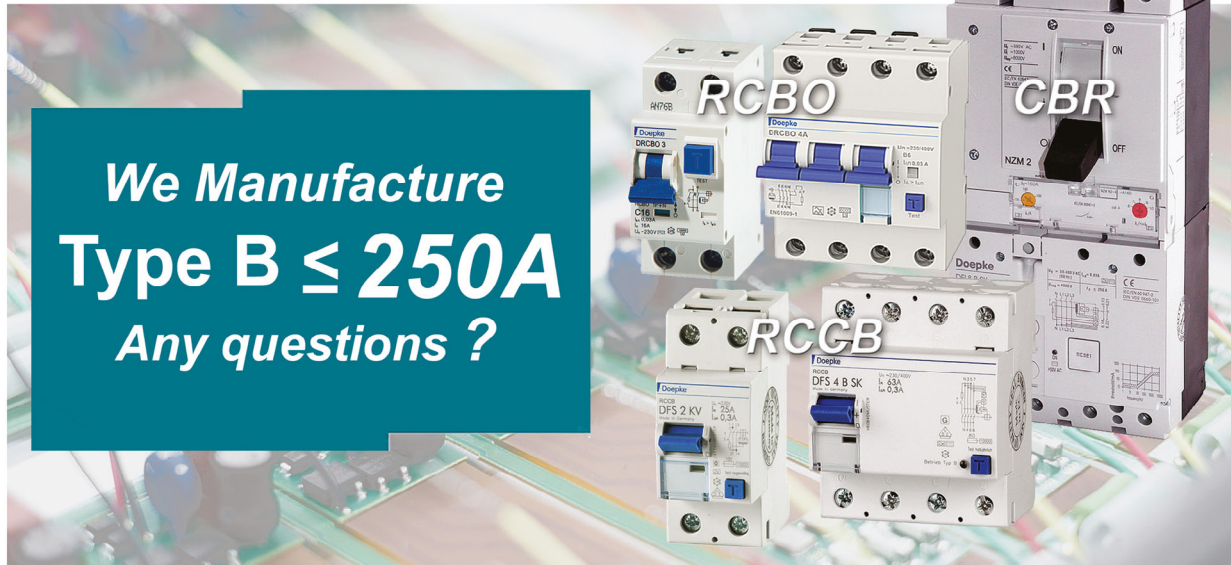


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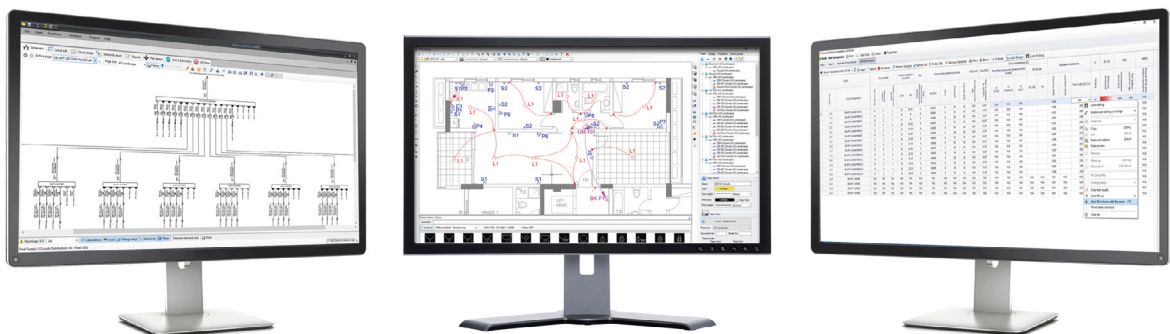
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## Mythbusters #9

# "Flexible cables are not permitted in fixed installations"

By James Eade BEng (Hons) CEng MIET

This myth was inspired by a comment on the IET EngX Forum and is not uncommon. The origins of it are unclear but seem to date back to the 15th Edition of the IEE Wiring Regulations (if not before) and are believed to have stemmed from the types of insulation materials used for flexible cables in years gone by.

In the 16th Edition, there were definitions for flexible cables (for example, a cable designed to be flexed in use) and flexible cords (a flexible cable with conductor cross-sectional areas (csa) of 4 mm<sup>2</sup> or less), but no reference to them being specifically prohibited.

Like phase separation, the memories of some old requirements linger on. In the 16th Edition (including AM2, 2004), Regulation 521-01-04 did state that "A flexible cable or flexible cord shall be used for fixed wiring only where the relevant provisions of the regulations are met." This requirement does come across in a negative fashion, giving the impression that flexible cables may be used as something of a last resort. Interestingly, this requirement still exists today in BS 7671:2018+A2:2022 in Regulation 521.9 as follows:

### 521.9 Use of flexible cables

*521.9.1 A flexible cable shall be used for fixed wiring only where the relevant provisions of BS 7671 are met. Flexible cables used for fixed wiring shall be of the heavy duty type unless the risk of damage during installation and service, due to impact or other mechanical stresses, is low or has been minimized or protection against mechanical damage is provided.*

**NOTE:** Descriptions of light, ordinary and heavy duty types are given in BS EN 50565-1.

Continuing with the current edition, Regulations 521.9.2 and 521.9.3 go on to require flexes to be used for connecting equipment that may be moved during use. The definition of flexible cords has also gone, leaving just flexible cables listed in Part 2. However, there is still no prohibition on their use.

The main differences between cables used for installations and flexible cables are the use of Class 5 finely stranded conductors rather than Class 1 (solid) or Class 2 (semi-stranded), coupled with differences in insulation materials to allow for the flexibility. Such cables are in widespread use from construction sites to events (where they are used almost exclusively), as well, of course, as final connections in installations for lighting fixtures or from fused connection units to equipment such as heaters, for example.

**The main differences between cables used for installations and flexible cables are the use of Class 5 finely stranded conductors rather than Class 1 (solid) or Class 2 (semi-stranded), coupled with differences in insulation materials to allow for the flexibility.**

Having decided to wire your installation in flexible cable, what are the "relevant provisions of BS 7671" alluded to in 521.9.1? As well as complying with the general rules, there are a couple of key points to note with this as follows:

- The flexible cable should have appropriate mechanical robustness for the application as described in the note to the Regulation which refers to BS EN 50565-1. This Standard describes various categories, summarized thus:
  1. "Heavy duty" describes the stresses that might be expected in, for example, industrial and agricultural premises.
  2. "Ordinary duty" describes the stresses that might be expected in, for example, domestic, commercial and light industrial applications.
  3. "Light duty" applications might include flexible cables for small appliances.
  4. "Extra light duty" applications are, for example, very small appliances such as electric shavers, chargers for mobile phones, etc. Where this protection cannot be achieved using the cable alone, suitable additional mechanical protection should be provided.
- The temperature rating of the flexible cable should be suitable for the connected wiring accessories (Regulation 526.4).
- Wiring terminations may need to be finished in an appropriate termination as required of Regulation Group 526.9. Guidance Note 3 has details on appropriate wiring accessory terminals and their markings in Table 2.1.



- Generally, all the current-carrying capacity and voltage drop tables in Appendix 4 are for Class 1 and Class 2 stranding, with the exception of Tables 4F1 to 4F3. The current carrying capacity and voltage drop may need to be corrected if using tables for other cables, such as PVC cables complying with the insulation and temperature requirements of Table 4D2. Information is given in Section 2.4 of Appendix 4.
- Far from being prohibited, flexible cables are required in some parts of BS 7671:2018+A2:2022 and examples include:
  - Regulation 422.3.201 permits their use for locations where a particular risk of fire exists, although has some requirements for their construction or protection as detailed in Regulation Group 521.9.
  - Regulation 413.3.4 has a particular requirement concerning their use in parts of the installation with protective measure double or reinforced insulation.
- Regulation 418.3.6 for electrical separation to more than one item of equipment requires flexible cables to incorporate a protective conductor.
- They are required to be used for suspended current-using equipment (Regulation 522.7.2).
- They are required in installations in flexible structures, or where structures are intended to be moved (Regulation 522.15.2).
- There are minimum cross-sectional areas for flexible cables "for any other application" in Table 52.3.
- Flexible cables are required for the connection of equipment that may be regularly or occasionally moved in use (Regulations 521.9.2 and 521.9.3).
- Flexible cables are required a method of connection of equipment having a high protective conductor current as detailed in Regulation 543.7.1.202.
- Some Part 7 special locations

specify certain wiring systems for which flexible cables are options, or mandated as noted in Regulation 522.15.2: (Regulation Group 704.522.8, Regulation 711.52, Regulation 717.411.3.1.2, Regulation Group 717.52, Regulation 721.521.2, Regulation 740.521.1, Regulation 740.55.1.1).

As ever, it is worth reviewing the fundamental principles in Part 1. Of relevance, here are Regulations 132.6 and 132.7 for the cross-sectional area of conductors and types of wiring and installation methods, plus Regulation Group 133 for the selection of equipment. Flexible cables can tick all the boxes and, if the extra cost over more rigid types is not a concern, then there is no reason why they can't be used.

With thanks to Graham Kenyon for his contributions to this article.

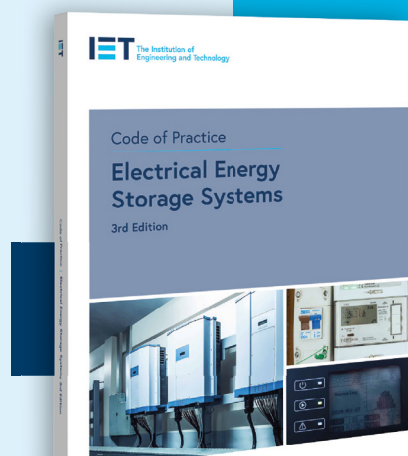


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This Code of Practice looks at electrical energy storage systems applications and provides information for practitioners to safely and effectively specify, design, install, commission, operate and maintain a system.

Changes in this edition include:

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- updates to schematics for domestic use
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# Surge Protective Devices (SPDs)

By: Craig O'Neill BEng (Hons) - Senior Engineer at the IET

Surge Protective Devices (SPDs) can be used to help protect an electrical installation and its connected equipment from the potentially harmful effect of transient overvoltages.

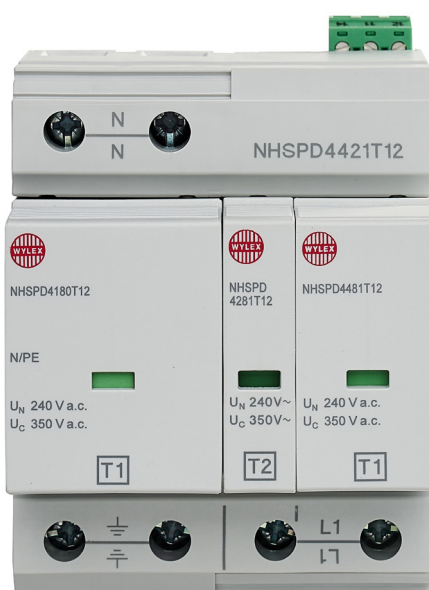
The effects of a surge can result in either instant failure or damage to the equipment, only evident over a longer period of time. SPDs are usually installed within a consumer unit or a distribution board to protect an electrical installation and connected equipment, but can also be installed locally to protect an individual item of equipment. A surge can be transmitted via other incoming services such as telephone lines, some cable TV networks etc., so it is important to remember to consider all routes a surge can enter the property. For information regarding overvoltages transmitted by information and communication technologies, see BS EN 50174, BS EN 62305-4, PD CLC/TS 61643-22 and, for telecoms systems in general, see BS 6701.

There are three common types of SPD:

1. Type 1 SPD installed at the origin, for example, main distribution board.
2. Type 2 SPD installed at sub-distribution boards.  
(Combined Type 1 and 2 SPDs are available and are usually installed in consumer units.)
3. Type 3 SPD installed close to the protected load. These must only be installed as a supplement to a Type 2 SPD.

Where multiple SPD devices are required for protection throughout the installation, they must be coordinated in accordance with Regulation 534.4.4.5 to ensure correct operation. SPDs supplied by different manufacturers should be confirmed for suitability as required by Regulation 536.4.203.

Figure 1 Surge protector (Reproduced with permission of Electrium)



## What are transient overvoltages?

Transient overvoltages can be defined as short duration, high magnitude voltage peaks with fast rising edges, commonly referred to as "surges", which can range from a few volts to many thousands of volts on a low-voltage consumer network, for no more than millisecond duration.

These surges occur due to the sudden release of energy previously stored or induced by other means.



These surges occur due to the sudden release of energy previously stored or induced by other means.



can then find its way into electrical installations, naturally occurring either indirectly from lightning strokes or directly from lightning strikes, or created by the switching and operation of certain equipment within an installation.

## How do transient overvoltages occur?

Transient overvoltages occur when equipment likely to produce switching overvoltages, or disturbances exceeding the applicable rated impulse voltage of equipment according to Table 443.2 of BS 7671, are installed locally. Equipment such as large inductive or capacitive equipment, motors, transformers, capacitor banks, storage units or high current loads.

Historically, this has not been an issue within domestic installations but, more recently, installations are changing with the advent of recent technologies such as electric vehicle charging, air/ground source heat pumps and speed-controlled washing machines. These technologies have made transients more likely to occur within domestic installations at some level.

Transient overvoltages due to atmospheric origin can occur if either the property itself or nearby electrical transmission infrastructure suffers a hit by lightning strokes. These types of transient overvoltages are most likely to happen when a direct lightning stroke on an adjacent overhead power or telephone line causes the transient overvoltage to conduct along the lines into nearby properties, which can cause considerable damage to the electrical installation and associated equipment.

BS EN 62305-2 contains information required for risk management for protection against transient overvoltages due to direct or nearby lightning strokes on the structure.



# Determining the maximum earth fault loop impedance for protective devices to BS EN 60898 & BS EN 60947-2

By: Joseph Cannon MSc IEng MIET – Electrical Consultant

## Why determine and record the maximum permitted earth fault loop impedance for a protective device?

When selecting a device for fault protection, whilst utilizing the protective measure automatic disconnection of supply (ADS), it must be ensured that the device will disconnect in the required time, as stated in the Regulation contained within 411.3.2 of BS 7671:2018+A2:2022.

This can be confirmed by ensuring the maximum measured earth fault loop impedance ( $Z_s$ ) is less than or equal to the maximum  $Z_s$  permitted by the device. The maximum permitted  $Z_s$  should be recorded on the generic schedule of circuit details from Appendix 6 of BS 7671:2018+A2:2022 when compiling forms for initial verification and periodic inspection and testing.

A circuit-breaker or a moulded case circuit-breaker (MCCB) that is manufactured to BS EN 60898 or BS EN 60947-2 respectively are commonly used to provide ADS as well as overload protection within an electrical installation and, whilst the focus of this article is on fault protection, the Regulations within 433 of BS 7671:2018+A2:2022 cover the requirements for protection against overload current.

## What is the maximum disconnection time when employing automatic disconnection of supply as the protective measure?

Regulations contained within 411.3.2 of BS 7671:2018+A2:2022 set out the

disconnection time requirements when utilizing ADS as the protective measure.

The required disconnection time is dependent on the following items:

- the system voltage to earth ( $U_0$ );
- the earthing arrangement;
- if the circuit is a distribution circuit or final circuit;
- the rated current of the circuit; and
- whether or not the circuit includes a socket-outlet.

The examples in Table 1 are based on a TN earthing arrangement, with a nominal voltage to earth of 230 V, and include their maximum disconnection time.

These examples cover the most common scenarios in a TN system, although to establish the required disconnection time for a circuit, including when a TT system is employed, see Regulations within 411.3.2 of BS 7671:2018+A2:2022.

## Devices for fault protection

This article is based on utilizing devices manufactured to BS EN 60898 and BS EN 60947-2 to provide fault protection for ADS. It is worth mentioning that

fault protection can be provided by an alternative device. The most common scenario for this is when utilizing a residual current device (RCD) for fault protection purposes. This occurs mostly when a TT earthing system is utilized.

This article is based on using thermal magnetic devices to BS EN 60898 and BS EN 60947-2 for fault protection purposes. Other devices are beyond its scope.

## Selecting a device for fault protection

As mentioned in the first section, the overload protective device is also usually utilized for fault protection purposes, therefore it is selected based on the characteristics of the circuit it is supplying. Section 433 of BS 7671:2018+A2:2022 PROTECTION AGAINST OVERLOAD CURRENT gives the requirements to be met in relation to overload protection.

Generally, the current rating of the device ( $I_n$ ) is selected once the load of the circuit ( $I_b$ ) has been determined and follows the general requirement  $I_n \geq I_b$ .

Another consideration is the start-up current of the connected equipment. Circuit-breakers or MCCBS to

Table 1 TN earthing arrangement disconnection times

Example	Arrangement	Maximum disconnection time
1	Final circuit up to 63 A, including a socket-outlet	0.4 s
2	Final circuit up to 32 A that serves fixed equipment only	0.4 s
3	Distribution circuit	5 s
4	Final circuit exceeding 32 A that does not serve a socket-outlet	5 s

BS EN 60898 or BS EN 60947-2 respectively, have tripping curves B, C or D to allow for different levels of start-up current and it is worth noting that as the tripping curve increases alphabetically, the current required to operate the device instantaneously also increases. Due to this, it is advantageous to select the device with the lowest letter alphabetically that will permit the required start-up current requirements of the load.

Another requirement to be met when selecting the device is that it is rated for the possible fault current at its installation point. This requirement is set out in Regulation 434.5.1 of BS 7671:2018+A2:2022.

**How to determine the maximum  $Z_s$  of the selected device**

Following the selection of a device from the previous section, the maximum permitted  $Z_s$  must be obtained to ensure compliance with the disconnection time as stated in Regulations from 411.3.2 of BS 7671:2018+A2:2022.

It is common practice in smaller installations to use Table 41.3 from BS 7671 to determine the maximum permissible  $Z_s$  for a circuit-breaker to BS EN 60898, however, Appendix 3 of BS 7671:2018+A2:2022 states:

*The maximum values of earth fault loop impedance to achieve the disconnection time vary with the different types of protective devices and also between manufacturers. Wherever possible designers should use the manufacturer's specific data.*

The values in Table 41.3 are obtained from the time/current graphs in Appendix 3. The formulae from Regulation 411.4.4 of BS 7671:2018+A2:2022 state:

**Formula 1** extracted from Regulation 411.4.4 of BS 7671:2018+A2:2022  
The characteristics of the protective devices [...] and the circuit impedances shall fulfil the following requirement:

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

Rearranging this formula to make  $Z_s$  the subject matter gives the following:

**Formula 2** extracted from Appendix 3 of BS 7671:2018+A2:2022

$$Z_s = \frac{U_0 \times C_{min}}{I_a}$$

Where:

$C_{min}$  is a correction factor to account for voltage variations. This is given as 0.95 in Appendix 3 of BS 7671:2018+A2:2022.  
 $U_0$  is the nominal AC rms line voltage to Earth.  
 $I_a$  is the current causing operation of the device in a specified time. This is obtained from manufacturer's data and is covered in the next section.

**How to obtain  $I_a$  from Appendix 3**

To find the  $I_a$  of the selected protective device, the manufacturer's time/current graphs are required. Values from Table 41.3 are based on the time/current values from Appendix 3 of BS 7671:2018+A2:2022.

Figure 1 is extracted from BS 7671:2018+A2:2022 to illustrate how the values from Table 41.3 are obtained. This graph represents thermal magnetic circuit-breakers. The magnetic representation on the graph for the selected circuit-breaker is the vertical line that starts at 0.1 s and ends at 2 s. The thermal representation follows on from this, which starts at 2 s and is represented by a curve that concludes at the top of the graph where the size of the device is indicated.

With the correct graph selected, a horizontal line is drawn in relation to the disconnection time required. The red line on Figure 1 indicates a time of 0.4 s on the y axis of the graph. The next step is to draw a second line vertically at the point in which the horizontal line intersects the time current/curve of the selected device. The vertical line will enable determination of the current required for operation from the x axis.

The  $I_a$  for a 50 A device from the graph with a 0.4 s disconnection time in this case is 1,000 A. This intersects with the magnetic representation for the device.

A second example is indicated with a blue line on the graph. This again is for the 50 A device, although with a 5 s disconnection time, the  $I_a$  for a 50 A device in this case is 500 A. This intersects with the thermal representation for the device.

**How to calculate  $Z_s$  once  $I_a$  has been determined**

With the value of  $I_a$  determined for a 50 A device's 0.4 s and 5 s disconnection times, the maximum permitted  $Z_s$  can now be obtained using Formula 2. This is carried out below:

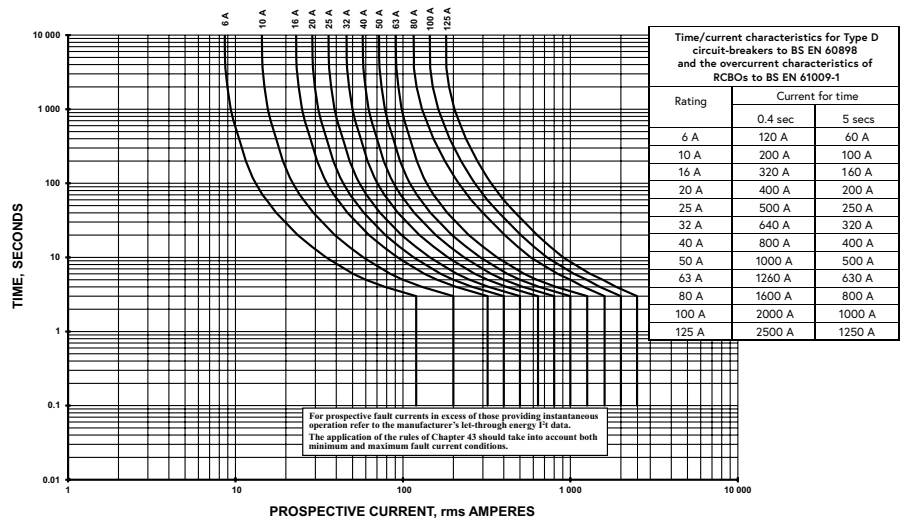
**0.4 s disconnection time:**

$$Z_s = \frac{U_0 \times C_{min}}{I_a}$$

$$Z_s = \frac{230 \text{ V} \times 0.95}{1000 \text{ A}}$$

$$Z_s = 0.22 \Omega$$

**Figure 1 Figure 3A6 from Appendix 3 of BS 7671:2018+A2:2022**



# Determining the maximum earth fault loop impedance for protective devices to BS EN 60898 & BS EN 60947-2

## 5 s disconnection time:

$$Z_s = \frac{U_0 \times C_{min}}{I_a}$$

$$Z_s = \frac{230 \text{ V} \times 0.95}{500 \text{ A}}$$

$$Z_s = 0.44 \Omega$$

When the calculated values are compared with the values from Table 41.3, they are identical.

## How to obtain $I_a$ from manufacturer's data

Obtaining the  $I_a$  from a manufacturer's graph is no different to what was carried out in the previous steps, although the graph may look a little different. One of the differences can be that the manufacturer has the tolerances of their device built into the time/current curves. When calculating the maximum  $Z_s$ , it should always be based on the worst case scenarios. If the graphs have the tolerance included, the highest magnitude of current must be selected from the curve and due to the current and impedance being inversely related, this will give a lower maximum  $Z_s$  to be met. Some time/current curves do not have the tolerance built into them and in these instances, the manufacturer will declare a tolerance, for example,  $\pm 20\%$ . If this tolerance is not included in the graph, it must be included in the maximum  $Z_s$  calculation. An example of this based on a 20% tolerance is indicated in Formula 3.

**Formula 3** maximum  $Z_s$  formula with the tolerance of the device accounted for:

$$Z_s = \frac{U_0 \times C_{min}}{I_a \times 1.2}$$

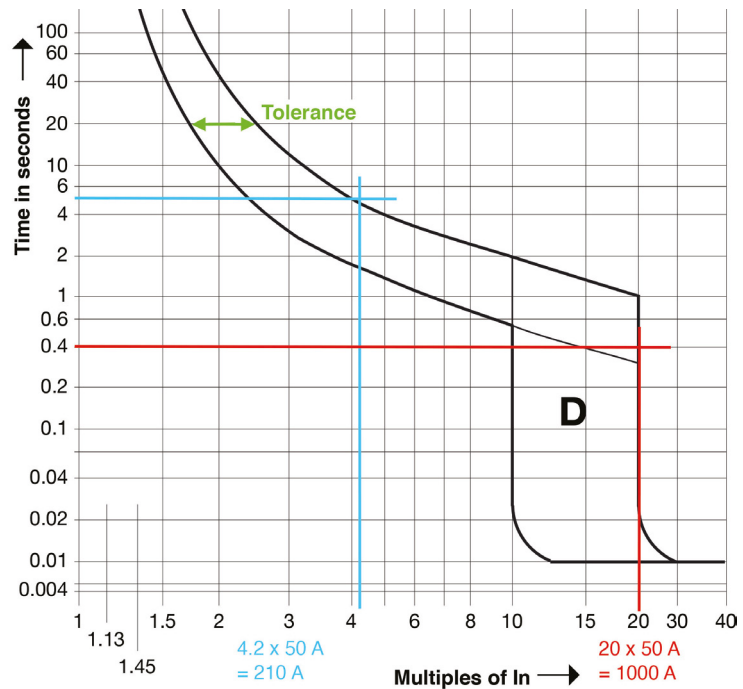
Figure 2 depicts how to obtain the maximum  $Z_s$  from a specific protective device where the tolerance of the device is depicted on the time/current curve.

The values of  $Z_s$  from Figure 2 have been calculated and are recorded below based on a 50 A protective device. This has been carried out for both the 0.4 s and 5 s disconnection times:

(a) 0.4 s = 0.22  $\Omega$

(b) 5 s = 1.04  $\Omega$

Figure 2 Time/current curve of a manufacturer's device



When the values above are compared with the values from BS 7671:2018+A2:2022, the 0.4 s disconnection time is identical, although when a 5 s disconnection time is permitted, the maximum permitted  $Z_s$  is considerably higher. This can be advantageous when designing a circuit with a 5 s disconnection time.

## How to obtain $I_a$ when settings are present on an MCCB

While the examples given above are based on circuit-breakers, the principle for obtaining the  $I_a$  for a thermal magnetic MCCB is the same, however, there may be settings on the device to take account of.

Other than the most basic MCCBs, most will have a setting for adjusting the thermal setting characteristic of the device, and also have a setting present for the magnetic characteristics. The basic settings are listed below:

- $I_r$ : adjusts the long-time current thermal setting; and
- $I_{sd}$  (or  $I_m$ ): adjusts short-term magnetic setting

The  $I_r$  adjustment is dependent on the manufacturer, although this can be a factor of the  $I_n$  value, such as 0.8-1.0. As an example, an MCCB with an  $I_n$  rating of 160 A with an  $I_r$  setting of 0.8 would give an  $I_r$  of 128 A ( $160 \text{ A} \times 0.8 = 128 \text{ A}$ ).

Similarly, the  $I_{sd}$  setting can be somewhere around 1.5 – 10, which is a factor based on the  $I_n$  or  $I_r$  setting of the device. As an example, using the  $I_r$  value obtained above and an  $I_{sd}$  setting of 5, the  $I_{sd}$  would be 640 A ( $128 \text{ A} \times 5 = 640 \text{ A}$ ).

Once the values above have been ascertained, the steps below will enable the establishment of the maximum  $Z_s$  for the corresponding 0.4 s and 5 s disconnection times.

## 0.4 s disconnection time

For the 0.4 s disconnection time, it is not necessary to consult the graph as  $I_{sd}$  equals  $I_a$ . Referring to the previous section, a factor may be required to account for the tolerance of the device. For the example below, a tolerance of 20% is used, although the manufacturer's data shall be consulted for this value.

$$Z_s = \frac{U_0 \times C_{min}}{I_a \times 1.2}$$

$$Z_s = \frac{230 \times 0.95}{640 \times 1.2}$$

$$Z_s = 0.28 \Omega$$

## 5 s disconnection time

To obtain the  $I_a$  for a 5 s disconnection time, the time/current graph would be referenced to obtain the  $I_a$ . Utilizing the

graph in Figure 2, the values of current on the x axis gives a multiple of  $I_n$  rather than an actual current figure. If we did this as a multiple of  $I_r$  (128 A) we would get  $4.2 \times 128 = 538$  A, where 4.2 is the multiple of  $I_r$  as obtained previously. With the current  $I_a$  obtained, the maximum permitted  $Z_s$  can now be calculated as shown below.

$$Z_s = \frac{U_0 \times C_{min}}{I_a}$$

$$Z_s = \frac{230 \times 0.95}{538}$$

$$Z_s = 0.40 \Omega$$

### Correction factor due to temperature rise under load

The method used in this article does not include a correction factor for the increase in resistance caused by the increase in temperature of the conductor under load. When designing a circuit, the temperature rise is built into the cable design calculation. When testing is carried out to obtain the measured value of  $Z_s$  in accordance with Regulation 643.7.3 of BS 7671:2018+A2:2022, it is carried out at an ambient temperature. Due to the increase in resistance with the increase in temperature when the cable carries the circuit's load, a factor is applied to the maximum permitted  $Z_s$  for the circuit's protective device. Formula 4 should be applied when comparing the maximum permitted  $Z_s$ , with the  $Z_s$  obtained from the testing procedure.

**Formula 4** extracted from Appendix 3 of BS 7671:2018+A2:2022

$$z_s(m) \leq 0.8 \frac{U_0 \times C_{min}}{I_a}$$

Where:

$Z_s(m)$  is 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 ( $\Omega$ ).

**0.8** is the factor to take into account the increase of resistance of the conductors with the increase of temperature due to the load current.

$U_0$  is the nominal AC rms line voltage to Earth.

$I_a$  is the current in amperes causing operation of the protective device

within the time stated in Table 41.1 (of BS 7671:2018+A2:2022), or within 5 s according to the conditions stated in Regulations contained within 411.3.2.3.  $C_{(min)}$  is the minimum voltage factor to take account of voltage variations depending on time and place, changing of transformer taps and other considerations.

### Devices other than thermal magnetic devices

Although the focus of this article is limited to thermal magnetic devices, devices are available with electronic trip units. These are generally used to obtain selectivity between devices where this cannot be achieved by their thermal magnetic counterparts. When designing for selectivity, manufacturer's/third party design software makes comparison of the time/current curve simpler to ensure selectivity is achieved.

If the device's maximum  $Z_s$  is not obtainable, for example, due to a third party design, some manufacturers provide a formula for working out the maximum  $Z_s$ , although this usually limited to a 0.4 s disconnection time.

Formula 5 was derived from a Schneider technical data sheet based on the Compact NSX, with a micrologic 2.2 trip unit. This formula is informative only.

**Formula 5** maximum  $Z_s$  formula derived from Schneider's technical data sheet 002 Issue 3.

$$Z_s(m) = \frac{U_0 \times C_{min}}{I_n \times I_o \times I_r \times I_{sd} \times 1.1}$$

Where:

$Z_s(m)$  is 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 ( $\Omega$ ).

$U_0$  is the nominal AC rms 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.

$I_n$  is the rating of the circuit-breaker.

$I_o$  is the long-time dial setting (coarse).

$I_r$  is the long-time dial setting (fine).

$I_{sd}$  is the short-time dial setting.

**1.1** is the 10 % tolerance for the  $I_{sd}$  short-time pickup current setting.

### Summary

It was found that when using manufacturer's data, as opposed to the values from Table 41.3 of BS 7671:2018+A2:2022, a higher maximum  $Z_s$  can be permitted when designing circuits such as distribution circuits that permit a 5 second maximum disconnection time.

Although the time/current curve method used in this article is the fundamental method of obtaining the maximum permitted  $Z_s$ , when researching manufacturer's data sheets, the maximum  $Z_s$  may already be stated for 0.4 s and 5 s disconnection times. Some manufacturers may also give a multiplication factor of  $I_n$  to obtain  $I_a$ . Something to consider if using older data sheets with the maximum  $Z_s$  published, it must be ensured that the  $C_{min}$  factor is applied, as this only made it into BS 7671 in 2015 (BS 7671:2008+A3:2015).

Protective device manufacturers may also have online tools and free software packages available to obtain the maximum  $Z_s$  of their devices and this is the most accurate way of determining the maximum  $Z_s$  of the device, although older devices may not be contained within these packages. These tools are advantageous when using devices with electronic protection that may be required to achieve selectivity. Most electrical design software packages have all the required maximum  $Z_s$  values contained within their software.

### Caveat

This article is for informative use only. When obtaining the maximum  $Z_s$  of a device, it must be ensured the values obtained are correct for the device make and model selected. Any examples given in this article are for the purposes of explanation and not factual values. The liability for ensuring the correct maximum  $Z_s$  obtained lies with the person carrying out the work. Please consult the manufacturer when obtaining the calculation methods required for their devices.



# Isolation and switching for mechanical maintenance

By: Michael Peace CEng MIET MCIBSE - Senior Engineer at the IET

The topic of heat-damaged shower pull cords was discussed on the IET EngX forum at the end of 2022, and not for the first time either.

During the debate, and to avoid the problem of heat-damaged isolators, the question was asked whether isolators for equipment such as showers and ovens could be omitted and is it acceptable to rely on isolation at the consumer unit? This article answers the debate by looking at the practicalities and requirements of BS 7671:2018+A2:2022 with respect to isolation and switching for mechanical maintenance.

## What are the requirements for isolation?

BS 7671 is non-statutory but the Electricity at Work Regulations 1989 (EAWR) are written into law.

The EAWR are general in their application and refer throughout to "danger" and "injury". Danger is defined as "risk of injury" and "injury" is defined in terms of certain classes of potential harm to persons. Injury is stated to mean death or injury to persons from:

- electric shock;
- electric burn;
- electrical explosion or arcing; or
- fire or explosion initiated by electrical energy.

Regulation 12(1)(b) of EAWR states "where necessary to prevent danger, suitable means shall be available for [...] the isolation of any electrical

Figure 1 Rotary isolator (Reproduced with permission of Eaton)



equipment", where "isolation" means the disconnection and separation of the electrical equipment from every source in such a way that the disconnection and separation is secure.

## What are the requirements of BS 7671:2018+A2:2022 for isolation?

The main requirements for isolation and switching are provided in Chapter 46 and Section 537 of BS 7671:2018+A2:2022.

With respect to switching off for mechanical maintenance, the term isolation can be broadly split into three categories covering different parts of the installation:

1. installation;
2. circuits; and
3. equipment.

## Installations

Chapter 46 of BS 7671:2018+A2:2022 sets out the requirements for isolation and switching and Regulation 462.1 states that "Each electrical installation shall have provisions for isolation from each supply."

This is provided in the form of a main linked switch or linked circuit-breaker located as near as practicable to the origin of the installation as a means of switching the supply on load, as set out in Regulation 462.1.201 of BS 7671:2018+A2:2022.

Figure 2 Main switch disconnector (Reproduced with permission of Electrium)



## Circuits

Regulation 462.2 of BS 7671:2018+A2:2022 requires every circuit to be provided with isolation for all live conductors, except those detailed in Regulation 461.2 of BS 7671:2018+A2:2022, which provides

exceptions for TN-C-S and TN-S systems where the neutral or PEN conductor is reliably connected to Earth.

**Figure 3 Circuit-breaker (Reproduced with permission of Electrium)**



**Equipment**

Devices for isolation and switching or plugs and socket-outlets can be used to provide isolation for equipment. Note that for plugs and socket-outlets, isolation is achieved by withdrawal of the plug from the socket-outlet. The switch of a socket-outlet is not required to be suitable for isolation, see '(6)' to Table 537.4 of BS 7671:2018+A2:2022. Where mechanical maintenance may involve a risk of physical injury, means for switching off shall be provided in accordance with Section 464 of BS 7671:2018+A2:2022.

**Figure 4 50 A isolator switch for equipment (Reproduced with permission of Electrium)**



**What are the requirements of BS 7671:2018+A2:2022 for switching off for mechanical maintenance?**

Regulation 464.2 of BS 7671:2018+A2:2022 requires suitable means to prevent equipment from being inadvertently or unintentionally reactivated during mechanical maintenance, unless the means of switching off is continuously under the control of any person performing such

maintenance. This is typically an isolation device designed to allow a padlock to be installed to ensure safe isolation and prevent inadvertent re-energization.

**Which devices are suitable for isolation?**

Table 537.4 of BS 7671:2018+A2:2022 provides guidance on protective, isolation and switching devices and their suitability for isolation, emergency switching off and functional switching. This includes a wide range of devices from circuit-breakers to contactors. Where protective devices are suitable and can be used for isolation of circuits, this is marked on the side of the device as shown in Figure 5.

**Figure 5 Isolation symbol (see IEC 60617 identity number S00288)**



**IEC 60617 - Graphical Symbols for Diagrams**

Table 1 of BS EN 60947-3:2015 provides a useful summary of the different types of equipment and definitions (see Figure 6).

**Figure 6 BS EN 60947-3:2015 Table 1 summary of equipment definitions**

Functions		
Making and breaking current	Isolating	Making, breaking and isolating
Switch 	Disconnecter 	Switch-disconnector 
Fuse-combination units		
Switch-fuse single opening <sup>a</sup> 	Disconnecter-fuse single opening <sup>a</sup> 	Switch-disconnector-fuse single opening <sup>a</sup> 
Switch-fuse double opening <sup>b</sup> 	Disconnecter-fuse double opening 	Switch-disconnector-fuse double opening <sup>b</sup> 
Fuse-switch single opening <sup>a</sup> 	Fuse-disconnector single opening <sup>a</sup> 	Fuse-switch-disconnector single opening <sup>a</sup> 
Fuse-switch double opening <sup>b</sup> 	Fuse-disconnector double opening 	Fuse-switch-disconnector double opening <sup>b</sup> 

NOTE Equipment shown as single opening may comprise multiple openings in series.

<sup>a</sup> The fuse may be on either side of the contacts of the equipment.  
<sup>b</sup> Depending on the design, breaking may take place on one or both sides of the fuse-link.

**Where should an isolator be located?**

The isolator needs to be installed so that it is clearly identified by position or labelling. Regulation 537.3.2.4 states that: "Devices for switching off for mechanical maintenance shall be clearly identified by position or durable marking so as to be identifiable for their intended use." "Identified by position" means, for example, if it can clearly be seen that the purpose of an isolator is for a particular piece of equipment. If it is decided to locate the isolator away from the equipment for a particular reason, it shall be clearly identified.

**Is it acceptable to isolate at the consumer unit for mechanical maintenance?**

There is nothing in BS 7671:2018+A2:2022 to prevent isolation at the consumer unit for mechanical maintenance. The installation can be isolated by operating the main switch, as it is required to be a double-pole device suitable for switching the supply on load and as a means of isolation, in accordance with Regulation 462.1.201. The installation could be considered to be under continuous control or locked off if required.

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## Isolation and switching for mechanical maintenance

Figure 7 Manufacturer's instructions for an electric shower

Switch off at isolating switch when not in use. This is a safety procedure recommended with all electrical appliances.

The main consideration is the type of equipment connected and what is required in the manufacturer's instructions. Frequently switching a high current inductive load is likely to reduce the lifespan of the protective device. It's important to remember that the primary function is a protective device.

Then there are the practicalities to consider. For example, isolation at the consumer unit in a dwelling to carry out a maintenance task to replace equipment which takes 15 minutes once every five years may be acceptable. Whereas the isolation of an office block or house of multiple occupancy to carry out maintenance work on a more frequent basis will be more inconvenient and probably not acceptable.

### Can I use a protective device for isolation?

Isolating an individual circuit as opposed to the whole installation using the main switch is more desirable as there is less inconvenience when others are using the installation.

The requirements for isolation and switching in TT systems are different to that for TN systems. For a TN-S system, where the neutral conductor can be considered to be reliably at earth potential, the neutral need not be disconnected, therefore it is permissible to use the protective device for isolation (see Regulation 531.2.2 of BS 7671:2018+A2:2022).

For TT systems, the neutral must be disconnected for isolation. This could be achieved by using double-pole protective devices, but it is important to note that most readily available devices are single-pole, therefore this method of isolation would not be suitable for TT installations.

Whilst it is acceptable to use a protective device for isolation, it should be remembered that where a protective

Figure 8 Manufacturer's instructions for an extractor fan

#### Wiring

- i. Switch off mains supply before making electrical connections. If in any doubt, contact a qualified electrician.
- ii. These units are for fixed wiring only. A flexible cord must not be used. All wiring must be fixed securely and the cable to the fan should be a minimum of 1 mm<sup>2</sup> in section. All wiring must comply with current I.E.E. Regulations or local regulations if outside the UK.
- iii. A double pole fused spur having contact separation of at least 3 mm in all pole must be used and fitted with a 3 A fuse.
- iv. The fan is double insulated and does not require an earth connection.
- v. Fan should not be accessible to a person using either the shower or bath.

device such as circuit-breakers, AFDDs, RCBOs and RCDs are used for isolation, the primary function of these devices is protection and as a consequence are not intended for frequent load switching.

Where a protective device is used for frequent duty, the number of operations and load characteristics according to the manufacturer's instructions should be taken into account. This is stated in '(5)' to Table 537.4 of BS 7671:2018+A2:2022.

### What do manufacturer's instructions say?

Regulation 134.1.1 of BS 7671:2018+A2:2022 requires the installer to take account of manufacturer's instructions. The advice provided in manufacturer's instructions vary.

Looking at the manufacturer's instructions for a 10.5 kW shower, the general safety section states that a suitable double-pole isolation switch for supply disconnection must be incorporated in the fixed circuit in accordance with current wiring rules. At this point, it could be assumed that isolation at the consumer unit is acceptable but it's important to read further.

Item 3.8 of the electrical installation section on page three of the manufacturer's instructions recommend switching off at isolating switch when not in use, as shown in Figure 7. Given the message that "this is a safety procedure recommended with all electrical appliances", it is difficult to see how omitting a local isolator could be justified.

The example shown in Figure 8 is of manufacturer's instructions for an extractor fan. It states that a double-pole fused spur having contact separation of at least 3 mm in all poles must be used and fitted with a 3 A fuse.

### What do the product standards say?

The international standard for household and similar products is the IEC 60335 series. Clause 7.12.2 of IEC 60335-1:2020 Household and similar electrical appliances – Safety – Part 1: General requirements states:

*7.12.2 If a stationary appliance is not fitted with a supply cord and a plug, or with other means for disconnection from the supply mains having a contact separation in all poles that provide full disconnection under overvoltage category III conditions, the instructions shall state that means for disconnection must be incorporated in the fixed wiring in accordance with the wiring rules.*

### Summary

Isolation at the consumer unit is permitted but it's important to consider the practicalities and requirements of the manufacturer of the equipment.

Where single-pole protective devices are used, consideration for the type of earthing system is required. Where protective devices are used for isolation, it is important to take account of the manufacturer's instructions with regards to the number of mechanical and electrical operations.

Manufacturers of electrical equipment often recommend the installation of device(s) for isolation and switching because turning off the equipment when not in use is a safety procedure recommended with all electrical appliances.

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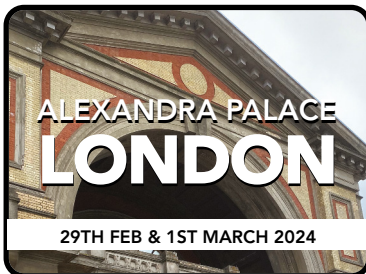


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