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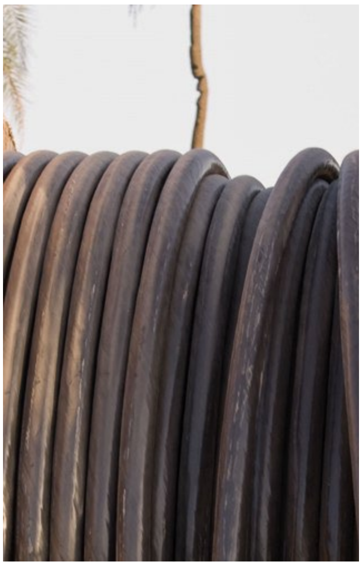


Thermoplastic (PVC) or Thermosetting (XLPE) SWA cable?

By: **Michael Peace CEng MIET MCIBSE**

Which cable type should you choose?

A question that arises periodically on the IET Engineering Communities forum concerns the different types of steel wired armoured (SWA) cables and the associated current-carrying capacity.

What are the different types of SWA cable?

The two types of SWA cable referred to in Appendix 4 of BS 7671:2018+A2:2022 are thermoplastic insulation, which is polyvinyl chloride (PVC), and thermosetting insulation, which is cross-linked polyethene (XLPE).

PVC insulated and PVC sheathed SWA cables were manufactured to BS 6346 *Electric cables. PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V*. The standard was originally published in 1969. Prior to this, PVC SWA cables were manufactured to BS 3346:1961 *Armoured PVC-insulated cables*.

However, BS 6346, the standard for PVC cables, was withdrawn in 2011. SWA cables are generally only manufactured with XLPE insulation to either BS 5467, BS 6724 or BS 7846, as listed in Table 4A3 in BS 7671.

BS 5467 *Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1 000 V and 1 900/3 300 V for fixed installations.*
BS 6724 *Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1 000 V and 1 900/3 300 V for fixed installations, having low emission of smoke and corrosive gases when affected by fire,* if a low smoke zero halogen (LSZH) sheath is required.
BS 7846 Electric cables. *Thermosetting insulated, armoured, fire-resistant cables of rated voltage 600/1 000 V for fixed installations, having low emission of smoke and corrosive gases when affected by fire, for fire resistant applications.*

PVC insulated and sheathed SWA cables may be still manufactured to the withdrawn standard in small quantities, primarily used for traffic signals. The vast majority of SWA cables though will be XLPE insulated, and have been for the last twenty years.

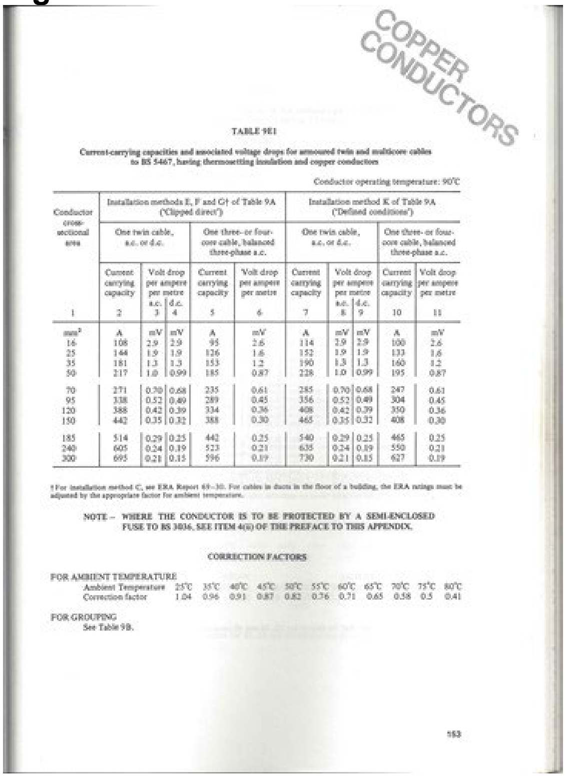
It is also worth pointing out that aluminium wire armoured (AWA) cables also exist, typically used for single core conductors due to their non-ferrous properties.

When did thermosetting XLPE SWA cables first appear in the IEE Wiring Regulations?

The British Standard for thermosetting cables, BS 5467, was originally published in 1977. The first appearance of thermosetting SWA cables was in the Fifteenth Edition of the IEE Wiring Regulations in 1981, as shown in Table 9E1 (Figure 1). Note that the conductor cross sectional area starts from 16 mm². This was because at the time, cable manufacturers only had the machinery to make the change for the larger sizes, so it was agreed to test the water with the market first before they all invested in new machinery to cover the smaller sizes, a kind of ‘soft launch’. The benefit in uplift from current ratings is not as significant on the smaller sizes, and equipment that required the smaller size conductors was less likely to capable of operating at the higher 90 °C.

In the Sixteenth Edition of the IEE Wiring Regulations in 1991, the table was relabelled Table 4E4A as we know it today and the table included information for conductor sizes from 1.5 mm² - 400 mm².

Figure 1: Extract from Fifteenth Edition of the IEE Wiring Regulations 1981



COPPER CONDUCTORS

TABLE 9E1

Current-carrying capacities and associated voltage drops for armoured twin and multicore cables to BS 5467, having thermosetting insulation and copper conductors

Conductor operating temperature: 90°C

Conductor cross-sectional area	Installation methods E, F and G† of Table 9A ('Clipped direct')					Installation method K of Table 9A ('Defined conditions')				
	One twin cable, a.c. or d.c.			One three- or four-core cable, balanced three-phase a.c.		One twin cable, a.c. or d.c.			One three- or four-core cable, balanced three-phase a.c.	
	Current carrying capacity	Volt drop per ampere per metre a.c.	Volt drop per ampere per metre d.c.	Current carrying capacity	Volt drop per ampere per metre	Current carrying capacity	Volt drop per ampere per metre a.c.	Volt drop per ampere per metre d.c.	Current carrying capacity	Volt drop per ampere per metre
1	2	3	4	5	6	7	8	9	10	11
mm²	A	mV	mV	A	mV	A	mV	mV	A	mV
16	108	2.9	2.9	95	2.6	114	2.9	2.9	100	2.6
25	144	1.9	1.9	126	1.6	152	1.9	1.9	133	1.6
35	181	1.3	1.3	153	1.2	190	1.3	1.3	160	1.2
50	217	1.0	0.99	185	0.87	228	1.0	0.99	195	0.87
70	271	0.70	0.68	235	0.61	285	0.70	0.68	247	0.61
95	338	0.52	0.49	289	0.45	356	0.52	0.49	304	0.45
120	388	0.42	0.39	334	0.36	408	0.42	0.39	350	0.36
150	442	0.35	0.32	388	0.30	465	0.35	0.32	408	0.30
185	514	0.29	0.25	442	0.25	540	0.29	0.25	465	0.25
240	605	0.24	0.19	523	0.21	635	0.24	0.19	550	0.21
300	695	0.21	0.15	596	0.19	730	0.21	0.15	627	0.19

† For installation method C, see ERA Report 69–30. For cables in ducts in the floor of a building, the ERA ratings must be adjusted by the appropriate factor for ambient temperature.

NOTE – WHERE THE CONDUCTOR IS TO BE PROTECTED BY A SEMI-ENCLOSED FUSE TO BS 3036, SEE ITEM 4(ii) OF THE PREFACE TO THIS APPENDIX.

CORRECTION FACTORS

FOR AMBIENT TEMPERATURE

Ambient Temperature	25°C	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C
Correction factor	1.04	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58	0.5	0.41

FOR GROUPING
See Table 9B.

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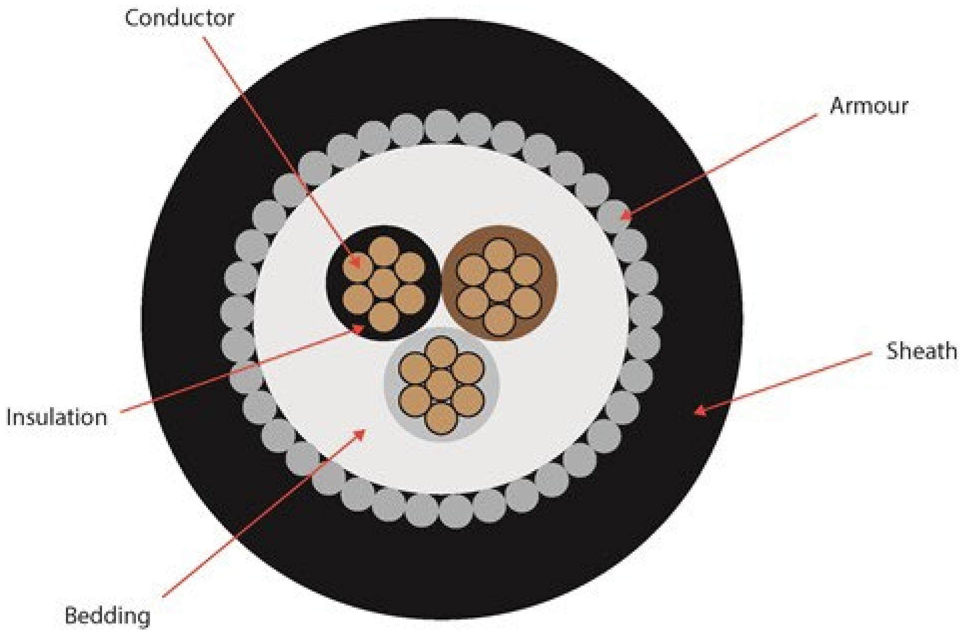
The construction of an SWA cable

Figure 2 illustrates a typical SWA cable construction and its constituent parts. When we refer to a particular type of cable, such as PVC or XLPE, it is the material used for the insulation which is referred to. Whilst the insulation material used is XLPE, the bedding and sheath are made from PVC. The table below indicates the typical construction and materials used in an XLPE armoured cable.

Conductor	Copper
Insulation	XLPE
Bedding	PVC
Armour	SWA
Sheath	PVC

Figure 2: Cable construction



What are the advantages and disadvantages of thermosetting insulation?

Besides having a higher temperature rating, thermosetting insulation offers higher insulation resistance values, increased mechanical protection and resistance to chemical corrosion and water. There are also disadvantages to thermosetting insulation, since it is more difficult to strip than thermoplastic insulation.

When it comes to recycling, usually only the metals, the copper conductors and/or the steel or aluminium armouring is considered due to the value of these metals. However, PVC materials can be recycled and made into something else, whereas XLPE cannot be melted as it is cross-linked.

Under fire conditions PVC cables create toxic fumes and large quantities of smoke, potentially making escape more difficult. PVC material is used for the bedding and sheath components of XLPE cables. If the cables are installed indoors and a low smoke zero halogen (LSZH) solution is required, LSZH SWA cables manufactured to BS 6274 should be specified, as they do not contain PVC or any other halogenated material.

Does thermosetting insulated SWA cable have higher current carrying capacity than thermoplastic insulated SWA cable?

Appendix 4 of BS 7671:2018+A2:2022 includes the current-carrying capacities for SWA cables. Table 4D4A is for multicore armoured thermoplastic cables and Table 4E4A is for multicore armoured thermosetting cables, as seen in Figure 3 and Figure 4.

When making a direct comparison of current-carrying capacity for thermoplastic and thermosetting cables in Table 4D4A and 4E4A, the current-carrying capacity of thermosetting cables is higher when compared with the equivalent thermoplastic cable. The increased current-carrying capacity is due to a higher conductor operating temperature of 90 °C. It is important to read the notes next to table 4E4A, as they provide guidance regarding compatibility.

Figure 3: Table 4D4A of BS 7671:2018+A2:2022

COPPER CONDUCTORS

TABLE 4D4A – Multicore armoured 70 °C thermoplastic insulated cables (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	21	18	22	19	22	18
2.5	28	25	31	26	29	24
4	38	33	41	35	37	30
6	49	42	53	45	46	38
10	67	58	72	62	60	50
16	89	77	97	83	78	64
25	118	102	128	110	99	82
35	145	125	157	135	119	98
50	175	151	190	163	140	116
70	222	192	241	207	173	143
95	269	231	291	251	204	169
120	310	267	336	290	231	192
150	356	306	386	332	261	217
185	405	348	439	378	292	243
240	476	409	516	445	336	280
300	547	469	592	510	379	316
400	621	540	683	590	-	-

Figure 4: Table 4E4A of BS 7671:2018+A2:2022

COPPER CONDUCTORS

TABLE 4E4A – Multicore armoured 90 °C thermosetting insulated cables (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	27	23	29	25	25	21
2.5	36	31	39	33	33	28
4	49	42	52	44	43	36
6	62	53	66	56	53	44
10	85	73	90	78	71	58
16	110	94	115	99	91	75
25	146	124	152	131	116	96
35	180	154	188	162	139	115
50	219	187	228	197	164	135
70	279	238	291	251	203	167
95	338	289	354	304	239	197
120	392	335	410	353	271	223
150	451	386	472	406	306	251
185	515	441	539	463	343	281
240	607	520	636	546	395	324
300	698	599	732	628	446	365
400	787	673	847	728	-	-

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Regulation 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Regulation 512.1.5).

What is compatibility?

Regulation 512.1.5 of BS 7671:2018+A2:2022 sets out the requirements for compatibility as shown in Figure 5. The intention of this Regulation is to ensure that every item of equipment will not cause harmful effects to other equipment with regards to EMC and temperature ratings.

Figure 5: Regulation 512.1.5 of BS 7671:2018+A2:2022

512.1.5 Compatibility

Every item of equipment shall be selected and erected so that it will neither cause harmful effects to other equipment nor impair the supply during normal service including switching operations.

Switchgear, protective devices, accessories and other types of equipment shall not be connected to conductors intended to operate at a temperature exceeding 70 °C at the equipment in normal service unless the equipment manufacturer has confirmed that the equipment is suitable for such conditions. The 70 °C limit is met if the live conductor size is chosen based on the current rating for 70 °C cables of similar construction.

See also Regulation 526.2 concerning electrical connections, Regulations 523.1 and 536.4.202 and Table 4A3.

The designer of the fixed installation shall verify that the installed fixed equipment, where relevant, is designed and manufactured in accordance with the Electromagnetic Compatibility Regulations 2016 and, upon request, the responsible person for the fixed installation shall provide the required documentation as specified by the Electromagnetic Compatibility Regulations.

NOTE 1: Information on the parameters to be considered is given in Section 444. The level of detail of the documentation may vary from very simple information to much more detailed documentation for complex installations involving important potential EMC aspects.

NOTE 2: The responsible person referred to in this regulation is as defined in the Electromagnetic Compatibility Regulations 2016 as the installer.

NOTE 3: Where the current rating is to be based on 70 °C, current-carrying capacities given in Tables 4D1 to 4D5 or 4H1 to 4H4 of Appendix 4 may be used for 90 °C thermosetting insulated cables.

It is stated that:

> *"Switchgear, protective devices, accessories and other types of equipment shall not be connected to conductors intended to operate at a temperature exceeding 70 °C at the equipment in normal service unless the equipment manufacturer has confirmed that the equipment is suitable for such conditions".*

This is also reinforced in Regulation 523.1 and footnote [b] in Table 52.1 of BS 7671:2018+A2:2022.

Figure 6: Table 52.1 BS 7671:2018+A2:2022

TABLE 52.1 – Maximum operating temperatures for types of cable insulation

Type of insulation	Temperature limit[a]
Thermoplastic	70 °C at the conductor
Thermosetting	90 °C at the conductor[b]
Mineral (Thermoplastic covered or bare exposed to touch)	70 °C at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 °C at the sheath[b, c]

[a] The maximum permissible conductor temperatures given in Table 52.1 on which the tabulated current-carrying capacities given in Appendix 4 are based, have been taken from IEC 60502-1 and BS EN 60702-1 and are shown on these tables in Appendix 4.

[b] Where a conductor operates at a temperature exceeding 70 °C it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection.

[c] For mineral insulated cables, higher operating temperatures may be permissible dependent upon the temperature rating of the cable, its terminations, the environmental conditions and other external influences.

NOTE: For temperature limits applicable to specific types of cable or insulation, refer to the cable specification or manufacturer.

Which table do I use for current-carrying capacity for thermosetting SWA cables?

As SWA cables are primarily manufactured using thermosetting insulation, you would be forgiven for thinking that the correct table to use would be Table 4E3A or Table 4E4A of BS 7671:2018+A2:2022, as these are the tables for current-carrying capacities for thermosetting cables. However, these ratings are for conductor operating temperatures of 90 °C.

If manufacturers do not confirm their equipment is suitable to operate at a temperature in excess of 70 °C, the tabulated current-carrying capacities in Table 4E3A or Table 4E4A of BS 7671:2018+A2:2022 cannot be used.

Note 3 of Regulation 512.1.5 of BS 7671:2018+A2:2022 states that, where the current rating is based on 70 °C, the tables for thermoplastic cables should be referenced instead, as shown in Figure 3.

Most electrical design software packages have an option to use thermoplastic, thermosetting or thermosetting limited to 'run at 70 °C', in which case, the current carrying capacities and voltage drop values are taken from Table 4D3A, 4D4A. 4D3B and 4D4B of BS 7671:2018+A2:2022 for thermoplastic cables.

Which 'k' value do I use for current-carrying capacity for thermosetting insulation?

The limiting factor of 70 °C conductor operating temperature for selection of cables for current carrying capacity is related to deterioration of equipment or accessories caused by constant loads of long duration. When carrying out fault current calculations, the value of k, for calculation of the effects of fault current, may be taken to correspond to the final temperature for thermosetting insulation.

For example, as shown in Table 43.1 of BS 7671:2018+A2:2022 below, the final temperature for 90 °C thermosetting insulation is 250 °C (k =143), compared with 70 °C thermoplastic insulation which has a final temperature of 160 °C (k =115) for conductors < 300 mm² and 140 °C (k = 103) for conductors > 300 mm². This could provide advantages for thermosetting insulation over thermoplastic insulation as higher fault currents can be achieved, but a key constraint is that the thermosetting insulation is not in contact or mixed with thermoplastic insulated cables.

Examples of instances where a reduced CSA could be selected when compared with that of a thermoplastic insulated cable include:

- When omission of overload protection (for a fixed load) is utilised, and using a device for fault protection only
- When carrying out energy let through calculations for a protective device like a BS EN 60947-2 MCCB
- When using an RCD for fault protection

Table 43.1 of BS 7671:2018+A2:2022

TABLE 43.1 –
Values of k for common materials, for calculation of the effects of fault current for disconnection times up to 5 seconds

	Conductor insulation							
	Thermoplastic				Thermosetting		Mineral insulated	
	90 °C		70 °C		90 °C	60 °C	Thermoplastic sheath	Bare (unsheathed)
Conductor cross-sectional area	≤ 300 mm²	> 300 mm²	≤ 300 mm²	> 300 mm²				
Initial temperature	90 °C		70 °C		90 °C	60 °C	70 °C	105 °C
Final temperature	160 °C	140 °C	160 °C	140 °C	250 °C	200 °C	160 °C	250 °C
Copper conductor	k = 100	k = 86	k = 115	k = 103	k = 143	k = 141	k = 115	k = 135/115[a]
Aluminium conductor	k = 66	k = 57	k = 76	k = 68	k = 94	k = 93		
Tin soldered joints in copper conductors	k = 100	k = 86	k = 115	k = 103	k = 100	k = 122		

Why is the temperature rating of switchgear, protective devices, accessories and other types of equipment limited to 70°C?

The IEC 61439 series of standards sets out the requirements for low-voltage switchgear and controlgear assemblies. PD IEC TR 61439-0:2022 *Guidance to specifying assemblies* states: “The temperature performance of assemblies in accordance with the IEC 61439 series assumes the temperature of the conductors outside the assembly, in normal service, is a maximum of 70 °C.”

In conclusion, assemblies to the IEC 61439 series are included in Regulation 512.1.5 of BS 7671:2018+A2:2022. Switchgear, protective devices, accessories and other types of equipment shall not be connected to conductors intended to operate at a temperature exceeding 70 °C at the equipment in normal service unless the equipment manufacturer has confirmed that the equipment is suitable for such conditions.

Summary

Most SWA cables are thermosetting insulated. Thermosetting cables are capable of operating at conductor operating temperatures of 90 °C, but it should be verified with the equipment manufacturer that this is safe. Unless this is confirmed, the current carrying capacities identified in Table 4D3A or Table 4D4A of BS 7671:2018+A2:2022 for thermoplastic SWA cables should be used.

Acknowledgments

I would like to extend thanks to Joe Cannon for suggesting the idea for the article and his valuable contributions. I met Joe at the Elex show in Bolton this year, where we originally discussed the idea.

I would also like to extend sincere thanks to the following individuals and organisations for contributing their technical expertise:

- The British Cables Association (BCA)
- Leon Markwell
- Mark Coles
- Paul Sayer
- Paul Skyrme

Further reading

BS 7671:2018+A2:2022 *Requirements for Electrical Installations.*

PD IEC TR 61439-0:2022 *Low-voltage switchgear and controlgear assemblies- Part 0: Guidance to specifying assemblies*

BS 5467 *Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1 000 V and 1 900/3 300 V for fixed installations.*

BS 6724 *Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1 000 V and 1 900/3 300 V for fixed installations, having low emission of smoke and corrosive gases when affected by fire,* if a low smoke zero halogen (LSZH) sheath is required.

BS 7846 *Electric cables. Thermosetting insulated, armoured, fire-resistant cables of rated voltage 600/1 000 V for fixed installations, having low emission of smoke and corrosive gases when affected by fire, for fire resistant applications.*

High Protective Conductor Currents in Electrical Installations

By: **Richard Giddings IEng MIET ACIBSE**

Richard Giddings returns to Wiring Matters with this article looking at the standardisation of conductor currents.

Introduction

Historically, protective conductors were only required in electrical installations as a means of providing shock protection to metallic (Class I) equipment, in combination with automatic disconnection of supply.

Such protective conductors, often referred to as ‘earthing conductors’, if designed correctly would provide a low impedance path between typically an item of equipment and the earthing terminal at the installation’s origin.

Should a fault develop making any exposed conductive part of the equipment live, the low impedance path to earth, would enable a current to flow, which in a correctly designed system would enable a protective device, such as fuse or circuit-breaker to operate. This would therefore automatically disconnect the supply and remove the shock hazard.

Such conductors in these circumstances would only carry a current during fault conditions.

This philosophy is still unchanged in BS 7671:2018+A2:2022, the current version of the standard.

However, with the advent and development of equipment containing electronics, which now forms the vast part of almost all electrical installations, protective conductors are called upon to provide an additional role; a role which in many cases will result in current flow in these conductors under normal operating, non-fault conditions.

Many readers will have heard the term ‘functional earthing’ which is where a piece of equipment needs a permanent functional connection to earth in order to operate correctly as well as safely. Very often this is to allow by-products of electrical or electronic noise filtering or power conversion processes to safely dissipate energy to earth. Generally, the functional earth and protective earth are the same conductor.

Where the protective conductor path may become disconnected, thereby losing its effectiveness, these functional earth currents may have nowhere to flow, and may cause any exposed conductive parts of equipment on the circuit to rise in potential with respect to true earth – paradoxically posing a shock hazard.

BS 7671 first introduced measures to deal with these ‘high protective conductor currents’ as they are known, in the 1994 amendment to BS7671:1992 and in those days dedicated a ‘special locations’ section, Section 607, to it.

As usage of equipment generating such currents increased, it became apparent that the requirement should no longer be thought of as a 'special location' – with consequently, the requirements being embodied in the main text of BS 7671.

High protective conductor currents may often be experienced wherever electronic equipment containing switched mode power supplies, variable speed drives, lighting control and dimming, as well as audio/visual or communications and technology equipment exists. Product standards relating to the manufacture of domestic appliances in the UK generally allow an upper limit of 3.5mA protective conductor current to such items.

This needs careful assessment at design stage, particularly the cumulative effects – not only for known existing equipment, but also the likelihood of future needs.

Where do measures against high protective conductor currents need to be considered?

BS 7671:2018 +A2:2022 requires special measures to be adopted, where either:

- an individual item is to be connected having a protective conductor current exceeding 10 mA; or
- cumulative protective conductor currents exceeding 10 mA may exist in final or distribution circuits.

Equipment manufacturers should be consulted to ascertain this information.

Guidance on the levels of expected protective conductor current can be found in clause 13.2 of BS EN 60335-1:2012+A15:2021 *Household and similar electrical appliances – Safety – Part 1: General requirements.*
For information and telecommunications technology equipment, maximum allowable protective conductor currents are specified in clause 5.7.5 of BS EN 62368-1:2014+A11:2017 *Audio/video, information and communications technology equipment – Part 1: Safety requirements.*

In order to mitigate the risk of the protective conductor becoming broken or disconnected, BS 7671 recognises two approaches on circuits where high protective conductor currents may exist:

- a larger conductor than that required for shock protection and thermal performance alone – to offer increased physical strength – particularly at terminations; and
- duplicated separate conductors.

Fixed equipment

Although BS EN 62368-1 applies to the manufacture of audio/video & information and telecommunications technology equipment, it does specify minimum sizes for mains supply flexible cables to such items, which can be used as a reference.

BS 7671:2018+A2:2022 however, in regulation **543.7.1.202,** requires a single item of equipment in which the **protective conductor current exceeds 10 mA** to be either:

- permanently wired in, with a protective conductor sized as per regulation **7.1.203**;

- connected via a plug and socket outlet complying with BS EN 60309-2 (colloquially known as a ‘Commando’ type plug) with a protective conductor in the flexible cable of cross-sectional area (csa) not less than 2.5 mm^2 for plugs rated at 16 A, and not less than 4 mm^2 for plugs rated above 16 A; or

- connected with a protective conductor complying with the ‘normal’ requirements of Section 543 of BS 7671 but in combination with an earth monitoring system complying with BS 4444.

Regulation **543.7.1.203** stipulates requirements for final or distribution circuits, where the total protective conductor current is likely to exceed 10 mA. It requires one or more of the following:

- A single protective conductor, meeting regulations 543.2 (relating to conductor type) and 543.3 (relating to preserving electrical continuity), having csa of not less than 10 mm^2 (to give a **mechanically robust** connection).

- A single protective conductor, meeting regulations 543.2 and 543.3, having csa of not less than 4 mm^2 being enclosed, for example in a conduit, to provide **additional protection against mechanical damage**.

- Two individual protective conductors, meeting the requirements of Section 543.to give a **duplicated conductor path**. These could be of different types (for example copper conductor run in an earthed metallic conduit).

  Where the two individual protective conductors are run within a multicore cable, the total csa of all the conductors - including the line and neutral conductors - shall be not less than 10 mm^2.

- An earth monitoring system to BS 4444, which automatically disconnects the supply if a continuity fault occurs in the protective conductor.

- Connection of the equipment to the supply by means of a double-wound transformer or equivalent unit, with the protective conductor of the incoming supply being connected to the exposed conductive parts of the equipment and to a point of the secondary winding of the transformer. The protective conductors between the equipment and the transformer will need to comply with one or more of the arrangements described in the preceding four bullet points.

Circuits serving socket outlets

These type of circuits are probably the most commonly occurring to be serving equipment producing protective conductor currents, regardless of whether within residential or non-residential properties.

For any final circuit with a number of socket-outlets or connection units intended, or considered likely, to supply several items of equipment where it is probable that the cumulative protective conductor current may exceed 10 mA, high integrity protective conductor connections complying with regulation **543.7.1.203** are needed.

Ring Final Circuits

Where a standard ring final circuit is employed, complying with Appendix 15 of BS 7671 (using typically 2.5 mm^2 live conductors and 1.5 mm^2 cpcs) it can be appreciated that the total csa of all of the live and protective conductors will easily exceed 10 mm^2 – hence satisfying regulation **543.7.1.203**.
Spurs however to the ring, will need special consideration and their own high-integrity protective conductor connections complying with regulation **543.7.1.203.**

Radial Circuits

A radial circuit will pose more of a problem, since by definition it will only have one protective conductor.

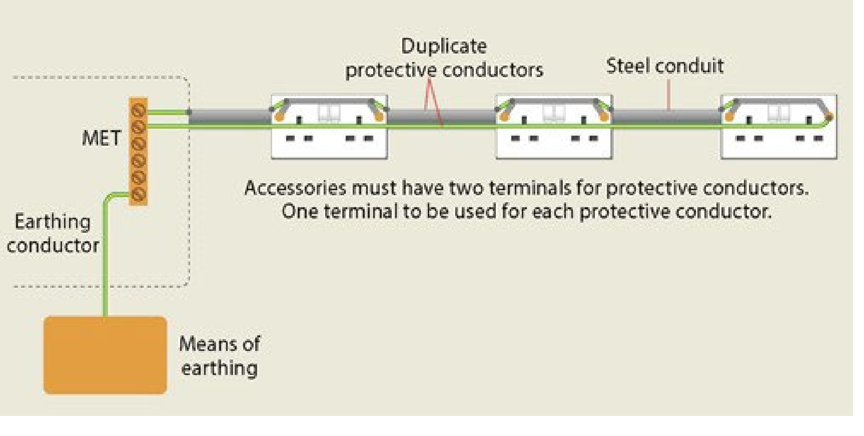
Regulation **543.7.2.201** now permits either of the following arrangements:

- The protective conductor being connected as ring. In practice this will necessitate a separate protective conductor being taken from the last socket-outlet on the circuit back to the distribution board.

  NOTE - To reduce interference effects, the duplicated protective conductor should be run with, or in close proximity to, the other conductors of the circuit. This is also a requirement of regulation **6.1**, as it should be remembered that the duplicated protective conductor could feasibly act also as a path for fault protection currents.

- A separate protective conductor being provided at the final socket outlet by perhaps connection to metal conduit, trunking or other metalwork that fulfils the requirements for a protective conductor.

Figure 1: Radial circuit with separate duplicated protective conductor



Labelling

Although BS 7671 has no requirements for labelling the actual outlets or sockets serving equipment with high protective conductor currents, it does require information to be provided at the distribution board serving such circuits.

Regulation **543.7.1.205** requires relevant information to be visible to any person who may be modifying or extending such circuits. Regulation **514.17** requires this warning notice to be provided and as it is a warning and not just for information, it must be installed on the consumer unit or distribution board.

Figure 2: Example of a label affixed near a distribution board that serves circuits with high protective conductor currents

DB1
The following have high protective conductor current:
1 Ring final circuit (sales office)
2 Radial final circuit (packaging/dispatch)

Practical considerations and best practice

Dual terminations at accessories

Although no longer a specific requirement of BS 7671:2018 +A2:2022, the practice of terminating cpc conductors separately, using wiring accessories with dual earth terminals, ought to be considered as good practice by designers and installers.

Such wiring accessories, particularly socket outlets to BS 1363, now feature in the majority of wiring accessory reputable manufacturers' ranges, and no longer carry the premium cost that they once did.

Figure 3: Typical twin 13A BS 1363 socket with dual earth terminals

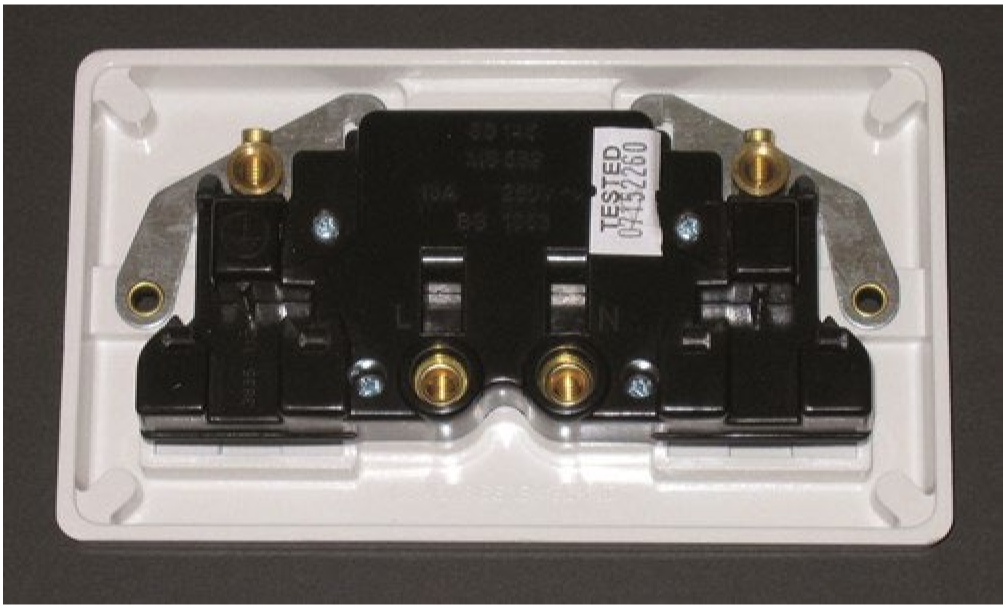
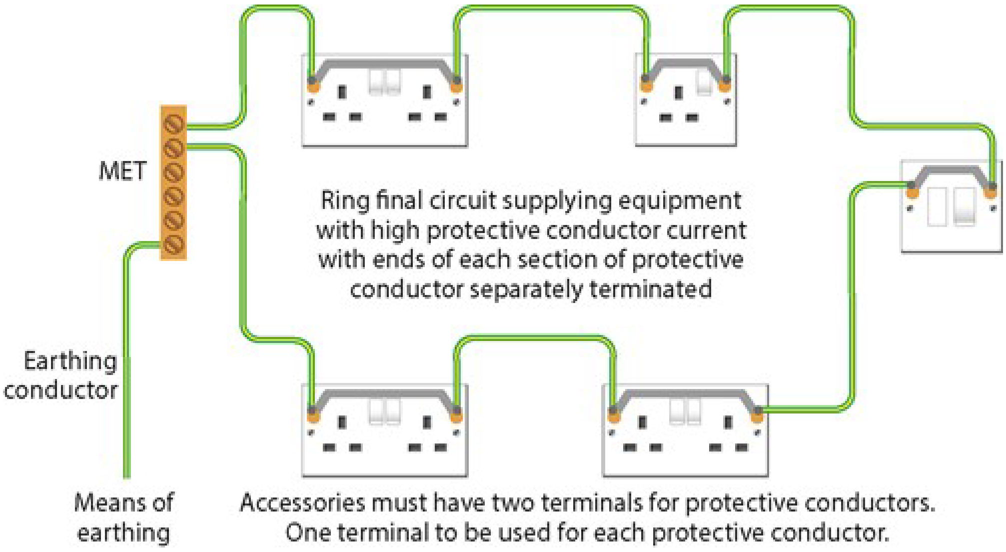


Figure 4: Typical ring final circuit, showing good practice of terminating cpcs on separate terminals



Protective conductors run individually

Where protective conductors are run separately, perhaps as a solution to deal with radial circuits or spurs to ring final circuits, consideration needs to be given to the physical strength and hence resilience of such conductors, as well as the conductor's ability to carry fault protection currents.

The designer/installer should also consider Regulation **543.1.1**, where minimum cross-sectional areas are stipulated. Notably, where a conductor is run without mechanical protection or as an integral part of cable, it shall be 4mm^2. This, as can be appreciated, results in a stranded conductor which is less likely to break or snap off at terminations, compared with a solid conductor.

Other issues to consider – unwanted tripping of RCDs

Unwanted tripping of RCDs is a phenomenon that is likely where such devices protect circuits with high protective conductor currents. This risk is more likely on circuits serving socket-outlets, where the designer/installer may not know exactly the usage pattern or loadings posed by the end users.

Arguably, such circuits are also likely to serve multiple items of equipment with relatively low load, albeit capable of cumulatively generating relatively high protective conductor currents.

Regulation **531.3.2** makes specific reference to this, emphasizing the fundamental requirement to divide the installation into several final circuits.

Of note, this regulation requires that the accumulation of such currents downstream of an RCD or RCBO should not exceed 30 % of the rated residual operating current of the device. With the common need for 30 mA RCD protection, this effectively limits the earth leakage current to less than 10 mA per device.

It should also be noted that under the product standards for RCDs and RCBOs, (commonly to BSEN 61008 series and BSEN 61009 series), such a device may operate at any residual current in excess of 50 % of its rated residual operating currents.

The regulation also now requires consideration of the use of RCBOs (as opposed to grouped circuits on a single RCD) for use in residential buildings as a measure to mitigate the effects of unwanted tripping and minimize inconvenience.

Summary

High protective conductor currents are now common place due to much of the electronic equipment now in use. As a consequence, the need to consider the hazards posed is a must.

In many cases, careful consideration by the designer and simple workmanship issues can achieve compliance with the requirements of BS 7671:2018+A2:2022, often without incurring additional cost.

With circuits supplying socket-outlets in any building type, where final equipment type and usage is unknown, arguably applying the techniques outlined in this article ought to now be considered the norm.

TESP - the industry's voice on skills

By: **Ruth Devine, TESP**

The Electrotechnical Skills Partnership (TESP)'s Employer Chair Ruth Devine looks at future skills developments and how TESP is supporting the industry…

The only constant in life is change – and when it comes to skills, the electrotechnical industry is continually having to adapt to a changing technical education landscape. On the horizon are several policy developments in England that will impact our sector:

- Widespread T Level adoption.
- Qualifications reform at Level 3 and below.
- Potential funding for additional specialist Level 3 qualifications.
- Employer Representative Bodies working on Local Skills Improvement Plans.
- Further Education colleges now have a statutory obligation to review how well their training provision meets local needs.

Effectively delivering the future skills needed in a fast-changing world needs a simplified and integrated skills system that is understood and trusted. Clear routes to industry recognition, effective careers and training guidance and ensuring a strong core of occupational competence are all vital, and support both the Building Safety and Net Zero agendas.

But who is coordinating these developments from a sector perspective, keeping abreast of how developments are likely to impact our sector's skills needs and ensuring electrotechnical employers can input and influence at Government level? The Electrotechnical Skills Partnership (TESP) represents the industry to policymakers and works alongside partners and stakeholders to promote sector-wide occupational competence.

Originally formed in 2015, TESP was incorporated as a not-for-profit Community Interest Company in 2019. The five founding members are the JIB, ECA, Select, National Electrotechnical Training and Unite the Union. It's important to understand TESP's activity is focussed on supporting all employers and individuals working in or wishing to join the sector, regardless of membership, and it works closely with other industry organizations including the IET, awarding organizations, training providers, and enterprise certification bodies.

TESP exists to support electrotechnical employers access the skills needed and to improve our sector's skills landscape. We provide a unified voice on skills matters to all four UK Governments, working closely with relevant departments and the Construction Leadership Council to ensure the specific needs of our sector are listened to and represented.

Our sector has a long, successful track record in technical education. Industry recognizes the importance of sufficient work-based training to ensure safety, quality and performance in a high-risk occupation. The Installation Electrician apprenticeship is consistently the most popular technical apprenticeship, well before the introduction of employer-led standards in England. Starts in 2022 are well above pre-pandemic levels. We had an apprenticeship end point assessment decades before it was mandated across all English apprenticeships. We have a large training provider network across the UK. And there's a huge range of employers working hard behind the scenes to train apprentices and make our sector successful; four of this year's Top 50 SME apprenticeship employers are electrical contractors. All this has been achieved without a mandatory training levy. So we have a well-established foundation, but there's still lots to do.

In terms of TESP's work, the activity we undertake is all around developing and promoting the right training routes to competence, building a workforce that's fit for the future:

Research

We regularly commission high quality Labour Market Intelligence (LMI) research so we can be certain our industry positions are objective and well-informed to meet employers' future challenges. New LMI will be commissioned next year.

Employers tell us the future skills needed are not just focused on technical competence. Management and commercial skills, creativity, problem solving, design, integration, using data and digital capabilities all feature prominently.

In September, TESP published Pye Tait research which confirms that the projected demand for the installation of electric vehicle charging points can be readily accommodated by the UK's workforce of fully qualified electricians. This is a great opportunity for our industry and the findings further strengthen the case against the proposed use of non-qualified and under-qualified personnel to undertake this safety-critical work.
The concept of the Electrician-plus model is increasingly important, meaning the core foundation of occupational competence is developed via an apprenticeship or equivalent work-based training, with CPD and upskilling qualifications on top for specialist technologies, including low carbon technologies.

Qualifications

Working with awarding organizations (AOs), TESP supports various technical strands of work related to qualification design, development, mapping, strengthening prerequisites and promoting the correct industry messaging.

When further government guidance is published around the qualifications reform at Level 3 and below, we will be digesting the information, supporting AOs and engaging industry employers to shape the future.

We also support employer groups developing and reviewing apprenticeships in the sector, including the Fire Emergency and Security Systems (FESS) employer group, as well as the electrotechnical apprenticeships (Installation Electrician and Domestic Electrician)

Experienced Worker Assessment

In 2020 we developed and launched the Experienced Worker Assessment (EWA) process to recognise the significant population of part-qualified industrial electricians. Those who complete the EWA gain a Level 3 qualification aligned to the apprenticeship standard and take the industry's assessment of competence, the AM2.

Following the launch of the Domestic Electrician apprenticeship, the related EWA process is currently in the late stages of development with industry stakeholders, to allow equivalent recognition to the standard for electricians working in the domestic market. Eligibility, technical entry qualifications and centre requirements will be strengthened, recognizing this is a sector that historically has had shorter entry routes without robust assessment of competence.

Forums

We have recently launched a Training & Qualifications Forum for interested employers and training providers to receive skills updates. It is held twice a year to provide updates on the latest industry developments in areas such as T-Levels, EAS, guidance for recognition of prior learning, ECS, qualifications reforms and more.

We represent the industry from a skills and training perspective on several forums, including the Electrotechnical Assessment Specification Management Committee and the OZEV EVCP Installation Safety Working Group.

The Electrotechnical Assessment Specification, EAS, sets out the conditions for certification or registration bodies – the most prevalent being Certsure and NAPIT – to assess enterprises. IET publishes EAS and acts as secretariat for the Management Committee. Fairly recently, EAS tightened up its approach to recognising qualifications for applicants wishing to become a Qualified Supervisor. EAS now publishes a Qualifications Guide listing the acceptable qualifications for each work category. Subjective auditable evidence routes are gone, and, bar the work category for work in dwellings, all qualification routes are aligned to the apprenticeship standard. With the recent launch of the new domestic electrician apprenticeship, it is hoped the Management Committee will soon be persuaded to adopt this as the benchmark for robust occupational competence.

It is likely that additional work categories will come into EAS, including solar PV, electric vehicle charging points, micro wind and electric energy storage systems. All crucial to achieving a net zero future, and all are technologies that require core electrotechnical competence as a starting point to ensure quality, safety and performance. The Electrician-plus model is crucial here for ensuring industry standards are upheld.

The new domestic electrician standard and changes to the core electrotechnical apprenticeship will encompass EVCP installation as a fundamental skill for an electrician, no matter which context they operate in.

TESP is working with industry to ensure additional qualifications required are developed in time, and that these qualifications have robust entry prerequisites.

Careers Support

In addition to our technical activity around qualifications, apprenticeships and qualifying existing workers, we also have initiatives aimed at promoting the industry, encouraging industry experts to share their experience with students and helping to improve the quality and relevance of training delivery:

- The Electrical Careers website gives advice and guidance on careers and training routes for all entry points to become an industry-recognised electrician, from school leavers to career changers.
- TESP's industry-recognised Training Routes show the paths to becoming a qualified electrician across all four nations of the UK.
- To tackle undesirable behaviour and mis-selling from certain training providers, TESP has launched the 'Rogue Trainers' campaign to help people understand which qualifications they should be looking for, tips on choosing a reputable training provider and red flags to avoid being misled.
- The Industry into Education campaign encourages employers to engage more closely with Further Education providers to inspire people into our industry and to provide a learning experience that is closely linked to reality. There are many different ways to get involved, from supporting T-Level placements to becoming a STEM Ambassador.
- TESP's Data Dashboard is an interactive online tool providing instant facts and figures about the industry profile across the UK, highlighting the significant and growing contribution to the economy.

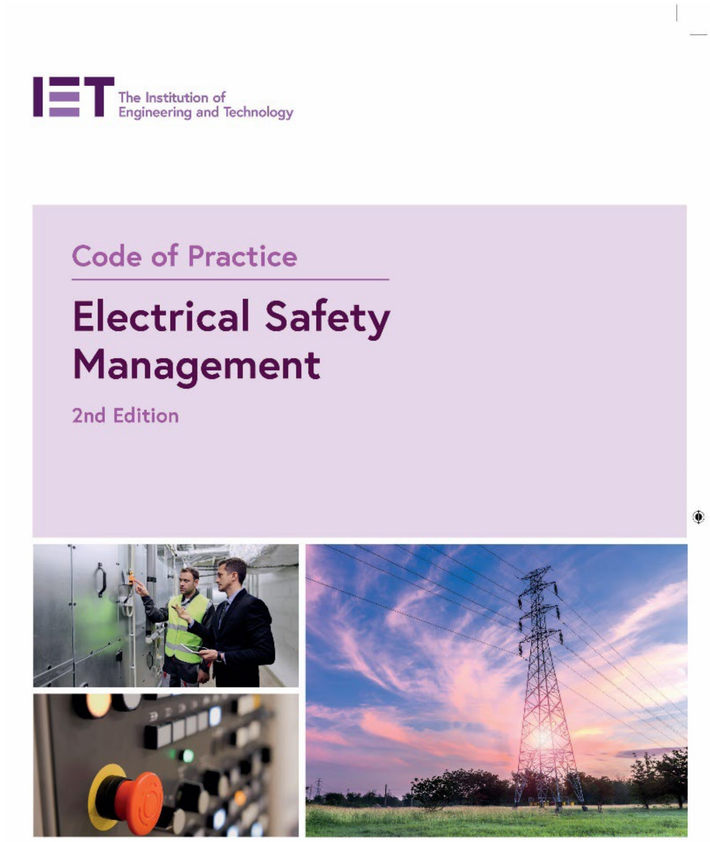
Looking to the future…

Ensuring there is sufficient equity and diversity across the industry remains a persistent challenge. We are exploring initiatives with partners to help shift the balance and improve inclusion of underrepresented groups. Diversity and employer engagement benefit businesses, as well as increasing competitive advantage, it enhances attractiveness to the younger generation. Tacking systemic structural issues in such a large workforce will take years to resolve so we need to accelerate our combined efforts.

Although we may be facing some difficult economic times ahead, this is a tremendously resilient sector with clear opportunity ahead. TESP looks forward to working with the industry and its employers to ensure we have the skills infrastructure needed to support this.

www.the-esp.org.uk

Code of Practice for Electrical Safety Management, 2nd Edition



Pre-order your copy today!

Pre-order your copy of the Code of Practice for Electrical Safety Management, 2nd Edition from the IET bookshop.

This 2nd Edition of the Code of Practice delivers good practice guidance enabling individuals and their organisations to have a level of knowledge and understanding to manage the risks associated with an electrical system.

The publication has been updated to include considerations around the management of change, the implications of outsourcing work on electrical equipment and installations, and an updated self-assessment tool to identify what systems exist and how effective they are in managing responsibilities