WiringMatters

Your insight into BS 7671

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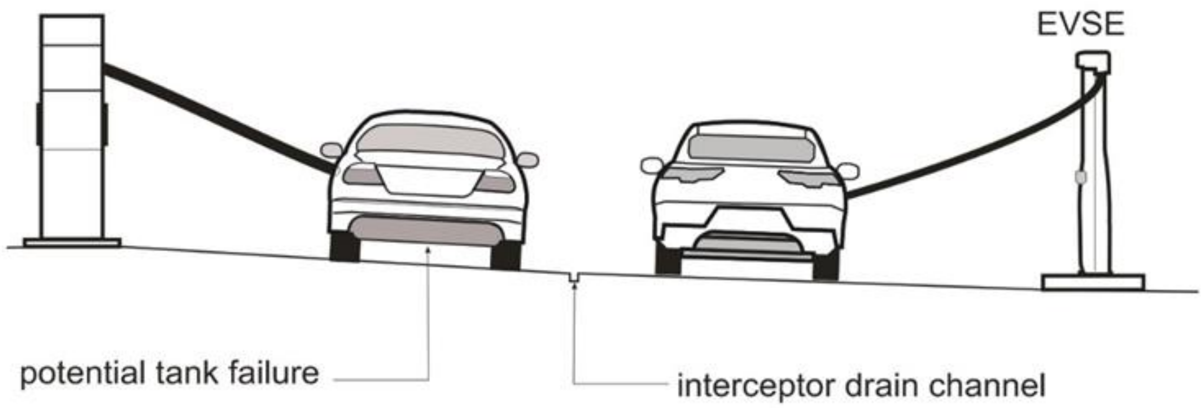


Some EVSE installations aren't "normal"

By: **Gareth Bourhill IEng, MIET, MEI, GCGI, FAPEA**

The requirements for the appropriate design, selection, installation, verification and maintenance of electric vehicle supply equipment (EVSE) have been around for some time now. However, with the constant evolution of better EVSE equipment and charging technology, as well as the rapidly changing electric vehicle (EV) battery and on-board charging technology, it is a challenge for those bodies responsible for writing standards and codes of practice to keep up with the changes. Add into that mix updates and amendments to BS 7671 and it is little wonder that the IET published a new edition of the *Code of Practice for Electric Vehicle Charging Equipment Installation* in 2023.

The *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition* took into account legislative changes reflecting:

- new regulations covered in the Smart Charging Regulations 2021;
- changes to Part S of the Building Regulations 2022;
- physical installation requirements and accessibility for Part M of the Building Regulations and PAS 1899 guidance;
- new guidance on the installation of telecommunications and auxiliary cabling;
- the revision of the requirements of a simultaneous contact assessment to accommodate a mix of earthing arrangements;
- considerations for fire safety in EV charging installations (recognizing RiscAuthority publication RC59) for domestic and commercial properties;
- new and updated appendices covering:
    - installation practices for earth electrodes;
    - Mode 4 charging equipment, including details of pantograph connectivity systems for heavy goods vehicles (HGVs) and public service vehicles (PSVs); and
    - guidance regarding the minimum depth of buried cables and minimum height of overhead suspended cables in different environments.
- extended guidance covering earth fault loop impedance and residual current device (RCD) testing, including use of vehicle simulators for Mode 3 charging equipment and testing in prosumer's electrical installations;
- an expanded distribution network operator (DNO) notification section to include vehicle-to-grid (V2G) and vehicle-to-home (V2H) applications; and
- updated guidance on inductive charging installations.

Although this is well and good for those designers and installers that install EVSE in domestic, commercial, retail and industrial settings (as long as they consider exactly the location of where the EVSE is being installed), as I'm sure readers of *Wiring Matters* will know only too well, there are always situations that are not "normal"!

It is one of those situations that falls into my specialist area of work. In the *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition*, in Section 4.2, the publication mentions "potentially explosive atmospheres". I think it goes without saying that most people, both technically competent and non-technical, would understand that electricity, electrical equipment and EVs being charged, are not items that one would wish to install in a potentially explosive atmosphere, due the ignition risk of non-ex certified equipment, the likelihood of uncontrolled electrical sparks (especially where DC is involved) and hot surfaces.

Section 4.2.2 of the *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition* specifically mentions "fuel filling stations"

Given the many thousands of fuel filling stations storing and dispensing hydrocarbon fuels, and their ideal locations on the UK's road network, it was of course going to be the case that the operators of those facilities, particularly those being approached by EVSE charging companies and equipment suppliers, would install EVSE on their filling stations. It was also a way of indicating that those selling hydrocarbon fuels wished to be seen as embracing and promoting "greener" alternatives, and it allowed those fuel retailers to offer their customers a variety of fuels.

The IET and the Association for Petroleum and Explosives Administration (APEA) worked together to publish a supplementary guide, *Electric Vehicle Charging Installations at Filling Stations*, in 2020. That publication provided the unique and critical information that should be applied when EVSE is being considered, or being installed, in those locations. The publication gave specific details to be followed, model examples of survey sheets and paperwork to be completed and retained, and references to other technical publications and codes of practice.

It was five years ago that the supplement was published and of course, as mentioned earlier, lots of changes have taken place since then, so it's now time that the supplement is reviewed, updated and a new edition published.

Following the completed technical review and update of the supplement by the IET and the APEA, a new, second edition will very soon be available from the IET bookshop.

So, what does this updated second edition take into account? Primarily, of course, the review considered the appropriate parts of all other applicable standards that have been updated since 2020, the amendments to the appropriate parts of BS 7671 and the changes to the *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition*. The updated supplement has also taken into account the appropriate parts of the fuel filling station technical guidance document and code of practice that practitioners really know as the "Blue Book", or to give it its full title, *Guidance for Design, Construction, Modification, Maintenance and Decommissioning of Filling Stations, 5th Edition*. This industry publication is jointly published between the APEA and the Energy Institute (EI), and was announced and published to the industry in November 2024.

Running in parallel to that, the APEA and the IET formed a technical committee, with myself representing the APEA and chairing the group, and Graham Kenyon as lead technical author. We had all the interested stakeholders involved, including the Health and Safety Executive (HSE), Petroleum

Enforcement Authorities (PEAs), and EVSE installers and providers, to review and update the supplement.

In some ways, this technical work was simpler than the first edition as we were not sitting down with a blank sheet of paper and starting from scratch. We already had a document that we simply needed to refresh and update, taking into account the points and documents already mentioned.

Firstly, for those readers of *Wiring Matters* that design, install and maintain EVSE, is the EVSE and/or charging bays actually on a filling station? Just because the equipment or charging bay isn't in the known hazardous areas of the filling station, doesn't mean you are not installing on a filling station and you can install as per any other industrial or commercial installation. You certainly can't.

In the UK, a filling station is the curtilage of land detailed and noted on the site plans (likely the land title deeds), with the local PEA then granting a storage certificate for the safe delivery, storage and dispensing of petroleum spirit to the site duty holder under the Petroleum (Consolidation) Regulations 2014.

If your EVSE sits within that curtilage, then you are installing on a filling station, so installation needs to comply with the details in *Electric Vehicle Charging Installations at Filling Stations****,*** *2nd Edition* and with the appropriate parts of the 5th Edition of the "Blue Book". Disappointingly, many don't understand that until too late, which can be costly, but if energized, also down right potentially dangerous.

Under the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR), activities and equipment outside a known hazardous area that can have a detrimental effect on the safety of those flammable atmospheres, must also be subject to the DSEAR risk assessment and that's important on a fuel filling station.

Are electrical contractors, engineers and practitioners confident their professional insurances cover them for such installations?

If something goes wrong, does the designer, installer, verifier and maintenance companies/individuals have professional insurances and competencies for working in such environments? As I mentioned, although the EVSE will not be in a hazardous area, the work is still on a filling station.

Installation of a secondary substation, excavations for foundations and cable duct routes, and installation of DC voltage cables, are not for the inexperienced on a fuel filling station with all the infrastructure and below ground services and fuel systems.

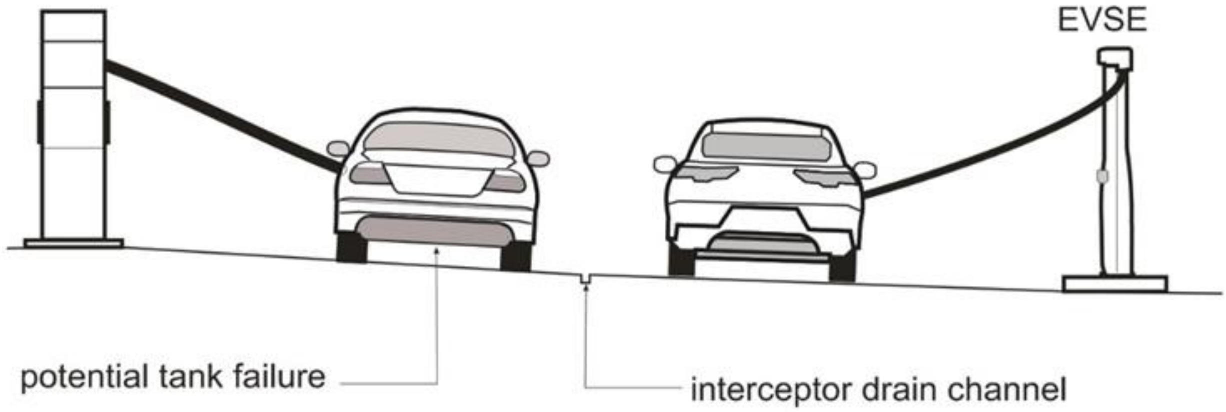
I would also suggest, if the EVSE is being considered on a plot of land adjacent to an existing filling station that is owned by another party, the designer still needs to consider the proximity of the EVSE and charging bays to the filling station with regard to detrimental effects. A quick call to the local petroleum officer will assist in that suitability.

So, what's new, and what's been added and changed?

From the "Blue Book", we have a new requirement and example figure that designers and installers must consider regarding any likely extent of liquid fuel spills, dependent upon paving, drainage and degree of containment.

For example, if there is a gradient sloping towards an EV charging area from the fuel filling area, such that fuel from a spill may run into the charging area, consideration should be given to the installation of a suitable drainage channel to divert any spilt fuel to the site oil/water separator.

Figure 1 Consideration of site gradients and possible need for a drainage channel, copyright © APEA



Also, from the updated "Blue Book", clauses 9.5.11 "Electric Vehicle Supply Equipment (EVSE)" and 9.10.1.3 "Verification of electrical installation and equipment in non-hazardous areas", are both cross-referenced in the *Electric Vehicle Charging Installations at Filling Stations, 2nd Edition* supplement.

The new supplement has re-enforced the differences between a "normal" EVSE installation and one on a fuel filling station. The model survey and electrical risk assessment forms have been reviewed and updated. A very important part of the supplement, like the first edition, is a full two-page flowchart that considers every single scenario with regards to electrical loads, earthing system type, availability of a sufficient electricity supply connection, and earthing and simultaneous contact assessment. Flowcharts are simple – the outcome is either "yes" or "no". There is no middle ground. A huge amount of work went into that flowchart that allows the reader of the supplement to make a sound judgement on whether EVSE can be installed or not.

It is a requirement, and stated in the publications, that the EVSE must be interlocked with the fuel filling station emergency shutdown system. That is, if a site emergency occurs on the fuel filling station, activation of any of those emergency shutdown devices will automatically operate the primary protection device for the EVSE to the "open" position. Ideally, this is carried out by a fibre optic link.

It's also a requirement that if the fuel filling station needs to be closed for any reason, the method of that closure automatically prevents the EVSE from charging an EV. We know that's a contentious item for the EVSE charging company or operator, but something they need to understand is that it is different from any other commercial or industrial operation.

One area where we see issues, and is perhaps a critical item that's not been carried out appropriately and is mentioned in the *Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition*, is the appropriate fire risk assessment.
It goes without saying that a fire within an EVSE ~~piece of equipment~~ or car being charged is not a good thing in general, but on a filling station, the consequences could be so much greater! It certainly isn't "normal".

For myself, as someone who has designed and been involved with fuel filling stations for all of my career, I see these facilities as being "normal".

For those contractors and engineers that may be competent, and who design, install, verify and maintain EVSE in domestic, commercial and industrial settings, being asked to do the same type of install on a fuel filling station is certainly far from being “normal”.

Obtaining, reading and understanding the peculiar requirements, and executing them, will be essential for a safe installation.

This new and updated supplement will be invaluable in allowing persons to meet their obligations.

Electric Vehicle Charging Installations at Filling Stations, 2nd Edition will be available to purchase in April 2025 from the IET bookshop.

Exploring wiring systems for unearthed DC solar PV systems

By: **Peter Monfort BSc (Hons) MIET**

Introduction

The UK is committed to reaching net zero by 2050 and coupled with volatile energy prices, home and business owners are looking to invest in low carbon technology (LCT) with an aim to reduce energy costs and CO_2 emissions.

Retrofitting direct current (DC) solar photovoltaic (PV) systems, especially cable routes, can be challenging to fit around existing services, be aesthetically pleasing and meet the requirements of BS 7671:2018+A2:2022+A3:2024.

In the UK, unearthed DC solar PV systems are adopted and use double or reinforced insulation as the protective measure. As such, DC solar cables designed to BS EN 50618 are already familiar to many, but new innovations are hitting the market, designed to aid designers, and these raise challenging questions in relation to safety.

This article will be formed of two parts. Part 1, published in the March 2025 issue of *Wiring Matters*, explores the possibility of using steel wire armoured (SWA) cable as an installation method for unearthed DC solar PV systems, for instance, permitting the connection of the PV modules to an inverter.

Part 2 will be published in a future issue of *Wiring Matters* and will consider whether or not the proliferation of safety measures built into modern inverters and associated electronic equipment might permit the use of new wiring systems and installation methods.

What protection method is used in unearthed DC solar PV systems?

The IET *Code of Practice for Grid-connected Solar Photovoltaic Systems, 2nd Edition* describes a PV module as a current limiting device with the short-circuit current of a PV array being not much greater than its operating current. Lack of significant fault current means a PV array requires a different approach when designing suitable fault protection.

In relation to the installation of cables, the current limiting nature of PV circuits means that additional protective measures are required to provide for fire and shock protection and Section 5.10.3 of the *IET Code of Practice for Grid-connected Solar Photovoltaic Systems, 2nd Edition* states:

> *All wiring systems shall have cables selected and erected to minimize the risk of earth faults and short circuits. All wiring systems shall be installed in accordance with Chapter 52 of BS 7671 to meet the requirements of Section 412 for double or reinforced insulation.*

Why are DC solar PV systems unearthed?

Solar systems utilize inverters to convert the DC supply from the PV modules to alternating current (AC). Whilst inverters comprising isolating transformers exist and utilize an earthed DC system, in the UK, solar inverters are predominantly transformerless, using an unearthed DC system, and are preferred since they generally have higher efficiency and improved earth fault sensitivity.

What cables are commonly used to meet these requirements?

Insulated and sheathed cables, *without metallic armouring or screens*, such as those to BS EN 50618, are commonly used to meet the requirements of Section 412 of BS 7671:2018+A2:2022+A3:2024 for double or reinforced insulation, and cables installed within buildings may need to meet additional requirements, such as the use of cables of limited smoke production.

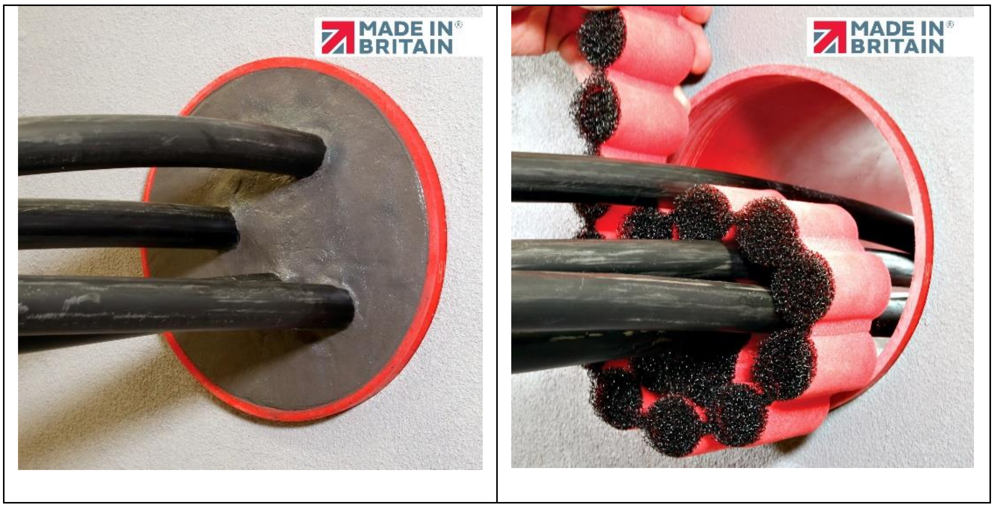
What installation methods are suitable?

The IET *Code of Practice for Grid-connected Solar Photovoltaic Systems, 2nd Edition* recommends that the cables shall not be directly buried in walls or otherwise directly encased in the fabric of the building, and where burial in walls cannot be avoided, they should be suitably protected from mechanical damage and a plan showing cable locations shall be provided.

It further recommends that solar PV DC cables buried in the ground shall be buried at a suitable depth and be protected against mechanical damage and impact in accordance with Regulation 522.8.10 of BS 7671:2018+A2:2022+A3:2024, by installation within an underground conduit or duct meeting the classification of N750 according to BS EN 61386-24:2010 *Conduit systems for cable management - Particular requirements. Conduit systems buried underground (incorporating corrigendum November 2010)*. Additional measures are to be taken to limit access to rodents, rabbits, etc. at the open ends of the conduit as they enter/leave the ground, by the use of suitable filling materials meeting the requirements of the manufacturers of the conduit or duct and the cables installed within it.

It is also important to ensure that ducts are sealed with waterproof fillers where required, since ducting can fill with water and cables left lying in water may absorb moisture into the sheath and insulation over time (see Figure 1).

Figure 1 Examples of sealing ducts. Photographs reproduced by permission of AC Cable Solutions.



Regulation 712.521.101 of BS 7671:2018+A2:2022+A3:2024 also states:

> *Cables on the DC side shall be selected and erected so as to minimize the risk of earth faults and short-circuits. This shall be achieved by using:*
> *(i) single-core cables having a non-metallic sheath, or*
> *(ii) insulated (single-core) conductors installed in individually insulated conduit or trunking. Cable(s) shall not be placed directly on the surface of the roof.*
> *Other types of wiring system providing an equivalent degree of safety are not precluded. NOTE: BS EN 50618 describes cables intended for use at the direct current (DC) side of photovoltaic systems.*

Why is protection by SELV, PELV or double or reinforced insulation required on the unearthed DC side of solar PV systems (BS 7671:2018+A2:2022+A3:2024, Regulation 712.410.102)?

There are, in fact, three things to consider in understanding why wiring systems (and other equipment) on the DC side are required to meet either the requirements for double or reinforced insulation, or alternatively, the requirements for separated extra-low voltage (SELV) or protective extra-low voltage (PELV):

1. Reducing the risk of short-circuits leading to arcs, sparks and hence, fire, even if there is no overcurrent. Regardless of whether the inverter has separation between AC and DC sides, it helps prevent shorts between positive and negative within individual strings (overcurrent protection is usually only provided in multiple strings). This helps reduce risks of arcing and fire. The inverter may detect the condition and shut down, but unless there are DC power optimizers that also operate, the panels will continue to generate and feed any short-circuit fault.

2. Protection against electric shock from the DC source, particularly where the nominal voltage on the DC side exceeds the relevant limits for SELV and PELV. In addition, where the inverter

does not have protective separation between AC and DC sides, the conditions for SELV or PELV cannot be met. Electrical equipment on the DC side should be considered energized, even when the inverter is disconnected from the DC and/or AC sides (see Regulation 712.410.101 BS 7671:2018+A2:2022+A3:2024).

3. Protection against faults that might cause the presence of AC on the DC side, and against contact with AC voltages to Earth, in systems with inverters not having separation between AC and DC sides.

Why might a designer wish to use SWA cable for unearthed DC solar PV connections?

SWA cable is used in AC systems where there is an increased risk of mechanical damage. The steel wire and the heavy-duty outer sheathing provides mechanical protection from minor abrasion and impact that might arise in environments such as being buried direct in the ground or where it may suffer from impact damage. The armouring does not protect against severe mechanical damage caused by puncturing or cutting through the steel, but it may provide protection from electric shock, since the armour is required to be earthed by Regulation 522.8.10 of BS 7671:2018+A2:2022+A3:2024. The protective measure used in this scenario is automatic disconnection of supply (ADS). For example, if a metal spade is driven through a buried SWA cable, current will flow through a live conductor, through the metal spade and back along the steel wire, causing disconnection by a protective device.

Designers of unearthed DC solar PV systems may have to consider where there is a risk of mechanical damage to a string cable, for example, cables connecting ground mounted arrays may be buried. As such, an installer may opt for using SWA cable as a possible design solution, however, there are further considerations which need to be taken into account before such a decision can be made.

Does SWA cable meet with the requirements of the protection method double or reinforced insulation?

In the UK, Regulation 712.312.2 of BS 7671:2018+A2:2022+A3:2024, does not permit the earthing of one of the live conductors of the DC side unless there is at least simple separation between the AC and DC side. As DC conductors within solar PV systems are typically unearthed, BS 7671:2018+A2:2022+A3:2024 denotes the protection method under Regulation 712.410.102 stating:

On the DC side, one of the following protective measures shall be applied:
(i) double or reinforced insulation (Section 412)
(ii) extra-low voltage (SELV or PELV) (Section 414)

In the case of SWA cable manufactured to BS 5467, BS 6724 or BS 7846, these do not meet the requirements of indent (i) above, since the single cores are not double insulated from each other. The insulated cores lay next to each other and additionally, the filler material (bedding) does not have any insulation properties (See Figure 2).

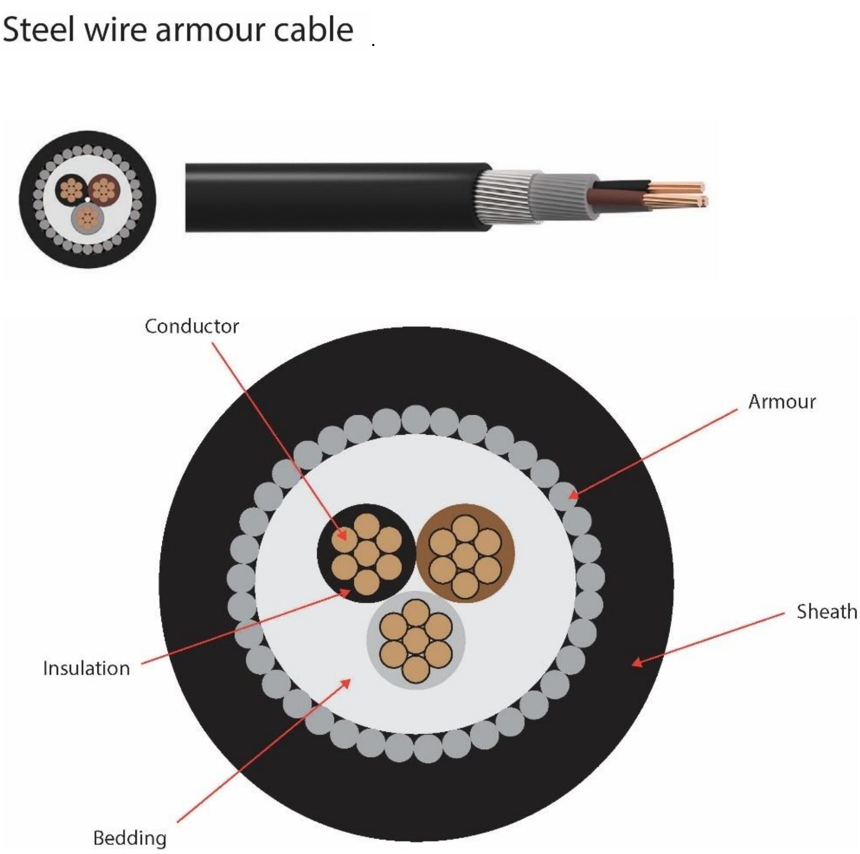
Regulation 712.412.101 of BS 7671:2018+A2:2022+A3:2024 also states:

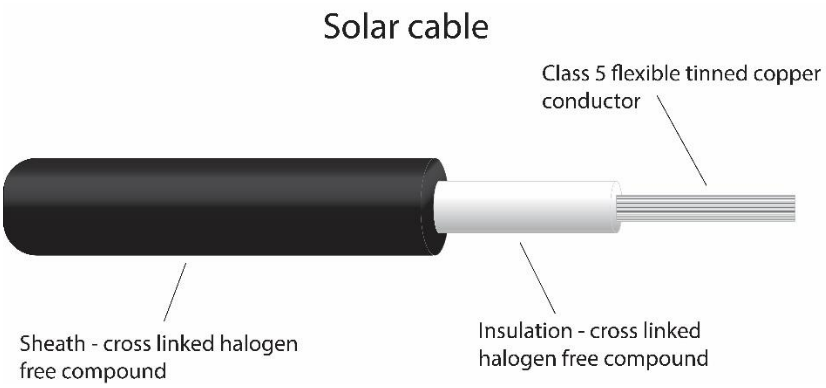
The electrical equipment, for example PV modules, wiring system (e.g. combiner box, cables) used on the DC side (up to the DC connection means of the PV inverter) shall be Class II or equivalent insulation. NOTE: For wiring systems, see Regulation 412.2.4.

Regulation 412.2.4.1 of BS 7671:2018+A2:2022+A3:2024 requires that in the case of wiring systems meeting the requirements of Regulation Group 412.2 relating to the requirements for basic protection and fault protection, where the protective measure of double or reinforced insulation is used, the mechanical protection is provided by *the non-metallic sheath of the cable or non-metallic trunking or ducting*. Users of the Standard may take from this the important point that it is best to avoid bringing unearthed DC wiring systems into close proximity to metal work that may become live due to a fault.

(Note: cables are often incorrectly referred to as double insulated, rather than insulated and sheathed. The reasoning is a wiring system is not classed as 'equipment', however, a wiring system which is insulated and sheathed is deemed to meet the requirements of 412.2. (See *Wiring Matters* Issue 75, May 2019, Mythbusters #4.)

Figure 2 Steel wire armour and solar cable~~. Image courtesy of Arena Training Centre~~





Can I use an insulated and sheathed cable comprising a steel wire armour outer?

Where a manufacturer produces an SWA cable that replaces the single insulated conductors with insulated and sheathed cores, surrounded by steel wire armour and exterior sheath, whilst such a cable might have elements constructed in accordance with a relevant British or Harmonized Standard, the armoured ‘part’ of the cable would mean the final cable assembly is non-standard. If a designer selected such a cable, this would be a departure from BS 7671:2018+A2:2022+A3:2024 and they would need to state the design as being no less safe, despite its use in accordance with Regulation 133.1.3 of BS 7671:2018+A2:2022+A3:2024.

What design considerations must I address if I wish to use insulated and sheathed cable comprising a steel wire armour outer direct in the ground?

Regulation 522.8.10 of BS 7671:2018+A2:2022+A3:2024 states that:

> *Except where installed in a conduit or duct which provides equivalent protection against mechanical damage, a cable buried in the ground shall incorporate an **earthed** armour or metal sheath or both, suitable for use as a protective conductor.*

Thus, the use of insulated and sheathed cables with an SWA exterior would require the armour to be earthed via one or more protective conductors when buried direct in the ground. Nevertheless, with unearthed DC solar PV systems, this would not be possible and any attempt to earth the armouring, either on the AC or the DC side, would not result in earthed armouring and may cause unintended consequences and introduce additional hazards. Regulation 522.8.10 of BS 7671:2018+A2:2022+A3:2024 would therefore require a suitable duct to be used, negating the need for armouring in the first place.

What if I choose to depart from BS 7671:2018+A2:2022+A3:2024?

Regulation 21 and 22 of The Electrical Safety, Quality and Continuity Regulations 2002 (ESQCR) specifically state that installations operating as a switched alternative in parallel to a distributor’s network must fully comply with British Standard requirements (i.e. BS 7671). The use of a cable buried direct in the ground without an earthed metal sheath or armour does not meet the requirements and is therefore not permitted.

Installers of unearthed DC solar PV systems should adhere to the Energy Networks Association (ENA) engineering documents relating to connection procedures. For systems where micro-generating plant with an aggregate registered capacity of 16 A (3.68 kW) per phase, or less, are installed, this would be Engineering Recommendation G98 Issue 1 Amendment 6 September 2021. For systems where generation is in excess of 16 A (3.68kW) per phase installers, this would be Engineering Recommendation G99 Issue 1 – Amendment 10, 4 March 2024. Both of these Recommendations require compliance with BS 7671.

Can I use insulated and sheathed cable with an SWA exterior in ducting or other locations?

The requirements of Regulation 712.521.101 of BS 7671:2018+A2:2022+A3:2024 state that:

> *Cables on the DC side shall be selected and erected so as to minimize the risk of earth faults*.

The use of insulated and sheathed cables with an SWA exterior will clearly have been chosen as a consequence of a designer being concerned that mechanical damage could occur and thus, steel wire could become live in the event of damage which could turn an unearthed DC system into an earthed DC system and introduce other potential hazards (for example, no method of providing ADS).

Regardless, Regulation 712.312.2 of BS 7671:2018+A2:2022+A3:2024 states:

> *Earthing of one of the live conductors of the DC side is permitted, if there is at least simple separation between the AC side and the DC side;*

In the case of a transformerless inverter, this is not permitted. The fundamental rule for protection against electric shock is a requirement in Section 410 of BS 7671:2018+A2:2022+A3:2024:

> *The fundamental rule of protection against electric shock, according to BS EN 61140, is that hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous-live, both under normal conditions and under single fault conditions.*

This might lead a designer to assume that insulated and sheathed cables with an SWA exterior would be fine to use on unearthed DC solar PV systems because a single fault would only result in damage to the sheathing, but clearly there would be a risk that such damage would more than likely result in a fault to earth.

Given that solar PV cable is required to meet the requirements of the protective measure of double insulation, this regulation seems to suggest that installers should be wary of introducing a fault to metal work, even where two faults (damage to sheath and damage to insulation) would need to occur. Indeed, BS EN 61140 states:

> *If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.*

With respect to wiring systems in general, BS 7671:2018+A2:2022+A3:2024 is clear with the requirements in Regulation 412.2.4.1:

> *Wiring systems installed in accordance with Chapter 52 are considered to meet the requirements of Regulation 412.2 if: (i) the rated voltage of the cable(s) is not less than the nominal voltage of the system and at least 300/500 V, and (ii) adequate mechanical protection of the basic insulation is provided by one or more of the following: (a) The* ***non-metallic*** *sheath of the cable (b)* ***Non-metallic*** *trunking or ducting complying with the BS EN 50085 series of standards, or* ***non-metallic*** *conduit complying with the BS EN 61386 series of standards.*

In the case that insulated and sheathed cables with an SWA exterior are installed using any other method of installation other than buried direct, whilst not specifically prohibited, this regulation implies that mechanical protection should be provided by *non-metallic* trunking or ducting and the introduction of metal armouring is therefore undesirable.

Summary

Traditional wiring systems, such as suitably impact rated insulated ducting to N750 and insulated and sheathed cable, meet the requirements of BS 7671 and provide adequate safety to human beings and livestock.

The use of single insulated SWA cable for unearthed solar DC cabling is not permitted by BS 7671 as it does not provide double insulation between the string conductors.

Insulated and sheathed cables with an SWA exterior may arguably be permitted for unearthed solar PV cabling where it is not directly buried in the ground. Where it is buried direct in the ground, the cable must be earthed in accordance with Regulation 522.8.10 which is not possible in an unearthed system and is therefore not permitted.

Other cables, such as insulated and sheathed cables wrapped in a 'tough sheath', could be used where there is a concern about cables being damaged as they are drawn into ducting or conduit.

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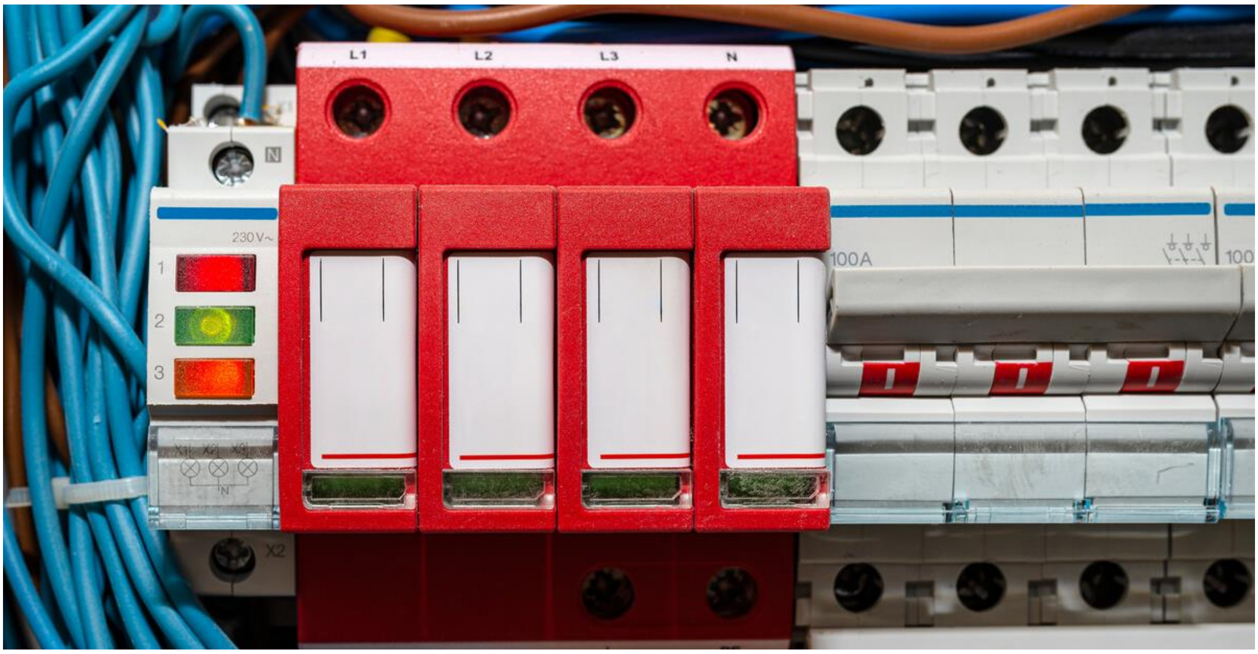
References

- Buried conduits and ducts
- Mythbusters #4 Double insulated cables



Integration of devices and components

By: **Michael Peace CEng MIET**

A question that is often asked relates to the issue of whether mechanical and electrical devices, and other such components from one manufacturer, can be integrated into existing low-voltage assemblies from a different manufacturer. This article looks at the issues associated with using electrical devices and components, such as surge protective devices (SPDs), which may not have been specifically declared as suitable by the assembly manufacturer.

What are low-voltage switchgear and controlgear assemblies?

The BS EN 61439 and BS EN IEC 61439 series provide requirements for low-voltage switchgear and controlgear assemblies. Examples of such equipment include consumer units, distribution boards and panel boards. BS EN 61439-3 includes requirements for assemblies that are commonly products referred to as consumer units (CUs) which this article generally focusses upon.

For the purposes of this article, the relevant clauses of the following apply:

- BS EN 61439-1:2011 and BS EN IEC 61439-1:2021 *Low-voltage switchgear and controlgear assemblies. General rules.*
- BS EN 61439-3:2012 and BS EN IEC 61439-3:2024 *Low-voltage switchgear and controlgear assemblies. Distribution boards intended to be operated by ordinary persons (DBO).*

What devices and components can be integrated into low-voltage switchgear and controlgear assemblies?

Examples of devices and components that can be integrated into low-voltage switchgear and controlgear assemblies include circuit-breakers, control devices, timers and SPDs. Most manufacturers offer consumer units and distribution boards that come complete with SPDs. However, some manufacturers also offer standalone devices.

What are the requirements of BS 7671 for integration of devices and components?

Regulation 536.4.203 of BS 7671:2018+A2:2022+A3:2024 provides requirements for integration of mechanical and electrical devices and components as below:

> *The relevant part of the BS EN IEC 61439 series shall be applied to the integration of mechanical and electrical devices and components, e.g. circuit-breakers, control devices, busbars into an empty enclosure or existing low voltage assembly.*
>
> *In low voltage assemblies to the BS EN IEC 61439 series, e.g. consumer units, distribution boards, incorporated devices and components shall only be those declared suitable according to the assembly manufacturer's instructions or literature.*

What are the particular points embodied in Regulation 536.4.203?

Two key points to address are:

1. The practice of installing devices of one manufacturer into an assembly of another manufacturer.
2. The practice of installing new or replacement devices into an existing assembly, even if both are from the same manufacturer.

The notes to Regulation 536.4.203 contain some important aspects of clarification to address common misconceptions. Below is an extract from the notes:

> ***NOTE 1:*** *The use of individual components complying with their respective product standard(s) does* ***not indicate their compatibility*** *when installed* ***with other components*** *in a low voltage switchgear and controlgear assembly.*
>
> ***NOTE 2:*** *Incorporated components inside the assembly can be from different manufacturers.* ***It is essential that all incorporated components should have had their compatibility*** *for the final enclosed arrangements verified by the original manufacturer of the assembly* ***and be assembled in accordance with their instructions e.g. the consumer unit****, distribution board manufacturer. … If an assembly* ***deviates from its original manufacturer's instructions****, or* ***includes components not included in the original verification****, the person introducing the deviation becomes the original manufacturer with the corresponding obligations.*

Note 1 and note 2 are intended to be warnings, because devices are frequently type-tested and assigned ratings, for example, a thermal/current rating and short-circuit rating for *unenclosed in free air*. When integrated into an assembly, these free air ratings can be altered due to mutual grouping effects, ambient temperature and reduced clearances. Also, introducing a device not previously included in the verification/testing could adversely affect another device, for example, its temperature rise. This is covered later.

It is essential that guidance is sought from the *original* CU manufacturer regarding suitability for any addition, alteration or modification to the CU. Regulation 510.3 of BS 7671:2018+A2:2022+A3:2024 requires that every item of equipment selected and erected shall take account of manufacturer's instructions.

Who is the original manufacturer of the CU and what are their responsibilities?

The BS EN IEC 61439 series defines the original manufacturer and makes several references, which can be summarized as:

> The **organization that has carried out the original design and the associated verification of the CU with the components** (enclosures, busbars, circuit-breakers, etc.) and which can be assembled in accordance with the original manufacturer's instructions in order to produce various assemblies.

The Electrical Equipment (Safety) Regulations 2016 highlights specific responsibilities of the manufacturer which include:

> *Before placing electrical equipment on the market, a **manufacturer must ensure** that it has been designed and manufactured in accordance with the principal elements of the safety objectives and labelling of electrical equipment is marked with the name, registered trade name or registered trademark of the manufacturer; and a single postal address at which the **manufacturer** can be contacted.*

Why is it important that manufacturers verify equipment that is integrated into a CU?

Using a spare way of a consumer unit is very convenient. It is often assumed that devices and components, such as circuit-breakers and SPDs, with similar dimensions are compatible or won't have any detrimental effects, however, this may not be the case. There are a number of safety requirements in the BS EN IEC 61439 series that the CU manufacturer must verify. Temperature rise is one key requirement.

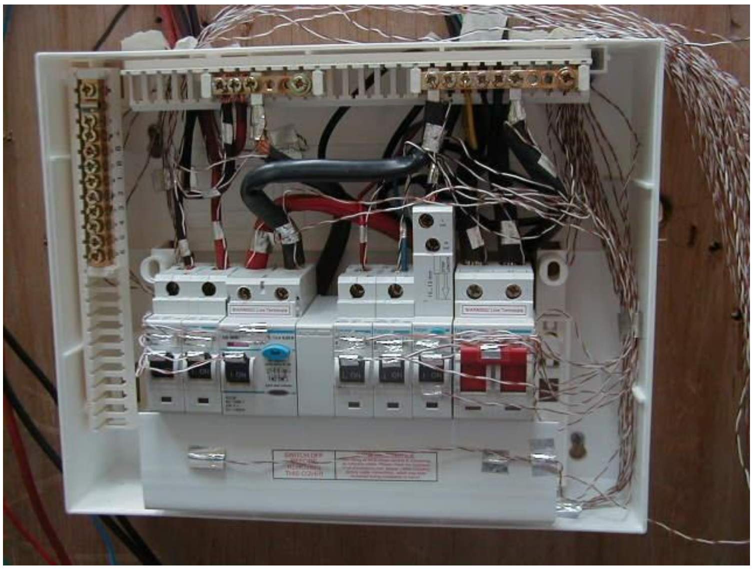
Why are manufacturers required to verify that temperature rise limits are not exceeded?

A critical safety verification is to confirm that the temperature rise limits are not exceeded, including those for built-in components, terminals for external insulated conductors, busbars and conductors, and manual operating means.

The BS EN IEC 61439 series prescribes various methods to verify temperature rise, including testing and calculation. Calculation can be a complex method. Frequently, software is used to meet PD IEC TR 60890:2022 *A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation. Part 0: Guidance to specifying assemblies,* which is a method of temperature-rise verification. Also, temperature-rise verification by calculation in accordance with the BS EN IEC 61439 series requires additional safety margins to avoid hot spots, for example, components are de-rated.

Temperature rise by testing requires thermocouples to be placed at points prescribed by BS EN IEC 61439. Some of these locations are shown in Figure 1.

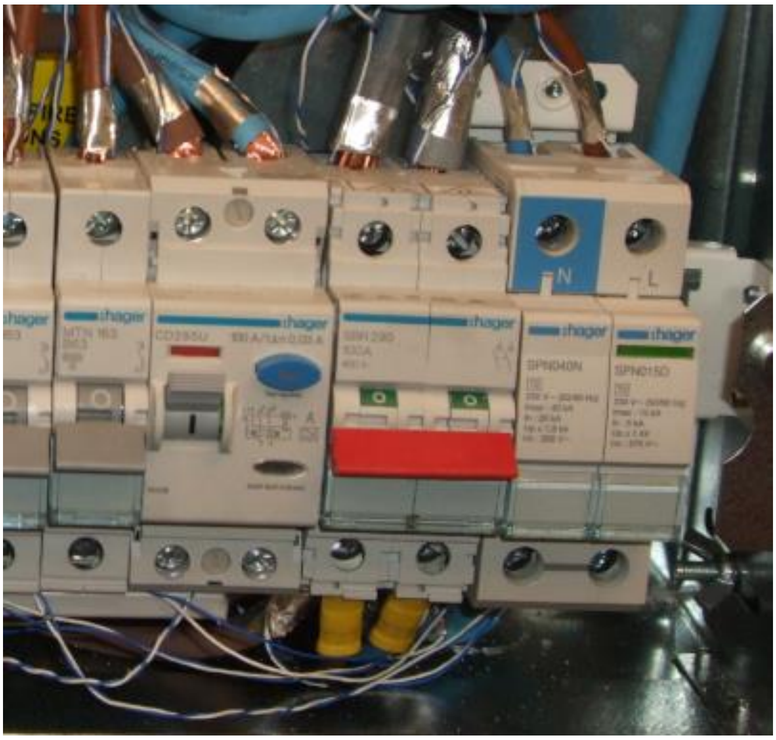
Figure 1 Temperature rise testing thermocouples placed at designated points prescribed by BS EN 61439. Image reproduced by permission of Hager Group



How can adding an unverified device create temperature rise issues?

Figure 1 shows a CU under temperature rise test *without any device adjacent* to the main switch. If a device, for example, an SPD, was subsequently added, this would reduce the heat liberated from the main switch. Even if the SPD has minimal heat dissipation, it can insulate the side of the switch and this specific arrangement needs to be verified, as shown in Figure 2.

Figure 2 Temperature rise testing thermocouples placed at designated points with SPD adjacent to the main switch. Image reproduced by permission of Hager Group



What other verifications are required to be carried out by the CU manufacturer?

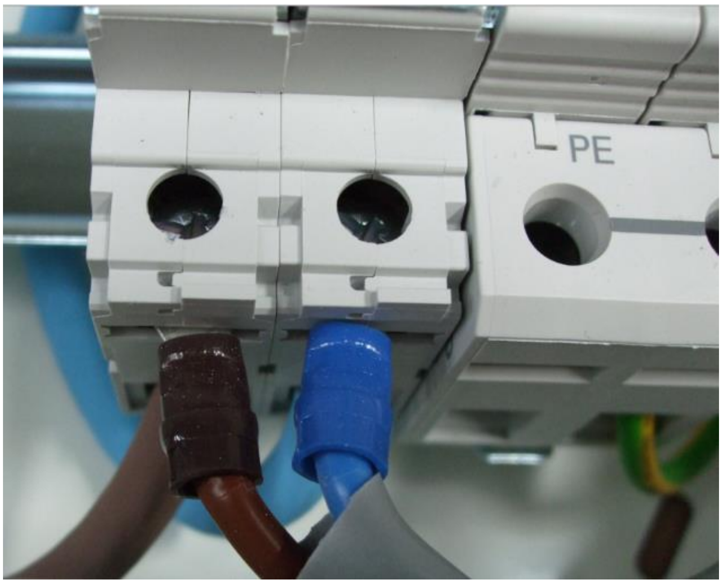
The BS EN IEC 61439 series prescribes a number of design verifications including:

- strength of materials and parts;
- degree of protection of enclosures;
- clearances and creepage distances;
- protection against electric shock and integrity of protective circuits;
- incorporation of switching devices and components;
- internal electrical circuits and connections;
- terminals for external conductors;
- dielectric properties;
- verification of temperature rise;
- short-circuit withstand strength;
- electromagnetic compatibility; and
- mechanical operation.

Incorporation of switching devices and components, together with correct electrical connections, is critical to avoiding overheating connections and, potentially, fire.

The device connections used in the original CU verification are essential to the final arrangements covered by the certification and declarations from the CU manufacturer. Figure 3 shows an example of where SPD connections do not share the same terminal opening as the main conductors but utilize the bi-connect terminals to provide a suitable electrical connection.

Figure 3 Example of where terminals use a specific arrangement for a suitable electrical connection. Image reproduced by permission of Hager Group



It should be noted that product standards such as BS EN 60898-1 *Electrical accessories. Circuit-breakers for overcurrent protection for household and similar installations - Circuit-breakers for a.c. operation*, typically set limits during certain tests. Some device tested values can be close to the limits, whilst others can be significantly lower, for example, 50 % reduced power loss and 64 % reduction in energy let-through under short-circuit, than the product standard limits. This means that CU test arrangements with these devices would produce more favourable results than with devices at their product standard limits. This means that devices are not automatically interchangeable with others of similar dimensions and markings.

What if I install devices and components that have not been verified by the CU manufacturer?

If any devices and components are installed, that have not been verified by the CU manufacturer, the installer takes responsibility. It becomes the responsibility of the installer to undertake appropriate verification to ensure conformity with the relevant product standards and the low voltage directive (LVD)/The Electrical Equipment (Safety) Regulations 2016. This leaves the installer in a difficult position. This situation is explained in Note 2 of Regulation 536.4.203 of BS 7671:2018+A2:2022+A3:2024, referred to in this article.

Summary

BS 7671:2018+A2:2022+A3:2024 does not prevent mixing manufacturers, however, the arrangements must be validated.

Whilst devices and components may appear to be compatible in terms of manufacturer and dimensions, the CU manufacturer should be contacted to ensure compatibility. It is important that proof of the confirmation is obtained and it is recommended to append it to the electrical certification.

Unless devices/modifications are approved by the CU manufacturer, the simplest and safest option, is to install devices, such as circuit-breakers and SPDs, in a separate assembly. Another option is to contact the manufacturer to ask if it is permissible to add devices, such as SPDs.

Mixing devices and components in an assembly that have not been verified for such arrangements could invalidate any warranty or result in an unsafe situation. In the event of death, injury, fire or other damage, it is likely that the installer would be held accountable.

Further reading

- BEAMA technical bulletin on safe selection of devices for installation into assemblies
- GAMBICA technical guide to the requirements

Acknowledgments

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