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

By: **Michael Peace CEng MIET MCIBSE**

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

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

What are the requirements for cables buried in the ground?

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

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

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

Alternatively, Regulation 522.8.10 of BS 7671:2018+A2:2022 permits an unarmoured cable to be buried in the ground that is installed in a conduit or duct that provides equivalent protection against mechanical damage.

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

The note to Regulation 522.8.10 of BS 7671:2018+A2:2022 cites BS EN 61386-24 as the standard for underground conduits. BS EN 61386 is titled, *Conduit systems for cable management, Part 24: Particular requirements — Conduit systems buried underground*. The word duct is not included in the standard. However, BS EN 61386-24 provides requirements for nominal sizes of ducts or conduits from 25 mm to 250 mm in diameter.

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

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

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

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

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

What does 'suitably identified' mean?

Regulation 522.8.10 of BS 7671:2018+A2:2022 states that buried conduits and ducts shall be suitably identified. Ducts are usually identified by colour according to the service, for example, black is used for low-voltage electricity, red is used for high-voltage electricity, yellow for gas and blue for water.

The Streetworks UK publication provides guidelines on colour coding of underground utilities. This publication is aimed at contractors working on public highways, such as work for a DNO's network, but there is nothing to prevent the publication being used for general electrical installations.

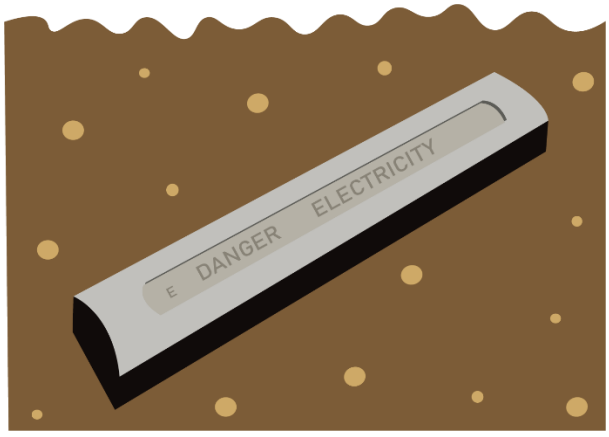
What is suitable marking for buried cables?

Regulation 522.8.10 of BS 7671:2018+A2:2022 requires the location of buried cables to be marked by cable covers or a suitable marker tape. Cable covers or marker tape is laid above the buried duct or cables to provide an early warning that electric cables are present (see Figure 1 and Figure 2). Some marker tapes include a metallic strip which can be detected using a cable detection tool.

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

Figure 1 Cable marker tape

Figure 2 Concrete cable cover for buried cables



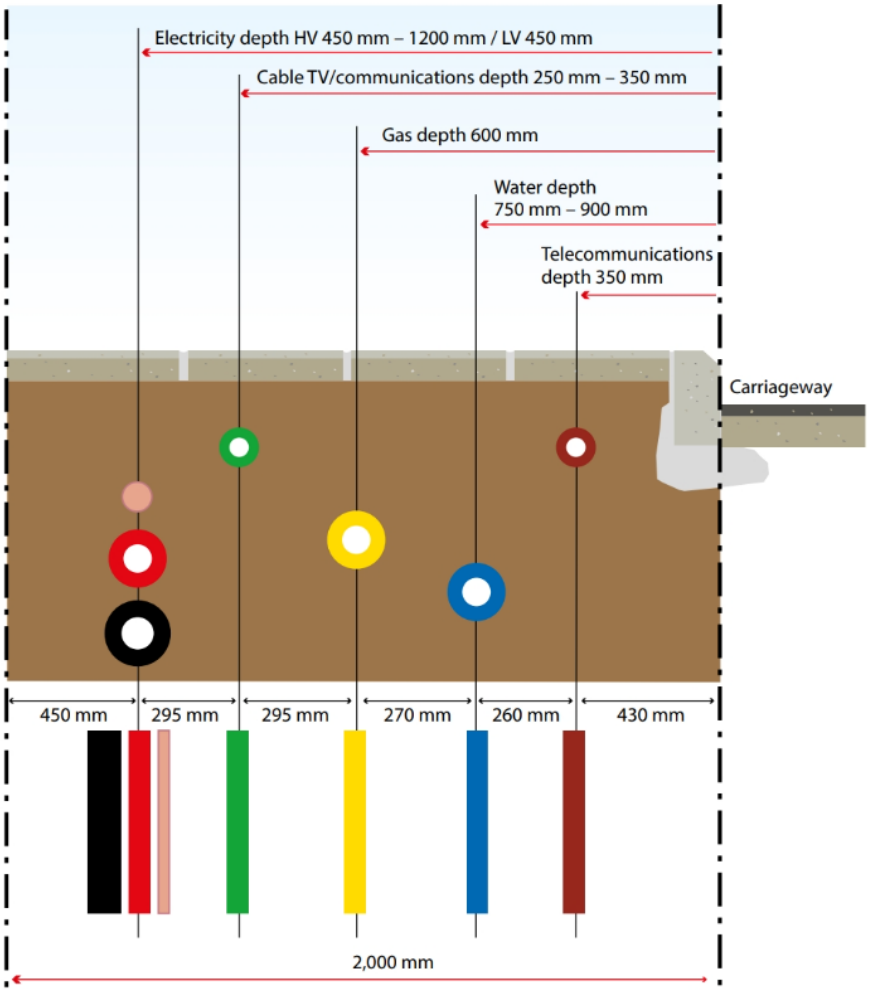
What are the sufficient depths for buried cables, conduits and ducts?

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

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

The Streetworks UK publication also provides guidelines on recommended minimum depths for buried services in a 2 m footway (see Figure 4). For low-voltage cables, a minimum depth of 450 mm is recommended. As with identification, there is nothing to prevent installers choosing to use these depths for general electrical installations; however, this is not a requirement called for in BS 7671:2018+A2:2022.

Figure 3 Recommended minimum cable depths for footways



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

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

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

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

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

In some special installations or locations, such as those detailed in Part 7 of BS 7671:2018+A2:2022, minimum depths of burial are specified. It should be noted that these are minimum depths, not targets, and deeper burial may be necessary in some cases to prevent damage by reasonably foreseeable disturbance of the ground. Such locations include:

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

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

Where armoured cables are not earthed

Earthed armoured cables are typically associated with the protective measure automatic disconnection of supply (ADS). If any of the live conductors come into contact with the earthed armour, the associated protective device disconnects the supply in accordance with Section 411 of

BS 7671:2018+A2:2022. There would be no advantage providing earthed armouring for unearthed DC systems such as EV charging and the DC side of PV systems, in fact, doing so could create a hazardous situation.

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

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

The protective measure used for the DC side of PV systems is typically double or reinforced insulation in accordance with Section 412 of BS 7671:2018+A2:2022. The principle of this protective measure is that the insulation prevents live conductors coming into contact with each other and with metallic parts, reducing the possibility of short-circuit or earth faults occurring. The requirements in Regulation 712.521.101 of BS 7671:2018+A2:2022 and Section 412 are therefore clear, in that cables should have a non-metallic sheath, or be installed in insulated conduit or trunking and the risk of contact with earth minimized.

Are there any other considerations when using ducts?

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

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

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

Safety

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

Summary

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

The rating and depth of ducting will depend on the ground conditions and the expected use. Where doubt exists, a civil engineer should be consulted.

Consideration should be given to the suitability of cables installed in ducts which may become waterlogged.

Ducts should be sealed at both ends to prevent mechanical damage, ingress of water or solids, gas accumulated in the ground from entering the building, or damage from fauna such as rodents or rabbits.

Armoured cables are not suitable for the DC side of unearthed PV systems where the protective measure is double or reinforced insulation.

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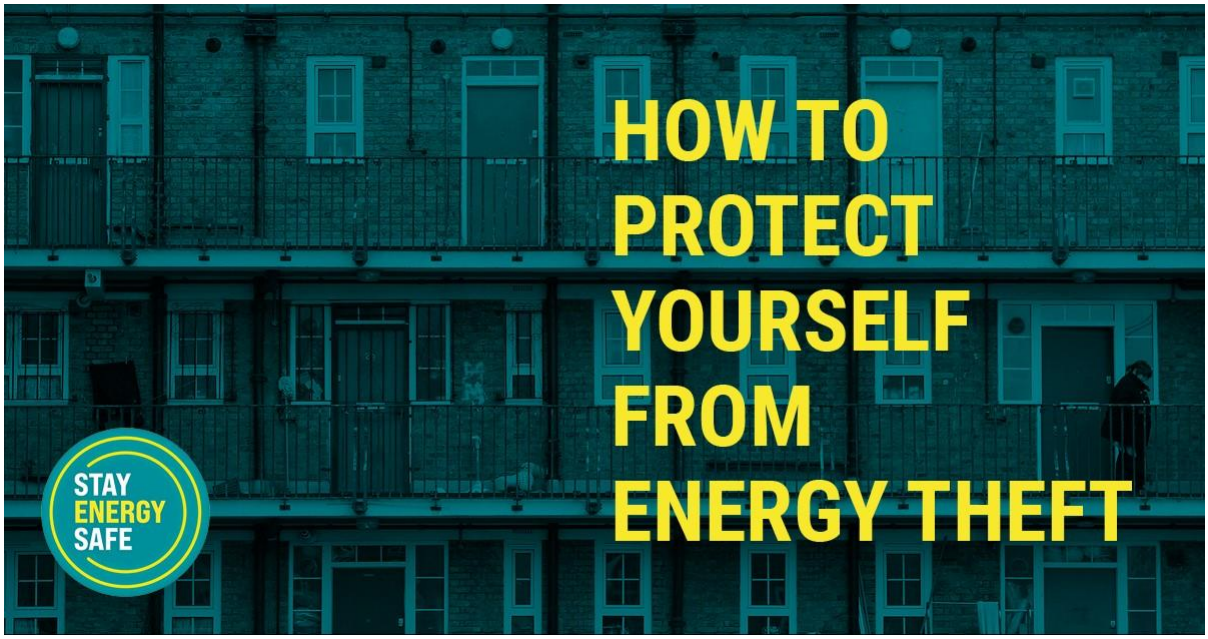


Theft of energy

By: **Crimestoppers, in partnership with the IET**

As people and businesses struggle with the cost of energy, the temptation to go rogue arises.

Electrical installers who visit and work on commercial and residential properties can be the first ones to spot when something is wrong, such as when energy is being stolen.

In 2023, research showed that 43 percent of electricians and gas engineers were asked by customers about tampering with meters to make them run slowly (according to Direct Line Business Insurance).

Meter tampering is extremely dangerous and can cause electric shocks, severe burns, electrocutions and house fires. Anyone attempting to bypass meters puts people who work and live in the property and surrounding area in danger, as well as the engineers who have to repair and replace equipment and wiring.

A London landlord was caught stealing electricity worth over £90,000 and passed the savings on to his tenants, however, this act was putting his tenants in severe danger. Not only was he ordered to repay the £90,000, he was also sentenced to nine months in jail - saved from a longer sentence as he had no previous convictions.

In another example, a son living with his mother caused her tragic death after arranging for the meter to be bypassed so he could save some money on electricity bills. This led to electrical sparks that caused a fire and consequently, his mother died due to smoke inhalation.

Importance of speaking up

If you feel uncomfortable confronting customers directly, **Stay Energy Safe** offers a 24/7 reporting service via an online form or by phone on **0800 023 2777**.

Stay Energy Safe, operated by the independent charity **Crimestoppers**, provides a secure platform for reporting energy theft.

Once Stay Energy Safe receives the report, they check and sanitize the information to ensure your anonymity and send it to the relevant energy supplier so that the case can be investigated.

If something doesn't look right, it probably isn't. More engineers speaking up means more lives saved and fewer tragedies.

IET Wiring Regulations and the evolution of digital publications

By: **Steven Devine**

In this forever evolving realm of the electrotechnical industry, staying updated with the latest regulations and guidance is not just a professional obligation but a fundamental aspect of ensuring safety and efficiency in electrical installations. Among these regulations, BS 7671 holds a paramount position as the standard for electrical installations in the UK. However, with the advent of digitalization, there's a shift in how electricians, lecturers, and students access and utilize this crucial document and associated guidance, promising a multitude of benefits for competence improvement within the industry.

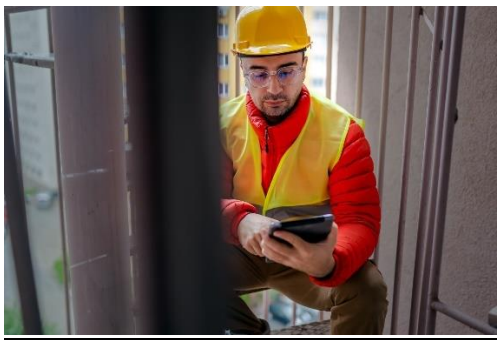
What is a digital subscription?

The IET offers a digital subscription service to BS 7671, the IET Wiring Regulations, and its associated guidance books. The digital packages available vary depending on the needs of the user including, single user, multi user and educational user packages ranging from Bronze to Gold.

More information on the subscriptions and packages available can be found here Digital subscriptions to BS 7671 and IET guidance.

What are the benefits?

Accessibility and convenience



The transition from traditional hardcopy formats to digital access brings unparalleled convenience. Electricians can now access BS 7671 on various devices, anytime and anywhere, eliminating the constraints of physical copies. Lecturers can seamlessly integrate relevant sections into their teaching materials, enhancing the learning experience for students. Moreover, students themselves can delve deeper into the regulations, fostering a more comprehensive understanding of electrical design and installations.

Real-time updates

Digital platform subscriptions from reliable sources, such as Vital Source, facilitate instantaneous updates to regulations and associated guidance. Electricians can stay abreast of amendments and revisions in real-time, so that the latest requirements can be complied with. This dynamic nature of digital access prevents the dissemination of outdated information and enhances the safety and reliability of electrical installations. What's more is that as it is subscription based, there are no additional charges when the publications are updated.

Enhanced searchability and navigation

One of the most significant advantages of digital access is the ability to search and navigate through documents quickly and efficiently. Electricians can easily locate specific regulations and guidance pertinent to their projects, saving valuable time and effort. This feature is particularly beneficial during on-site inspections or troubleshooting, where swift access to relevant information is paramount. Search results can also provide valuable insight to publications that may not have been previously known to the user. The IET's suite of publications authored by industry leading experts is vast. Any searches carried out by users can show results from the entire suite of publications available.

Interactive learning tools

Digital platforms offer opportunities for interactive learning through multimedia elements such as videos, animations and simulations. Lecturers can incorporate these tools into their curriculum to elucidate complex concepts and enhance student engagement. Interactive learning not only improves comprehension but also fosters practical skills application, better preparing learners for real-world scenarios.

Durability and preservation

Digital publications offer significant advantages over their physical counterparts when it comes to durability and preservation. Traditional books, magazines and documents are susceptible to physical wear and tear. They can be damaged by environmental factors such as moisture, fire, pests and mishandling. In contrast, digital publications, stored electronically, are immune to these physical threats. In addition to this, cloud storage can ensure that your digital content is preserved.

Theft prevention and security

Theft is a constant concern for physical publications, particularly when it comes to colleges and training centres. Digital publications, however, can be protected through a variety of security measures. Access to digital content can be restricted through passwords and encryption. This provides a system that offers complete control of the required publications to the colleges and training centres. Many colleges are already experiencing the benefits of their subscription to the IET's digital publications.

Cost-effective distribution

Digital publications significantly reduce the need for shipping and transportation, leading to multiple benefits. Unlike physical books and documents, which require substantial resources to print, package and transport, digital publications are delivered instantly over the internet. This eliminates the environmental impact associated with the production and movement of physical goods, such as fuel consumption, greenhouse gas emissions and packaging waste. Moreover, the reduction in shipping and transportation costs translates to savings for both publishers and consumers, making digital publications a more economical choice. This streamlined distribution process not only makes content more accessible globally but also contributes to a more sustainable and efficient publishing industry.

So, with all these positive benefits, are there any disadvantages to using digital publications over physical ones? While I have encountered a few, they pale in comparison to the overwhelming advantages.

Disadvantages

Battery

One of the potential drawbacks of digital publications is their reliance on battery-powered devices for access. Unlike physical books, which require no power to read, digital publications necessitate the use of electronic devices such as e-readers, tablets or smartphones. These devices depend on batteries, which can deplete over time and may require recharging at inconvenient moments. In situations where access to electricity is limited or unavailable, such as during travel or in remote locations, this dependency can become a critical issue.

Personal preferences

Despite the numerous advantages of digital publications, some people simply prefer physical books, and this preference is largely a matter of personal choice. For many, the experience of holding a physical book, turning its pages, and even the scent of the paper, creates a sense of ownership and substance that digital formats cannot replicate. Ultimately, the choice between digital and physical publications often boils down to individual preferences and the unique experiences each format provides.

Education

As with any new concept, it can take a while to adapt. During this transition, there will no doubt be some challenges to overcome. Longstanding, well-rehearsed teaching methods might not integrate well with the use of digital publications. This will mean new methods for delivering educational content need to be adopted. This might seem like a burden in the short-term.

Adaptation of examinations

As digital access becomes prevalent, awarding organizations need to adapt their examinations to reflect this shift. Many traditional exams contain elements that are designed to determine that a learner can navigate through the relevant publications using contents and index pages. With searchable content on digital platforms, questions that have been designed in this way will not be necessary. Instead, exams need to be designed to assess candidates' understanding and how to apply the regulations when it comes to electrical design. This shift encourages critical thinking and problem-solving skills, aligning with the demands of the modern industry. Not having to manually search through publications means that learners have the opportunity to spend more time gaining an understanding of the content that they are reading rather than looking for the content.

Industry advancement

Embracing digital access to BS 7671 and adapting examinations accordingly fosters a more competent workforce within the electrical engineering industry. Competent electricians, equipped with digital subscriptions to IET publications, have access to up-to-date regulations and guidance, and contribute to safer and more efficient electrical installations. Moreover, access to critical information promotes innovation and continuous improvement within the industry, driving progress and sustainability.

Conclusion

In conclusion, the transition to digital access of BS 7671 heralds a new era of competence improvement within the electrical engineering sector. By embracing the benefits of accessibility, real-time updates, enhanced searchability and interactive learning, electricians, lecturers and students can elevate their proficiency and contribute to a safer and more efficient industry. Additionally, the adaptation of examinations to accommodate digital access ensures that industry standards remain aligned with technological advancements, paving the way for continued growth and innovation.

Neutral current diversion (NCD) – industry research

By: **Mark Coles**

The IET, working with industry partners NICEIC, ECA, Electrical Safety First, NAPIT and SELECT, are reaching out to electrical installers and electrical inspectors for their help in the research of 'neutral current diversion'.

There's not a lot of data available in the public domain but that's where you come in!

What is neutral current diversion?

In the event of a lost protective earthed neutral (PEN) conductor on a TN-C (PME) electrical supply, the installation loses its intended connection to neutral and Earth. Current is then 'diverted' and will find its way back to the supply transformer any way it can. One common route is through shared metallic pipework, such as gas and water pipes.

Before we get ahead of ourselves, let's look at PEN conductors.

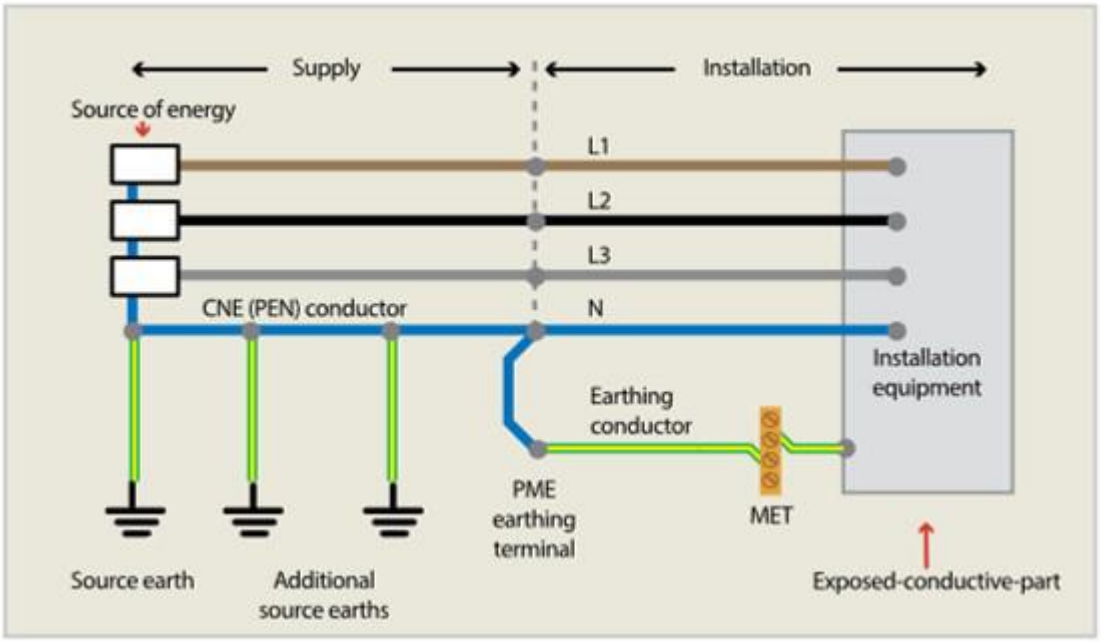
What is a PEN conductor?

A PEN conductor is a single conductor that has the combined function of neutral and protective earth in one conductor of a TN-C low-voltage distribution network. Conventionally, for a three-phase distribution, the cable will be three solid cores, which are L1, L2 and L3, with wire armourings which is the PEN conductor. An example of this type of cable is a concentric cable to BS 7870-3.40 *LV and MV polymeric insulated cables for use by distribution and generation utilities - Distribution cables of rated voltage 0.6/1 (1.2) kV. Specification - XLPE insulated, copper wire waveform concentric cables with solid aluminium or stranded copper conductors (Implementation of HD 603)* (see Figure 1).

Figure 1 Example of a concentric cable to BS 7870-3.40

At the cutout, i.e., the original of the electrical installation, the PEN conductor is separated into its two component parts and, from that point onwards into the installation, separate neutral and protective conductors exist (see Figure 2).

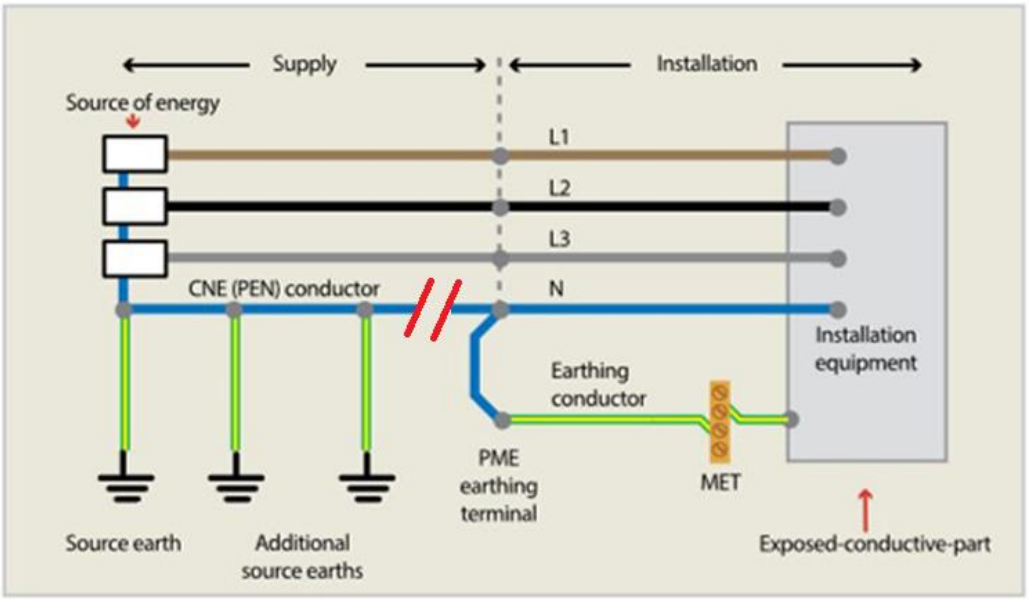
Figure 2 PME system



What is a lost PEN conductor?

It's exactly that, a severed, deteriorated or broken conductor that no longer provides a connection to the means of earthing (see Figure 3).

Figure 3 PME system showing a broken PEN conductor



The causes of lost PEN conductor incidents are, for example, a severance caused by road excavation works or deterioration at cable joints in the ground where moisture has been able to corrode the conductor.

What are the risks?

When a lost PEN incident occurs, a number of risks arise, such as:

- overheating of earthing and bonding conductors;
- voltages approaching 400 V appearing on a single-phase installation;
- damage to electrical appliances due to being exposed to line-to-line voltages;
- overheating of metallic gas pipes;
- fire; and
- explosion.

Consider the position of the lost PEN conductor on the network. It could affect a single dwelling, for example, or one hundred houses. These two scenarios highlight that expected neutral current diversion is hard to quantify in terms of the routes along which currents will flow back to the supply transformer and the accumulative size of current in amps.

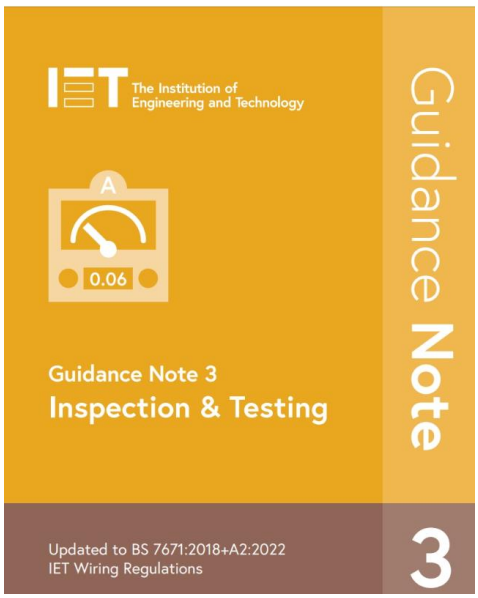
How big is this problem?

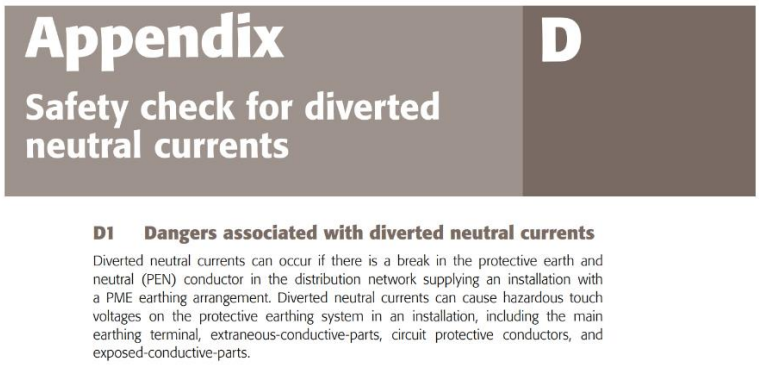
As mentioned earlier, there is not a lot of data available. We are asking electrical installers and electrical inspectors to report incidences of neutral current diversion.

How do I assess if neutral current diversion is present?

The IET's *Guidance Note 3: Inspection &d Testing, 9th Edition*, has a dedicated annex, 'Annex D – Safety check for diverted neutral currents', which advises on safe working practices and methods of detection.

Figure 4 Extract from IET's Guidance Note 3





It is very important that a check for neutral current diversion is carried out before any work is undertaken.

How do I report neutral current diversion?

Should neutral current diversion be detected, we ask that you submit your findings. A QR code will be made available by all stakeholders in addition to a weblink in trade magazines and social media which will take you to the relevant website. You will be presented with a number of simple questions, three of which will be:

1. what was the voltage/current that you measured?
2. did you call 105 to report the incident?
3. postcode of the installation.

What happens next?

The research period will run for six months and the submissions will be reviewed. What happens next depends on what is uncovered. If there are lots of incidences in one area then the DNO in that area will be made aware of the size of the problem. If there are lots of incidences countrywide then every DNO will be alerted of the size of the problem. It may be that the group decides to inform the Government should the findings indicate a problem wider than expected.

In any event, the findings will influence guidance for electrical installers and electrical inspectors.

Further information

- IET *Guidance Note 3: Inspection & Testing, 9th Edition*
- IET Wiring Matters: Broken PEN (Issue 84, March 2021)