Supplementary equipotential bonding

by Mark Coles

Courtesy of Yorkshire Water

Questions relating to the requirements for supplementary equipotential bonding are frequently asked; a very common one is *where* should it be installed.

This article looks at the requirements for supplementary equipotential bonding in BS 7671:2008, where supplementary equipotential bonding should be installed and offers help on the process of evaluation.

TERMINOLOGY

Firstly, it is important that the terminology is correct. Earthing and bonding are two different concepts yet the terms are often used together. Once we have established that "earth-bonding"* is a nonsensical expression and should never be used, we can look at the requirements of supplementary equipotential bonding in BS 7671:2008.

***Earthing and bonding are two separate concepts**

Earthing

Connection of the exposed-conductive-parts of an installation to the main earthing terminal of that installation.

An example of earthing is where the metallic outer-case of a class I appliance is connected by the circuit protective conductor to the means of earthing providing a safe path for fault or high leakage/high protective conductor currents.

Equipotential bonding

Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential.

There are two types of equipotential bonding conductor:

Main protective bonding conductor *Used to connect extraneous-conductive-parts, such as a metallic water pipe, to the main earthing terminal.*

Supplementary equipotential bonding conductors *Used to supplement to fault protection by maintaining various exposed conductive-parts and extraneous-conductive-parts at substantially the same potential, such as the connection of all exposed-conductive-parts and extraneous-conductive-parts that can be touched by livestock in an agricultural installation.*

HISTORY

The change from the 14th to the 15th Edition of the IEE Wiring Regulations in 1981 created a big upheaval in the electrical installation industry as many new concepts were introduced and many existing practices were expanded or enhanced - one of those being supplementary equipotential bonding. To a great extent, the 15th Edition was based on CENELEC harmonised documents (HDs) (more so now with the introduction of the 17th Edition).

HD 384.4.41 was the basis for Chapter 41 of the 15th Edition - *Protection against electric shock,* which had requirements for supplementary equipotential bonding in Regulation 413-7, reproduced here:

413-7 Within the zone formed by the main equipotential bonding, local supplementary equipotential bonding connections shall be made to metal parts, to maintain the equipotential zone, where those parts -
(i) are extraneous conductive parts, and
(ii) are simultaneously accessible with exposed conductive parts or other extraneous conductive parts, and
(iii) are not electrically connected to the main equipotential bonding by permanent and reliable metal-to-metal joints of negligible impedance.
NOTE - Where local equipotential bonding is provided in accordance with Regulation 413-7, metalwork which may be required to be bonded includes baths and exposed metal pipes, sinks, taps, tanks, and radiators and, where practicable, accessible structural metalwork

Those far reaching changes, issued on 31st March 1981, are still being felt today with designers and specifiers still implementing the requirements for supplementary equipotential bonding from the 15th Edition. Much of the confusion can be attributed to the note of Regulation 413-7 which required the bonding of all metallic items, essentially, those within the designated equipotential zone. This led to the installation of supplementary equipotential bonding of general metallic items such as baths, ceiling grids, hand rails, kitchen sinks, radiators, pipework at boilers, etc. Thankfully, we have moved on from this general concept.

THE REQUIREMENTS FOR SUPPLEMENTARY EQUIPOTENTIAL BONDING

We'll look at the requirements for supplementary equipotential bonding then at instances where it would be required.

Initially, the scene is set by Regulation 410.3.7 which requires that if the conditions of a protective measure cannot be met, supplementary provisions shall be applied to achieve the same degree of safety.

What is a protective measure?

There are four protective measures generally permitted by BS 7671:2008, given in Regulation 410.3.3:
(i) Automatic disconnection of supply (Section 411)
(ii) Double or reinforced insulation (Section 412)
(iii) Electrical separation for the supply to one item of current-using equipment (Section 413)
(iv) Extra-low voltage (SELV and PELV) (Section 414).

A note at the end of this Regulation acknowledges that, in electrical installations, the most commonly used protective measure is automatic disconnection of supply.

DISCONNECTION TIMES

Regulation 411.3.2.6 states that where automatic disconnection cannot be achieved in the required time, supplementary equipotential bonding shall be provided.

In this instance, if disconnection will not occur in the required 0.4 s, for example, supplementary equipotential bonding is used to hold various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential to limit the risk of a dangerous electric shock - this clears the confusion created by Regulation 413-7 of the 15th Edition.

Do bear in mind that supplementary equipotential bonding need not be physically carried out by the installation of single-core green-and-yellow conductors in every instance. There may be a situation where, for example, two simultaneously accessible metallic parts are in reliable contact and the resistance between the two parts is sufficiently low.

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Where doubt exists regarding the effectiveness of supplementary equipotential bonding, Regulation 415.2.2 requires that the resistance, R, between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts fulfils the following condition:

In a.c. systems $R \leq \frac{50\ V}{Ia}$

Where:
Ia is the operating current in amperes of either:

- the protective device for RCDs, IΔn.
- overcurrent devices, the current causing automatic operation in 5 s

Example 1
Let's take the scenario that the protective device is an RCD rated at 30 mA:

$R \leq \frac{50\ V}{Ia}$

$R \leq \frac{50\ V}{0.03}$

$R \leq 1666\ \Omega$

Therefore, a maximum resistance of 1666 Ω will ensure there is sufficient current to operate the RCD. Note that the touch voltage may rise above 50 v; the value of 50 v is used as a constant in the formula to ensure sufficient current is flowing to operate the RCD.

Example 2
Let's take the scenario that the protective device is a BS EN 60898 Type B circuit-breaker, rated at 32 A. First we must establish the current causing operation of the circuit-breaker by referring to the correct time/current characteristics graph in Appendix 3 of BS 7671.

Therefore, looking at fig. 1 (extract from fig.3.4 of BS 7671:2008), we can establish that the current causing operation of the circuit breaker is 160 A.

$R \leq \frac{50\ V}{Ia}$

$R \leq \frac{50\ V}{160}$

$R \leq 0.31\ \Omega$

Therefore, a maximum resistance of 0.31 Ω will ensure there is sufficient current to operate the circuit breaker within five seconds.

Note that in fig. 1 the current causing operation of the device between 0.1 and 5 s is the same; this will not be the case for fuses. If many circuits are present in a particular area and are protected by different protective devices/types, etc., the worst case characteristic should be used.

The IET publication, Guidance Note 3, with the latest edition due for imminent publication, advises that the resistance of supplementary equipotential bonding conductors should be no more than 0.05 Ω. When verifying supplementary equipotential bonding conductors, Regulation 612.2.1 requires that a continuity test be made with a recommendation that the test instrument has a no-load voltage of between 4 V and 24 V, d.c. or a.c. and a short-circuit current of not less than 200 mA.

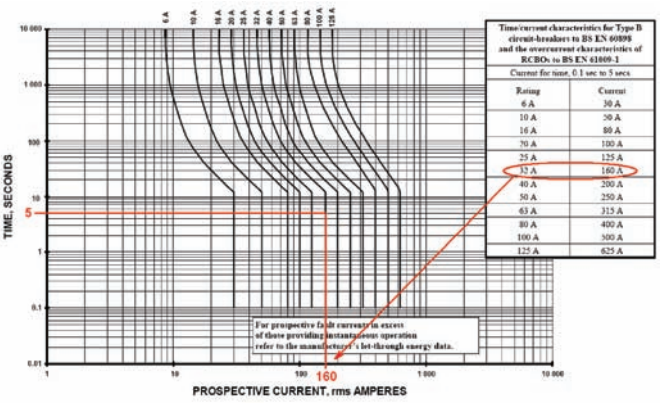

Figure 1: Time/current characteristics of circuit-breakers to BS EN 60898 Type B and BS EN 61009-1

WORKING STANDARDS

The installation of supplementary equipotential bonding does not mean that a lower standard of work is permitted, nor the requirements for fault protection or the need to disconnect the supply for other reasons, such as protection against fire, thermal stresses in equipment, etc., can be omitted.

Regulation 522.6.1 requires that the correct wiring system is selected for the application to minimize the risk of damage arising from mechanical stress, e.g. by impact, abrasion, penetration, tension or compression during installation, use or maintenance.

Fundamentally, this means that if there is a danger of a metallic part not forming part of the electrical installation becoming live due to damage to a cable, then the protection of that cable is paramount and must form part of the design. Simply installing supplementary equipotential bonding as a means of omitting mechanical protection will just result in more metallic parts becoming live in the event of damage to a cable.

SIZING OF SUPPLEMENTARY EQUIPOTENTIAL CONDUCTORS

BS 7671:2008 has requirements for the sizing of supplementary equipotential bonding conductors in Regulation 544.2, the table shown overleaf, fig. 2, will aid with the choice of conductor.

WHERE SUPPLEMENTARY EQUIPOTENTIAL BONDING IS REQUIRED

Ultimately, responsibility is with the designer of the installation, who is a competent person, fully aware of the installation conditions and will use their skill and engineering

Size of CPC mm²	Minimum cross-sectional area of supplementary bonding conductors					
	Exposed-conductive-part to extraneous-conductive-part		Exposed-conductive-part to exposed-conductive-part		Extraneous-conductive-part to extraneous-conductive-part (1)	
	mechanically protected mm²	mechanically protected mm²	mechanically protected mm²	mechanically protected mm²	mechanically protected mm²	mechanically protected mm²
1.0	1.0	4.0	1.0	4.0	2.5	4.0
1.5	1.0	4.0	1.5	4.0	2.5	4.0
2.5	1.5	4.0	2.5	4.0	2.5	4.0
4.0	2.5	4.0	4.0	4.0	2.5	4.0
6.0	4.0	4.0	6.0	6.0	2.5	4.0
10.0	6.0	6.0	10.0	10.0	2.5	4.0
16.0	10.0	10.0	16.0	16.0	2.5	4.0

Figure 2: Minimum cross-sectional area of supplementary equipotential bonding

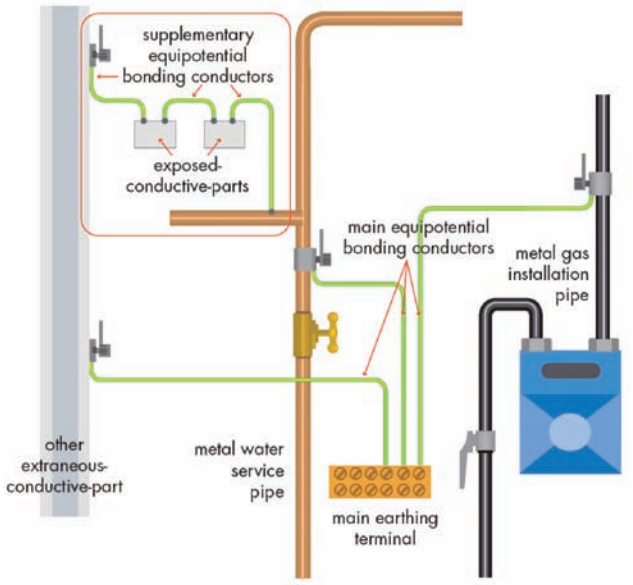

Figure 3: Application of supplementary equipotential bonding

judgement to design the installation accordingly.

Where supplementary equipotential bonding is required, it may involve the entire installation, a part of the installation, an item of equipment or a location, etc. Where supplementary equipotential bonding is installed, it should include all simultaneously accessible exposed-conductive-parts of fixed equipment and all extraneous-conductive-parts.

Exposed-conductive-part
Conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails.

An example of an exposed-conductive-part is the metallic outer case of an electrical class I appliance, designed to be connected to the means of earthing at all times of operation

Extraneous-conductive-part
A conductive part liable to introduce a potential, generally Earth potential, and not forming part of the electrical installation.

An example of an extraneous-conductive-part is a metallic water pipe which is buried in the ground and subsequently enters a building

To generalise, as stated earlier, supplementary equipotential bonding is required where a disconnection time can not be met or where a Special Installation or Location, i.e. those in Part 7 of BS 7671:2008, has an increased risk of electric shock. The following Sections of Part 7 directly reference supplementary equipotential bonding - note that other measures will be necessary to meet the requirements of BS 7671:2008.

Section 701 - Locations containing a Bath or Shower
Section 701 now has a relaxed requirement for supplementary equipotential bonding when the following three conditions of Regulation 701.415.2 are met;
(i) All final circuits of the location comply with the requirements for automatic disconnection
(ii) All final circuits of the location have additional protection by means of a 30 mA RCD
(iii) All extraneous-conductive-parts of the location are effectively connected to the protective equipotential bonding

Section 702 - Swimming Pools and Other Basins
Supplementary equipotential bonding will connect all extraneous-conductive-parts in zones 0, 1 and 2 to the protective conductors of exposed-conductive-parts of equipment situated in these zones, in Regulation 702.411.3.3.

Regulation 702.522.21 requires that in zones 0, 1 and 2, any metallic sheath or metallic covering of a wiring system shall be connected to the supplementary equipotential bonding. The note at the end of this Regulation states that cables should preferably be installed in conduits made of insulating material. This is a relaxation from the 16th Edition as Regulation 602-06-01 states that in zones A and B, a surface wiring system shall not employ metallic conduit or metallic trunking or an exposed metallic cable sheath or an exposed earthing or bonding conductor.

Regulation 702.55.1 permits the installation of an electric heating unit embedded in the floor, provided that it incorporates an earthed metallic sheath, is covered by an embedded earthed metallic grid and connected to the supplementary

equipotential bonding of the location (other requirements are also necessary).

Section 705 - Agricultural and Horticultural Premises

Supplementary equipotential bonding is required to connect all exposed-conductive-parts and extraneous-conductive-parts that can be touched by livestock, the metal grid laid in the floor, concrete reinforcement in general or reinforcement of cellars for liquid manure (other requirements are also necessary), in Regulation 705.415.2.1.

Regulation 705.544.2 requires that supplementary equipotential bonding conductors are protected against mechanical damage and corrosion and chosen to avoid electrolytic effects, with examples given as:
(i) Hot-dip galvanized steel strip with dimensions of at least 30 mm × 3 mm
(ii) Hot-dip galvanized round steel of at least 8 mm diameter
(iii) Copper conductor having a minimum cross-sectional area of 4 mm^2.
Other suitable materials may be used.

Section 706 - Conducting Locations with Restricted Movement

In a conducting location with restricted movement, Regulation 706.410.3.10 requires that a supply to fixed equipment shall incorporate supplementary equipotential bonding is used to connect exposed-conductive-parts of fixed equipment and the conductive parts of the location where automatic disconnection of the supply is the protective measure. Part e) of this Regulation requires that where the protective measure is PELV, equipotential bonding is provided between all exposed-conductive-parts, all extraneous-conductive-parts inside the conducting location with restricted movement, and the connection of the PELV system to Earth.

Section 740 - Temporary Electrical Installations for Structures, Amusement Devices and Booths at Fairgrounds, Amusement Parks and Circuses

Regulation 740.415.2.1 reiterates the requirements of 705.415.2.1, shown above under Agricultural and Horticultural Premises.

CONCLUSION

To summarise, supplementary equipotential bonding is required where a disconnection time can not be met or where a Special Installation or Location, i.e. those in Part 7 of BS 7671:2008, has an increased risk of electric shock. Confusion created by Regulation 413-7 of the 15th Edition of the IEE Wiring Regulations, which effectively required supplementary equipotential bonding to connect all accessible metallic parts within the equipotential zone, has been clarified by Regulations 411.3.2.6 and 415.2. Other installations, such as those of hazardous locations, will have further requirements for supplementary equipotential bonding to reduce the risks of sparking due to the build up of static electricity, for example. In such installations, the requirements of BS 7671 will be supplemented by the requirements or recommendations of other British Standards or by the requirements of the person ordering the work.

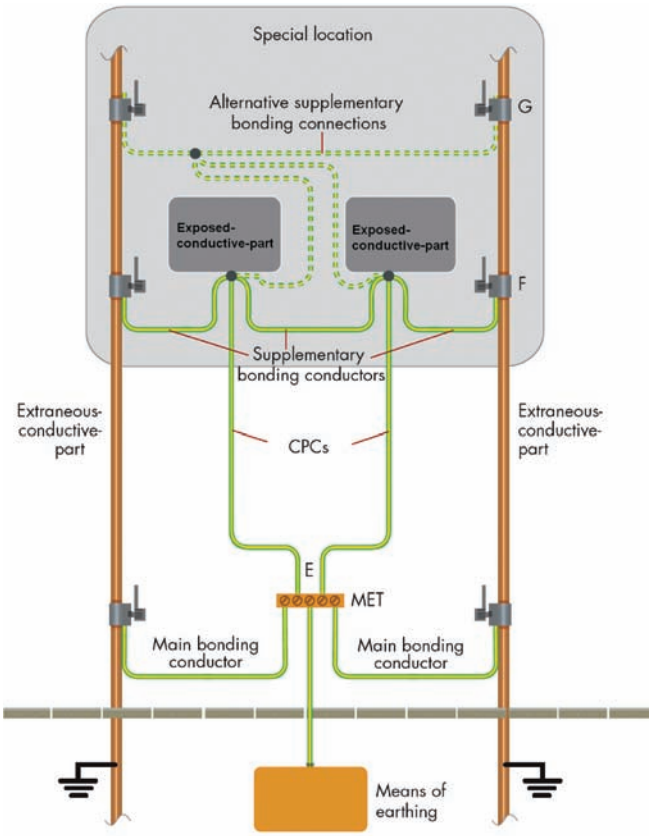

Figure 4: Application of supplementary equipotential bonding in a Special Location

FURTHER INFORMATION

- BS 7671:2008 Requirements for Electrical Installations, IEE Wiring Regulations, Seventeenth Edition Guidance Note 3 - Inspection and Testing
- PD CLC/TR 50404:2003 Electrostatics — Code of practice for the avoidance of hazards due to static electricity
- BS EN 60079 Electrical apparatus for explosive gas atmospheres (suite of standards)
- BS EN 60079–14:2003 Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines) ■

Thanks to Richard Rennie of Yorkshire Water for the image used.