When is TN-C-S PME and when isn't it?

When is TN-C-S PME or PNB and what are the earthing & bonding requirements?

Executive Summary

This guide explains there are two variants of TN-C-S earthing arrangements, PME and PNB. Although they are both TN-C-S they are fundamentally different and can adopt different earthing and bonding requirements, either that of TN-C-S or TN-S. Here we explain what is PNB and the differences to PME.

1. Introduction

There is often confusion around the earthing and bonding of electrical systems supplied by a transformer, typically a private or dedicated transformer. Further confusion occurs with what is the correct terminology of the supply and how the regulations for earthing and bonding need to be applied. This has significant impact on the design and use of material resources and can also affect periodic inspections leading to 'unsatisfactory' reports.

This guidance will help you identify there is a difference between PME (protective multiple earthing) and PNB (protective neutral bonding), the correct terminology and how to apply the regulations.

2. What is TN-C-S?

A TN-C-S earthing system is a single source of supply with direct connection of the source with Earth at one or more points (denoted by the first letter T) and exposed-conductive-parts of the installation are directly connected by a protective conductor with the source earth (denoted by the second letter N).

The subsequent letters C-S mean that both the neutral conductor and the protective conductor are combined in the supply and separate in the installation.

Essentially this means that in a TN-C-S system the neutral and earth are combined within the supply and separate within the installation. The means of earthing is provided from the combined protective and neutral conductors of the supply.

Figure 1 from BS 7671:2018+A2:2022 shows a TN-C-S (PME) system where the neutral and protective functions are combined into a single conductor (PEN or protective earth neutral) in a part of the system.

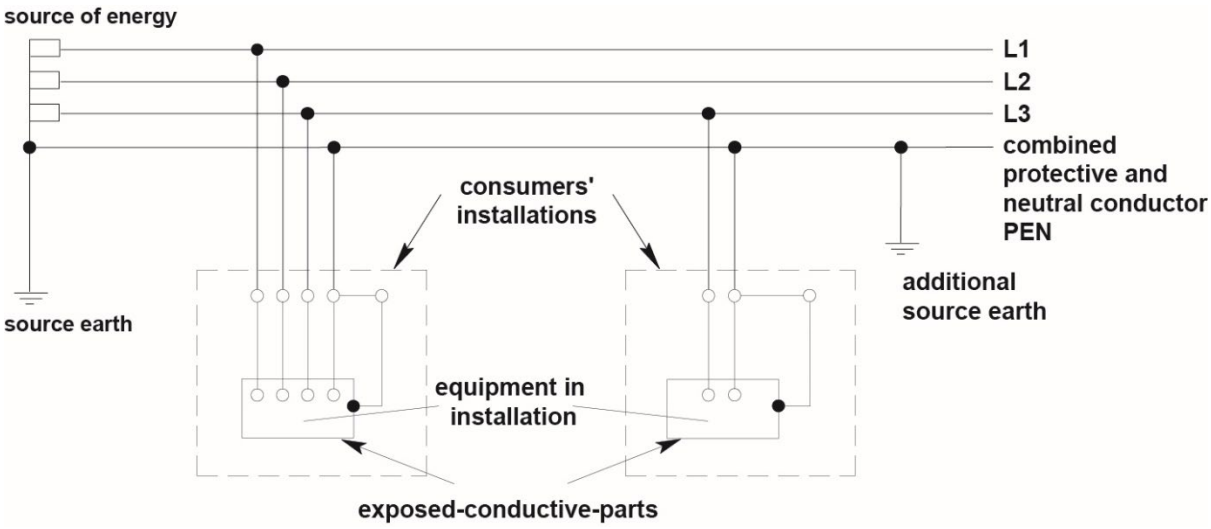

Figure 1 - TN-C-S (PME) system taken from Figure 3.9 of BS 7671:2018+A2:2022 with thanks to BSI and IET for permission to use the image

Neutral and protective functions combined in a single conductor (PEN) in part of the system.

This particular type of earthing system is also known as protective multiple earthing (PME) because the system PEN conductor is earthed at **two or more points.**

All exposed-conductive-parts of an installation are connected to the PEN conductor via the main earthing terminal and these terminals are linked together.

Letter	Designation	Meaning
T	Terre (Earth)	Direct connection of one point to Earth
N	Neutral	Direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in AC systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a line conductor)
C	Combined	Neutral and protective functions combined in a single conductor (PEN conductor)
S	Separate	Protective function provided by a conductor separate from the neutral conductor or from the earthed line (or, in AC systems, earthed phase) conductor
C-S	Combined then separate	Both the neutral conductor and the protective conductor are combined in the supply and separate in the installation.

Table 1 - System type designation letters and their meanings

3. When is TN-C-S PME?

TN-C-S is considered PME (protective multiple earthing) when the supply PEN (protective earth neutral) or CNE (combined neutral earth) conductor is earthed at **multiple points** of the supply, as well as the source itself, therefore providing a low-impedance path to Earth for all parts of the PEN conductor. It is the most common form of connection to installation and is shown in Figure 2.

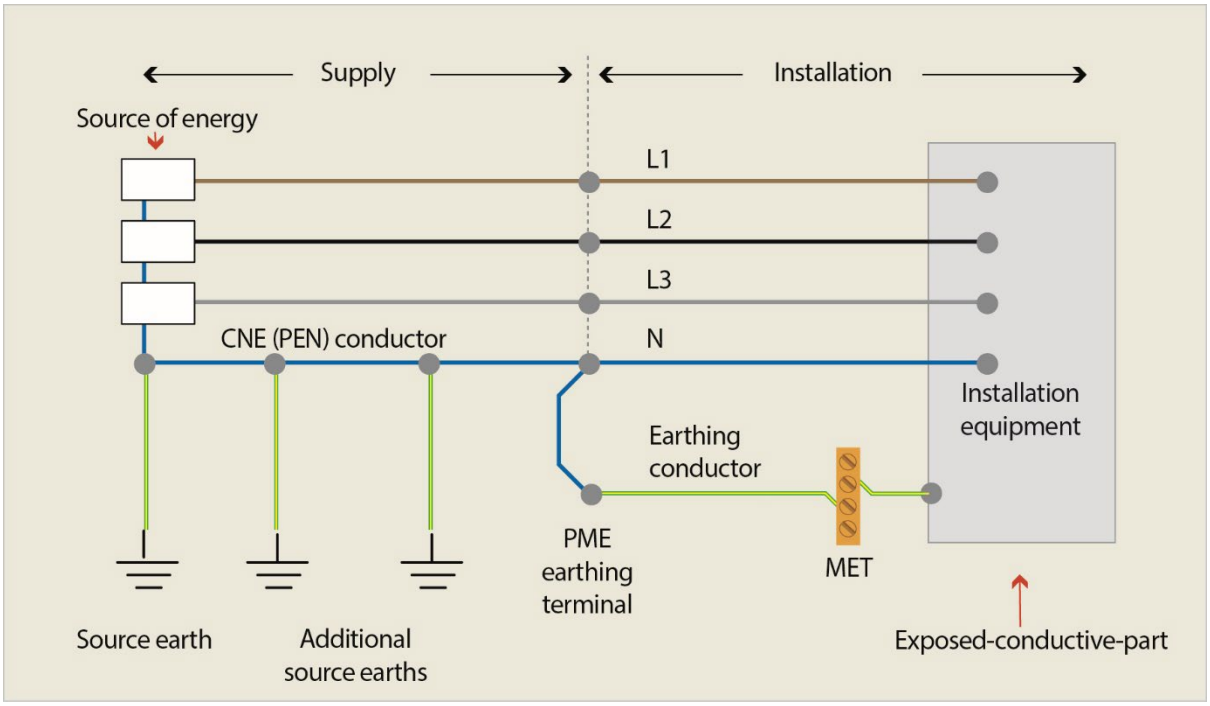

Figure 2 - TN-C-S PME Earthing system figure 4.6 as provided by the IET Guidance Note 8 (5th edition) with thanks to BSI and IET for permission to use the image

TN-C-S PME protective conductor sizing

The protective conductor *(sometimes referred to as the main earthing conductor)* shall be sized in accordance with *Regulation 543.1.1* of BS 7671:2018+A2:2022 where the cross-sectional area of every protective conductor, other than a protective bonding conductor, shall be:

(i) calculated in accordance with Regulation 543.1.3, or
(ii) selected in accordance with Regulation 543.1.4.

Calculation in accordance with Regulation 543.1.3 is necessary if the choice of cross-sectional area of line conductors has been determined by considerations of short-circuit current and if the earth fault current is expected to be less than the short-circuit current.

If the protective conductor:
(iii) is not an integral part of a cable, or
(iv) is not formed by conduit, ducting or trunking, or
(v) is not contained in an enclosure formed by a wiring system,

the cross-sectional area shall be not less than 2.5 mm^2 is provided, and 4 mm^2 copper equivalent if protection against mechanical damage copper equivalent if mechanical protection is not provided (see also Regulation 543.3.1).

For a protective conductor buried in the ground Regulation 542.3.1 for earthing conductors also applies. The cross-sectional area of a protective bonding conductor shall comply with Section 544.

Regulation 543.1.3 method uses the adiabatic equation for calculating the cross-sectional area of a protective conductor for disconnection times not exceeding 5 seconds.

Where calculated, the cross-sectional area of the protective conductor shall be not less than the value determined by the following formula or shall be obtained by reference to BS 7454:

$$S = \frac{\sqrt{I^2 t}}{k}$$

where:

S is the nominal cross-sectional area of the conductor in mm^2

I is the value in amperes (rms for AC) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability (I^2t) of that protective device

t is the operating time of the protective device in seconds corresponding to the fault current I amperes

k is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures and can be found in Tables 54.2 to 54.6 of BS 7671.

Regulation 543.1.4 utilises a tabulated method for sizing the minimum cross-sectional area of protective conductor in relation to the cross-sectional area of the associated line conductor.

This method is often a more practicable method of sizing the protective conductor by using Table 54.7 and Table 43.1, 54.2 to 54.6 of BS 7671 as follows:

Cross-sectional area of line conductor S	**Minimum cross-sectional area of the corresponding protective conductor**	
	If the protective conductor is of the same material as the line conductor	**If the protective conductor is not of the same material as the line conductor**
(mm^2)	**(mm^2)**	**(mm^2)**
S ≤ 16	S	$\frac{k_1}{k_2} \times S$

16 < S ≤ 35	16	$\frac{k_1}{k_2} \times 16$
S > 35	$\frac{S}{2}$	$\frac{k_1}{k_2} \times \frac{S}{2}$

where:

k_1 is the value of k for the line conductor, selected from Table 43.1 in Chapter 43 according to the materials of both conductor and insulation.

K_2 is the value of k for the protective conductor, selected from Tables 54.2 to 54.6, as applicable.

Table 2 - Table 54.7 from BS 7671:2018+A2:2022

TN-C-S PME main protective bonding sizing

For installations in which a PME earthing facility is used as the means of earthing *Regulation 542.3.1* requires the earthing conductor to also meet the cross-sectional area requirements of *Regulation 544.1.1* for main protective bonding conductors i.e., the cross-sectional area of the earthing conductor should be able to meet the requirements for a main protective bonding conductor given in Table 54.8 of BS 7671:2018+A2:2022 which is summarised below in Table 3 matching the size of the PEN conductor as shown in Figure 2 to the minimum size of main protective bonding conductor.

The increased size of the bonding conductor and the requirement to install an earthing conductor sized appropriately to take into account the main protective bonding requirements in remote buildings with extraneous conductor parts is due to the risk of increased touch voltage in the event of an open-circuit PEN conductor on the distributors network.

Copper equivalent cross-sectional area of the PEN conductor (mm²)	**Minimum copper equivalent cross-sectional area of the main protective bonding conductor (mm²)**
≤ 35	10
>35 up to 50	16
> 50 up to 95	25
> 95 up to 150	35
> 150	50

Table 3 - Minimum cross-sectional area of main protective bonding conductors where PME conditions apply taken from BS 7671 Table 54.8

Whilst the issue of an open-circuit PEN conductor is rare and is the distributor's responsibility, it could have serious consequences to the consumer's electrical installation.

Diverted neutral currents can occur if there is a break in the protective earth and neutral (PEN) conductor in the distribution network supplying an installation with a PME earthing arrangement. Diverted neutral currents can cause hazardous touch voltages on the protective earthing system in an installation, including the main earthing terminal, extraneous-conductive-parts, circuit protective conductors, and exposed-conductive-parts.

IET Guidance Note 3 (9th edition) Appendix D1 recommends a series of checks for diverted neutral currents where there is a TN-C-S earthing arrangement, or where PME conditions apply.

If you suspect an open-circuit PEN conductor, commonly known as a *'broken PEN conductor'* the Electricity Safety, Quality and Continuity Regulations (ESQCR) deem the connection with Earth of the neutral of the supply is permanent and it is the responsibly of the local distributor to ensure this is maintained:

Regulation 114.1 states:

"For a supply given in accordance with the Electricity Safety, Quality and Continuity Regulations, it shall be deemed that the connection with Earth of the neutral of the supply is permanent"

If an open-circuit PEN conductor is suspected, call 105 immediately to report an emergency to the local electrical distributor without delay.

4. What is PNB?

PNB refers to protective neutral bonding and is a method of earthing, similar to PME, where the neutral earth connection is installed at or adjacent to the customers installation instead of the transformer position.

PNB is a TN-C-S system, but it is not PME

PNB variant of TN-C-S is confined to cases where the low voltage (LV) connections are made at just **one** point on the distribution network. This is common at either a dedicated transformer for a **single** customer connection, or in locations, usually rural where a pole mounted transformer is dedicated to a **single** customer connection.

This guide explains the difference between TN-C-S PME and TN-C-S PNB.

5. When is TN-C-S PNB?

TN-C-S PNB is found where there is **only one** point in the network at which the consumer's installation is connected to a single source of supply – i.e., direct supply to an individual customer fed directly from the transformer. In this arrangement the PEN or CNE conductors is connected to the Earth at that point, or at another point nearer the source.

ENA (Energy Networks Association) Engineering Recommendation G12/4 recommends that the distance between the connection to Earth and the consumers

intake shall be 40 m or less, however, in order to minimise the risk of voltage rise in the event of a broken neutral this connection should be made as close as practicable to the consumers supply terminals.

This is sometimes carried out at a location near the consumer's main switchgear position or inside the main switchgear with a neutral earth link.

For the purpose of this guidance, we have omitted the installation of the PEN conductor as it falls outside of BS 7671 and assumed the consumer's installation begins at the neutral earth link at either a location near the consumer's main switchgear or inside the main switchgear.

Under ESQCR the consumer cannot install a PEN conductor, this is the responsibly of the DNO (distribution network operator) or iDNO (independent distribution network operator). There may be instances where the installation owner is responsible for the HV (high voltage) and LV (low voltage) installation, making them both the DNO (or iDNO) and the consumer. In all cases the ESQCR must be followed.

The ESQCR can be found online here:

[The Electricity Safety, Quality and Continuity Regulations 2002 provided by legislation.gov.uk]

A diagram of a TN-C-S system with PNB is shown in Figure 3, with examples of a PNB neutral earth link (also commonly known as a N-E link) provided in switchboards, such as form 4 switch panel, shown in Figure 4 and Figure 5.

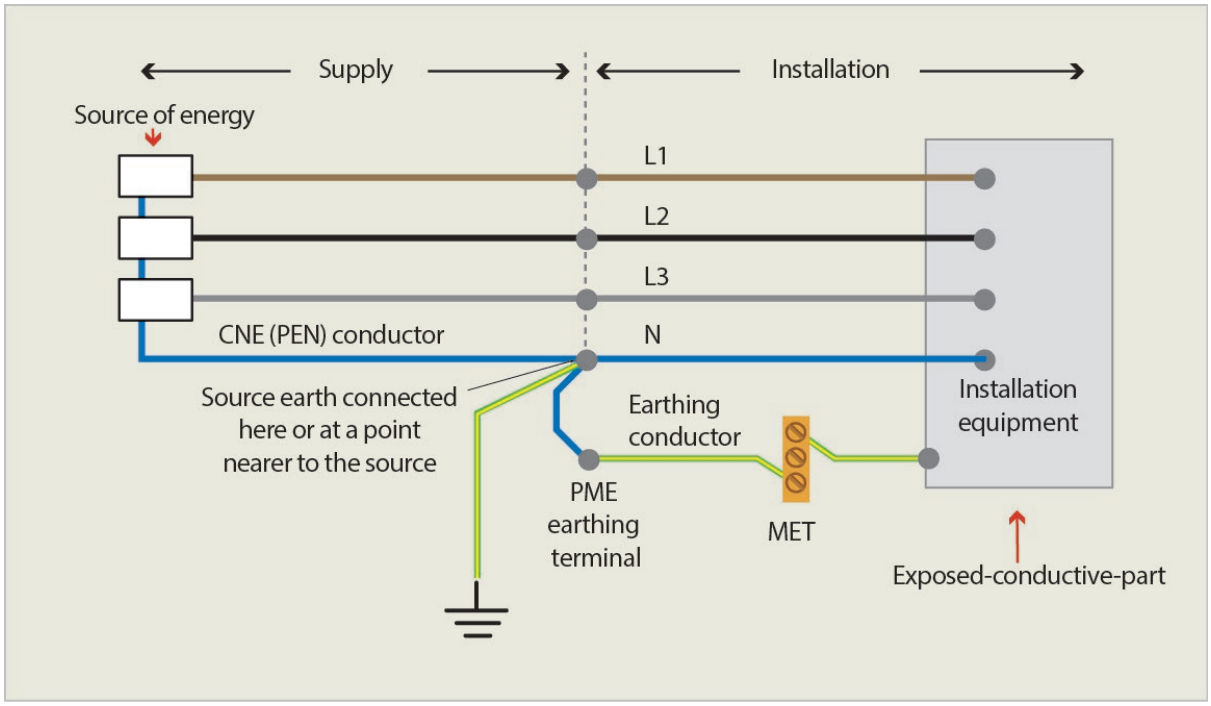

Figure 3 – TN-C-S PMB Earthing system figure 4.8 as provided by the IET Guidance Note 8 (5th edition) with thanks to BSI and IET for permission to use the image

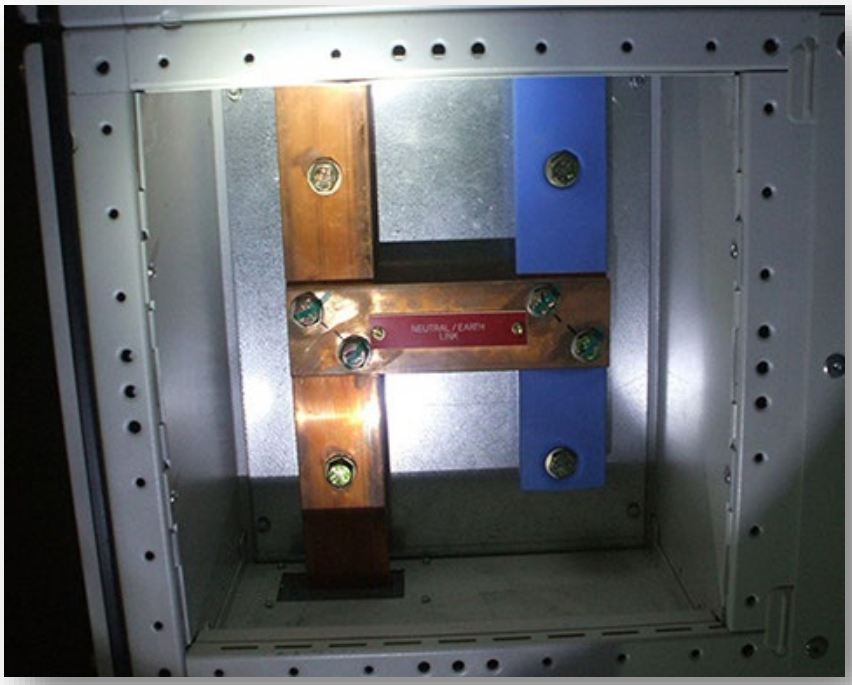

Figure 4 - Neutral - Earth link in a switchboard with thanks to of J.Peckham for permission to use the image

Figure 5 - Neutral - Earth link in a switchboard with thanks to EJ Parker Group (Panelco) for permission to use the image

Does TN-C-S PME and TN-C-S PNB differ in terms of earthing and bonding?

Yes, a TN-C-S PNB installation can usually be 'considered' TN-S for earthing & bonding arrangements as the risk of loss of neutral is minimal as it is controlled and would only be lost due to a deliberate malicious act. However, it is worth noting that designers should **always** confirm any particular requirements of the relevant local Distribution Network Operator (DNO) as a DNO may require that their PNB installations require a larger size of protective bonding conductor and take be treated as PME to take account of local network conditions.

TN-C-S PNB protective conductor sizing

The protective conductor *(sometimes referred to as the main earthing conductor)* shall be sized in accordance with Section 543 of BS 7671, note that PME conditions do not apply in this case.

TN-C-S PNB main protective bonding sizing

For installations where PME conditions do not apply, *Regulation 544.1.1* requires the main protective bonding conductors to have a cross-sectional area of:

a) not less than half that required for the earthing conductor; and
b) not less than 6 mm^2 but need not be more than 25 mm^2 if the conductor is of copper or, if of another metal, a csa affording equivalence conductance.

As PME conditions do not apply, you are not required to install an earthing conductor sized appropriately to take into account the main protective bonding requirements in remote buildings with extraneous conductor parts as per Regulation 544.1.1.

BS 7671:2018+A2:2022 also clarifies that where such installations serve more than one building, i.e., remove buildings, the main protective bonding conductor can be selected in accordance with the characteristics of the distribution circuit protective conductor for that particular building.

This means for TN-C-S PNB installations, the adoption of a TN-S earthing & bonding arrangement can be used. This is highly advantageous saving resources of copper and installation time.

Where PME conditions do not apply, the cross-sectional area of copper main protective bonding conductors for installations is shown in Table 4, where the minimum size main protective bonding conductor is 6 mm^2 and a maximum size of 25 mm^2.

Line conductor cross sectional area (mm^2)	Earthing conductor cross sectional area (mm^2)	Main protective bonding conductor cross sectional area (mm^2)
4	4	6
6	6	6
10	10	6
16	16	10
25	16	10
35	16	10
50	25	16
70	35	25
95	50	25
120	70	25
150	95	25
185	95	25
240	120	25
300	150	25
400	240	25

Table 4 – Extract from Table 5.1 from IET Guidance Note 8 where maximum size main protective bonding conductor need not be no greater than 25 mm^2 where PME conditions do not apply

6. Summary

TN-C-S is available as PME or PNB, be aware that both systems exist and the differences that they provide.

When an installation is **TN-C-S PNB** you may in most cases 'consider' this the same as TN-S for sizing the main earthing and main protective bonding conductors where the maximum size main protective bonding conductor need not be no greater than **25 mm^2 copper conductor.**

When an installation is **TN-C-S PME** you treat this the same as TN-C-S for sizing the main earthing and main protective bonding conductors where the main maximum size main protective bonding conductor need not be no greater than **50 mm^2 copper conductor.**

However, as advised by the Note above Table 54.8 of BS 7671:2018+A2:2022, designers should **always** confirm any particular requirements of the relevant local Distribution Network Operator (DNO) as a DNO may require a larger size of protective bonding conductor to take account of local network conditions.

ECA, Rotherwick House, 3 Thomas More Street, St. Katharine's & Wapping, London E1W 1YZ
Tel: 020 7313 4800 **Email**: info@eca.co.uk **www.eca.co.uk**
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