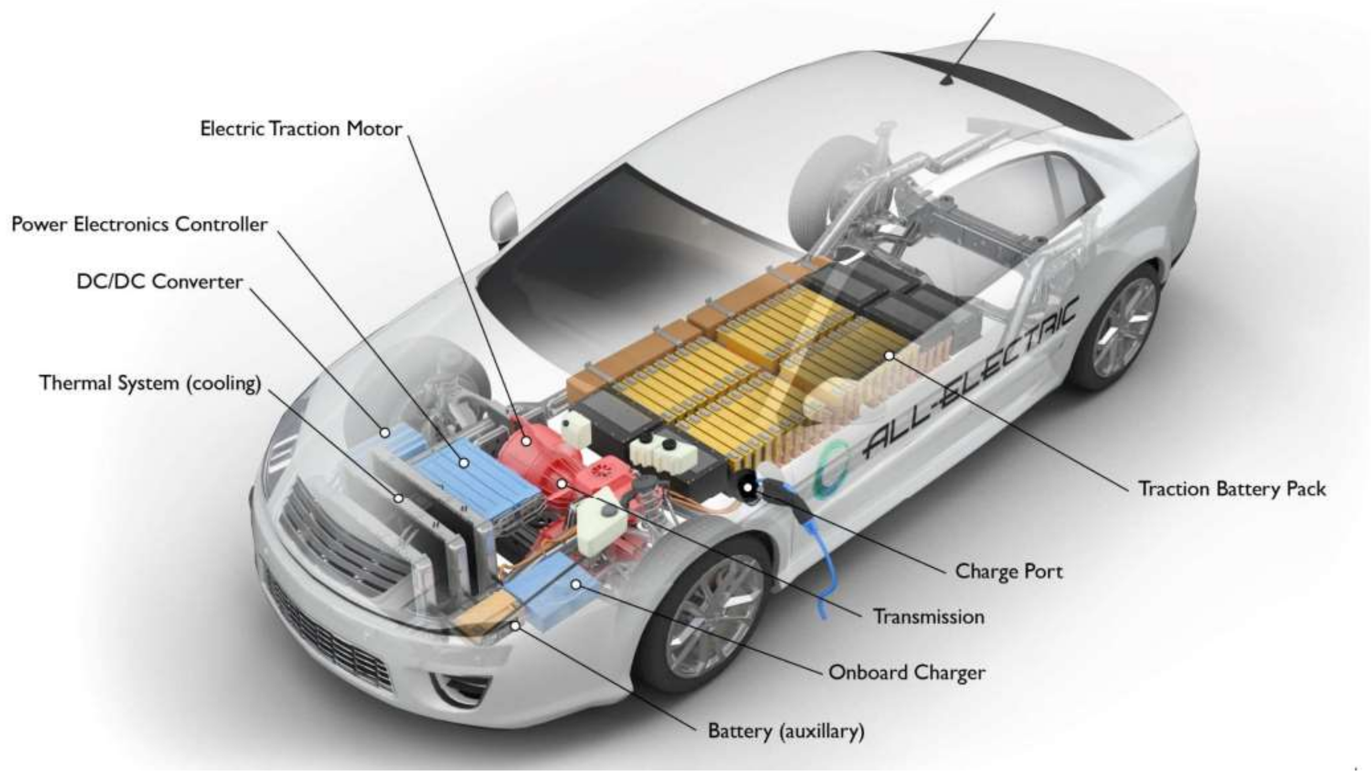
Electric Vehicle Charging

ELECTRIC VEHICLE CHARGING SOLUTIONS

Under The Bonnet

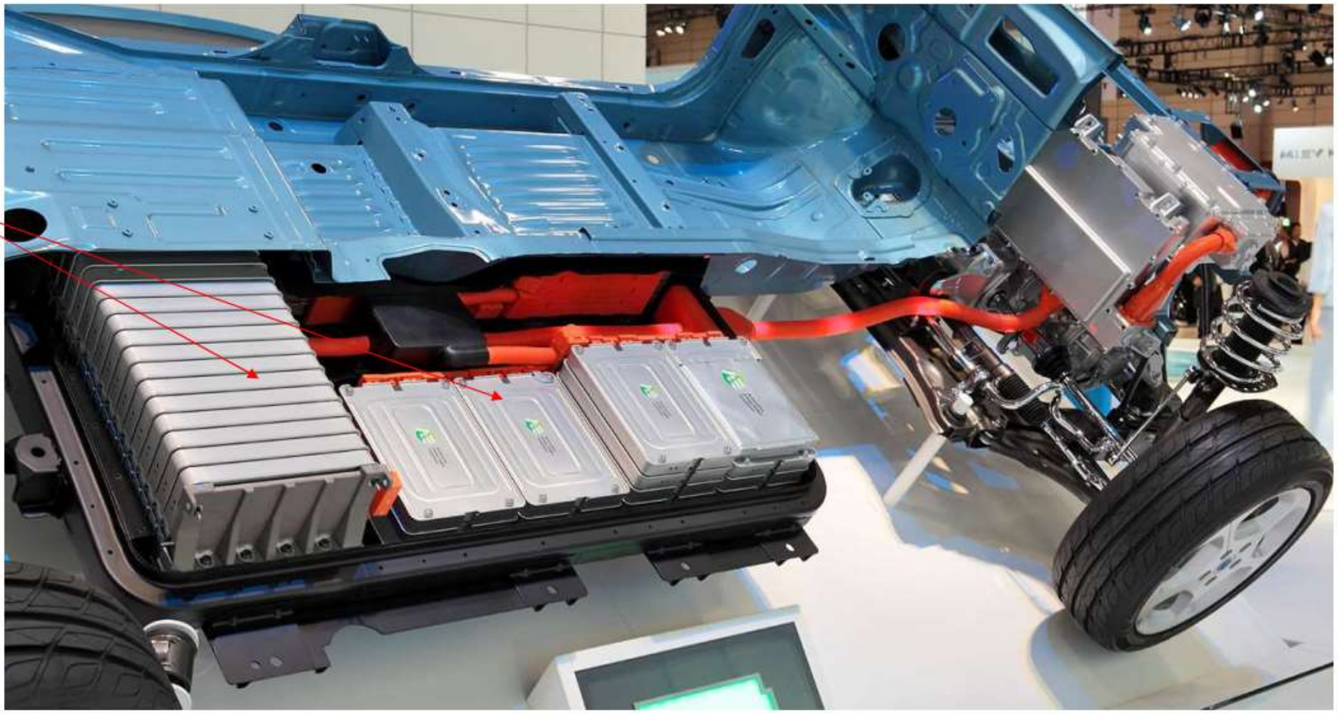
All-Electric Vehicle



The Batteries

Nissan Leaf
cutaway
showing batteries

Lithium Ion (Li-ion)
technology is
generally used



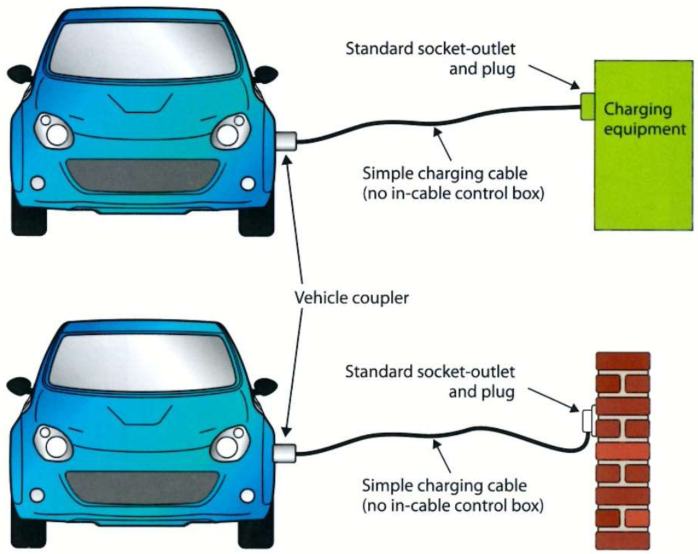
Charging Equipment for Modes 1,2,3,and 4

2.2.1 Mode 1 charging

In Mode 1 charging, connection of the electric vehicle to the AC supply network utilizes standardized socket-outlets not exceeding 16 A and not exceeding 250 V AC single-phase or 480 V AC three-phase, at the supply side, and utilizing the power and protective earth conductors (according to BS EN 61851-1). Refer to Figure 2.1 below.

Note: Mode 1 is no longer a mainstream charging technology.

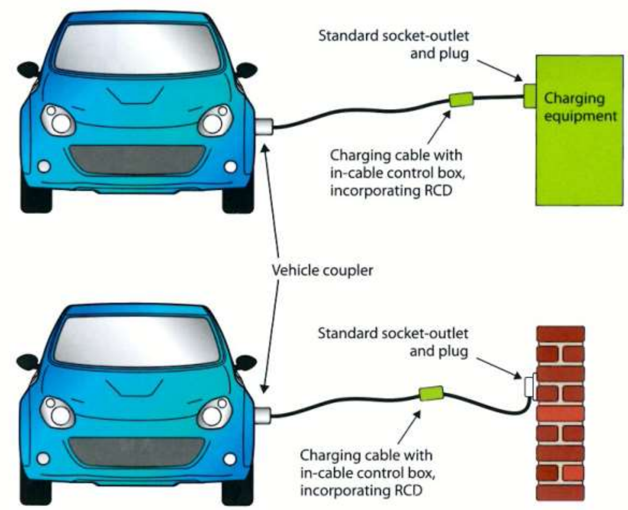
▼ **Figure 2.1 Mode 1 charging**



2.2.2 Mode 2 charging

Mode 2 charging describes the minimal charging solution for single-phase domestic socket-outlets. It provides charging currents of 10 A or less. In Mode 2 charging, connection of the EV to the AC supply network utilizes standardized socket-outlets not exceeding 32 A and not exceeding 250 V AC single-phase or 480 V AC three-phase, at the supply side, and utilizes the power and protective earth conductors together with a control pilot function and system of personnel protection against electric shock (BS EN 62752) between the EV and the in-cable control box (ICCB). Refer to Figure 2.2 below.

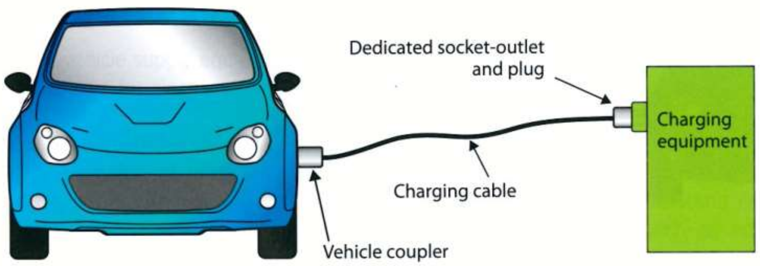
▼ **Figure 2.2 Mode 2 charging**



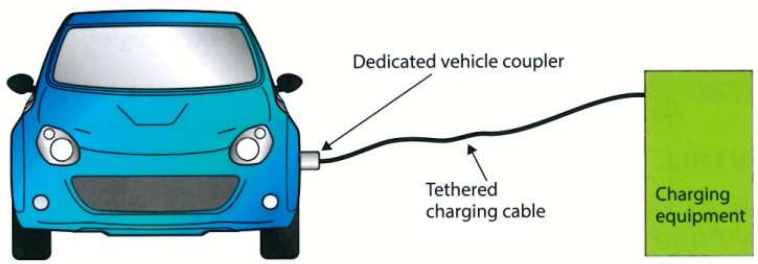
2.2.3 Mode 3 charging

In Mode 3 charging, connection of the EV to the AC supply network utilizes dedicated EVSE where the control pilot function extends to control equipment in the EVSE, permanently connected to the AC supply network. The EVSE may be supplied from a three-phase AC supply and will often incorporate BS EN 62196-2 Type 2 plugs where tethered cables are not used. Refer to Figures 2.3 and Figure 2.4 below.

▼ **Figure 2.3 Mode 3 charging (dedicated socket-outlet)**



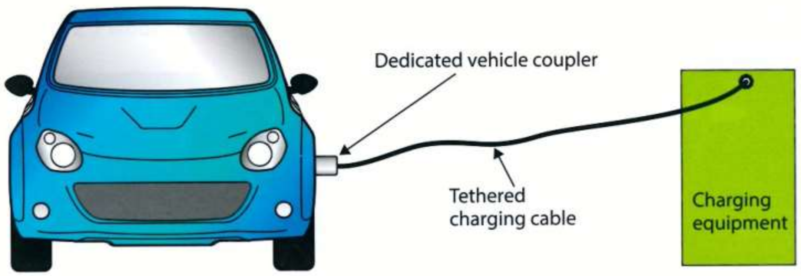
▼ **Figure 2.4 Mode 3 charging (tethered charging cable)**



2.2.4 Mode 4 charging

In Mode 4 charging, connection of the EV to the AC supply network utilizes an off-board charger where the control pilot function extends to equipment permanently connected to the AC supply. Refer to Figure 2.6 below.

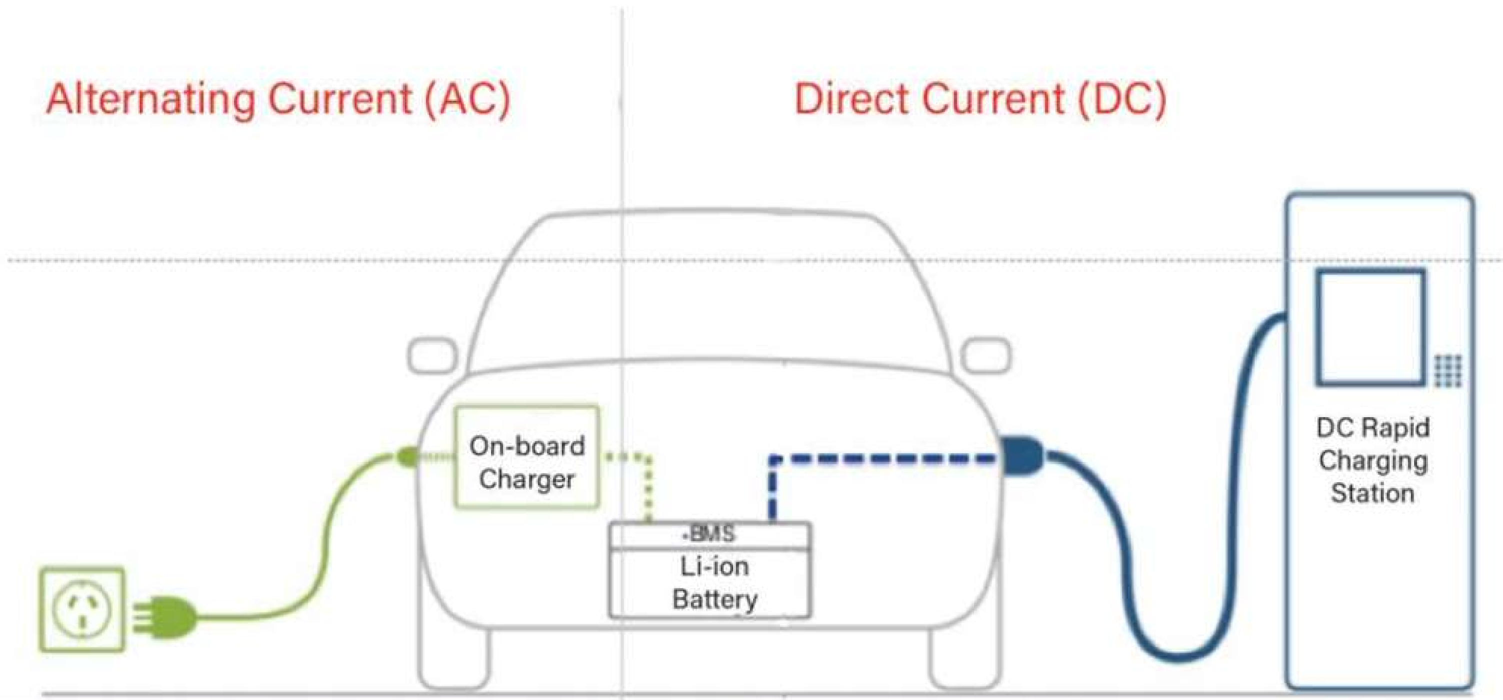
▼ **Figure 2.6 Mode 4 charging**



In Mode 4 charging, either single-phase or three-phase AC is converted to DC within the electric vehicle charging equipment. The resulting DC is supplied to the electric vehicle via a charging cable that is tethered to the electric vehicle charging equipment.

Due to its greater complexity, DC charging equipment tends to be in the form of larger units that are usually designed to be wall- or floor-mounted. Refer to Figure 2.7 below.

AC versus DC Charging



While every EV needs an onboard charger, size constraints reduce charge.

High voltage DC chargers can take a lot of power and feed it directly to the battery.

Electrical Vehicle Chargers

There are 3 main types of EV charging. Rapid, fast, slow, and represent the power output, measured in kW and charging speeds available to charge an Electric Vehicle (EV)

Mode 2: **Slow chargers** up to 3kW generally for residential overnight charging and a 6 to 12 hour time to fully charge pure-EV, or 2 to 4 hours for Petrol Hybrid EV (PHEV) using In cable control box (ICCB) connected by a 3 pin or Type 2 plug and socket

Mode 3: **Fast Chargers** include chargers with outputs from 7kW to 22kW and typically charge an EV in 3 to 4 hours. Common fast charger connectors are tethered Type 1 or Type 2 socket (via a connector cable supplied with the vehicle).

Mode 4: **Rapid Chargers** can be one of 2 types. AC or DC Current. AC chargers rated at 43kW utilizing tethered Type 2 connector. Most DC chargers are rated at 50kW. Both will charge the majority of EV's to 80% between 30 to 60 minutes, depending on battery capacity. Tesla super chargers are also rapid DC and charge output is about 120kW. The DC chargers utilize tethered CCS, CHAdeMO or Tesla Type 2.

Mode 4

- **Rapid chargers** are one of two types – AC or DC [Alternating or Direct Current]. Current Rapid AC chargers are rated at 43 kW, while most Rapid DC units are at least 50 kW. Both will charge the majority of EVs to 80% in around 30-60 minutes (depending a battery capacity). Tesla Superchargers are also Rapid DC and charge at around 120 kW. Rapid AC devices use a tethered Type 2 connector, and Rapid DC chargers are fitted with a CCS, CHAdeMO or Tesla Type 2.

All rapid Chargers utilize tethered cables

50kW DC charging utilizes 2 types of connectors
43kW DC charging utilizes 1 type of connector
120kW DC charging for Tesla super charge system

Mode 3

All Fast Chargers, are typically rated at either 7kW or 22kW single phase or three phase. The majority (at present) are 7kW and untethered, although some home and workplace installed units have tethered cables. All of which are AC into the vehicle.

Type 2 –
7-22 kW AC

Type 1 –
7 kW AC

Commando –
7-22 kW AC

7kW fast charging on a range of 3 connector types
22kW fast charging on 2 type of connector
11kW fast charger is available on the Tesla Destination network.

Mode 2

Slow Charging units predominantly rated at 3kW, with some bollard and lamppost chargers rated at 6kW. The most common method of residential overnight charging, taking between 6 to 12 hours. Not restricted to home use, as some workplace and public locations can be found.

Same connection types as fast chargers
+ Standard 3 pin 13A socket connection.
Predominentley untethered cable connections

In cable control box (ICCB) mode 2 chargers.

DC Connectors

- Japanese JEVS (CHAdeMO)
- European Combined Charging System (CCS or "Combo")
- Tesla's proprietary supercharger connector

AC Connectors

- UK 3-Pin (BS 1363)
- Industrial Commando (IEC 60309)
- American Type 1 (SAE J1772)
- European Type 2 (Mennekes, IEC 62196)

HM Government Department of Transport Industrial Strategy

April 2021 Electric Vehicle Charging in Residential and Non-Residential Buildings Proposal to Mandate the install on all New: May be moved… again…

Policy Proposition: Residential Buildings

The government proposes every new residential building, with an associated car parking space, to have a charge-point. - Includes major redevelopment

The government proposes every residential building undergoing major renovation, with **10 car parking spaces**, to have **cable routes** for electric vehicle charge-points **in every car parking space.**

Policy Proposition: New Non-Residential Buildings

The government proposes every new non-residential building, and every non residential building undergoing a major renovation, with **more than 10 car parking spaces** to have **1 charge-point and cable routes** for an electric vehicle charge-point for **1 in 5 spaces**.

Policy Proposition: Existing Non-Residential Building

The government proposes a requirement of at least **1 charge-point** in existing non-residential buildings **with more than 20 car parking spaces**, ***applicable from 2025***

HM Government Department of Transport Industrial Strategy

April 2021 Electric Vehicle Charging in Residential and Non-Residential Buildings Proposal to Mandate the install on all New: **May be moved… again…**

- Government proposes minimum 7kW charge point for residential and non-residential
- 7kW future proof standard for Home EV charging
- 7kW also better enables use of smart charging benefits
  - Managing supply to vehicle over time
  - Reduces impact on local network
  - Could reduce the spare capacity needed

HM Government Department of Transport Industrial Strategy

April 2021 Electric Vehicle Charging in Residential and Non-Residential Buildings Proposal to Mandate the install on all New: May be moved… again…

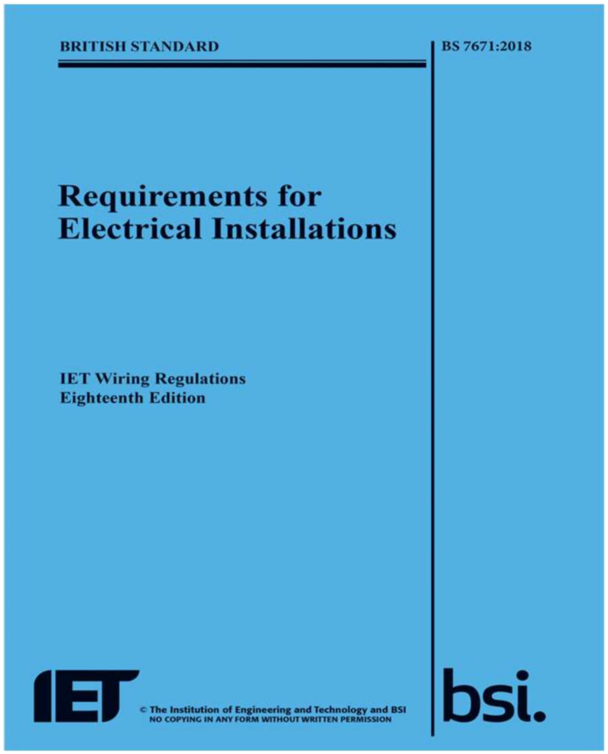
- 98% of journeys in UK are less that 50 Miles.
- Many drivers will access charge point at home and never go to public charge point
- Where suitable parking space exists - Vast Majority of electric vehicles will charge at home
- Cheaper, especially charging overnight and lower tariffs.
- Home charging will include multi story dwellings
  - Shared and assigned parking spaces
- Lampposts and Bollards also 7kW charge points
- Lock off and coded access points would also be a prerequisite..

HM Government Department of Transport Industrial Strategy

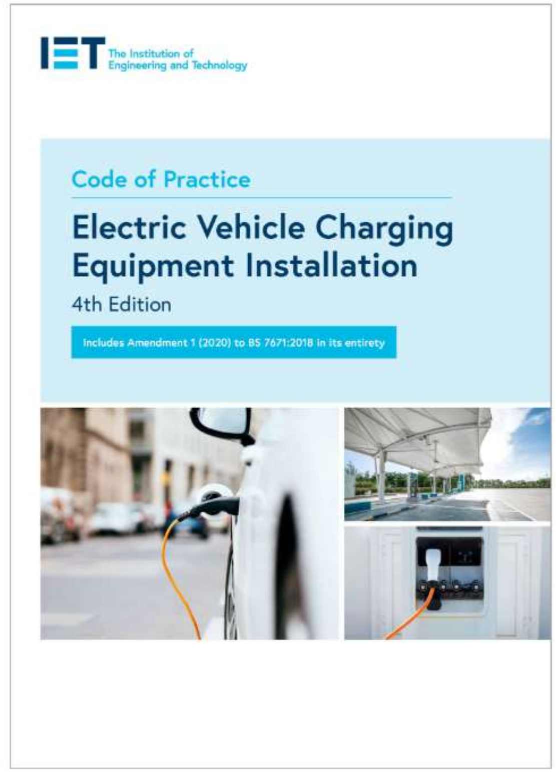
April 2021 Electric Vehicle Charging in Residential and Non-Residential Buildings Proposal to Mandate the install on all New: May be moved… again…

- **Situation different for car parks in multi-dwelling buildings**
- *Large number of charge points will require large supply connection?*
- *May introduce a supply that is not needed*
- *Level of upgrade dependant on capacity available, additional costs to install*
- New products will offer load management services and battery storage.
- **Modulate the charge amount or shift timing, "**diversity factor DNO can apply to a development". Reduces cost of install
- Non residential buildings Government to specify charge point must be 7kW

Installation must conform to BS7671 18th Edition Wiring regulations

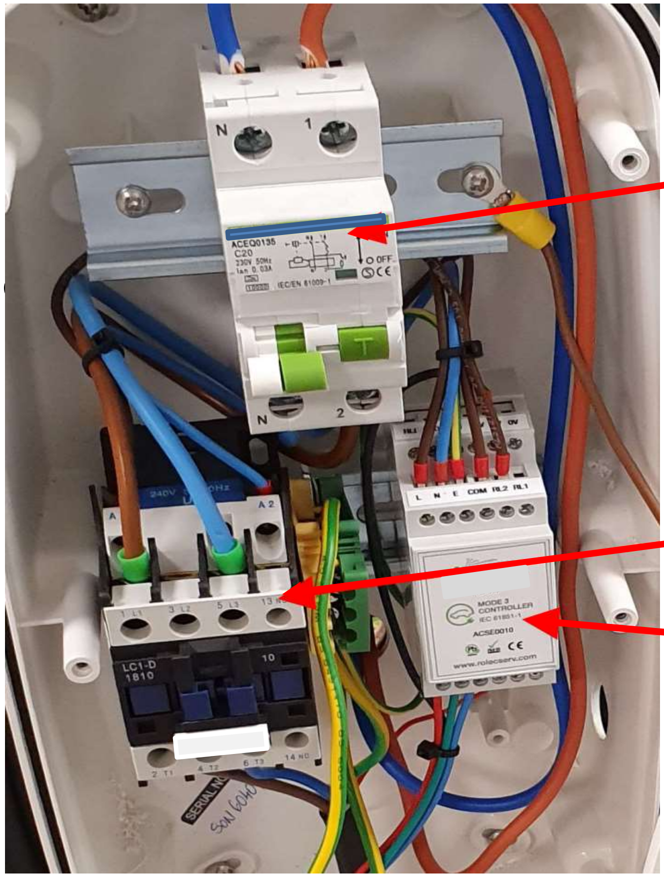


BS7671 IET 18th Edition Wiring Regulations



IET Code of practice (COP)
Provides detailed guidance to comply with BS7671

Generic internal arrangement for Mode 3 Charger



Protective Device – Circuit breaker & RCD (RCBO)

Contactor connects AC supply to the Vehicle

Controller communicates with the vehicle on board charging system before allowing the contactor to energize

EVSE- Electric vehicle Charging equipment

- Most electric vehicles can charge from a conventional three-pin socket using the mode 2 charging Equipment often supplied with the vehicle.
- Wide power range of EVSE, from 6A to over 100A
- EVSE increasingly forms part of onsite generation and energy storage solutions, enabling the vehicle to act as part of the energy storage device that can be charged as well as discharged via the charging infrastructure.
- BS EN 61851 series of standards specifies the design performance requirements for electric vehicle conductive charging equipment
- EVSE shall also comply with EMC Regulations 2016 and electrical equipment (safety) regulations 2016, and be CE marked accordingly
- EVSE installations must comply with BS7671 2018 IET wiring regulations

Basic requirements

- There should be selectivity between any RCD installed at the connecting point or incorporated in the charging equipment and the protection at the origin of the circuit. From code of practice EVCE Installations (IET Standards) 2018 6.12.2 (see regulations 314.1 (i) and 536.4.1.4 BS 7671

- From code of practice EVCE Installations (IET Standards) 2018 3 5.6.2 selectivity, under some circumstances, discriminations is not practicable, for example, where cables are concealed in a wall at a depth less than 50 mm

- Security features Code of practice 2.4.5: Installations in publicly accessible location, incorporate features to prevent access to the use of the equipment.
  Note: Drive ways on residential properties are not deemed publicly accessible locations, but may require security features, to limit the risk of illegal use of socket outlet.

- DC fault current above 6mA is part of the ICCB this allows the Type A RCD/RCBO to be used, if this is not present a type B RCD will have to be installed

Residential EV Installer considerations

Major consideration for EV car charging installations

Alternative sources of supply

PV, energy storage systems, back up generators, UPS.

When alternative supply is used the earthing arrangement may change.
Earth loop impedance changes
Can have impact on installation

There may also be installations where the car battery can be utilized as part of an off grid, or additional energy supply for the building. Charging during low cost periods and supplying the energy needs during higher costs period

Residential EV Installer considerations

Major consideration for EV car charging installations

Demand

In dwellings/Buildings, the total electrical demand, (maximum demand after diversity) including the electric vehicle charging equipment, must not exceed the rating of the DNO cut out fuse, from 63A, 80A 100A…

In some cases charging equipment may contain demand limiting capabilities that enable diversity to be applied to the charging unit.

Generally no diversity is allowed for car charging equipment.

Major consideration for all EV car charging installations

Installed, “within fabric of building – Garage”, Or “on external wall”

Determines the type of earthing system that can be utilized, without considering other solutions

Garage - within fabric of building, the existing earth arrangement may be used without any modification. TN-C-S (PME) OK for example. Tethered lead type only. Plug in – Mode 2 must be as External

External, the earthing arrangement would need to be changed if this is a TN-C-S This is also generally true for TN-S earthing systems unless the DNO can guarantee it will never be changed to a TN-C-S system in the future. Or consideration for installing device as indicated in regulation 722.411.4.1.

Earthing arrangement importance for EVSE

TN-C systems

The final circuit supplying a charging point shall not include a PEN (combined Protective Earth-Neutral conductor) see regulation 722.312.2.1

ESQCR 2002 prohibits the use of Protective Earth and Neutral (PEN) conductors in consumer's installations
At the point of entry to building the neutral termination is also connected to an earth terminal to supply a separated earth into the building. This arrangement now becomes a TN-C-S supply.

TN-C-S Systems

Regulation 722.411.4.1 imposes particular requirements for TN-C-S systems and a PME earthing facility.

What letter means:-

T = Terra	Earth
N = Neutral	Neutral
C = Combined	This combined Neutral and earth at service head
S = Separate	and then separated as N and E continue into the building

TN-S systems

i) DNO must guarantee TN-S is TN-S and will not be converted to TN-C-S in future.
ii) If not, must be treated as a TN-C-S system (PME) Protected multiple earth
iii) A guaranteed TN-S system, private 11KV transformer, charging equipment may be connected to the existing earthing arrangement, regardless of being installed within the building or not.
iv) The installer must ensure earthing and bonding arrangements meet current BS7671 requirements for TN-S systems.

TN-C-S Systems
Are the most common forms of “Earthing” systems for the UK. Particularly houses.

722.411.4.1. AMD 2 now provides options for added protection against losing Neutral in TN-C-S system

Why does it need to be a TT arrangement

Neutral return cable broken

TN-C-S (PME) open circuit PEN conductor

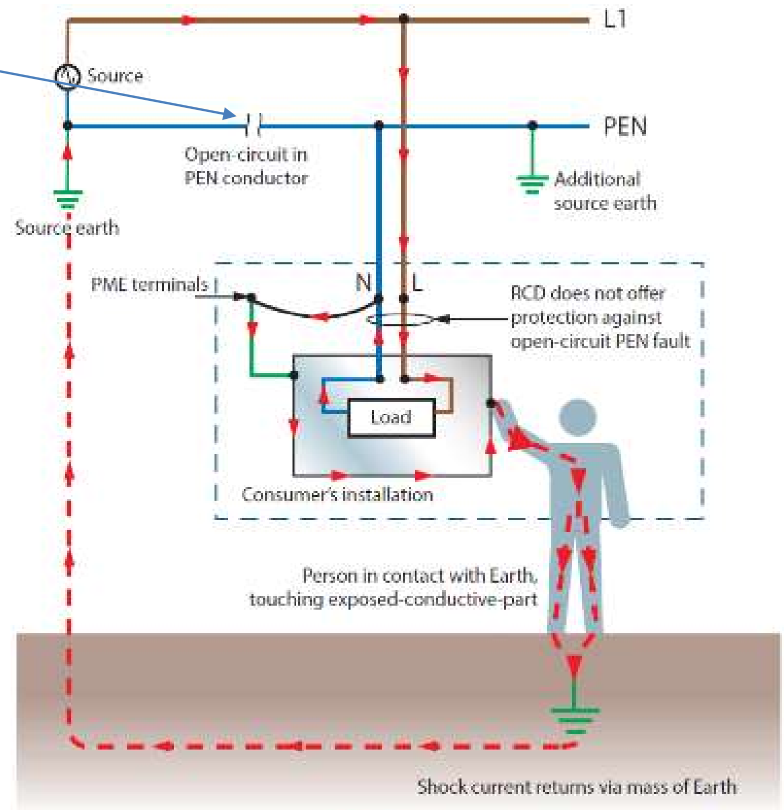


FIG 2 Open circuit PEN conductor

Within the building, equipotential boding provide smaller risk of potential difference in touch voltages.

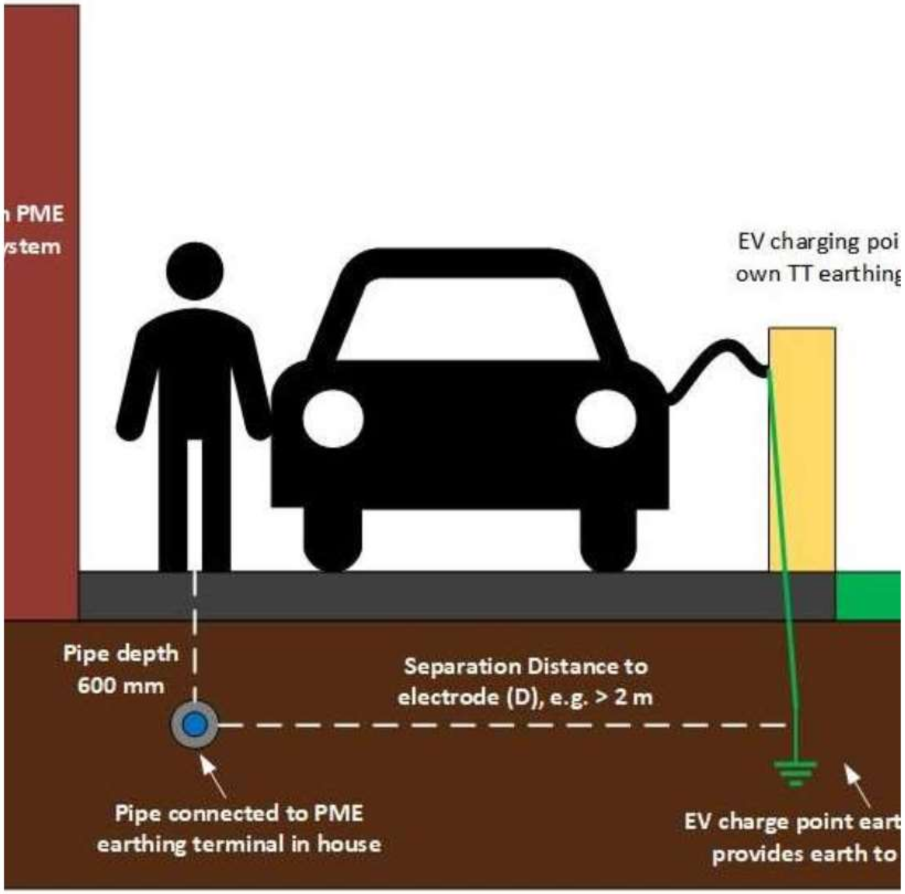
All earth bonding, and metal equipment could have up to 230V potential

External contact with metal and ground/earth would result in return path back to transformer via person.

Gas/Water pipes etc.. Bonded, offers alternative route to earth, reduces the potential difference to ground through person. Still dangerous.

Updated guidance on using TT earth arrangement from a TN supply

Semi detached building



Unsafe practices noticed

Also recognised that the Rod may still be connected to the building earth system by virtue of proximity to underground metal work of the building:

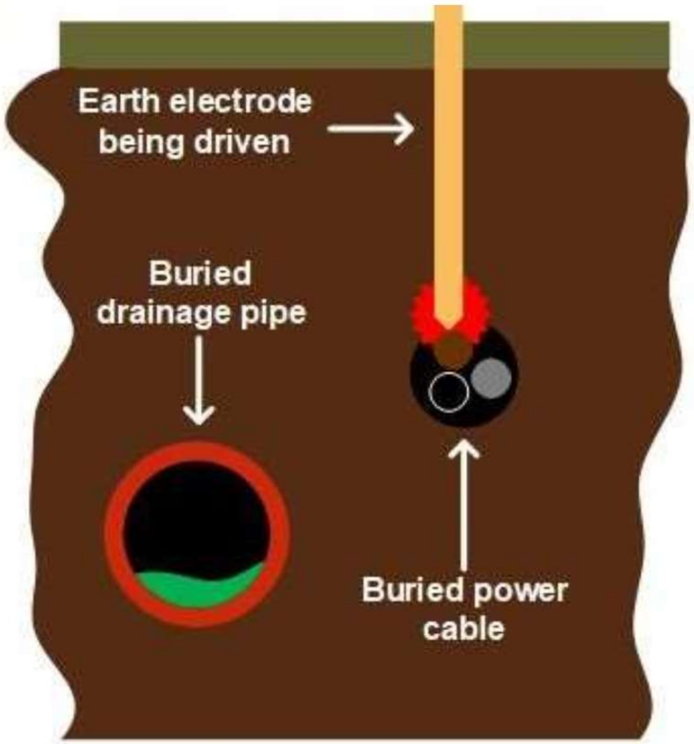
Gas and Water pipes bonded or the metal structure of the building

2 Meter distance if referenced.

Updated guidance on using TT earth arrangement from a TN supply

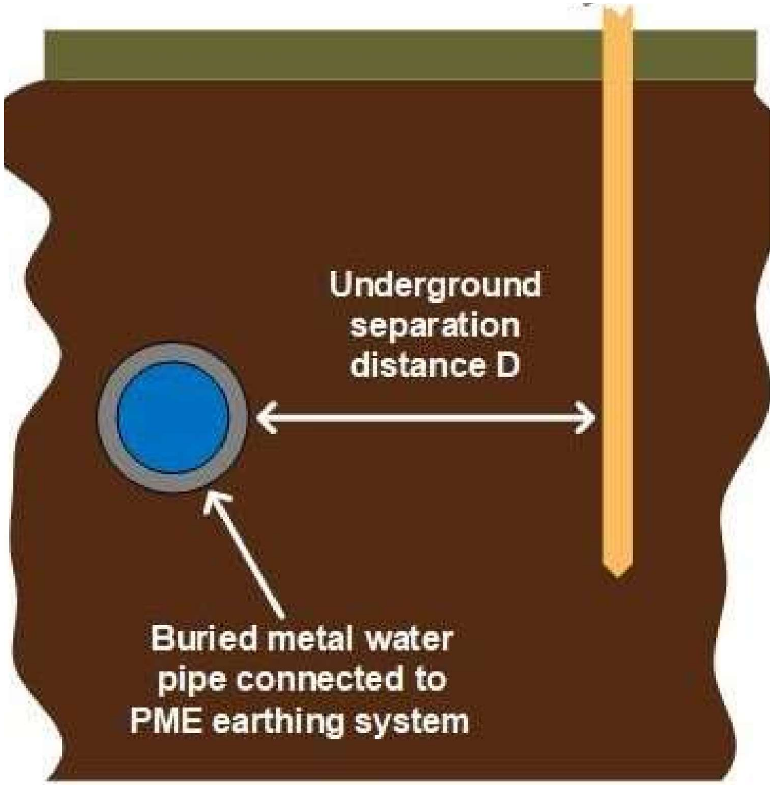
Determine when it is unsafe to use TT arrangement in TN supply earthing

Risks with driving in electrodes



Ensure adequate separation distances below ground between the TT earth electrode, and the buried conductive parts connected to the TN earthing arrangements.

And in some instance's distribution network operators require a greater separation distance. 2 meters



TT for Charger socket outlet for domestic
TN-C-S – PEN (PME) arrangement

A TT may be installed if distances secure

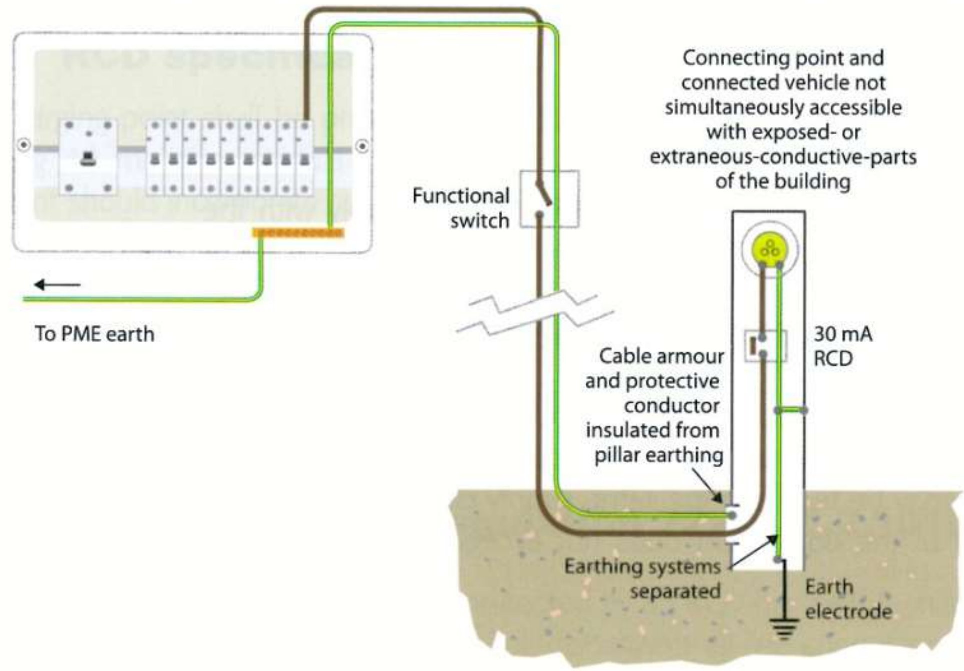
MCB within consumer unit typical 32A 6mm SWA supply to charger socket Mode 2 (6mm cable to allow for future upgrade to Mode 3)

PME earth from consumer unit must not connect to the TT earth arrangement used for the socket supplying the charger within the cable.

PME earth must not connect to any exposed or extraneous parts of the TT earth arrangement.

Earth electrode cable, table 54.1 BS7671
If cable buried 2.5mm protected by metal conduit. 16mm if not protected

Figure 6.2 – Typical domestic PME supply schematic with connecting point supplied by a simultaneously inaccessible 'TT' circuit



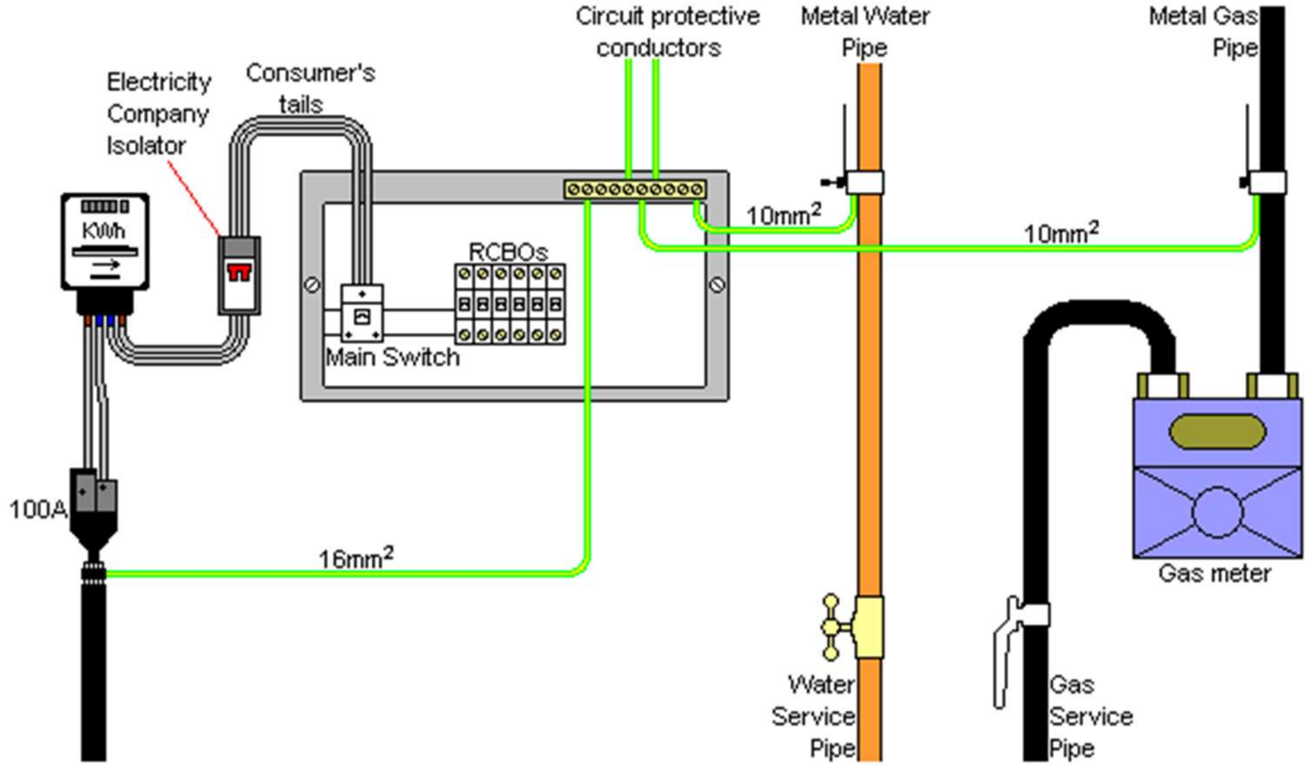
Note: Neutral omitted for clarity.

TN-S system

3 independent cables supply Live, Neutral and Earth

The earth connection is either the lead sheathing or steel wire armored the earthing conductor normally 16mm for residential properties is clamped to the supply cable sheath to create the earth return path connections from the property

If DNO cannot guarantee TN-S will not be changed to a TN-C-S in the future, this must be considered as same as TN-C-S.
DNO generally do not guarantee this.



TN-C-S system

Two cables supply Live, Neutral only at the incoming point of the building before the meter the supply is TN-C, it is illegal to use this arrangement within buildings in the UK

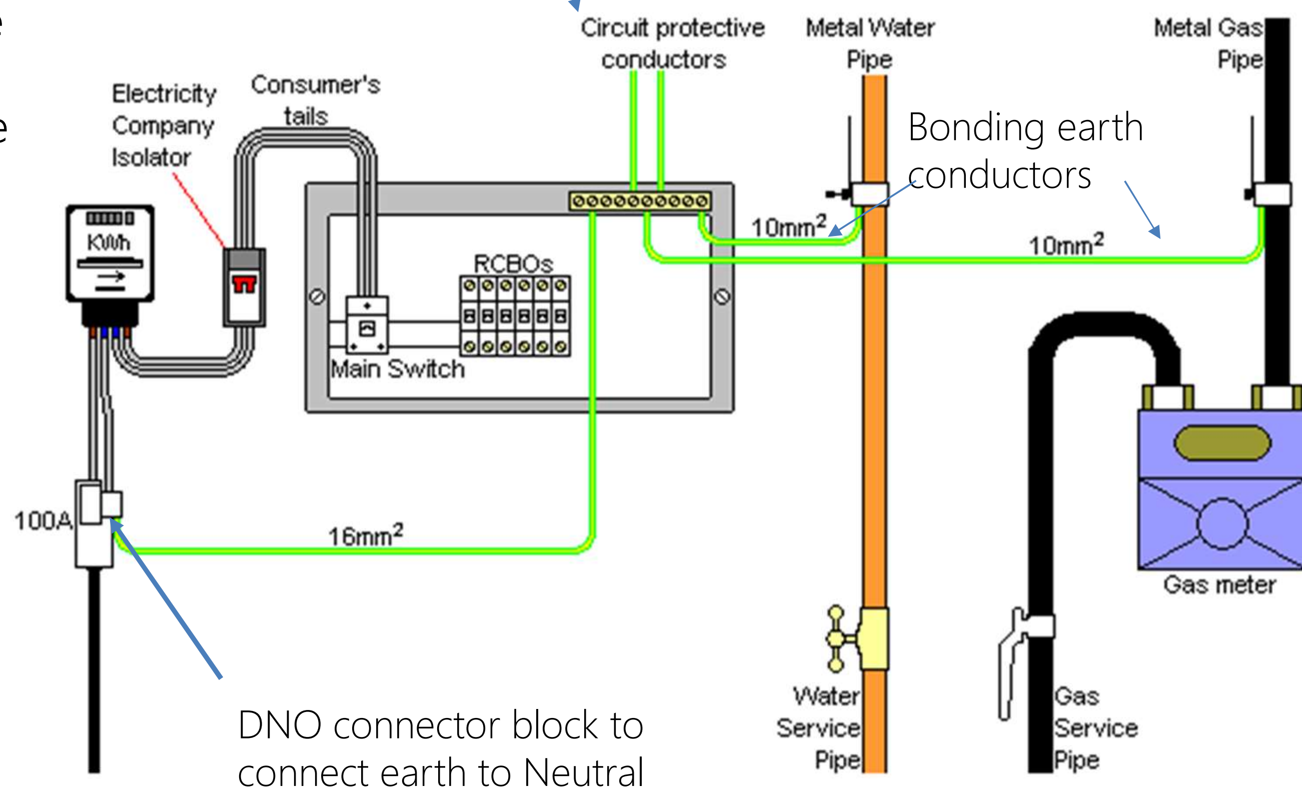
Neutral has the earthing conductor connected DNO connector block

Becomes a TN-C-S within building.

If the Neutral return cable is broken the earth return is also lost. This could lead to neutral return voltages now being present in all protective and bonding conductors in the building

CPC earth to all final circuits

Bonding earth conductors



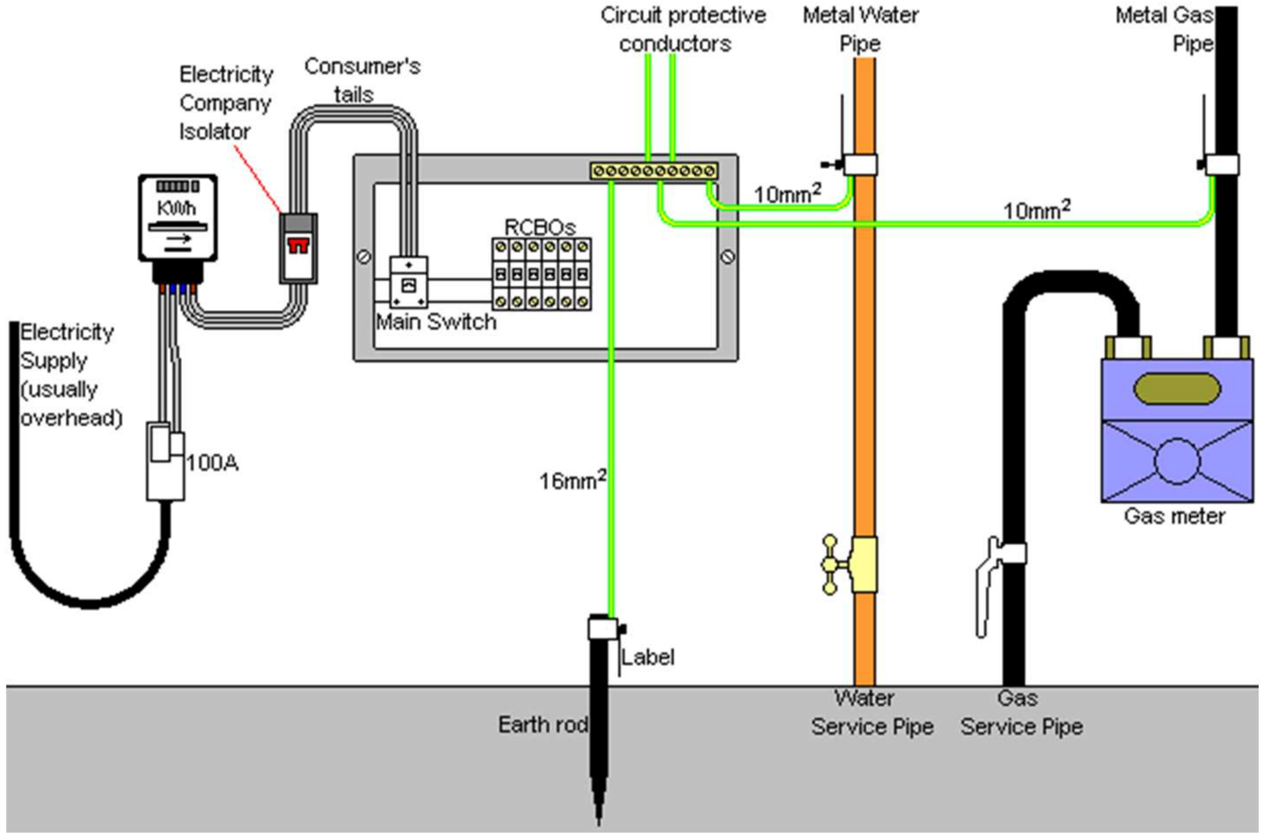
DNO connector block to connect earth to Neutral

TT system

Two cables supply Live & Neutral only at the incoming point of the building before the meter the supply. Generally this supply is via overhead cable.

The electrical installer must install an earth rod to create a protective earth arrangement for the installation.

This supply arrangement can be connected directly to the car charging supply arrangement with no additional changes.



722.411.4.1.

A PME may be used if one of the following options are followed for residential dwellings

Residential EV Installer considerations - Options

722.411.4.1.

Exception now is an earth rod for EV installs

The following ways are how monitoring and protecting can be achieved

1. 3 phase supply, if this is a balanced load at all times the need for an earth rod is not required

2. Install a large earthing plate / mesh / many rods??? To improve the primary earth of the property?

722.411.4.1.

3. (iii) discuses a 3 phase installation and states that the voltage to true Ground, the conductive mass of Earth does not rise above 70VRMS.

must not trip within 5 seconds, but need not operate before 4 seconds
and must not reclose if the fault is still present (above 70VRMS)
This can be within the EV equipment, or outside the EV equipment.

Regulations suggest this can be achieved using the monitoring device using a small earth electrode buried in the ground to for mass of Earth and measure for voltage rise.

Or

The 3 phase voltages within the charger can be measured in relation to each other using algorithms to determine voltage rise.

722.411.4.1.

4. Probably the easiest one to achieve

Indent (IV) single phase installations, the voltage is measure between Line Voltage and neutral if they exceed 10% either way so below 207V rms and above 253V rms If these limits are exceeded the device must trip and isolate the Line, Neutral and Earth conductors.

Finally

(V) Allows for alternative devices, not necessarily as previously given, that can monitor and protect and does not result in a lesser degree of safety than using (iii) or (iv).
This allows for new innovations to be used without the need to provide amendments to BS7671.

Electric Vehicle Charging

ELECTRIC VEHICLE CHARGING SOLUTIONS