Wiring Matters
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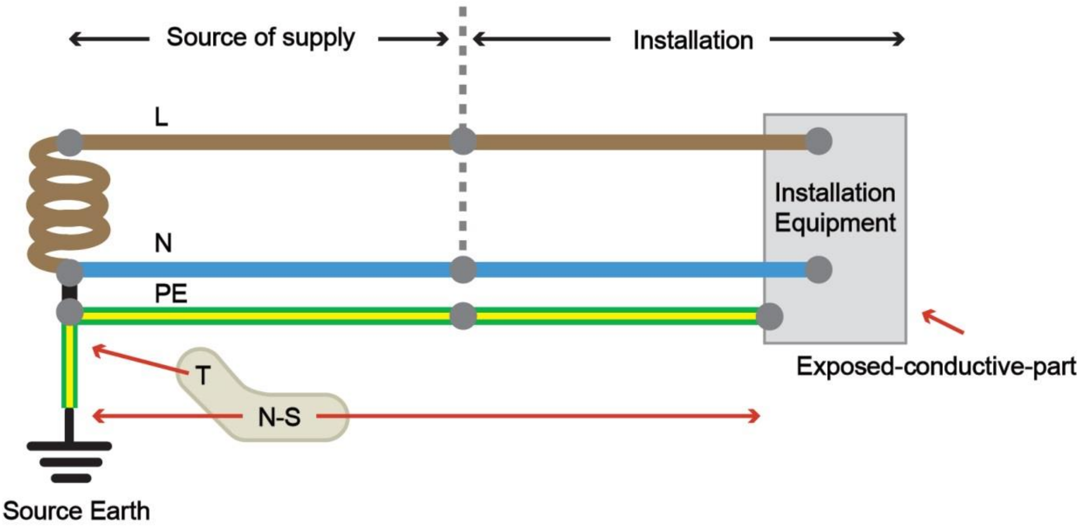
IT systems in railways

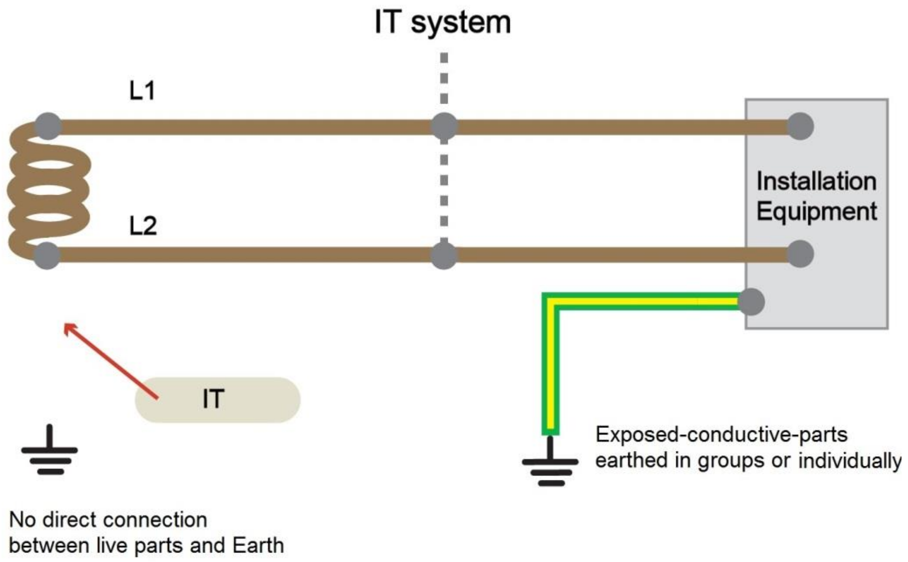
Tim Granger MEng CEng MIET, from Mott MacDonald, talks us through IT systems in railways.

BS 7671 covers the three primary types of earthing arrangement: TN, TT and IT. The majority of electricians and electrical engineers will be very familiar with the TN type, including TN-C, TN-S, and TN-C-S variations, as these are by far the most common type of supply provided by Distribution Network Operators (DNOs). The TN arrangement is deemed suitable for most installations as the provision of a protective earthing conductor ensures that under earth fault conditions there is a large amount of fault current and thus the protective devices are able to disconnect faults within the times required by BS7671.

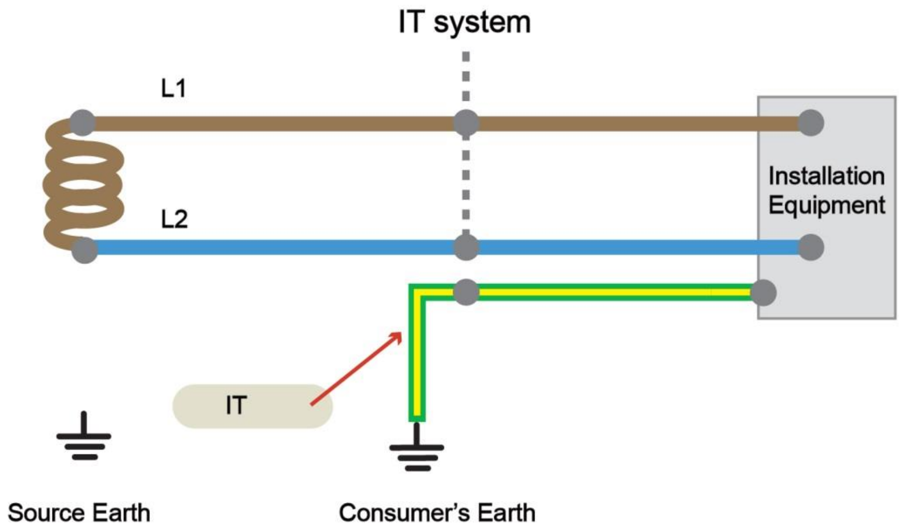
TN-S system



Although less common, most people in the industry will also have some experience of the TT arrangement. These are more usually found in rural or remote areas where the use of overhead cables for transmission purposes leaves the PEN conductor more susceptible to damage. Instead, an earth electrode is provided at the supply transformer and the onus is on the consumer to maintain an earth electrode on their property. The downside of a TT installation is the high external loop impedance (Ze) value, which results in a relatively low fault current and therefore requires an RCD at the source in order to effectively disconnect earth faults.



The third type of earthing arrangement, and the particular focus of this article, is the 'IT' type, in which the source transformer is isolated from earth, whilst all exposed conductive parts of the installation are connected to earth electrodes. So what are the benefits and where are IT systems used? To answer these questions it's best to first look at how the system operates, especially in a fault situation.



It is worth noting the colour scheme shown in the diagram above, in particular the fact that both cores are live so there is no neutral. The two live cores are usually referred to as L1 and L2 even though the system is effectively a single-phase system; due to this, and to ease identification, Network Rail use brown and black for L1 and L2 respectively.

Normal Operation

We saw earlier that the source transformer is isolated from earth. This is true in the sense that there is no direct connection to earth (technically, BS 7671 allows for a direct connection if through a high impedance); however, this is only part of the story as the system is naturally earthed by the stray capacitances of the cables. This capacitance means that in normal operation there is a small amount of leakage current. This current can generally be considered insignificant and has no adverse effect on operation or safety.

First earth fault situation

Should there be a breakdown in the insulation, or a direct short to earth at some point in the circuit, the real benefit of the IT is seen. With no connection to earth at the source, there is no return path for the earth fault current, and current is therefore limited by the capacitances previously mentioned. So in a fault situation the touch voltages are limited to only a few volts and the equipment remains operational. This is the main benefit of using an IT system and, consequently, BS 7671 gives no requirement to disconnect the supply under first earth fault conditions as long as one of the following is permanently installed and gives an audible and/or visual signal:

- insulation monitoring device;
- residual current monitoring device; or
- insulation fault location system

Alternatively, the first fault can be disconnected using an appropriate detection device with trip unit, however, this loses the fault resilience benefit of the IT system.

Second earth fault situation

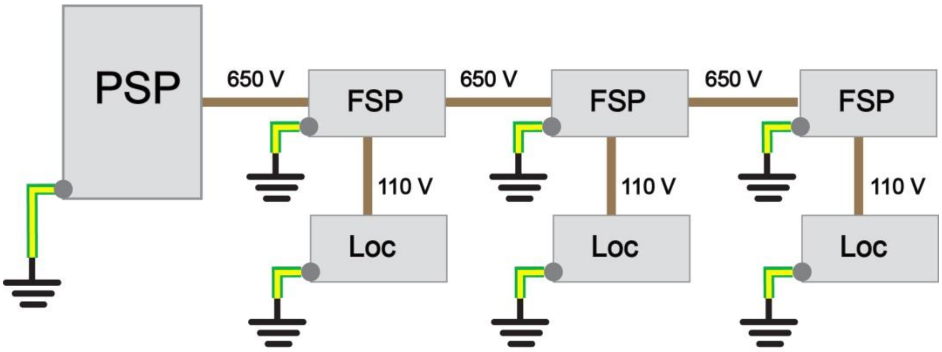
Whilst the system can happily operate with a single earth fault, should a second fault occur on the opposite phase to the first fault there is potential for significant current to flow and, consequently, BS 7671 has requirements for protection against electric shock similar to TN systems; these conditions are covered in Regulation 411.6.4 of BS 7671.

Railway signalling power supplies

One area of industry where the IT earthing is significantly used is the rail industry, particularly as a way of providing power to the signals and other equipment located trackside along the route. The primary reason for this is due to its resilience against earth faults, making it ideal for a system that is critical from both a safety and an operational perspective. In the last forty or so years there have been three main arrangements used:

- Class I individually earthed;
- Class I collectively earthed; and
- Class II individually earthed.
  (Classes I and II in accordance with IEC 61140.)

We'll have a brief look at each of these in turn, but first we'll start with an overview of what a typical signalling power supply system looks like; this is based on the Network Rail catalogue of standards, which cover the design and maintenance of all the equipment they own, that is, the majority of the rail infrastructure in England.



Principal Supply Point (PSP)

This is where the incoming 400 V supply is converted to the distribution voltage of, typically, 650 V. Most PSPs use a 400 V DNO supply as one of the main power sources, with additional sources either being taken from the traction power system (25 kV overhead line in the north or 750 V DC third rail in the south) or a standby diesel generator. It is also typical for a PSP on an important route, to have an uninterruptible power supply (UPS) so that the supply is maintained during the changeover between primary and secondary power sources. The PSP is also where we find the permanent insulation monitoring device as well as various other remote condition monitoring systems.

An example of a PSP, copyright Mott MacDonald Ltd.

Functional supply point (FSP)

These are some of the grey cases that you'll see if you look out of the window when you're on a train. The primary equipment that the FSP houses is one or more 650 V to 110 V transformer(s), but the FSP also houses lockable switchgear to allow for safe working practices within the case and at other FSPs/Locs further downstream on the 650 V feeder. In some instances, the term FSP is used to describe the above equipment found within a Loc (or other trackside equipment housing); it does not necessarily need to be a separate case.

Location Case (Loc)

Locs make up the bulk of the grey cases located trackside. They house the real working of the railway signalling installation, including systems that detect where the trains are, control the trackside signals, switch the points on the track to direct the train, and a whole host of monitoring and failsafe systems to provide a robust and, above all, safe arrangement. The equipment typically uses both a.c. and d.c. voltages less than 110 V, so the Loc cases also house a number of transformers and rectifiers to obtain the correct voltage from the incoming 110 V a.c. supply from the FSP.

Example of Locs, copyright Mott MacDonald Ltd

So with most signalling power supplies using the above arrangement, we can now go back to look at the three power supply arrangements found on the rail network.

Class I individually earthed arrangement

This is the oldest of the common arrangements and was in use until the mid-2000s. Trackside cables were of the two-core unarmoured variety, and each FSP was individually earthed using an earth rod/electrode. The issue with this system is that in the event of a second earth fault very little current flows as the earth path between faults is through the general mass of earth – with 650 V feeder lengths extending to a few miles, the earth fault loop impedance can easily reach to tens of thousands of ohms. It is clear that this is not compliant with the latest edition of the regulations and is therefore no longer being installed.

Class I collectively earthed arrangement

The difference with this system is that rather than having 2-core 650 V supply cables, a 3-core armoured cable is used. The third core and armour are used together in parallel as a CPC to equipotentially bond all PSPs and FSPs. This bond ensures that in a second fault situation there is a low impedance path as it is effectively a short circuit fault using the CPC to connect between the two phases. This collectively earthed arrangement meant that the system could disconnect second earth faults in a way that is compliant with BS 7671. The downside of this arrangement isn't so much a technical one (although terminating a 3-core armoured cable into an FSP designed for a 2-core rubber cable isn't without issue) but a financial and environmental one as you are paying to have 50% more copper than the older arrangement.

Class II individually earthed arrangement

The financial implications described above have been the primary driving force behind the latest iteration of signalling power supplies. This arrangement, which has been in use since 2013, goes back to using a 2-core unarmoured cable but, to get around second earth fault issues, Class II double insulated equipment is used within the FSPs. This satisfies the requirements of BS 7671 Regulation 410.3.3 by utilising *double or reinforced insulation* instead of the traditional *automatic disconnection of supply*. As a result, this arrangement has the benefit of lower capital cost whilst also satisfying the safety requirements.
So as you can see, there's a whole technical world behind the structures you see as you whizz past them on the train, and this is one of the few areas of industry where you'll find IT power distribution so widely used, all helping to keep the signals and trains running.