

Earthing and Equipotential Bonding

**Backgrounds and technical information in regards
to cabling systems**

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Introduction

Earthing and bonding

Abstract

When Nikola Tesla developed the first electrical machine in 1880, little did he know how strategically important electricity was going to be for the future and its revolutionary effect on society!

At the time, the “technology battle” was ranging between AC and DC power generation, each one vying to be selected as the standard way of generating and transmitting electrical power. For many reasons AC was selected worldwide as the standard. DC is now mostly used for metros, trams and in some countries for railways. In fact all these transport systems have a certain distance limitation, which enable DC power to be an efficient technology.

AC is mostly produced in power stations and is delivered by high voltage transmission cables, ranging from 110 KV to 380 KV.

At several distribution points, this high voltage is transformed to a lower voltage, typically 230V – 240 V or 110 V in North America.

Residential consumers are normally provided by a 3-wire cable consisting of single phase conductor, a neutral conductor and an earth conductor.

The electricity supplier connects their consumers directly from the nearest power station with a 4 wire power cable. This cable provides 3 phase conductors and a neutral conductor. Larger industrial consumers have their own transformers on site, which are supplied directly by the 3 Phases from their suppliers.

These 4 wires are distributed in the whole building. Typically, these conductors are called L1, L2 and L3 (or phase A,B,C). In North America the phase conductors are called hot conductors. The N (neutral) conductor is generally called the PEN (Protective Earthed Neutral) conductor. The reason is that it provides the combined functions of the N and PE conductors. Typically, there is a link between the PE and N at the sub distribution boards.

The PE conductor is mandatory for safety reasons and is therefore a separate conductor as in a power socket. Both the PE and N conductors will be connected together at the earthed star point. In the early days of electrical industrialization, it was common to reduce costs and copper conductors by using a PEN conductor to the sub distribution points as electrical devices were mostly lights and electrical machines. Even in the 1950s and 1960s when more electrical applications were used, there were no serious problems detected in the electrical systems.

All these devices have one thing in common- they are all resistive devices. That means there is no phase shift between voltage and current and more importantly no current on the PE

and any metallic parts connected to it. In this situation the earthing and bonding systems have just one major task:

Save human and animals life in case of an electrical fault.

Today the situation has been changed significantly and the PEN installation is a serious problem.

With the development of semiconductors electronic devices are found everywhere in the world. For the last 20 years many complex electronic devices have been developed including Microwaves, Computers, Monitors, security and alarm systems etc. Most devices need just a small amount of power, hence the use of step-down transformers to ELV voltages. Today, this is provided by power-delivering devices such as PoE enabled switches providing power to end-devices. They all work using the same principle of phase control. This generates a lot of harmonics, mostly n times of the fundamental supply frequency (50, 100, 150 Hz). At the same time more IT devices are installed and networked together. This will grow at an exponential rate with the proliferation of IP devices in many other technologies, not normally part of the IT discipline.

This cocktail of power delivering switches creating harmonics, and IT devices connected to the earthing systems may create dangerous and critical performance situations for many business and consumer users. The main reason for this situation is the power source for all these devices is still the same - the PEN reticulation method of delivering the power system. These systems haven't been changed for the last 100 years and all together generate issues like:

- Corrosion on metallic pipes
- Strange behaviour of electrical systems
- Components destroyed after lightning strike
- IT devices cannot connected
- Destroyed power supplies
- Destruction of electronic components after switch on a high-current device

The reasons are always the same. These include:

The common use of 4-wire systems (PEN);
The proliferation of power-delivering switches;
A bad earthing and bonding network installation or design

For IT networks it is important to understand that all these effects happen with all kinds of cabling technologies which include optical fibre, shielded and unshielded copper cabling.

EN 50174-2 in the current edition states clearly:

Earthing and bonding is applicable for both unshielded and shielded systems

Any other statement in conflict with this statement is misleading and wrong. This is especially true in the case of some suppliers on the market who claim that earthing and bonding have no effect on UTP installations. On the contrary, bad earthing and bonding will affect UTP installations as well as shielded. Just look at the typical electrical wiring installation which generally uses unshielded power cables. Bad earthing and bonding creates big problems on the electrical network!

What should be done to improve the situation?

For new buildings, the requirement in Europe is to use the 5 wire power cabling system. This is stated in EN 50310 and is becoming recognised by local experts and standards. It may sound unusual, but a 5 wire design is just a basic rule for electronic and electrical installations. If the current is provided by the L conductor in a 4-wire system, the return path is via the N conductor back to the source. The N and the whole earthing system and connected devices will be used as a return conductor. This is not the desired path!

Consultants have to be aware that all systems (electrical and electronic) have to be seen as a whole and that they work together when installed.

First of all a meshed earthing and bonding design is mandatory. That means that all metallic parts of a building will be connected at many points. The earthing system shall be part of the earliest building design phase and needs to be implemented in the base building. The steel armour of each floor shall be connected at several positions to the upper and lower levels. On each floor there shall be a termination point for the bonding terminal.

Note: Different systems shall be connected to the local bonding terminal.

PE of the power system

BC (bonding conductor) of the metallic parts like racks, pathways, raised floors etc.

Do not separate them!

In some literature the different systems are handled as separate parts and in the worst case have their own independent earthing points. This is wrong and can cause circulating current if those systems get connected together. The current is the result of the potential difference between the two earthing systems. This is the reason for using a meshed system of earthing!

Power distribution

For residential buildings and small buildings serviced directly by the power authority, 4-conductor power cables will enter the buildings.

In the main switchboard, there is a connection from the PEN conductor to the equipotential terminal bar. All metallic parts and systems which have to be part of the equipotential bonding system will be connected to this terminal bar.

Note: The link between the PE conductor and the PEN conductor shall be close to the source (transformer or point of supply) and **the only one** in the whole installation. Beyond this point all cables shall have either 3 or 5 conductors. EN 50310 prohibits the use of a PEN connection.

This guarantees that the PE conductor carries no current (unless there is an electrical fault) and the return current is only flowing through the N conductor. Therefore the total current at the main equipotential bonding bar is zero.

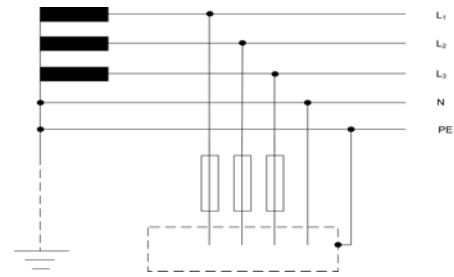


Fig 1:TN-S

In practice this can be checked by measuring at certain points with RMS test equipment. It is important to use RMS devices, otherwise harmonics won't be taken into account.

Some devices offer long term records. This is a useful feature to recognise short events e.g. switching of a large electrical device which generates high energy transients.

Improving the Earthing installation in Existing buildings

In existing installations a power audit is necessary to check out the current flow situation. This means that the first thing to do is to measure the current flowing through the PE conductor as mentioned before at several distribution points.

If a current is detected, the next step is to locate the link between the PE and N. Any PEN links have to be removed and a separate PE conductor installed.

This has to be done in all the buildings. After all PEN links have been removed the PE conductor shall be checked and may additionally be connected to some metallic parts.

A long term record needs to be kept to detect if and when situations occur which may create system shutdown. This occurs if say, large electrical machines are switched on or any other device which generates a large transient.

A transient or burst is a high energy impulse occurring in a very short period of time which is many times more than the normal current. If this impulse disturbs the normal operation, locate the PEN links and ensure there is adequate separation of those conductors from other metallic paths such as the metallic pathway system.

IT Connections

If electronic devices need to be connected together, the best option is fibre. Fibre systems do provide a galvanic separation and there is no potential difference.

In practice nearly all campus and backbone installations will be done in fibre. This avoids many problems. If a copper conductor (interface) is mandatory, the use of media converters may have to be considered. This is simple and has the same effect as if the whole link were fibre.

In the case of copper systems, there will be **no** detrimental effect if the whole power system consisted of the 5 conductor power cable system and the earthing and bonding is a meshed design.

In the case of 4 wire power cabling systems, it is recommended to change to a 5 wire system if possible. This means that an additional conductor to the existing power cable needs to be added. This is much easier than it sounds and solves easily many undesired situations.

Bonding

All metallic parts have to be bonded. In a rack, the rack manufacturer should supply all necessary instructions and screws. In the case of metallic panels, all of these have to be bonded to the rack. Metallic path ways and cable duct systems have to be bonded as well.

This will ensure that there is very low impedance to earth. Any EMI currents will flow through the low impedance earthed path rather than the IT network.

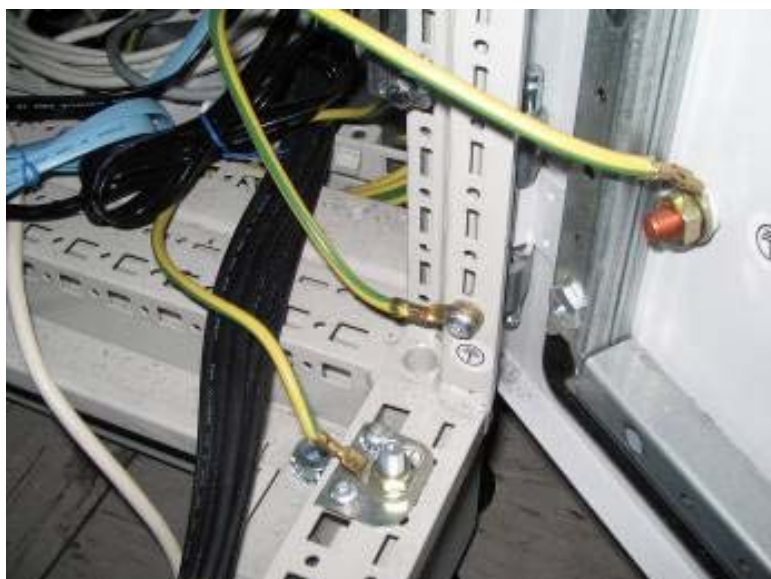


Fig 2: Bonded parts in a cabinet



Fig 3: Terminal bar in a cabinet

Cabling systems

If the desired cabling systems use metal patch panels, these have to be bonded to the rack. This is valid for any cabling system, whether it is optical fibre, shielded or unshielded copper cabling.

This can be done with a earthing clamp or by a low impedance connection of the patch panel to the rack or cabinet.

Note: It is important to ensure that a low impedance connection is provided. No paint or any insulation material shall be present between the rack/cabinet and the “ears” of the panels.

A more professional method is to use earthing clamps. This provides an excellent connection to the earthing system at all times.



Fig 4: Earthing clamp

Installation and termination of connecting hardware

In the past, ease of installation was often an argument in favour of UTP systems. However, this is now the reverse. To provide the desired performance, some UTP suppliers are using solid conductors for the horizontal cable and patch cords (should be stranded conductors) and furthermore require complicated installation procedures. The following table indicates the most optimistic expected electrical characteristics of copper cabling. The EMC and ANEXT margin are based on the expected specifications for 10 gigabit Ethernet channels, currently under development.

Cable type	Bandwidth	Diameter	EMC factor	ANEXT margin
Cat.6 UTP	250 MHz	6,5mm	40 dB	No margin
Cat.6 _A UTP	500 MHz	8,4 mm	40 dB	No margin
Cat 6 FTP	250 MHz	6.5 mm	60 dB	15 dB
Cat.7 PiMF	600 MHz	7,8 mm	80 dB	25 dB
Cat. 6 _A FTP	500 MHz	6,5 mm	60 dB	15 dB
Cat. 7 _A PiMF	1000 MHz	7,8 mm	80 dB	25 dB

Note: Most Shielded cables exceed values of IS 11801

In the case of shielded systems, the installation requirements are much more relaxed. Separation of the data cables (for ANEXT mitigation) is not necessary and separation from power cables is mostly handled by pathway systems. In the last couple of years, the product termination has been improved significantly. In the beginning, shielded system installation was a job for specialists, today it is for a much wider range of installers. In regards to shielded systems, installers were not confident in terminating the shield correctly.

In 2006 all these concerns and doubts have been dispelled. An example of overcoming these concerns is the introduction of the AMP Twist 6-S jack with the revolutionary AMP Twist tool.

The tool has the following main functions:

- sheath removal using the tripper function
- foil stripping
- Guarantee reliable terminations at all times

All these functions are done automatically and reliably. The other component is the jack itself. With the patent AWC technology and the fact that the jack consists of two parts, it takes only about 1 Minute to complete the termination.

This is the same as for UTP jacks. A great feature in the field is the AWC technology. During the termination, the jack is squeezed and the wires will be cut automatically.

All EMC relevant issues like multiple 360 degree shielded terminations and a fully closed housing are automatically performed by the jack design and construction.

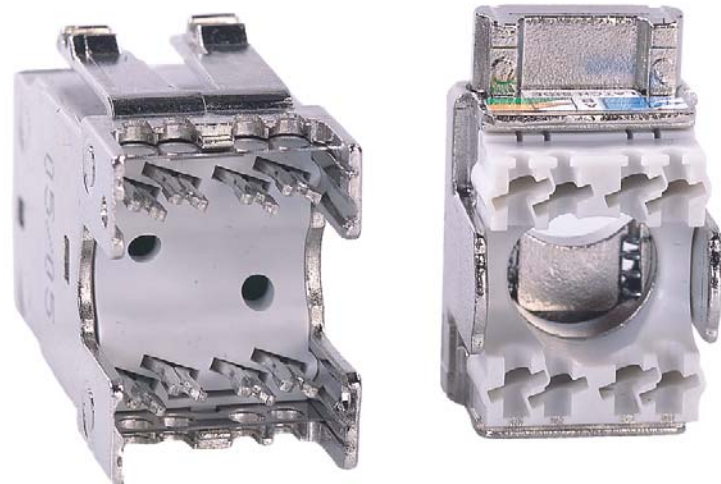
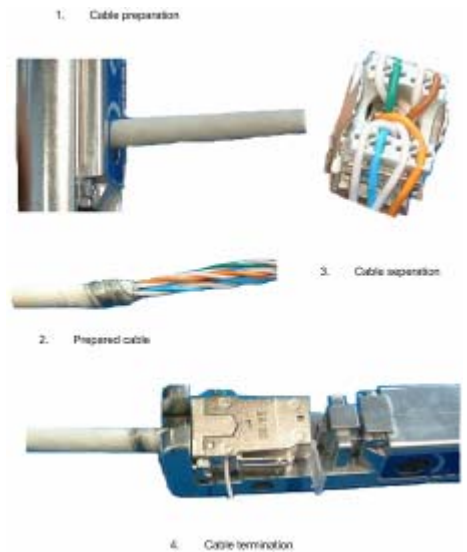


Fig.5 : Shielded jack

To provide a fully shielded channel, the patch cords have to support this. The patch-cord plug shall have a 360 degree shield design and a large contact surface for the internal Earthing clamps of the jack.



Metallic pathways

If a metallic pathway system is used, it has to be electrically bonded to all other metallic parts of the building. Multiple connections support the meshed earthing concept. The pathway system on a floor shall be connected to the nearest local Bonding busbar. From an EMC perspective the whole cabling channel shall be closed at all times. If this is not possible (e.g. wall) the installer has to “close” the channel with methods shown in figure 7B or C.

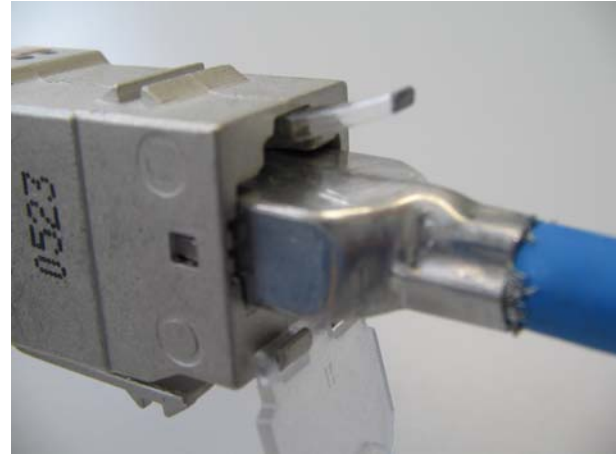


Fig. 6: EMT Plug

The pathway type used in the installation should be a cable tray as shown in Figure 8.

These metallic pathways are better suited to prevent EMI problems, especially for UTP cabling installations.

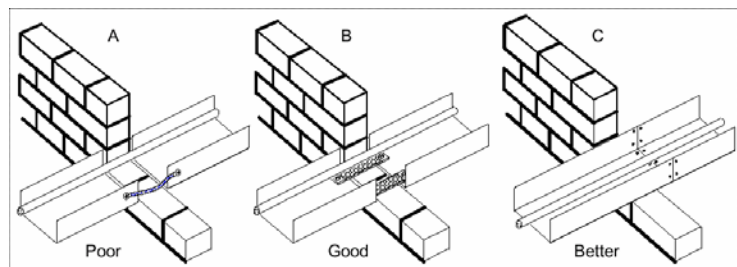


Fig 7: EMC consideration EN 50174-2

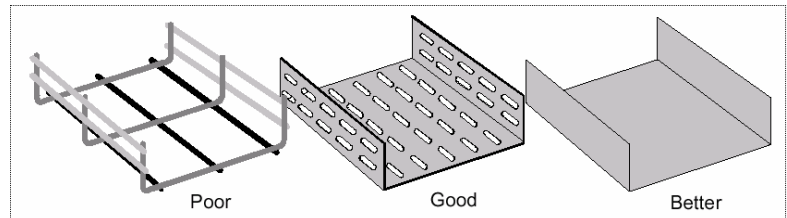


Fig. 8: Metallic cable trays EN 50174-2

Earthing of Cabinets/racks in a TR or ER

Each equipment cabinet/rack requires its own earthing connection to the TR earthing infrastructure. A minimum of a # 10 AWG (6mm²) green-yellow insulated copper conductor shall be used for this purpose. Each cabinet or rack shall have a suitable connection point to which the rack framework earthing conductor can be bonded.

Rack earth bus: A dedicated copper earth bar shall be attached to the rack. A bond between the earth bar or strip and the rack should exist. The mounting screws should be of the thread-forming type, not self-tapping or sheet metal screws.

Every structural member of the cabinet or rack shall be earthed. This is achieved by assembling the cabinet or rack in such a way that there is electrical continuity throughout its structural members, as described below:

1. For welded racks: the welded construction serves as the method of bonding the structural members of the rack together.
2. Bolt together racks: special consideration shall be taken while assembling bolted racks. Earth continuity cannot be assumed through the use of normal frame bolts used to build or stabilize equipment cabinets. Bolts, nuts and screws used for rack assembly are not specifically designed for earthing purposes. Additionally, most cabinets are painted. Since paint is not a conductor of electrical current, paint can become an insulator and negate any attempt to accomplish desired earthing. Most power is routed over the top or bottom of the rack. Without a reliable bond of all four sides of the rack, a safety hazard in case of contact with live feeds exists. Removing paint at the point of contact with assembly hardware is an acceptable method of bonding. This method is labour intensive but effective. An alternate method is the use of internal-external tooth lock washers. With the bolts torqued, an acceptable bond can be made. Two washers are necessary to accomplish this: one under the bolt head contacting and cutting paint and one under the nut.

It is recommended that rack-mounted equipment be bonded and earthed via the chassis, in accordance with the manufacturer's instructions. Provided the rack is bonded and earthed as detailed in the previous section, the equipment chassis should be bonded to the rack using one of the following methods:

1. To meet the chassis earthing requirements, the rack/cabinet manufacturer provides a separate earthing hole or stud. This should be used with a conductor of proper size to handle any fault currents up to the limit of the circuit protection device feeding power to the equipment unit. One end of this chassis earthing conductor will be bonded to the chassis hole or stud, and the other end will be properly bonded to the copper earth bar or strip.
2. If the equipment manufacturer suggests earthing via the chassis mounting flanges and the mounting flanges are not painted, the use of thread-forming tri-lobular screws and normal washers will provide an acceptable bond to the rack. If the equipment mounting flanges are painted, the paint can be removed, or the use of the same thread-forming screws and aggressive internal-external tooth lock washers, designed for this application, will supply an acceptable bond to safety earth through the rack.

Conclusion

Good Earthing and bonding of electrical and communication installations have always been a primary requirement for safety. As modern technology uses more complex communication techniques and higher operating frequencies, the EMC aspect of communication installation and equipment becomes more critical to the proper function of the communication system. The design and implementation of the earthing circuits and the bonding of all metallic components in a building need to be addressed as part of the overall electrical and communication systems.

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