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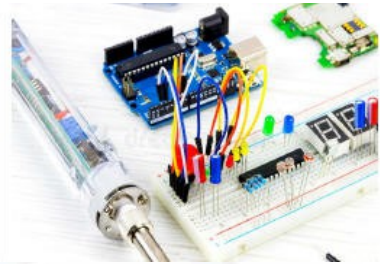
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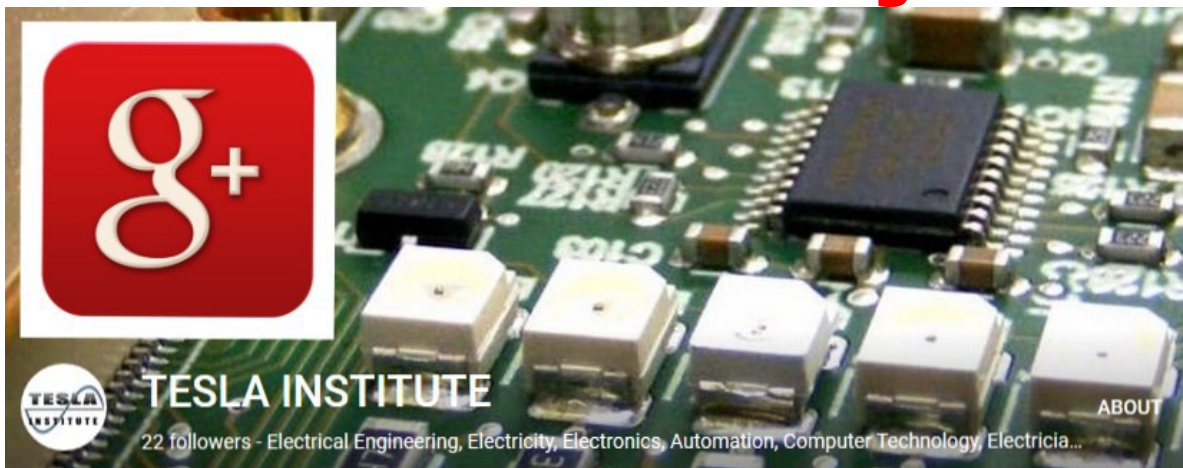
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Earthing system

In electricity supply systems, an earthing system or grounding system is circuitry which connects parts of the electric circuit with the ground, thus defining the electric potential of the conductors relative to the Earth's conductive surface. The choice of earthing system can affect the safety and electromagnetic compatibility of the power supply. In particular, it affects the magnitude and distribution of short circuit currents through the system, and the effects it creates on equipment and people in the proximity of the circuit. If a fault within an electrical device connects a live supply conductor to an exposed conductive surface, anyone touching it while electrically connected to the earth will complete a circuit back to the earthed supply conductor and receive an electric shock.

A protective earth (PE), known as an equipment grounding conductor in the US National Electrical Code, avoids this hazard by keeping the exposed conductive surfaces of a device at earth potential. To avoid possible voltage drop no current is allowed to flow in this conductor under normal circumstances. In the event of a fault, currents will flow that should trip or blow the fuse or circuit breaker protecting the circuit. A high impedance line-to-ground fault insufficient to trip the overcurrent protection may still trip a residual-current device (ground fault circuit interrupter or GFCI in North America) if one is present. This disconnection in the event of a dangerous condition before someone receives a shock, is a fundamental tenet of modern wiring practice and in many documents is referred to as automatic disconnection of supply (ADS). The alternative is defence in depth, where multiple independent failures must occur to expose a dangerous condition - reinforced or double insulation come into this latter category.

In contrast, a functional earth connection serves a purpose other than shock protection, and may carry power or signal current as part of normal operation. The

most important example of a functional earth is the neutral in an electrical supply system. It is a current-carrying conductor connected to earth, often, but not always, at only one point to avoid flow of currents through the earth. The NEC calls it a grounded supply conductor to distinguish it from the equipment grounding conductor. Other examples of devices that use functional earth connections include surge suppressors and electromagnetic interference filters, certain antennas and measurement instruments. Great care must be taken when functional earths from different systems meet to avoid unwanted and possibly dangerous interactions, for example lightning conductors and telecom systems must only be connected in a way that cannot cause the energy of the lightning strike to be redirected into the telephone network.

Regulations for earthing system vary considerably among countries and among different parts of electric systems. Most low voltage systems connect one supply conductor to the earth (ground).

People use an earthing system mainly for these applications:

To protect a structure from lightning strike, directing the lightning through the earthing system and into the ground rod rather than passing through the structure. Part of the safety system of mains electricity, preventing problems associated with floating ground.

The most common ground plane for large monopole antenna and some other kinds of radio antenna.

Low-voltage systems

In low-voltage distribution networks, which distribute the electric power to the widest class of end users, the main concern for design of earthing systems is safety of consumers who use the electric appliances and their protection against electric shocks. The earthing system, in combination with protective devices such as fuses and residual current devices, must ultimately ensure that a person must not come into touch with a metallic object whose potential relative to the person's potential exceeds a "safe" threshold, typically set at about 50 V.

Voltage networks above 240 volt to 1.1 kV, less accessible to the general public but mostly used in industrial/ mining equipment/machines, where a lot of labor force is involved, earthing system design is equally important from safety point of view and, earthing system is well taken care off with full protection devices.

In most developed countries, 220/230/240 V sockets with earthed contacts were introduced either just before or soon after World War II, though with considerable national variation in popularity. In the United States and Canada, 120 volt power outlets installed before the mid-1960s generally did not include a ground (earth) pin. In the developing world, local wiring practice may not provide a connection to an earthing pin of an outlet.

In the absence of a supply earth, devices needing an earth connection often used the supply neutral. Some used dedicated ground rods. Many 110 V appliances have polarized plugs to maintain a distinction between "live" and "neutral", but using the supply neutral for equipment earthing can be highly problematical. "Live" and "neutral" might be accidentally reversed in the outlet or plug, or the neutral-to-earth connection might fail or be improperly installed. Even normal load currents in the neutral might generate hazardous voltage drops. For these reasons, most

countries have now mandated dedicated protective earth connections that are now almost universal.

If the fault path between accidentally energized objects and the supply connection has low impedance, the fault current will be so large that the circuit over current protection device (fuse or circuit breaker) will open to clear the ground fault. Where the earthing system does not provide a low-impedance metallic conductor between equipment enclosures and supply return (such as in a TT separately earthed system), fault currents are smaller, and will not necessarily operate the over current protection device. In such case a residual current detector is installed to detect the current leaking to ground and interrupt the circuit.

IEC Terminology

International standard IEC 60364 distinguishes three families of earthing arrangements, using the two-letter codes TN, TT, and IT.

The first letter indicates the connection between earth and the power-supply equipment (generator or transformer):

T - Direct connection of a point with earth (Latin: terra)

I - No point is connected with earth (isolation), except perhaps via a high impedance.

The second letter indicates the connection between earth and the electrical device being supplied:

T - Direct connection of a point with earth

N - Direct connection to neutral at the origin of installation, which is connected to the earth

TN networks

In a TN earthing system, one of the points in the generator or transformer is connected with earth, usually the star point in a three-phase system. The body of the electrical device is connected with earth via this earth connection at the transformer.

The conductor that connects the exposed metallic parts of the consumer's electrical installation is called protective earth (PE; see also: Ground). The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system, is called neutral (N). Three variants of TN systems are distinguished:

Main characteristics

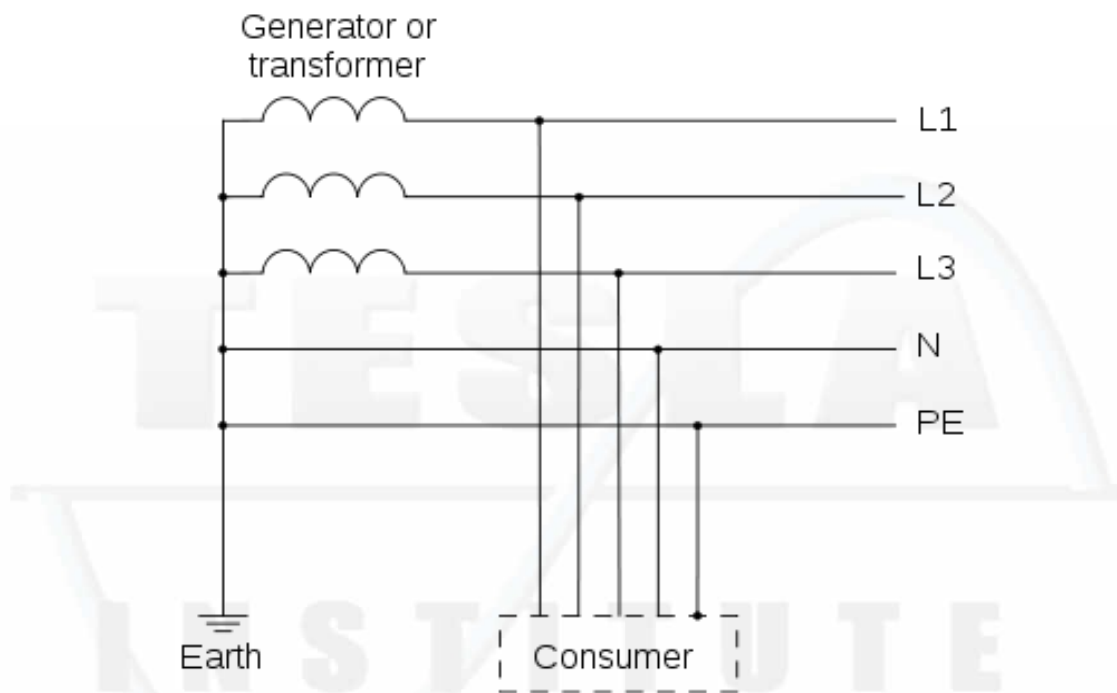
- Generally speaking, the TN system
 - Requires the installation of earth electrodes at regular intervals throughout the installation
 - Requires that the initial check on effective tripping for the first insulation fault be carried out by calculations during the design stage, followed by mandatory measurements to confirm tripping during commissioning
 - Requires that any modification or extension be designed and carried out by a qualified electrician
 - May result, in the case of insulation faults, in greater damage to the windings of rotating machines
 - May, on premises with a risk of fire, represent a greater danger due to the higher fault currents

- In addition, the TN-C system
 - At first glance, would appear to be less expensive (elimination of a device pole and of a conductor)
 - Requires the use of fixed and rigid conductors
 - Is forbidden in certain cases:
 - Premises with a risk of fire
 - For computer equipment (presence of harmonic currents in the neutral)

- In addition, the TN-S system
 - May be used even with flexible conductors and small conduits
 - Due to the separation of the neutral and the protection conductor, provides a clean PE (computer systems and premises with special risks)

TN-S

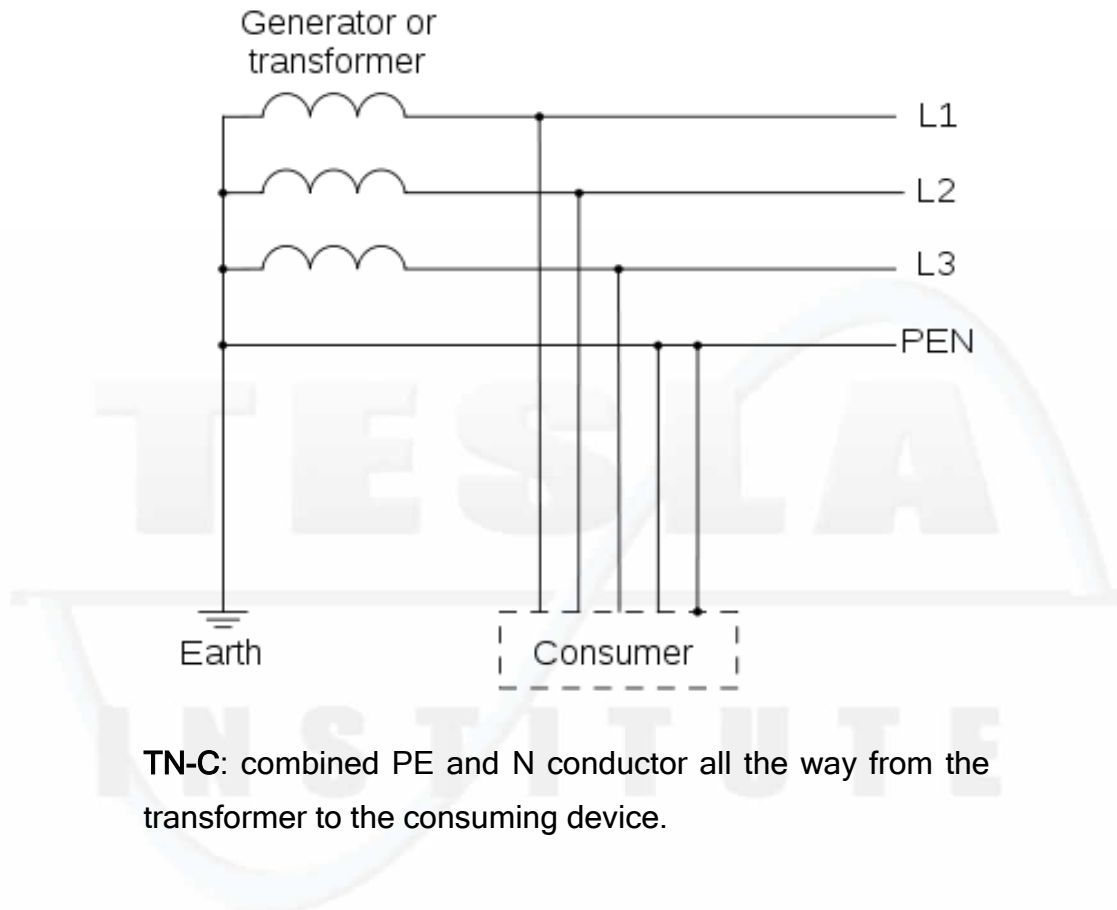
PE and N are separate conductors that are connected together only near the power source. This arrangement is a current standard for most residential and industrial electric systems particularly in Europe.



TN-S: separate protective earth (PE) and neutral (N) conductors from transformer to consuming device, which are not connected together at any point after the building distribution point.

TN-C

A combined PEN conductor fulfils the functions of both a PE and an N conductor.

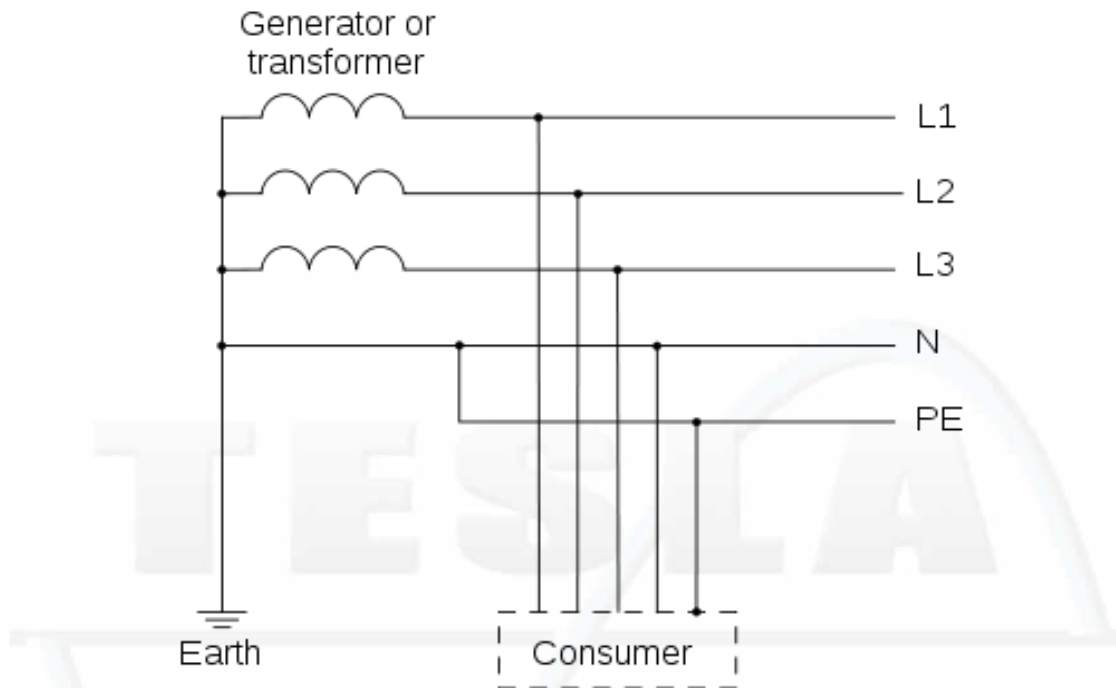


TN-C: combined PE and N conductor all the way from the transformer to the consuming device.

TN-C-S

Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N lines. The combined PEN conductor typically occurs between the substation and the entry point into the building, and separated in the service head. In the UK, this system is also known as protective multiple earthing (PME), because of the practice of connecting the combined neutral-and-earth conductor to real earth at many locations, to reduce the risk of electric shock in the

event of a broken PEN conductor - with a similar system in Australia and New Zealand being designated as multiple earthed neutral (MEN).



TN-C-S earthing system: combined PEN conductor from transformer to building distribution point, but separate PE and N conductors in fixed indoor wiring and flexible power cords.

It is possible to have both TN-S and TN-C-S supplies taken from the same transformer. For example, the sheaths on some underground cables corrode and stop providing good earth connections, and so homes where "bad earths" are found may be converted to TN-C-S. The main attraction of a TN network is the low impedance earth path allows easy automatic disconnection (ADS) on a high current circuit in the case of a live-to-PE short circuit as the same breaker or fuse will operate for either L-N or L-PE faults.

TT network

In a TT (Terra-Terra) earthing system, the protective earth connection for the consumer is provided by a local earth electrode, (sometimes referred to as the Terra-Firma connection) and there is another independently installed at the generator. There is no 'earth wire' between the two. The fault loop impedance is higher, and unless the electrode impedance is very low indeed, a TT installation should always have an RCD (GFCI) as its first isolator.

The big advantage of the TT earthing system is the reduced conducted interference from other users' connected equipment. TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free earthing. Also, TT networks do not pose any serious risks in the case of a broken neutral. In addition, in locations where power is distributed overhead, earth conductors are not at risk of becoming live should any overhead distribution conductor be fractured by, say, a fallen tree or branch.

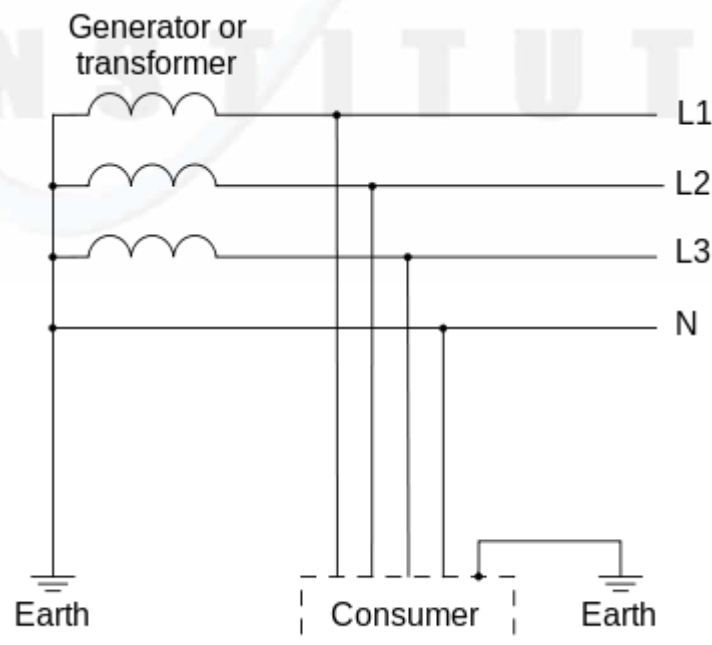
In pre-RCD era, the TT earthing system was unattractive for general use because of the difficulty of arranging reliable automatic disconnection (ADS) in the case of a live-to-PE short circuit (in comparison with TN systems, where the same breaker or fuse will operate for either L-N or L-PE faults). But as residual current devices mitigate this disadvantage, the TT earthing system has become much more attractive providing that all AC power circuits are RCD-protected. In some countries (such as the UK) is recommended for situations where a low impedance equipotential zone is impractical to maintain by bonding, where there is significant outdoor wiring, such as supplies to mobile homes and some agricultural settings, or where a high fault currents could pose other dangers, such as at fuel depots or marinas.

The TT earthing system is used throughout Japan, with RCD units in most industrial settings. This can impose added requirements on variable frequency drives and switched-mode power supplies which often have substantial filters

passing high frequency noise to the ground conductor.

Main characteristics

- Simplest solution to design and install. Used in installations supplied directly by the public LV distribution network.
- Does not require continuous monitoring during operation (a periodic check on the RCDs may be necessary).
- Protection is ensured by special devices, the residual current devices (RCD), which also prevent the risk of fire when they are set to ≤ 500 mA.
- Each insulation fault results in an interruption in the supply of power, however the outage is limited to the faulty circuit by installing the RCDs in series (selective RCDs) or in parallel (circuit selection).
- Loads or parts of the installation which, during normal operation, cause high leakage currents, require special measures to avoid nuisance tripping, i.e. supply the loads with a separation transformer or use specific RCDs



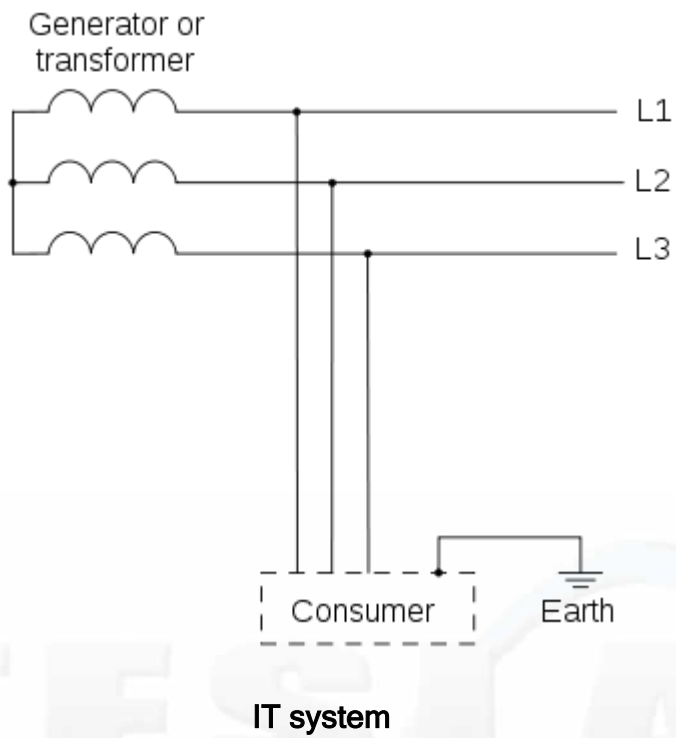
TT system

IT network

In an IT network, the electrical distribution system has no connection to earth at all, or it has only a high impedance connection. In such systems, an insulation monitoring device is used to monitor the impedance.

Main characteristics

- Solution offering the best continuity of service during operation
- Indication of the first insulation fault, followed by mandatory location and clearing, ensures systematic prevention of supply outages
- Generally used in installations supplied by a private MV/LV or LV/LV transformer
- Requires maintenance personnel for monitoring and operation
- Requires a high level of insulation in the network (implies breaking up the network if it is very large and the use of circuit-separation transformers to supply loads with high leakage currents)
- The check on effective tripping for two simultaneous faults must be carried out by calculations during the design stage, followed by mandatory measurements during commissioning on each group of interconnected exposed conductive parts
- Protection of the neutral conductor must be ensured as indicated in the page Protection of the neutral conductor inside chapter Sizing and protection of conductors



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Systems comparison

	TT	IT	TN-S	TN-C	TN-C-S
Earth fault loop impedance	High	Highest	Low	Low	Low
RCD preferred?	Yes	N/A	Optional	No	Optional
Need earth electrode at site?	Yes	Yes	No	No	Optional
PE conductor cost	Low	Low	Highest	Least	High
Risk of broken neutral	No	No	High	Highest	High
Safety	Safe	Less Safe	Safest	Least Safe	Safe
Electromagnetic interference	Least	Least	Low	High	Low
Safety risks	High loop impedance (step voltages)	Double fault, overvoltage	Broken neutral	Broken neutral	Broken neutral
Advantages	Safe and reliable	Continuity of operation, cost	Safest	Cost	Safety and cost

Other terminologies

While the national wiring regulations for buildings of many countries follow the IEC 60364 terminology, in North America (United States and Canada), the term "equipment grounding conductor" refers to equipment grounds and ground wires on branch circuits, and "grounding electrode conductor" is used for conductors bonding an earth ground rod (or similar) to a service panel. "Grounded conductor" is the system "neutral". Australian and New Zealand standards use a modified PME earthing system called Multiple Earthed Neutral (MEN). The neutral is grounded(earthed) at each consumer service point thereby effectively bringing the neutral potential difference to zero along the whole length of LV lines.

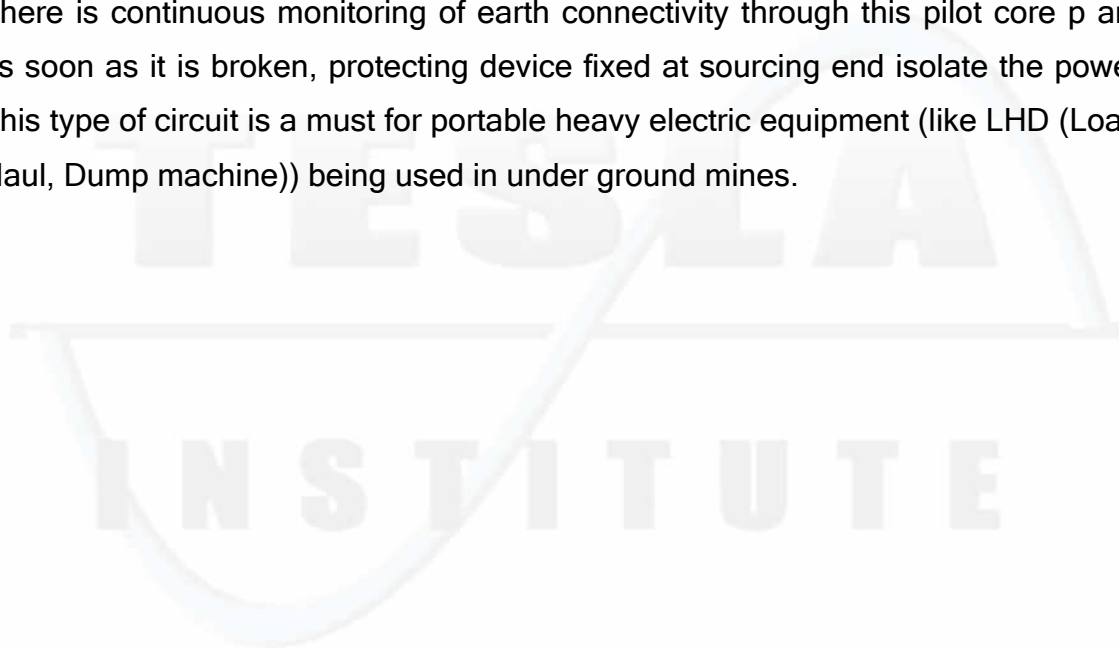
Earth leakage protection

Earth Leakage of current can be very harmful for human being if it is through them. To avoid accidental shock by electrical appliances/ equipment earth leakage relay/sensor are utilized at the source to isolate the power when leakage exceed certain limit. Earth leakage circuit breaker are used for the purpose. Current sensing breaker are called RCB/ RCCB. In the industrial applications, Earth leakage relays are used with separate CT(current transformer) called CBCT(core balanced current transformer) which sense leakage current(zero phase sequence current) of the system through the secondary of the CBCT and this operates the relay. This protection works in the range of mille Ampere and can be set from 30 mA to 3000 mA.

Earth connectivity check

Similar to TN-S system a separate core p is run from distribution/ equipment supply system. The difference is that this core P is not connected to earth at the sourcing end but connected to a protecting device which monitor earth connectivity. This core p is called pilot core. This core p is connected to earth at the distribution end through a diode circuit.

There is continuous monitoring of earth connectivity through this pilot core p and as soon as it is broken, protecting device fixed at sourcing end isolate the power. This type of circuit is a must for portable heavy electric equipment (like LHD (Load, Haul, Dump machine)) being used in under ground mines.



Properties

Cost

TN networks save the cost of a low-impedance earth connection at the site of each consumer. Such a connection (a buried metal structure) is required to provide protective earth in IT and TT systems.

TN-C networks save the cost of an additional conductor needed for separate N and PE connections. However, to mitigate the risk of broken neutrals, special cable types and lots of connections to earth are needed.

TT networks require proper RCD (Ground fault interrupter) protection.

Safety

In TN, an insulation fault is very likely to lead to a high short-circuit current that will trigger an overcurrent circuit-breaker or fuse and disconnect the L conductors. With TT systems, the earth fault loop impedance can be too high to do this, or too high to do it within the required time, so an RCD (formerly ELCB) is usually employed. Earlier TT installations may lack this important safety feature, allowing the CPC (Circuit Protective Conductor or PE) and perhaps associated metallic parts within reach of persons (exposed-conductive-parts and extraneous-conductive-parts) to become energized for extended periods under fault conditions, which is a real danger.

In TN-S and TT systems (and in TN-C-S beyond the point of the split), a residual-current device can be used for additional protection. In the absence of any insulation fault in the consumer device, the equation $I_{L1}+I_{L2}+I_{L3}+I_N = 0$ holds, and an RCD can disconnect the supply as soon as this sum reaches a threshold (typically 10-500 mA). An insulation fault between either L or N and PE will trigger an RCD with high probability.

In IT and TN-C networks, residual current devices are far less likely to detect an insulation fault. In a TN-C system, they would also be very vulnerable to unwanted triggering from contact between earth conductors of circuits on different RCDs or with real ground, thus making their use impracticable. Also, RCDs usually isolate the neutral core. Since it is unsafe to do this in a TN-C system, RCDs on TN-C should be wired to only interrupt the live conductor.

In single-ended single-phase systems where the Earth and neutral are combined (TN-C, and the part of TN-C-S systems which uses a combined neutral and earth core), if there is a contact problem in the PEN conductor, then all parts of the earthing system beyond the break will rise to the potential of the L conductor. In an unbalanced multi-phase system, the potential of the earthing system will move towards that of the most loaded live conductor. Such a rise in the potential of the neutral beyond the break is known as a neutral inversion. Therefore, TN-C connections must not go across plug/socket connections or flexible cables, where there is a higher probability of contact problems than with fixed wiring. There is also a risk if a cable is damaged, which can be mitigated by the use of concentric cable construction and multiple earth electrodes. Due to the (small) risks of the lost neutral raising 'earthed' metal work to a dangerous potential, coupled with the increased shock risk from proximity to good contact with true earth, the use of TN-C-S supplies is banned in the UK for caravan sites and shore supply to boats, and strongly discouraged for use on farms and outdoor building sites, and in such cases it is recommended to make all outdoor wiring TT with RCD and a separate earth electrode.

In IT systems, a single insulation fault is unlikely to cause dangerous currents to flow through a human body in contact with earth, because no low-impedance circuit exists for such a current to flow. However, a first insulation fault can effectively turn an IT system into a TN system, and then a second insulation fault can lead to dangerous body currents. Worse, in a multi-phase system, if one of the live conductors made contact with earth, it would cause the other phase cores to rise to the phase-phase voltage relative to earth rather than the phase-neutral voltage. IT systems also experience larger transient overvoltages than other systems.

In TN-C and TN-C-S systems, any connection between the combined neutral-and-earth core and the body of the earth could end up carrying significant current under normal conditions, and could carry even more under a broken neutral situation. Therefore, main equipotential bonding conductors must be sized with this in mind; use of TN-C-S is inadvisable in situations such as petrol stations, where there is a combination of lots of buried metalwork and explosive gases.

Electromagnetic compatibility

In TN-S and TT systems, the consumer has a low-noise connection to earth, which does not suffer from the voltage that appears on the N conductor as a result of the return currents and the impedance of that conductor. This is of particular importance with some types of telecommunication and measurement equipment.

In TT systems, each consumer has its own connection to earth, and will not notice any currents that may be caused by other consumers on a shared PE line.

Regulations

In the United States National Electrical Code and Canadian Electrical Code the feed from the distribution transformer uses a combined neutral and grounding conductor, but within the structure separate neutral and protective earth conductors are used (TN-C-S). The neutral must be connected to earth only on the supply side of the customer's disconnecting switch.

In Argentina, France (TT) and Australia (TN-C-S), the customers must provide their own ground connections.

Japan is governed by PSE law, and uses TT earthing in most installations.

In Australia, the Multiple Earthed Neutral (MEN) earthing system is used and is described in Section 5 of AS 3000. For an LV customer, it is a TN-C system from the transformer in the street to the premises, (the neutral is earthed multiple times along this segment), and a TN-S system inside the installation, from the Main Switchboard downwards. Looked at as a whole, it is a TN-C-S system.

In Denmark the high voltage regulation (Stærkstrømsbekendtgørelsen) and Malaysia the Electricity Ordinance 1994 states that all consumers must use TT earthing, though in rare cases TN-C-S may be allowed (used in the same manner as in the United States). Rules are different when it comes to larger companies.

In India as per CEAR, 2010, rule 41, neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2-phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station. The rule 42, Earth leakage protective device states that the supply of electricity to every

electrical installation other than voltage not exceeding 250 V below 5 kW, shall be controlled by an earth leakage protective device so as to disconnect the supply instantly on the occurrence of earth fault or leakage of current.

Application examples

In the areas of UK where underground power cabling is prevalent, the TN-S system is common.

Most modern homes in Europe have a TN-C-S earthing system. The combined neutral and earth occurs between the nearest transformer substation and the service cut out (the fuse before the meter). After this, separate earth and neutral cores are used in all the internal wiring.

Older urban and suburban homes in the UK tend to have TN-S supplies, with the earth connection delivered through the lead sheath of the underground lead-and-paper cable.

Older homes in Norway uses the IT system while newer homes use TN-C-S. Some older homes, especially those built before the invention of residual-current circuit breakers and wired home area networks, use an in-house TN-C arrangement. This is no longer recommended practice.

Laboratory rooms, medical facilities, construction sites, repair workshops, mobile electrical installations, and other environments that are supplied via engine-generators where there is an increased risk of insulation faults, often use an IT earthing arrangement supplied from isolation transformers. To mitigate the two-fault issues with IT systems, the isolation transformers should supply only a small number of loads each and should be protected with an insulation monitoring device (generally used only by medical, railway or military IT systems, because of cost).

In remote areas, where the cost of an additional PE conductor outweighs the cost of a local earth connection, TT networks are commonly used in some countries, especially in older properties or in rural areas, where safety might otherwise be threatened by the fracture of an overhead PE conductor by, say, a fallen tree branch. TT supplies to individual properties are also seen in mostly TN-C-S systems where an individual property is considered unsuitable for TN-C-S supply.

In Australia, New Zealand, India and Israel the TN-C-S system is in use; however, the wiring rules currently state that, in addition, each customer must provide a separate connection to earth via both a water pipe bond (if metallic water pipes enter the consumer's premises) and a dedicated earth electrode. In Australia and New Zealand this is called the Multiple Earthed Neutral Link or MEN Link. This MEN Link is removable for installation testing purposes, but is connected during use by either a locking system (locknuts for instance) or two or more screws. In the MEN system, the integrity of the Neutral is paramount. In Australia, new installations must also bond the foundation concrete re-enforcing under wet areas to the earth conductor (AS3000), typically increasing the size of the earthing, and provides an equipotential plane in areas such as bathrooms. In older installations, it is not uncommon to find only the water pipe bond, and it is allowed to remain as such, but the additional earth electrode must be installed if any upgrade work is done. The protective earth and neutral conductors are combined until the consumer's neutral link (located on the customer's side of the electricity meter's neutral connection) - beyond this point, the protective earth and neutral conductors are separate.

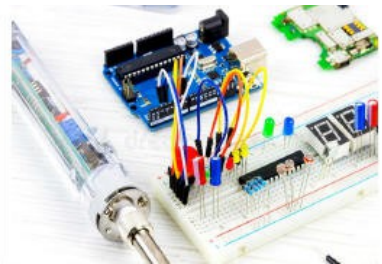
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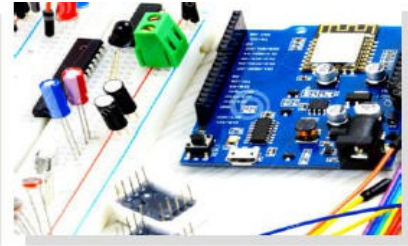


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