Ground (electricity)

From Wikipedia, the free encyclopedia
(Redirected from Earthing)

In electrical engineering, the term **ground** or **earth** has several meanings depending on the specific application areas. Ground is the reference point in an electrical circuit from which other voltages are measured, a common return path for electric current (**earth return** or **ground return**), or a direct physical connection to the Earth.

Fig. 1: A typical earthing electrode (left of gray conduit) at a home in Australia. Note the green and yellow marked earth wire.

Electrical circuits may be connected to ground (earth) for several reasons. In power circuits, a connection to ground is done for safety purposes to protect people from the effects of faulty insulation on electrically powered equipment. A connection to ground helps limit the voltage built up between power circuits and the earth, protecting circuit insulation from damage due to excessive voltage. Connections to ground may be used to limit the build-up of static electricity when handling flammable products or when repairing electronic devices. In some types of telegraph and power transmission circuits, the earth itself can be used as one conductor of the circuit, saving the cost of installing a separate run of wire as a return conductor. For measurement purposes, the Earth serves as a (reasonably) constant potential reference against which other potentials can be measured. An electrical ground system should have an appropriate current-carrying capability in order to serve as an adequate zero-voltage reference level. In electronic circuit theory, a 'ground' is usually idealized as an infinite source or sink for charge, which can absorb an unlimited amount of current without changing its potential.

The use of the term ground (or earth) is so common in electrical and electronics applications that circuits vehicles such as ships, aircraft, and spacecraft may be spoken of as having a "ground" connection without any actual connection to the Earth.

Contents

US vs. UK usage

The term 'ground' and 'grounding' are used in US electrical engineering to represent electrical equipment that is securely bonded to the ground (i.e. that on which we stand) for safety reasons. In the UK the equivalent terms are 'earth' and 'earthing'.

History

Long-distance electromagnetic telegraph systems from 1820 onwards used two or more wires to carry the signal and return currents. It was then discovered, probably by the German scientist Carl August Steinheil in 1836-1837 [1] (http://www.du.edu/%7Ejcalvert/tel/morse/morse.htm) , that the ground could be used as the return path to complete the circuit, making the return wire unnecessary. However, there were problems with this system, exemplified by the transcontinental telegraph line constructed in 1861 by the Western Union Company between Saint Joseph, Missouri, and Sacramento, California. During dry weather, the ground connection often developed a high resistance, requiring water to be poured on the ground rod to enable the telegraph to work or phones to ring.

Later, when telephony began to replace telegraphy, it was found that the currents in the earth induced by power systems, electrical railways, other telephone and telegraph circuits, and natural sources including lightning caused unacceptable interference to the audio signals, and the two-wire system was reintroduced.

Radio communications

An electrical connection to earth can be used as a reference potential for radio frequency signals for certain kinds of antennas. The part directly in contact with the earth (the *earth electrode*) can be as simple as a metal rod or stake driven into the earth (Fig. 1), or a connection to buried metal water piping (though this carries the risk of the water pipe being later replaced with plastic). Because high frequency signals can flow to earth through capacitance, capacitance to ground is an important factor in effectiveness of signal grounds. Because of this a complex system of buried rods and wires can be effective. An ideal signal ground maintains zero voltage regardless of how much electrical current flows into ground or out of ground. The resistance at the signal frequency of the electrode-to-earth connection determines its quality, and that quality is improved by increasing the surface area of the electrode in contact with the earth, increasing the depth to which it is driven, using several connected ground rods, increasing the moisture of the soil, improving the conductive mineral content of the soil, and increasing the land area covered by the ground system.

Some types of transmitting antenna systems in the VLF, LF, MF and lower SW range depend on a good ground to operate efficiently. For example, a vertical monopole antenna requires a ground plane that often consists of an interconnected network of wires running radially away from the base of the antenna for a distance about equal to the height of the antenna. Sometimes such a ground plane is supported above ground to reduce losses.

AC power wiring installations

In a mains electricity (AC power) wiring installation, the ground is a wire with an electrical connection to earth. By connecting the cases of electrical equipment to earth, any insulation failure will result in current flowing to ground that would otherwise energize the case of the equipment. A proper bonding to earth will result in the circuit overcurrent protection operating to de-energize the faulty circuit. By bonding (interconnecting) all exposed non-current carrying metal objects together, any fault currents in the system will not produce dangerous voltages which could cause electric shock.

The *power ground* grounding wire is (directly or indirectly) connected to one or more earth electrodes. These may be local, far away in the supplier's network, or in many cases both. This *grounding wire* is usually but not always connected to the *neutral wire* at some point and they may even share a cable for part of the system under some conditions. The ground wire is also usually bonded to pipework to keep it at the same potential as the electrical ground during a fault. Water supply pipes often used to be used as ground electrodes but this was banned in some countries when plastic pipe such as PVC became popular. This type of *ground* applies to radio antennas and to lightning protection systems.

A power ground serves to provide a return path for fault currents and therefore allows a fuse or breaker to disconnect the circuit. The power ground is also often bonded to a house's incoming pipework, and pipes and cables entering the bathroom are sometimes cross-bonded. This is done to try to reduce the potential difference between objects that can be touched simultaneously. Filters also connect to the power ground, but this is mainly to stop the power ground carrying noise into the systems which the filters protect, rather than as a direct use of the power ground.

Permanently installed electrical equipment usually also has permanently connected grounding conductors. Portable electrical devices with metal cases may have them connected to earth ground by a pin in the interconnecting plug. (see Domestic AC power plugs and sockets). The size of power ground conductors is usually regulated by local or national wiring regulations.

Power transmission

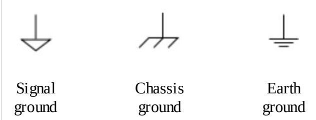
Some HVDC power transmission systems use the ground as second conductor. This is especially common in schemes with submarine cables as sea water is a good conductor. Buried grounding electrodes are used to make the connection to the earth. The site of these electrodes must be chosen very carefully in order to prevent electrochemical corrosion on underground structures.

In Single Wire Earth Return (SWER) AC electrical distribution systems, costs are saved by using just a single high voltage conductor for the power grid, while routing the AC return current through the earth. This system is mostly used in rural areas where large earth currents will not otherwise cause hazards.

A particular concern in design of electrical substations is earth potential rise. When very large fault currents are injected into the earth, the area around the point of injection may rise to a high potential with respect to distant points. This is due to the limited finite conductivity of the layers of soil in the earth. The gradient of the voltage (changing voltage within a distance) may be so high that two points on the ground may be at significantly different potentials, creating a hazard to anyone standing on the ground in the area. Pipes, rails, or communication wires entering a substation may see different ground potentials inside and outside the substation, creating a dangerous touch voltage.

Electronics

Signal grounds serve as return paths for signals and power (at extra low voltages, i.e. less than about 50 V) within equipment, and on the signal interconnections between equipment. Many electronic designs feature a single return that acts as a reference for all signals. Power and signal grounds often get connected together, usually through the metal case of the equipment.



Ground symbols[1]

Circuit ground versus earth

Voltage is a differential quantity, which appears between two points having some electrical potentials. To measure the voltage of a single point, a reference point must be selected to measure against. This common reference point is called ground and considered to have zero voltage. This signal ground may or may not actually be connected to a power ground. A system where the system ground is not actually connected to another circuit or to earth (though there may still be AC coupling) is often referred to as a floating ground.

Separating low signal ground from a noisy ground

In television stations, recording studios, and other installations where sound quality is critical, a special signal ground known as a "technical ground" (or "technical earth") is often installed, to prevent ground loops. This is basically the same thing as an AC power ground, but no appliance ground wires are allowed any connection to it, as they may carry electrical interference. In most cases, the studio's metal equipment racks are all joined together with heavy copper cables (or flattened copper tubing or busbars) and similar connections are made to the technical ground. Great care has to be taken that nobody places any AC-grounded appliances (heaters etc) on the racks, as a single AC ground connection to the technical ground will destroy its effectiveness. For particularly demanding applications, the main technical ground may consist of a heavy copper pipe, if necessary fitted by drilling through several concrete floors, so they can all be connected by the shortest possible path to a grounding rod in the basement.

Electrical shielding

A Faraday cage serves as an example of electrical shielding. Any excess charges deposited on the inner surface of a Faraday cage will migrate to the outer surface of the cage, where they can produce no electric fields within the enclosure. For this reason, the inside surface of a Faraday cage behaves like an infinite sink for electrical charge from the perspective of objects within. Even if the Faraday cage itself is not connected to the Earth, the inner surface of the cage can be used in place of an earth connection.

The shielding effect occurs regardless of whether the circuit is connected to the shield. If the circuit is not connected, however, parts of the circuit can capacitively couple to the shield and crosstalk into each other. Grounding the shield means that the circuit components will capacitively couple to ground instead, which is more manageable.

Lightning protection systems

Lightning protection systems form a very specialised application of grounding used in an attempt to lessen damage to man-made structures caused by lightning strikes. The concept and goal of lightning protection systems is to mitigate the extreme fire hazard which lightning poses to some types of man-made structures, especially those which are built of flammable materials, such as wood, or electrically resistant materials, such as brick, stone, or concrete. A lightning protection system is an attempt to provide a preferred, low-resistance path for the lightning circuit to follow, in order to lessen the heating effects of lightning's current flowing through or around flammable structural materials, or through porous materials which can contain water, such as brick, stone, or concrete, as the water contained in these rain-soaked masonry elements may explode when flashed to steam by lightning's heat.

To appreciate the limitations of lightning protection systems, it is important to understand the magnitude of lightning's energy. Because of the incredibly high electrical potential of lightning (often exceeding 100 million volts and 40,000 amperes), no lightning protection system can guarantee absolute safety from lightning to a structure, its contents, or its occupants. While lightning (as all electrical current) will tend to follow the path of least resistance, lightning will often follow many distinct paths, and secondary side-flashes can be enough to ignite a fire, blow apart brick, stone, or concrete, or injure occupants within a structure or building. Nonetheless, scientists, electrical engineers, and property insurers have accepted and relied upon the benefits of basic lightning protection systems for well over a century.[2]

The components of a basic lightning protection system are air terminals (i.e. lightning rods or strike termination devices), bonding conductors (usually heavy stranded copper or aluminum wires or thick braided or solid copper or aluminum straps), ground terminals (i.e. electrodes, ground or earthing rods, plates, or mesh), and all of the proper connectors and supports to complete the system. The air terminals are typically arranged at or along the upper points of a roof structure, and are electrically bonded together by bonding conductors (sometimes called "down conductors" or misleadingly called "downleads"), which are connected by the most direct route possible to one or more grounding or earthing terminals installed into the earth or ground.[3]

Some attempts at more sophisticated lightning protection systems may include other non-conventional devices or techniques in addition to those listed above, and controversially asserting to reduce an installation's likelihood of receiving lightning strikes, though no careful scientific studies have conclusively proven such claims. Examples of these non-conventional elements include devices or techniques such as "early streamer emission", "sparking-controlled leader triggers", "dissipation array systems", and "charge transfer systems". None of these devices or techniques are recognized by professional engineering associations such as IEEE or NFPA, nationally recognized testing laboratories (NTRLs) such as UL or CSA, or loss control insurers such as FM.[4][5]

An example of a structure vulnerable to lightning is a wooden barn near or at the top of a hill. In the event of lightning striking the barn, the wooden structure and possibly its contents, such as a loft full of dry hay, may be easily ignited by the extreme heat of lightning conducted through parts of the structure. A basic lightning protection system may be installed to help protect such a structure, so that if lightning strikes one or more of the air terminals (lightning rods), most of the lightning's current will follow the path of the lightning protection system, with substantially less current traveling through flammable materials.

Originally, scientists believed that such a lightning protection system of air terminals and "downleads" directed the current of the lightning down into the earth to be "dissipated". However, high speed photography has clearly demonstrated that lightning is actually composed of both a cloud component and an oppositely charged ground component. During "cloud-to-ground" lightning, these oppositely charged components usually "meet" somewhere in the atmosphere well above the earth to equalize and dissipate the previously unbalanced charges. In any case, the heat resulting from this electrical discharge flowing through flammable building materials is the hazard which lightning protection systems attempt to mitigate by providing a low-resistance path of rugged terminals and conductors to facilitate the lightning circuit, theoretically reducing the resistance and resulting heat. Again, no lightning protection system can be relied upon to "contain" or "control" lightning completely (nor thus far, to prevent lightning strikes) but they do seem to help immensely on most occasions of lightning strikes.

An example of man-made structures which utilize the structure as part of the lightning protection system are steel framed structures in which the frame is effectively bonded through its foundation with the earth. A metal flagpole with its foundation in the earth is an example of a structure which serves as its own extremely simple lightning portection system. Despite a flagpole being essentially a complete lightning protection system, including simultaneously serving as the air terminal, bonding conductor, and ground terminal, a flag hoisted upon the pole during a lightning strike may be completely incinerated.

In overhead transmission lines, a ground conductor may also be the top most wire on pylons, poles, or towers. This ground conductor is intended to protect the power conductors from lightning strikes. These conductors are connected to earth either through the metal structure of a pole or tower, or by additional ground electrodes installed at regular intervals along the line. As a general rule, overhead power lines with voltages below 50 kV do not have a ground conductor, but most lines carrying more than 50 kV do. Depending on local conditions and reliability requirements, an over head transmission line may have two overhead ground conductors. In such cases the pylons are either equipped with an additional crossbeam above the conductors, with two tops in form of a letter "V" or the ground conductors are mounted on the top of the topmost crossbeam. In some parts of the world, the ground conductor cable is used to support fibreoptic cables for data transmission (see OPGW).

Earthing system

In electricity supply systems, an earthing system defines the electrical potential of the conductors relative to that of the Earth's conductive surface. The choice of earthing system has implications for the safety and electromagnetic compatibility of the power supply. Note that regulations for earthing (grounding) systems vary considerably between different countries.

A functional earth connection serves a purpose other than providing protection against electrical shock. In contrast to a protective earth connection, a functional earth connection may carry a current during the normal operation of a device. Functional earth connections may be required by devices such as surge suppression and electromagnetic-compatibility filters, some types of antennas and various measurement instruments. Generally the protective earth is also used as a functional earth, though this requires care in some situations.

Busbars may be needed in situations requiring adequate ground conductors.

Ground mat

A ground mat or grounding mat is a flat, flexible pad used for working on electrostatic sensitive devices. It is generally made of a conductive plastic or metal mesh covered substrate which is electrically attached to ground. This helps discharge any static which a worker has built up, as well as any static on tools or exposed components laid on the mat. It is used most commonly in computer repair. Ground mats are also found on fuel trucks, which are otherwise insulated from ground as they make physical contact only with their (rubber and air) tires; obviously static discharge is undesirable during fuel-transfer operations. Similarly, in aircraft refueling, a ground cable connects the tanker (truck or airplane) to the fuel-seeking craft to eliminate charge differences before fuel is transferred.

In an electrical substation a ground mat is a mesh of conductive material installed at places where a person would stand to operate a switch or other apparatus; it is bonded to the local supporting metal structure and to the handle of the switchgear, so that the operator will not be exposed to a high differential voltage due to a fault in the substation.

See also

- Domestic AC power plugs and sockets
- Earthing systems
- Ground constants
- Virtual ground
- Ground loop
- Phantom circuit
- Phantom loop

Notes

1. ^ Electrical and electronics diagrams, IEEE Std 315-1975, Section 3.9: Circuit return.
2. ^ NFPA-780 Standard for the Installation of Lightning Protection Systems 2008 Edition
3. ^ Benjamin Franklin and Lightning Rods - Physics Today January 2006 (http://scitation.aip.org/journals/doc/PHTOAD-ft/vol_59/iss_1/42_1.shtml) , Accessed 2008-06-1 9:00pm GMT.
4. ^ Charge Transfer System is Wishful Thinking, Not Science (http://www.lightningsafety.com/nlsi_lhm/charge_transfer.html) , Accessed 2008-06-13 1:25pm GMT.
5. ^ Inefficacy of radioactive terminals and early streamer emission terminals (http://elistas.egrupos.net/cgi-bin/eGruposDMime.cgi?K9D9K9Q8L8xumopxC-qjd-uluCPSYTSCvthCnoqdy-qlhhyCVUQWQjfb7) , Accessed 2008-06-13 5:42pm GMT.

References

- Federal Standard 1037C in support of MIL-STD-188

External links

- The Electromagnetic Telegraph, by J. B. Calvert (http://www.du.edu/%7Ejcalvert/tel/morse/morse.htm)
- Grounding for Low- and High- Frequency Circuits (http://www.analog.com/static/imported-files/application_notes/600114286955201494896049269845513175558467302082 8AN_345.pdf) (PDF) — Analog Devices Application Note
- An IC Amplifier User's Guide to Decoupling, Grounding, and Making Things Go Right for a Change (http://www.analog.com/static/imported-files/application_notes/135208865AN-202.pdf) (PDF) — Analog Devices Application Note

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