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Grounding Myths

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1. Introduction

Electrical grounding and the electrical engineering field is full of misconceptions and myths that create confusion in the design and installation of grounding systems. Fortunately many of these myths are unsubstantiated and can be explained by using science. This paper focuses on explaining some of the most common myths.

2. Most Common Grounding Myths

This paper addresses the following grounding myths:

1. Low earth resistivity is important because it facilitates the operation of overcurrent protection devices like fuses and circuit breakers
2. Earthing and grounding are different.
3. All electrical currents return to the earth.
4. Galvanized rods have the same performance as copper-bonded rods.
5. Copper is used in ground rods because of its conductivity.
6. The diameter of ground rods has a significant impact on lowering ground resistance.
7. GEM increase the effective diameter of the ground electrode.
8. Electrical safety (equipment) grounding for the commercial and industrial (C&I) industries is the same as telecom and also substation grounding.
9. The equipotential bonding and grounding electrode systems of lightning protection systems provide safety to workers.

MYTH 1 - LOW EARTH RESISTIVITY IS IMPORTANT BECAUSE IT FACILITATES THE OPERATION OF FUSES AND CIRCUIT BREAKERS.

Many people relate electrical grounding with safety. For example, the most common misconception is that if the system is grounded it is safe from electric shock. Grounding is very specific, it means a connection to the ground. It is essential to understand distinction between **system ground** and **equipment ground**. Principles in this paragraph relate to solidly grounded systems.

The term system ground is used with respect to systems, such as generators, transformers, or batteries, where the meaning of grounding is to provide a connection from one conductor of the system to an electrode that is buried in the earth. However, not all systems are grounded nor is the electrode always in the earth. System grounding means the connection of earth ground to the neutral points of current carrying conductors such as the neutral point of a circuit, a transformer, rotating machinery, or a system, either solidly grounded or with a current-limiting device.

System grounding helps detect and clear ground faults. Equipment grounding provides a return path for ground-fault current. System grounding, or the intentional connection of a phase or neutral conductor to earth, is for the purpose of controlling the voltage to ground within predictable limits. [1]

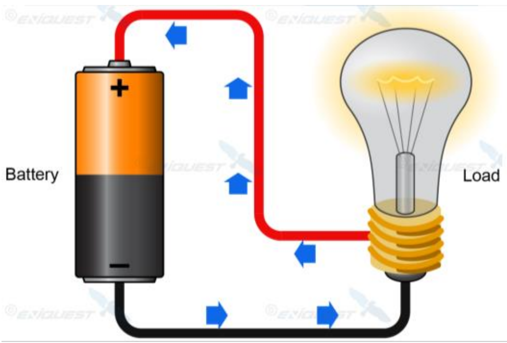
Earth is not an effective ground fault current path. For example, assume the system resistance to ground is 25 Ohms, which represents the minimum requirement by NEC and the system voltage is 120V. Using Ohms law we can calculate the current of 4.8A. The current is not high enough to trip the breaker rated for 20 A. In this scenario the current does not go to ground- it leaves the source and it returns back to the source. The electrical fault returns to the source by a neutral conductor. If the electrical system is insulated, like in the case of ungrounded delta configuration, the fault uses earth as a return path specifically it does not dissipate to the ground. It cannot be expected that a circuit connected to the earth will protect a person from an electrical shock. A ground rod will not protect a person from an electric shock.

To clear the electrical fault, the circuit has to be disconnected by tripping a circuit breaker. The low impedance effective ground fault path has to be established in the circuit. The lower the impedance of the path, the higher the fault current and the quicker the circuit breaker will turn off. For example, assume that the main breaker in an AC panel is rated for 100A. The breaker can be disconnected by a current that exceeds the 100A rating. Let's assume that the impedance of wires in the circuit that experiences an electrical fault is 0.208 Ohms and the voltage is 120V. Using Ohms law we can calculate a current of 577 A. This current is high enough to trip the breaker.

In an electrical circuit, current leaves the source and returns back to the source. If you take a battery, the circuit is complete only if one part of the circuit is connected to the positive terminal and the other part of the circuit is connected to the negative terminal. The circuit is not complete, if one side of the circuit is connected to the positive terminal of the battery and the negative side of battery is connected to ground. A lightbulb in this type of circuit will never light up. This demonstrates the fact that current is always trying to make it back to the source.

When referring to equipment ground, the term grounding can have various meanings. It may mean bonding or it may mean a direct connection to the earth. The latest revisions of NEC have made a significant effort to distinguish the two terms. The term Bonded (Bonding) by definition "Connected to establish electrical continuity and conductivity." Ground by definition is "The earth" and Grounded (Grounding) by definition is "Connected (connecting) to ground or to a conductive body that extends the ground connection." Equipment-grounding conductor serves a vital role in the overall electrical system. The equipment-grounding conductor is used to ground the noncurrent-carrying metal parts of equipment. Its function is to keep equipment as close as possible to ground potential and provide a safe path for ground-fault current to flow.

In conclusion, a proposed definition for the fault return conductor is to emphasize the need for a reliable low impedance path rather than an intentional connection to the earth. Figures 1 and 2 represent AC and DC closed circuits. In both circuits the **current leaves source and returns to the source**.



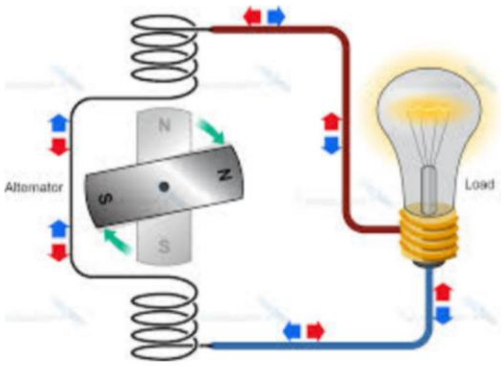


Fig. 1 DC Circuit

Fig. 2AC Circuit

MYTH 2 - EARTHING AND GROUNDING ARE DIFFERENT.

Earthing and Grounding are in fact the same. The definition of grounding by the National Electric Code (NEC): "A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or to some body that serves in place of the earth." The difference is in semantics. Part of the world influenced by the British Commonwealth chooses to call the process Earthing. In the USA the process is call Grounding. It is important to understand Earthing and Grounding are different *only in name.*

MYTH 3 - ALL ELECTRICAL CURRENTS RETURN TO THE EARTH

This is not true for the same reasons explained in myth 1. In an electrical circuit, current leaves the source and returns back to the source. Sometimes, it uses the earth as a return path to a source. It enters the earth via grounding system, but it does not stay in the earth, it returns back to the source. On the other hand, an equipment-grounding conductor serves a vital role in the overall electrical system. Equipment-grounding conductor is used to ground the noncurrent-carrying metal parts of equipment. Its function is to keep equipment as close as possible to ground potential and provide a safe path for ground-fault current to flow to the grounding system. A properly sized EGC protects circuit elements and equipment and ensures the safety of personnel from electric shock.

It is important to mention that the lightning charge and subsequent current does return to earth and it causes ground potential rise and voltage gradient that we have to be concern with, when completing system designs. Connection to the earth and proper bonding is important when designing lightning protection systems. Lightning standards address importance of minimizing potential differences using adequate bonding. Negative charges typically dissipate to the earth and positive charges dissipate in clouds.

MYTH 4 - COPPER AND GALVANIZED GROUND RODS PERFORM THE SAME.

Characteristic of both types of ground rods.

- Both rod types are composed of a steel core. Copper-bonded rods use cold drawn steel with a tensile strength of 90,000+ psi. Most galvanized steel rods use hot rolled steel with a tensile strength of 58,000+ psi. Higher tensile strength leads to less rod deformation during installation.
- The thickness and type of coating material determines corrosion resistance and service life.
  Copper-bonded steel rods are coated with 10 mils (.010" or .254mm) of copper and galvanized steel rods are coated with 3.9 mils (.0039" or .099mm) of zinc. The coating thickness is limited by hot dip galvanizing process. Copper protects the steel from corrosion. The zinc sacrifices itself for the steel in the form of sacrificial anode. When the zinc is consumed, severe corrosion sets in.

Historically there were three known studies conducted in the USA. They all compared resistance to corrosion and the service life of both types of ground rods. All studies mentioned below highlighted the performance differences namely in length of service life.

- Underground Corrosion – National Bureau of Standards from 1910 to 1955
- Naval Civil Engineering from 1962 to 1969
- National Electrical Grounding Research Project (NEGRP) from 1992 to 2002

Underground Corrosion – National Bureau of Standards from 1910 to 1955

In this study, 36,500 specimens representing 333 types of ferrous, nonferrous, and protective coating materials were tested in 128 test locations throughout the United States. This study is widely regarded as one of the most comprehensive corrosion studies ever conducted. Copper, copper clad and galvanized electrodes were also tested.

Copper clad steel samples were buried in 14 locations for 13 years. Based on the weight measurements, the average total penetration was 0.005 inches.
Copper clad steel samples were also buried in 29 other locations for 8 years. The average total penetration was 0.009 inches. nVent ERICO copper-bonded steel ground rods are coated with 0.01 inches of copper.
208 galvanized steel pipe specimens were buried for 10 years. The report states: "An analysis of these data showed that in most of the soils, zinc coatings of 0.0035 inches or

less were destroyed during the 10 year exposure period, and pitting of the underlying steel occurred." Corrosion accelerated in soils containing high concentrations of soluble salts.

Naval Civil Engineering from 1962 to 1969

Field testing of grounding electrodes, conducted by the Naval Civil Engineering Laboratory in cooperation with NACE in the early '60s establish the best type of electrode determined by easy to drive, resistant to corrosion and the electrodes should not cause corrosion to nearby metals.

Copper-bonded, galvanized, and stainless steel rods were tested among other materials. The study was concluded after 7 years. Galvanized and mild steel rods were prohibited for use by US NAVY.

The following observations were made:
Galvanized rods: "Most of the galvanizing had been lost. Rusting of the steel was greatest near the surface of the ground. Pitting was the worst near the tip of the ground rod.

Copper-clad rods: The copper cladding was virtually free of corrosion, but the steel core had corroded at the tip to a point 2 inches inside the cladding."

National Electrical Grounding Research Project (NEGRP) from 1992 to 2002

Started in 1992 by the Southern Nevada Chapter of the IAEI to compare long-term performance of different electrodes. The Study was governed by the Fire Protection Research Foundation part of NFPA®
Copper bonded and galvanized ground rods were included in the study. 16 different electrodes were installed in 7 different sites.
The following readings were obtained on a monthly basis for more than 10 years:

- Soil resistivity
- Ground electrode resistance
- Soil moisture
- Soil temperature

The data obtained in the study was summarized in annual reports.

At the end of the study the electrodes were removed for corrosion analysis.

- Balboa: January 29, 2001 (9 years)
- Pawnee: March 17, 2003 (11 years)
- Pecos: April 12, 2004 (12 years)
- Lone Mountain: April 14, 2004 (12 years)

The final report stated moderate to severe corrosion of galvanized rods and minimal corrosion of copper-bonded rods. Observations were the same at all sites. The results concurred with the two previous studies discussed. The corrosion data indicates that zinc plated ground rods have an average service life of 15 years and the copper coated ground rods have a service life of 40 years plus.

MYTH 5 - COPPER IS USED IN GROUND RODS BECAUSE OF ITS CONDUCTIVITY.

As discussed in Myth 3, the main reason ground rods are plated with copper is to extend the service life of steel core of ground rods. Copper resists corrosion in most soils.

The choice of material related to ground rod conductivity is not that important. For example, compare the resistivity of copper bonded ground rod [0.159 µΩm] and stainless steel (SS) ground rod [0.720 µΩm]. Despite the fact that the stainless steel ground rod resistivity is 22% higher than that of copper bonded steel, the SS ground rod is just as effective. Compared to the overall grounding “chain”, the contact to earth and earth itself can be 1000x magnitudes greater than the electrode system , so choice of metals regarding conductivity are not that critical.

MYTH 6 – THE DIAMETER OF GROUND RODS HAS A BIG IMPACT ON LOWERING GROUND RESISTANCE.

Rod diameter has minimal effect on lowering grounding system resistance. Refer to Figure 4. Variances in ground rod diameters are guided by industry standards and internal specifications of various utility companies. For example, a larger ground rod diameter is chosen by design engineer to extend the service life of the installation. In some other instances, a larger diameter ground rod would experience less deformation, when driving it into rocky soils. Increasing length of a ground rod has significant impact regarding resistance. Doubling the ground rod length can reduce the resistance up to 40%.

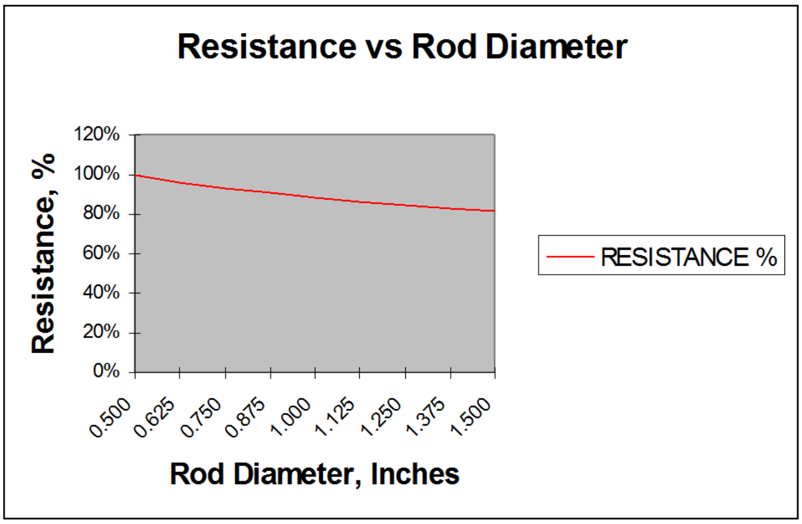


Fig. 4

MYTH 7 - THE COMMON MISCONCEPTION OF THIS MYTH IS THAT THE GEM INCREASES THE EFFECTIVE DIAMETER OF THE GROUND ELECTRODE.

To explain this phenomenon, we need to understand two concepts of electricity. **Ground Potential Rise** (GPR) and **Voltage Gradient** (VG)

Ground Potential Rise is the transient over voltage that enters the earth through an earth grid impedance in the form of current causing differences in potential that forms across the surface of the earth as the earth absorbs electricity in proportion to the level of conductivity of the earth and the distance from the entry point. The potential relative to a distant point on the Earth is highest at the point where the current enters the ground and declines with a distance from the source. Ground potential rise is a concern in the design of electrical substations, because the high potential may be a hazard to people or equipment. The GPR is also a concern in other electrical systems as well.

Voltage dissipates through the volume of the earth as a voltage gradient. **Voltage Gradient** is the electrical potential difference between two points separated by a certain distance. Volume of the earth can be used as a conductor. If we drive a ground rod and large energy is dissipated into it, the ground rod will have the highest potential rise. The contact resistance of the grounding electrode with the earth is very high. It typically takes about 25 to 50 feet to reach the remote earth, where the potential rise settles to a safe level.

Figure 3 shows how the fault energy moves through the multipath structure of the earth. The conductive path gets more complex, up until the voltage gradient decreases to a safe level.

GEM enhances the overall grounding system by creating a larger and more conductive volume adjacent to the ground rod, providing multiple paths of dissipation, which increases uniform distribution of energy, and also decreases the voltage gradient quicker and more effectively than could be achieved by the native earth. In other words, the first 6” to 12” diameter “ring” or “shell” accounts for about 70% of the current paths resistance due to current density, so as the current dissipates outward, higher resistivity soils have less of an impact, therefore replacing the 6” to 12” volume of the soil with GEM introduces a low-impedance path for the first “shell”, thereby improving performance. Figure 3 represents this phenomenon graphically.

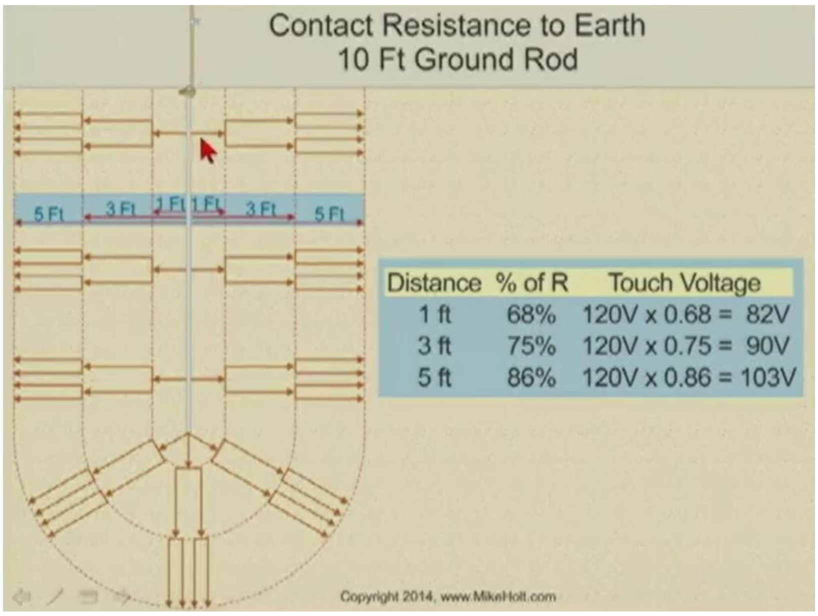


Fig. 3

MYTH 8 - ELECTRICAL SAFETY (EQUIPMENT) GROUNDING FOR C&I IS THE SAME AS TELECOM GROUNDING IS THE SAME AS SUBSTATION GROUNDING.

Grounding systems for specific industries have different nuances, but in general they serve similar purposes. Each industry follows specific standards, which guide the user in designing and installing safe grounding systems.

- The C&I follows National Electric code. The grounding principles were explained above.
- The Telecommunication industry follows Standards including TIA 607, ATIS and Telecordia, depending on specific data, telecom applications or segments.
- The substation grounding systems design and installation complies to Standard IEEE80. The design of substation grounding systems is more complex, because the level of currents are so much higher than NEC or Telecom, which makes it much more challenging to manage safety.

MYTH 9 – THE EQUIPOTENTIAL BONDING AND GROUNDING OF LIGHTNING PROTECTION SYSTEMS PROVIDE SAFETY TO WORKERS

The NFPA 780 (Standard for the Installation of Lightning Protection Systems) states in section 1.2 “Purpose” that the purpose of this standard is to provide for the practical safeguarding of persons and property from hazards arising from exposure to lightning. However, it is important to understand that lightning protection systems are designed to primarily protect structures and equipment, not people. A lightning protection system will not eliminate the potential of someone getting harmed or even being fatally injured.

The lightning energy needs to dissipate to the earth. The standards recommend impedance of a typical grounding system to earth is 10 Ohms or less. This value represents a minimum requirement and it does not resolve potential hazards by itself. In inadequate grounding system the lightning energy seeks a path to dissipate. The energy can cross flash and energize different conducting surfaces and create unsafe conditions, when proper bonding is not implemented. Since the charge of a lightning strike ranges from 30 to 200 kA, it imposes additional safety hazards, caused by ground potential rise and voltage gradient.

The ground potential rise (GPR) can be measured several miles from the epicenter of the strike. The GPR can also be detected as a transient energy on the electrical systems and can caused damage to electronic equipment. This is why an essential part of a lightning protection system is grounding and bonding. Lightning energy dissipates most effectively through multi path and multi directional grounding systems. Connection to earth and proper bonding is important. Lightning standards emphasize importance of minimizing potential differences using adequate bonding.

Conclusion

There are many more Myths that can be discussed. This paper covered the Myths that were in the scope of this assignment. This paper can be expanded in the future.

[1]NEC was the main document used as a reference material.