The Conflict Between Copper Grounding Systems and CP

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The common bonding of underground ferrous structures to massive copper grounding grids creates problems for corrosion engineers and their attempts to cathodically protect the ferrous structures. Conflicts between copper and ferrous underground systems are discussed and alternatives are presented.

Traditionally, most underground structures have been electrically bonded in common to reduce hazardous voltages associated with lightning and man-made fault currents or induced currents in the earth. A common grounding system provides an economical and lower resistance to remote earth than does an individual earthing connection. This tends to ensure a low resistance return path for power system earth return currents and fault currents. An additional benefit is minimizing earth potential gradients around individual earthing electrodes or elements. It also tends to reduce step and touch voltages at the surface of the earth. Further, redundancy is desirable in electrical grounding and earthing circuits for safety reasons, in case one or more conductors are cut or otherwise damaged.

Electrically interconnecting many dissimilar metals in the soil environment can lead to significantly increased corrosion rates on some of the underground structures. When materials such as black iron (BI), cast iron (CI), and ductile iron (DI) are interconnected, they are very close together in the electromotive series of metals and, therefore, each would suffer very little additional corrosion by connection to the other metal. Only normal soil instigated deterioration (corrosion) must be dealt with. In soils of low electrical resistivity, low pH, or other aggressive characteristics, corrosion of pressure piping systems still must be dealt with. This most commonly takes the form of dielectric protective coatings supplemented with cathodic protection (CP).

When a dissimilar metal couple is created by connecting BI, CI, or DI to copper or brass, a significant corrosion cell is created. Copper is electro-positive with respect to all ferrous construction materials. In addition, copper will not polarize readily as is the case for ferrous structures. Therefore, accelerated corrosion is the result on ferrous structures whenever they are directly coupled to bare copper in the soil.

The U.S. National Electrical Code (NEC)[1] does not require copper grounding. Instead, it requires that a "permanent" metallic earthing electrode and conductors must be used for earthing connections. Electrical practice in the U.S. does not make a clear distinction between "earthing" and "grounding," as is common in Europe. This article makes a clear distinction.

"Earthing" refers to a grounding electrode or grounding conductor in direct contact with the soil environment that makes an electrical connection to that environment. When measured, it is an expression of the ohmic resistance between the total contributions of all of the various grounding members and the soil environment to which they are connected. "Grounding" refers to the practice of providing metallic bonding conductors (conduit, ground wires, etc.) that are deliberately connected between various pieces of equipment and the earthing electrodes/conductors making up the plant's grounding grid.

The term "grounding grid" encompasses all electrically common grounding conductors, earthing conductors, earthing electrodes, and process piping that make up the overall, electrically continuous, plant grounding system. To distinguish these elements of the grounding system from a "CP groundbed," the term "anode-bed" is used.

Acceptable alternatives exist to the use of bare copper conductors and bare copper or copper-clad ground rods.

CP is routinely employed to overcome soil-instigated corrosion cells on power plants, industrial facilities, and on crude oil and natural gas production and transportation facilities. In most instances, the underground piping is provided with a dielectric coating to create a barrier between the pipe surface and the local soil or water environment. These coatings are supplemented with CP to prevent corrosion at "holidays," or voids in the protective coating. This provides a very economical CP system with minimum current demands. When such a system is directly connected to a bare copper earthing system, current demand may increase by several orders of magnitude. This creates a conflict between CP engineering design and electrical safety design. Alternatives do exist.[2]

Where impressed current systems using large current outputs are employed, cathodic interference between multiple, isolated underground structures becomes a significant design consideration. Normal practice is to bond all structures, including the electrical grounding grid, in common. Where massive copper grounding systems are employed, the bare copper grid creates a very large load upon the CP system. In some instances, current demand for the copper grounding system may be >90% of the total current output of the impressed current system. Whenever the impressed current CP system is not functioning, a strong galvanic couple is created between the underground ferrous piping and the copper grounding grid. This leads to accelerated corrosion of the ferrous structures. Even with the CP systems operating within their rated capacity, such low pipe-to-soil potentials may exist on some segments of the underground plant that serious corrosion losses are still experienced in those localized areas.

Acceptable alternatives exist to the use of bare copper conductors and bare copper or copper-clad ground rods. Some of these alternatives are: stainless steel (SS) ground rods; sacrificial anodes in cast, rod, or ribbon shapes; rebar or other iron rods in concrete; galvanized steel ground rods; galvanized steel cables; and the use of cathodically protected iron and steel shapes. Grounding grids have been constructed of wrought iron or mild steel rod and bar shapes for many decades in China, Germany, and Russia. CP frequently is applied to these ferrous grounding grids. Many of them have been installed without the benefit of CP.

Most electrical engineers specify copper for earthing electrodes since it is the preferred material of choice for electrical conductors. There also is the perception that copper does not corrode when buried in the soil. However, when copper is directly buried in the soil and completely isolated from other construction materials, it will corrode. In acidic soil conditions, the corrosion rate of copper may be greater than that of iron or steel. But if a copper earthing electrode is electrically interconnected with other engineering materials of construction (i.e., BI, CI, DI, or steel), the copper will be cathodically protected at the expense of the ferrous metal to which it is connected. Therefore, copper is a bad neighbor because its presence when in direct contact with the soil (not insulated) will accelerate corrosion on the other engineering metals in the earth to which it is connected.

In addition, copper does not polarize as readily as do ferrous structures. Therefore, the CP current density required to polarize the copper to an adequate potential necessary to protect a ferrous structure may be 10 to 20 times as high, on a per unit area basis, as that required to polarize ferrous structures. When one considers that the underground piping in production facilities is all coated pipe, it is not difficult to recognize that a bare copper pipe earthing system will place a very significant load on the CP system, if the underground piping is to be polarized to an adequate CP potential.

References

1. NFPA 70-1999, National Electrical Code (Quincy, MA, National Fire Protection Association, 1999).

2. E.L. Kirkpatrick, "Alternatives to Copper Grounding in Sites Requiring Cathodic Protection," MP 25, 9 (1986).

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Technical Editor's Note: *See p. 30 for an article on the fundamentals of cathodic interference.*