Alternatives to copper grounding in sites requiring cathodic protection*

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Common bonding of underground ferrous structures to massive copper grounding grids creates problems for corrosion engineers in attempts to cathodically protect these structures. Usual methods of electrical grounding are discussed. Lack of effective communication between engineering disciplines is recognized. Alternatives to conventional copper grounding electrodes are discussed with consideration given to permanence of the proposed electrodes. Examples of alternative grounding electrodes and systems employed over the past 25 y are presented.

Introduction

MOST UNDERGROUND STRUCTURES have been bonded in common to reduce hazardous voltages associated with lightning and manmade fault currents or induced currents in the earth. Common grounding provides an economical and low resistance ground for power systems; it also minimizes potential differences in the earth and between individual metallic structures.

Cathodic protection (CP) engineers have found themselves in disagreement with power or grounding engineers electrical isolation and common bonding of metallic structures to massive copper grounding grids or networks. While copper grounding has been the standard of the electrical industry almost since inception, use of copper causes severe corrosion problems for connected ferrous structures. Copper is cathodic to other materials of construction. This accounts, in part, for copper's permanence since other materials will sacrifice themselves to protect the copper. Elimination of copper grounding can extend the life of the other commonly grounded underground structures.

Generally, the corrosion control arguments, perceived as "black magic," are lost, to the requirements of established grounding practices. This is partially the result of the corrosion engineer's lack of effective communication with other engineering disciplines. The principles of galvanic corrosion and CP have not been effectively explained to engineers in the power industry. Over the years, some progress has been made toward pressing the case for selective electrical isolation. Earlier papers have dealt with isolation of cathodically protected structures from electrical grounding systems while maintaining AC electrical continuity.[1,2]

When protecting a short, isolated, well-coated, and small-diameter pipeline that has been provided with effective electrically insulating fittings at each end, all that may be required is a small sacrificial anode. As the structure becomes larger and more complex, current requirements increase. More and larger sacrificial anodes are required, or impressed current systems must be considered to meet these increased needs.

If dealing with a large, complex underground network, such as a pipeline compressor station or a power plant, many other underground structures enter the picture. At some point, it becomes imperative to consider common bonding of all underground structures to avoid deleterious cathodic interference effects on nearby isolated metallic structures influenced by large impressed current CP systems. When this is done, the electrical grounding grid is tied invariably in common with the structures to be protected. Electrical safety considerations concerning step potential, touch potential, and transfer potential may require common bonding of all structures to the grid.[3] Undoubtedly, this grid has been constructed of bare copper conductors and/or driven copper or copper clad ground rods.

Conflict

Copper-steel couples greatly accelerate the corrosion rate of the commonly bonded steel elements when CP is not applied.[4] There are numerous instances of corrosion leaks occurring on plant piping in commonly bonded systems. This frequently happens before the plant is operated, particularly when CP was not implemented in the early stages of the project. Corrosion control design requirements are adversely impacted by the excessive current requirements necessary to effectively polarize a copper cathode.[5]

Alternatives

There are acceptable alternatives to the use of bare copper conductors and ground rods including the following: Stainless steel ground rods; sacrificial anodes in cast, rod, or ribbon shapes; rebar or iron rods in concrete; galvanized steel ground rods and cables, as well as the use of cathodically protected less noble metals such as iron and steel.[6]

The National Electrical Code (NEC)[7] does not require copper grounding; instead, it requires permanence in metal electrodes and conductors to be used for grounding. Romanoff presented data in 1957 that shows the performance of copper in highly reducing soils, and those containing sulfides is not appreciably better than the performance of iron.[8] This observa-

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tion by Romanoff has been borne out in recent industry experience where severe corrosion of copper concentric neutral wires has caused failure in Underground Residential Distribution (URD) systems.[9] Copper experiences rapid corrosion in some soils. Additionally, we now have definitive evidence that an alternating current flow between soil and copper can contribute to an increased corrosion rate on the copper grounding conductor.[10] Even in soils where copper outperforms iron from a corrosion standpoint, copper may not have a sufficiently long service life to meet the life expectancy of the grounded structure or plant.

Corrosion engineers must overcome the "mind set" by power industry and electrical engineers over the exclusive use of copper as the only corrosion free material of choice for grounding systems. Copper's low volume electrical resistivity makes it an effective conductor and/or grounding electrode. In isolated systems it may perform admirably as a grounding electrode. The principle corrosion problem arises when the copper grounding system is tied in common with other underground metals. Since copper, as a part of an iron-copper couple, requires an inordinately large amount of direct current and is difficult to polarize, it places a burden on a CP system. This makes design of the CP system more difficult. Usually, the copper grid is placed in areas of the plant where it is already difficult to achieve CP on the underground piping because of the concentration of underground structures that increase the current required per unit volume in the soil. The net result is a requirement for a more elaborate CP system that may involve the expense of a distributed anode system.

Copper conductors may be insulated and still serve as a grounding conductor without serving the dual function of a conductor and a grounding electrode. If a sufficiently low resistance grounding system can be obtained with driven ground rods (or galvanic anodes), the grounding contribution of the bare copper conductor is not necessary. Case histories illustrate alternative grounding systems. Serious consideration should be given to these approaches to the problem.

Compressor stations

The author began designing zinc electrode grounding systems with neoprene insulated connecting cables for pipe line compressor stations 25 y ago. Since the underground piping was in common with the grounding system and was cathodically protected, there was no concern about galvanic corrosion losses on the zinc grounding electrodes. Use of the zinc grounding system made it easier to achieve effective levels of CP on the pressure and process piping close to the compressor building foundation. Similar systems have been used for years to ground pipeline motorized valves or to bleed off induced AC.[11]

Utility pier foundations

During recent dealings with a major southern electrical utility on corrosion control of power line structure footers, a review of the utility's standards drawings revealed drawings resembling Figure 1. A series of grounding resistance calculations was presented to show that very little grounding benefit was derived from installing a copper grounding plate beneath the poured pier.

Pier diameters ranged from 2.5 to 7.5 ft (0.76 to 2.3 m) and to 10 to 85 ft (3.4 to 26 m) in length. Using Institute of Electrical and Electronics Engineers (IEEE)[(1)] formulas,[12] the resistance to remote earth of a minimal column 2.5 ft (0.76 m) diameter by 20 ft (6.1 m) long with four number 16 (5.1 cm) rebars was calculated. When compared to the resistance to remote earth of a 1 ft (0.3 m) diameter copper plate, it was shown that the resistance of the four rebars was only 11 to 13% of the resistance of the copper plate, and the mutual interference (coupling) between the two closely spaced electrodes would further reduce the contribution of the grounding plate to the total resistance of the couple.

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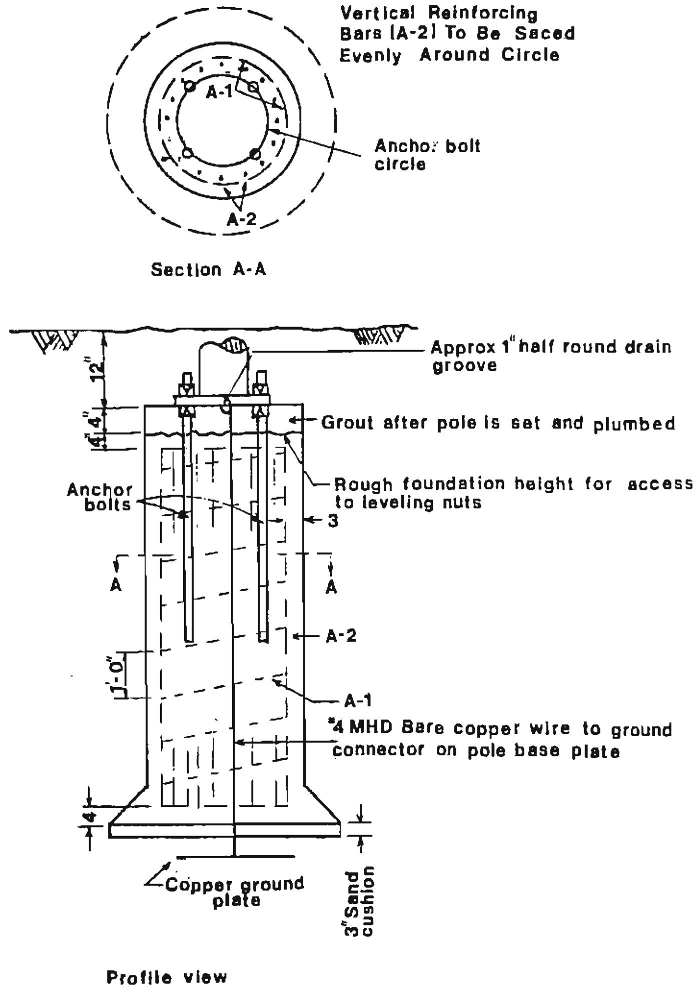

FIGURE 1 — Utility pole pier footing.

Clearly, there is little grounding benefit from providing the copper grounding plate under the poured pier. However, the copper grounding plate accelerates the corrosion rate on the galvanized steel pole that is in contact with the earth electrolyte. Because it requires approximately two orders of magnitude higher current density per unit area to protect bare copper in the soil compared to the current density required for iron in concrete, it can be seen that the copper represents a much greater liability from the corrosion standpoint than benefit from the grounding standpoint.[13]

Foundation grade beams

The NEC recognizes the use of rebar not less than 0.5 in. (13 mm), 20 ft (6 m) or more in length as a grounding electrode with the proviso that it is encased by at least 2 in. (5 cm) of concrete that is in direct contact with the earth. Steel below grade that is completely encapsulated in chloride free concrete may be expected to perform satisfactorily for long periods of time. Because of the large quantities of rebar that goes into the average commercial or industrial project, the grounding engineer should not want for an adequate ground. The biggest concern may be to limit the extent of the grounding network.

Substation grounding grid

Galvanized steel ground rods supplemented by CP have long been employed by the Rural Electrification Administration (REA) and others. More recently, entire grounding grids have been fabricated from galvanized steel rods and cable.[14]

Communications

Effective communications and education require more than talking or presenting your point of view. Effective communication with others requires understanding of the other person's viewpoint and problems. Engineers involved in forensic testimony have discovered that the successful trial lawyer has become far better versed in the engineer's specialty than the engineer would ever hope or desire to become in trial law.

When a corrosion problem arises from a grounding conflict, ask where and when there was a failure to communicate or educate. Corrosion engineers familiar with electrical grounding practices and principles can work effectively with other disciplines to meet the dual, and sometimes conflicting requirements of effective electrical grounding and corrosion control. By educating our electrical engineering counterparts about galvanic corrosion problems and offering acceptable alternatives to copper grounding electrodes, grounding networks can be obtained that are compatible with CP systems.

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