Conflict Between Copper Grounding and CP in Oil & Gas Production Facilities

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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. This article discusses the impact of the design and operation of massive copper grounding systems, ferrous underground piping, and cathodic protection in production facilities.

Traditional copper grounding systems are cost-effective. They reduce hazardous voltages associated with lightning and fault currents or induced currents in the earth to safe values.[1] Electrically interconnecting many dissimilar metals in the soil, however, can lead to significantly increased corrosion rates on some of the underground structures[2] and also places a tremendous load on the cathodic protection (CP) system.

Most electrical engineers specify copper for grounding electrodes because the metal is a good electrical conductor and because many perceive that it does not corrode when buried in the soil.[3] Nevertheless, copper does corrode when completely isolated. If it is electrically connected to ferrous metal, the copper will be cathodically protected at the expense of the ferrous metal. Also, copper does not polarize readily as does iron or steel. Consequently, it requires appreciably more current to protect ferrous structures connected to copper grounding than to protect the ferrous structures alone.

Case History: Pakistani Oil & Gas Production Facilities

Union Texas Pakistan (UTP) operates six major oil and gas production facilities and a number of smaller facilities in the Badin Block, Sindh Province. Figure 1 is an aerial view of one of the larger production facilities. These facilities are used to separate oil and gas, remove water, ship natural gas via pipeline, and store oil and distillate production in aboveground tank farms for later transport to refineries by tanker truck. Electrical power is generated on-site. The production facility discussed here handles both crude oil and natural gas and was brought online in about 1990.

CATHODIC PROTECTION

Initially, there were three CP rectifier (T/R) units at the facility. T/Rs 1 and 2 powered a total of 30 vertically installed distributed anodes around the perimeter of nine production tanks. T/R 3 powered a conventional remote vertical anode bed and was dedicated to CP of the incoming flow lines and trunk lines from remote production facilities. The three T/Rs, originally rated at 25 V 75 A direct current (DC), were capable of protecting the underground piping and minimal copper grounding system.

FIGURE 1

Aerial view of the Khaskeli Production Facility, which contains the Sindh Province discovery well.

COPPER GROUNDING

The original electrical grounding grid was constructed utilizing polyvinyl chloride-insulated copper conductor ranging in size from 16 to 95 mm^2. Grid conductors (70 or 95 mm^2) were connected to driven copper clad ground rods at 200 to 400 ft (61 to 122 m) spacing around the perimeter of the plant, with a few supplemental ground rods at major pieces of equipment.

Within the 5-year period prior to mid-1996, the grounding system was upgraded to "improve" the electrical grounding at each of the production facilities. This was considered necessary to ensure adequate fault-current protection should some electrical element short to ground. The upgrade consisted of bare-copper, 70- or 95-mm^2 cable laid in parallel with the existing insulated cable grounding grid. Each bare-copper grid was supplemented with additional copper ground rods, and a total of four "deep groundbeds" were installed. The deep groundbeds consisted of a copper plate ~1 m^2 in size and buried ~4 m deep. Three separate 95-mm^2 bare-copper conductors were exothermically welded to the copper ground plate and were brought up to a bus bar installed in an aboveground manhole. Given the very low electrical soil resistivity at this site (90 to 200 Ω-cm), the grounding system upgrade seemed unnecessary.

Following installation of the grounding system upgrade, corrosion failures became a serious problem at most of the production facilities. In a few instances, perimeter fencing fell down when the supporting poles corroded in two at grade level or underground because they had been bonded to the bare-copper grid. It was reported that numerous corrosion leaks, produced by active corrosion in flow lines, had been repaired. In some instances, entire segments of a pipeline were replaced with new pipe. Annual CP surveys indicated that the vast majority of the buried plant piping was not adequately cathodically protected following the grounding system upgrade. The majority of the underground piping exhibited pipe-to-soil (P/S) potentials less negative than –0.85 V referenced to a copper-copper sulfate ($Cu/CuSO_4$) electrode (CSE).

FIELD STUDY INITIATED

In late summer 1996, the author collaborated with in-country CP subcontractors and UTP personnel to conduct a detailed CP/electrical grounding survey of the major production facilities and most of the minor production facilities in Sindh Province.

Prior to this study, the company and contractor personnel disconnected the bonds to the perimeter fencing and disconnected most of the bare-copper perimeter ground loop from the plant grid. Perimeter-fence bonding is required at electrical-generating stations and at locations where external power is brought into a facility via overhead conductors[4] to protect personnel in the event of a falling conductor. Because neither of these conditions exist at the production facilities, perimeter fence grounding is not required. A perimeter-grounding conductor—with or without supplemental driven electrodes—would be beneficial if one needed to lower the resistance-to-remote earth of the overall grid. That was not the case.

RESISTANCE-TO-REMOTE-EARTH MEASUREMENTS

The investigators attempted to measure the combined plant/electrical grounding grid resistance-to-remote earth at one of the production facilities using the Institute of Electrical and Electronics Engineers (IEEE) Fall of Potential method.[5] The resistance-to-remote earth of the existing composite grounding grid and plant piping network was so low that it precluded measurement with available instrumentation. Neither of the alternating current ohmmeters available at the time of the survey could accurately measure a value of <0.005 Ω. Therefore, an alternative DC method was used. The differences in potential (ΔE) between the "on" and the "off" remote P/S potentials, measured while simultaneously cycling the T/R units, were used to calculate the resistance of the entire plant grounding grid to remote earth. These measurements were taken using a single, remote CSE placed

FIGURE 2

One of many excavations to disconnect bare copper conductors. Green PVC-insulated conductor in foreground is part of the original grid.

FIGURE 3

Technician servicing a resistor junction box at the Bukhari Gas Facility.

8,500 ft (2,590 m) from the plant site. When the interrupted P/S potential survey was conducted, the close P/S potential and the remote P/S potential were measured and recorded at each test site with the T/Rs both on and off. An average of the remote P/S ΔEs was divided by the portion of the T/R outputs that were contributing CP current to the plant piping only. This procedure disregarded the CP current that was applied to the flow lines.

The calculated resistance-to-remote earth of the production facility was 0.001294 Ω prior to removing the additional copper grounding and 0.00139 Ω after removing as much of the additional copper grounding as was safe and practicable (Figure 2). This represents a 7.7% increase in overall plant resistance. The final overall plant grid is still more than three orders of magnitude lower in resistance-to-remote earth than is required to operate a safe system, however. For on-site electrical power generation, an overall plant grounding grid resistance in the range of 5 to 25 Ω is considered adequate and safe. Therefore, the extensive grounding system upgrade was not necessary.

CP EVALUATION

The existing CP system was preferentially protecting the fire water (FW) loop and not providing enough CP current to the plant piping that contains the production fluids and gases. During the electrical grounding system digouts, deliberate cross bonds were made between FW piping and plant piping and between insulated plant grounding grid conductors and buried plant piping. This technique ensured adequate electrical continuity among the various systems—grounding grid conductors, production piping, and FW mains—to prevent cathodic interference problems. Cathodic interference had been noted at several locations. It usually occurred on the grounding grid that earlier had not been deliberately connected to the buried piping but was interconnected only by aboveground connections at various equipment skids. Approximately 890 lineal ft (271 m) of additional large-diameter, bare-copper grounding conductor was disconnected from the plant grid. As a result of work done during this study, neither the perimeter fencing nor the perimeter bare-copper grounding loop remained connected to the plant grid.

During the second survey, the researchers noted an acceptable decrease in P/S potentials on the FW lines because of the deliberate cross-bonding among the FW system, the buried plant piping, and the electrical grounding grid. At the same time, improvements were noted in plant piping and grid-conductor potentials. Because the remaining bare-copper grounding grid cannot be cut loose, the grid was bonded to the balance of the piping system; this was done to eliminate cathodic interference and to produce more uniform P/S potentials. Improving the cross-bonding and eliminating some of the bare-copper grounding led to more uniform and somewhat improved P/S potentials on the buried plant piping and eliminated cathodic interference among various elements of the underground system.

RECOMMENDATIONS

Specific CP system upgrade recommendations were made for each Badin Block facility.[4] They ranged from a few zinc anode and test lead installations in one remote production facility to the installation of one or two additional (and much larger) T/R units at some of the larger facilities. No upgrade in CP capacity was deemed necessary for many of the facilities. Removing excessive bare-copper grounding at these facilities was sufficient to restore effective levels of CP.

Two additional T/R installations were recommended at the plant discussed earlier. T/R 4 is a 10-V, 100-A unit powering a split horizontal distributed anode bed containing 11 anodes, installed on the west side of the plant. T/R 5 is a 10-V, 150-A T/R on the east side of the plant. This unit powers a 16-anode horizontal anode bed, which is fully remote from the plant piping. Thus, T/R unit capacity for the plant piping in the production facility was increased from 150 to 400 A—even after removing as much of the excessive bare-copper grounding as was practicable.

The investigators recommended using additional cross bonds and removing some of the resistor junction boxes (RJBs) that were used to cross-connect some of the plant piping (Figure 3). Some of the RJBs were appropriate to control P/S potentials on flow lines and other isolated piping. Within the plant site itself, however, the RJBs introduced unacceptably high resistances into the bonding circuits; this led to uneven P/S potentials and the possibility of cathodic interference on some of the underground structures. RJBs have also proven to be high-maintenance items.

RESULTS OF THE CP UPGRADE

The installation work for the CP system upgrades started in late 1997 and was finished 1 year later. All of the final data were gathered within a week of commissioning, which did not allow sufficient time for full polarization.[6] Nevertheless, the vast majority of the buried piping was adequately protected with a combined T/R output of 196.4 A, excluding current to the flow lines. The production facility covers a surface area of ~29.5 acres (12 ha). Therefore, the final average current density per unit area is ~6.658 A per acre (0.4 A per ha).

Conclusions

The grounding system upgrade, which was unnecessary from an electrical safety standpoint, completely overwhelmed the CP systems and led to excessive corrosion failures of the underground plant. As much bare copper as practical was disconnected and/or physically removed from the grid. Because of the presence of direct-buried high-voltage cables, more bare copper than was desirable remained in the ground. The remaining bare copper was successfully polarized by installing additional T/R capacity. A 167% increase in T/R and groundbed capacity was required.

References

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