

Supporting the Nation's Power Grid through Coatings Management

Proactive Coatings Maintenance Plans Abate Corrosion of Aging Electrical Transmission Structures

KATHY RIGGS LARSEN, ASSOCIATE EDITOR

The North American electricity infrastructure represents more than \$1 trillion in asset value and serves well over 100 million customers. It includes over 3,200 electric distribution utilities, more than 10,000 electric generating units with more than 1 million MW of annual generating capacity, and more than 300,000 miles (482,700 km) of transmission lines operating from 138 to 765 kV.¹⁻⁴ Millions of structures support these transmission lines; many of them are constructed of steel and it is crucial to protect these steel structures from corrosion so the integrity of the electrical grid is preserved and power transmission is not interrupted.



One of the great engineering achievements of the past 100 years, the North American electric grid was initially constructed in the 1890s and improved upon as technology advanced. It comprises a network of transmission lines, substations, and transformers that delivers electricity from power plants to homes and businesses. Over the years, the transmission lines have evolved into three major networks or power grids—the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. The Eastern and Western Interconnects are completely integrated with most of Canada or have links to the Quebec Province power grid, and both the Western and the Texas Interconnects are linked with different parts of Mexico. Virtually all U.S. utilities (except those in Alaska and Hawaii) are interconnected with at least one other utility by these major grids.⁴

Growth in power transmission during the 1950s through the 1980s led to the construction and installation of a large percentage of today's high-voltage transmission structures. NACE International member Curt Hickcox, vice president of Public Utilities Maintenance, Inc. (Queens Village, New York) and vice chair of NACE/IEEE joint Task Groups (TGs) 386⁽¹⁾ and 395⁽²⁾ that focus on coating maintenance for transmission structures, estimates there are ~2.5 million transmission structures (towers and poles) in North America, and ~500,000 of these structures are constructed of steel.

Approximately 66% of these towers and poles were built during the 1950s through the 1980s. Hickcox notes that ~63% of the towers and poles in use today, what he refers to as second-generation structures, have been constructed since 1970, and ~40% were built during the 1970s and 1980s.

Metal lattice towers are constructed of galvanized steel, aluminum, or black iron, and metal tubular poles are made of galvanized steel, carbon steel (CS),

or weathering steel. However, Hickcox says, the majority of these structures are galvanized steel that is either unpainted and weathered or previously painted. Although the steel structures are built with a design life of 80 to 100 years and can last indefinitely if properly maintained, the coating service life is much shorter and is largely dependent on the environment in which the structures are located and whether they are painted steel or galvanized steel. The average life of galvanizing on a transmission tower is 40 to 50 years, depending on the environment, Hickcox comments, noting that the galvanizing on a significant number of transmission structures in North America may be nearing the end of its service life.

"Many of these structures are near the 40-year mark," comments Hickcox. "These second-generation lines, due to their current age and large number of

structures, will significantly increase the overall maintenance work required to keep the transmission system safe and reliable, as many structures will require attention all at once."

The message that Hickcox and others in the corrosion industry want to convey to the electric utility industry, which often pushes transmission structures to the limits of their coating service life, is that proactive coating maintenance plans for these aging transmission structures should be developed now so that corrosion can be detected and addressed in its early stages, when corrosion mitigation is the most cost efficient. "The ultimate goal is to minimize overall cost over the life span of the structure by applying coatings that will provide the lowest applied cost-per-year protection," Hickcox remarks.

Transmission structures are susceptible to corrosion on both the below-grade

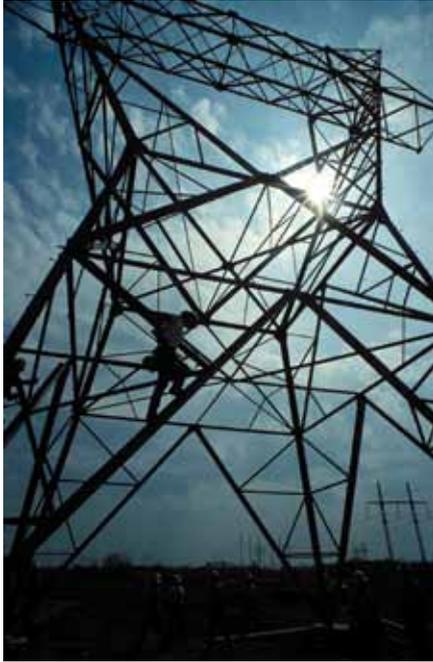


A painting crew coats a galvanized steel tower. Photo courtesy of Curt Hickcox, Public Utilities Maintenance, Inc.

(1) TG 386—Below-Grade Corrosion Control of Transmission, Distribution, and Substation Structures by Coating Systems.

(2) TG 395—Atmospheric (Above-Grade) Corrosion Control of Transmission, Distribution, and Substation Structures by Coating Systems.

portion of the structure that is buried in the ground and provides support, commonly referred to as the footing or foundation, and the above-grade portion of the structure that is aboveground and holds the transmission lines, Hickcox explains. Below-grade corrosion is affected by soil conditions as well as any stray current that may be present from



Workers conduct a final inspection of a newly installed galvanized steel transmission tower. Photo courtesy of Alan Holloman, Georgia Power Co.

other utility structures nearby. Most often, below-grade corrosion can only be detected by excavating the soil around the footing and examining the structure. Atmospheric corrosion impacts the above-grade portion of the structures and is influenced by the immediate environment—whether it's industrial with corrosive atmospheric emissions, coastal with atmospheric moisture and chlorides, dry with low atmospheric humidity and few pollutants, or a combination of several conditions. Above-grade corrosion can be seen from the ground or when flying over the structure.

Although the corrosion mechanisms for the below-grade and above-grade portions of the structures are quite different, coatings are used to protect both areas from corrosion. However, galvanizing and other coatings will eventually degrade to the point where they no longer protect the underlying steel substrate either below or above grade. As a structure's protective coating nears the end of its service life and the metal substrate starts to deteriorate from corrosion, the structural integrity of the tower or pole can be compromised depending on the degree of corrosion. This may pose a safety hazard for maintenance workers who climb the structures, as well as negatively

impact the integrity of the power grid and cause a widespread power outage, which can be very costly.

An Industry Cost-Saver: Catching Corrosion Early

Galvanized transmission structures constructed 30 to 40 years ago typically were coated with 6 to 8 mils (152 to 203 μm) of galvanizing, says NACE member Steve Feldman, director of sales—USA/Canada for PPG Protective & Marine Coatings (Pittsburgh, Pennsylvania) and a NACE-certified Level 3 Coating Inspector. Because corrosion grows at an exponential rate if the coating is not maintained, Feldman stresses that the above-grade portion of a tower or pole that was corrosion-free for 25 years or more can become 100% rusted in as little as 10 years once corrosion is initiated. He adds that maintaining the coating on a transmission structure when above-grade corrosion is in an early phase can extend the coating life of the structure for an additional 20 to 35 years (depending on the structure's atmospheric environment) at a substantial cost savings.

For example, Feldman explains, a structure in an early phase of corrosion with 5% rust—cosmetic rust known as “coffee stain” rust that mainly appears on edges and bolts—typically has 1 to 2 mils (25 to 51 μm) of galvanizing remaining on the substrate. Coating maintenance normally requires minimal surface preparation and the application of one coat (6 to 8 mils) of a zinc-rich coating, which can be accomplished while climbing the structure one time.

If coating maintenance is not performed during an early stage of corrosion and the structure moves to an intermediate corrosion phase where 50% of the structure is rusted—most of the original galvanization is gone; rust is flaking off and the structure is experiencing metal loss; and corrosion is found on bolts, angles, edges, and horizontal flat surfaces—more surface preparation using hand tools (wire brushing or scraping) is required, spot priming or a full prime coat should now be applied, and the structure may need



A recently repaired embedded steel footing is shown. Photo courtesy of Alan Holloman, Georgia Power Co.

to be climbed twice to clean, prime, and coat it with a protective zinc coating. Feldman notes that the cost to recoat a structure with 50% rust may be up to 40% higher than the cost to coat a structure with 5% rust.

In an advanced corrosion phase, where 100% of the structure has corrosion, Feldman comments that metal may need to be replaced, the structure's entire surface will need to be hand-cleaned and fully primed, and an intermediate coat or sealer may be required before applying the final zinc-rich coating, which may require the structure to be climbed three times to complete the coating work. The cost to repair and recoat a structure that is 100% rusted is typically more than double the cost to recoat a structure with 5% rust and ~1.5 times the cost to coat a structure with 50% rust, he says.

For utilities responsible for maintaining thousands of metal transmission structures, recoating structures before they move from an early stage of corrosion to a more advanced stage can save millions of dollars, Feldman emphasizes. "A proactive coating maintenance program will protect the steel structure and extend the asset life, ensure a stable electrical power supply, minimize outages, minimize lead exposure [which may be contained in the original coating], enhance the structure's aesthetics, and protect the electric grid of this country," he says.

Georgia Power's Coating Management Program

To safeguard the integrity of its transmission infrastructure, Georgia Power Co. (Atlanta, Georgia) implemented a coating management program in 1998, says NACE member Alan Holloman, chair of NACE/IEEE TGs 386 and 395 and transmission team leader, maintenance and reliability, with Georgia Power Co., which is the largest subsidiary of Southern Co., one of the nation's largest electricity generators with 27,000 miles (43,443 km) of transmission lines, 3,700 substations, and 300,000 acres (121,410 ha) of right of way. Holloman comments that Southern Co. has more than 250,000 transmission structures, including more than 55,000 made of steel, throughout Georgia, Alabama, the coastal region of Mississippi, and the Florida panhandle. Many of the steel structures are in environments that are very corrosive, he says.

"Our goal is to keep a structure in service as long as possible. Because galvanized steel has to be managed and maintained—particularly those structures that are 40 to 50 years old—it is important to have a thorough inspection program," Holloman remarks. He comments that Georgia Power has some galvanized steel structures in service in the northeastern part of Georgia that are over 100 years old.

The coating management program in place at Georgia Power incorporates an inspection and repair process that

pinpoints and resolves key maintenance issues on steel towers and poles, he explains, adding that the company continually evaluates and ranks its transmission structures against a specific standard, and recoats the steel structures based on their ranking. When the program was initiated, the entire transmission structure system was evaluated. All structures 50 years old and older were inspected first. When the assessment of those structures was completed, then all remaining structures were assigned to a maintenance cycle.

As part of the overall inspection program, a visual inspection of every transmission structure is currently done at least once annually from a helicopter or airplane and at least once every six years from the ground. Any abnormal situations are noted and assigned a priority code that designates a maintenance timeframe. Every 18 years, a ground line inspection—conducted in the 2-ft (0.6-m) sections above and below the ground line (known as the transition zone)—evaluates a structure's concrete foundations and metal footings for corrosion and metal loss.

The ground line inspection, conducted by a specially trained crew, calls for excavating and cleaning embedded steel footings. During a ground line inspection, a structure is rated on a scale of one (like new condition) to five (worst condition) and the data is collected in a hand-held computer. Depending on the rating, the structure is either coated or scheduled for repairs at the transition zone. During the ground line inspection,



The photos show a broken foundation found during inspection (left) and a repaired foundation with a ground line coating (right). Photo courtesy of Alan Holloman, Georgia Power Co.

the rest of the structure is visually assessed as well and any potential issues, including the quality of the coating, are noted and rated on the same scale.

Holloman notes that the ground line coating management program now has been through one complete maintenance cycle and all structures are scheduled to be inspected again on an 18-year cycle. This means that each year over the next 18 years, about 6% of the steel transmission structures will be scheduled for reinspection at the ground line.

Standards Being Developed for Coating Maintenance

One of the challenges facing the electric utility industry is staying focused on inspecting transmission structures and catching and repairing potential problems before they turn into real problems, Holloman observes. "We do not want to do things prematurely, but we don't want to have to make repairs because something failed. That is why it's so important to have a good, thorough inspection assessment and maintenance program," he says.

To help the electric utility industry develop both above-grade and below-grade coating maintenance plans for transmission structures, the two NACE/IEEE joint task groups—TG 395 and TG 386—are currently developing standard practices to assess and repair above-grade (TG 395) and below-grade (TG 386) coatings on in-service transmission, distribution, and substation structures. "We want to provide utilities with a tool that will help them to quickly put together a coating maintenance program, and these standards will provide a very good starting point," Hickcox says. The proposed standards, initiated four years ago, are the first to address above-grade and below-grade corrosion control for transmission structures.

The standard under development for above-grade coatings will provide a procedure that can be used to assess structures for atmospheric corrosion and assess a structure's risk level in terms of corrosion attack and degradation to the existing coating system. This will enable personnel responsible for maintenance painting to make informed decisions,

based on those assessments, regarding the necessity of a coating repair and the extent of the repair. The standard will also serve as a resource for preparing specifications to achieve the successful coating of utility structures. Some of the topics covered in the standard may include inspection and assessment, coating system selection, application methods, contractor qualification, and performance monitoring. The standard isn't expected to address mechanical or structural damage, mechanical or structural repairs, or structural integrity.

According to TG 386, the current procedure for assessing and repairing below-grade coatings on in-service steel transmission, distribution, and substation structures is a subject of much discussion and, in some cases, disagreement. A wide range of generic repair coatings is used for below-grade portions of transmission structures, including polyurethanes, epoxies, bitumen-based coatings, alkyds, and hot- and cold-applied tape-wrap systems, as well as various combinations of these coating systems and newly developed coating systems. This presents a very complex array of possible coating systems that may have been applied over the years to in-service transmission structures.

The standard being developed for maintenance of below-grade coatings will provide general coating repair guidelines for in-service CS and galvanized steel structures coated with polyurethanes, moisture-cure urethane (MCU) coal tar epoxy, coal tar epoxy, and cold-applied tape systems including petrolatum and polyethylene. It will also provide procedures for identifying structures that may be at higher risk for below-grade coating degradation, excavating and inspecting the selected structure, and assessing the level of risk to the structure in terms of corrosion attack and degradation to the existing coating system. Field repair technicians, inspectors, and others can refer to the standard when assessing the extent of needed repairs, prioritizing structures to be repaired, and applying repair coatings to the structure. Additionally, the standard will provide guidelines and repair procedures for coating systems most commonly applied to below-grade

structures and typical of what inspection and coating repair crews most often find. It won't address structural damage assessment, structural repairs, weathering steel, structural integrity, or concrete foundations and above-grade attachment points.

"We have just started to really focus on the transmission infrastructure at NACE and we've got to continue this endeavor and get more electric utilities involved with NACE. Individual utilities across North America would have input into what will make the best standard and what makes the best sense for managing and maintaining our system," says Holloman.

Both NACE and IEEE have sponsored balloting of the two standards to their membership. According to Hickcox (at press time), balloting has passed both standards and the NACE/IEEE task groups are now working to resolve negative comments. He expects the two standards to be published sometime in 2012. Additionally, other NACE task groups, which are part of Specific Technology Group (STG) 41—Electric Utility Generation, Transmission, and Distribution, are in the early stages of standards development that address original equipment coatings for transmission structures, including both below-grade and atmospheric exposure. More information about the NACE/IEEE joint task groups and the draft standards is available on the NACE Web site: www.nace.org.

Bibliography

C. Hickcox. "Maintaining the Electric Grid: It's Time." *JPCL* 27, 7 (2010).

References

- 1 "Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations," U.S.-Canada Power System Outage Task Force, April 2004.
- 2 "What is the Smart Grid?" U.S. Department of Energy, http://www.smartgrid.gov/the_smart_grid#smart_grid (October 24, 2011).
- 3 "The Changing Structure of the Electric Power Industry 2000: An Update," U.S. Energy Information Administration, DOE/EIA-0562(00), October 2000, pp. 13-14.
- 4 "What is the electric power grid, and what are some challenges it faces?" U.S. Energy Information Administration, http://www.eia.gov/energy_in_brief/power_grid.cfm (October 24, 2011). **MP**