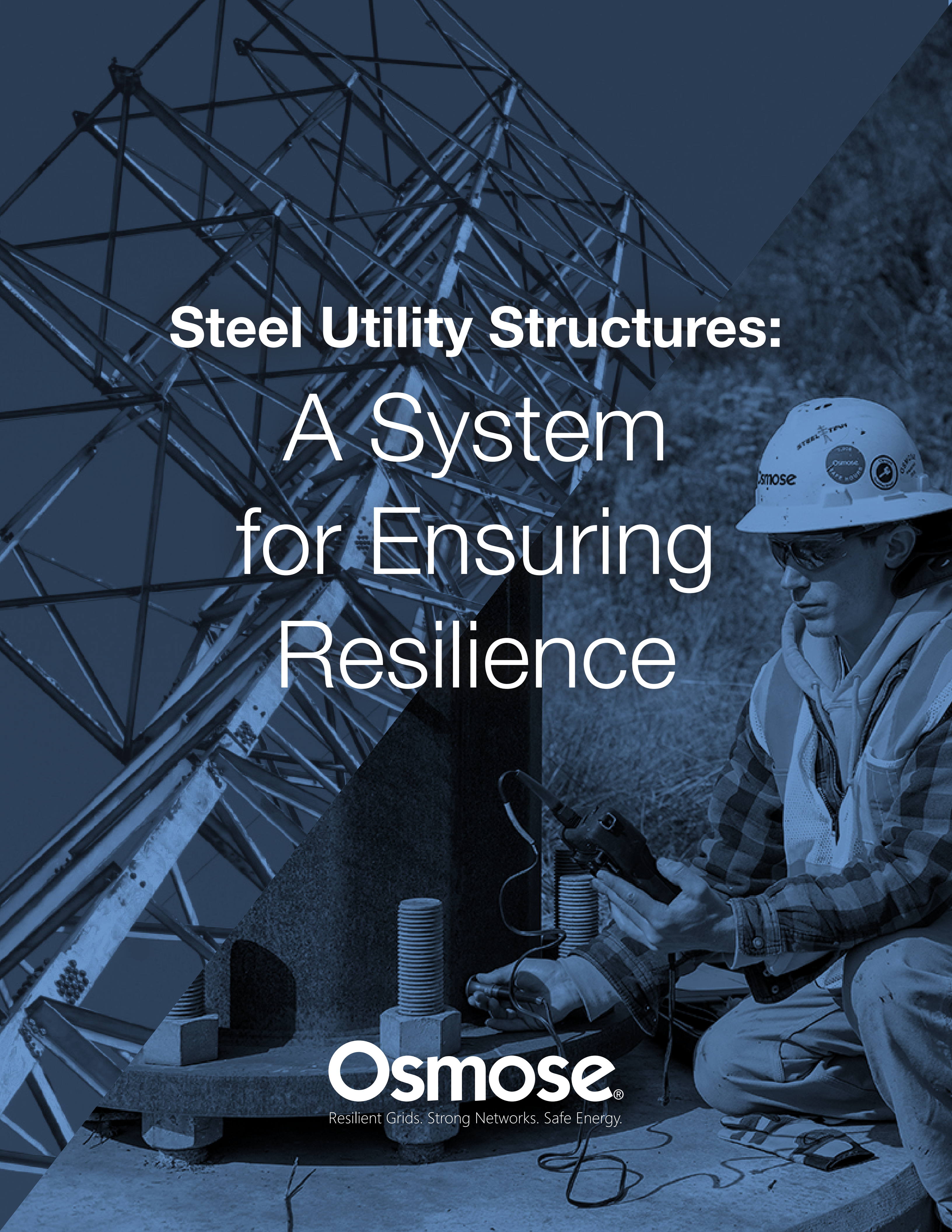

Steel Utility Structures:

A System for Ensuring Resilience

Osmose

Resilient Grids. Strong Networks. Safe Energy.

Summary

Steel structures are an essential component of America's electric grid infrastructure.

As they age, these structures require appropriate care or they will put the grid's resilience in jeopardy.

For more than 20 years, Osmose has pioneered effective processes for steel structure asset management. Osmose's methods offer utilities a thoroughly planned, systemic, and cyclical approach.

As old steel structures are increasingly found to be in poor condition — and demands on the grid grow — Osmose provides a strong best-practice process for utilities maintaining steel assets.

The Situation with Steel

The U.S. transmission and distribution (T&D) system is the world's largest machine. Paramount to electric distribution, it delivers power from nearly 3,000 power plants and thousands of renewable resources facilities (wind, solar, etc.) to virtually every building and facility in the nation.[1]

Once the envy of the world, America's energy infrastructure is aging and has fallen into decline, earning a C- grade from a leading engineering society.[2] Today, the U.S. has more power outages than any other developed country: average utility customers in the U.S. spent more time with their lights out than eight other industrial countries, according to one analysis.[3]

The industry faces a crisis whose source can be summed up in one word: steel.

Steel is just as vulnerable as wood to deterioration from climactic factors, but utilities have wrongly considered steel a perpetual building material. Instead of lasting forever, steel structures need to be maintained. Utilities have been slow to perform the necessary upkeep—let alone upgrade their systems—and that history of poor maintenance is compounding the problem.

Standard steel structure inspection methods also fall short. Utility employees may walk the T&D lines looking for visible issues, while all the time the most concerning problems are hiding under ground, where steel is corroding. Or, the unseen problem may be hanging high above – out of the employee's view - where insulator attachments or conductor problems can create structural risk.

1. National Academy of Engineering
2. American Society of Civil Engineers' Report Card for America's Infrastructure (2017)
3. "The US has more power outages than any other developed country. Here's why." Popular Science. August 2020. https://www.popsci.com/story/environment/why-us-lose-power-storms/

Outages on the Rise

Traditionally, severe weather events have represented the majority of power outages. That's being exacerbated, of late, by climate change. Outage hours in the United States rose 73% from in 2020 compared to 2019 according to PowerOutage.US.[4] Moreover, estimates of outage causes and conditions almost certainly do not reflect the true numbers, given the inherent tendency in self-reporting to err on the conservative side.

The surge of wildfires on the West Coast is one of the best examples of the convergence of climate change factors, severe weather, and transmission failures. Indeed, PG&E filed for voluntary Chapter 11 bankruptcy protection in 2019, succumbing to liabilities stemming from wildfires in Northern California in 2017 and 2018.[5] Wildfires and severe weather continue to rise in frequency and intensity, posing a grave threat to steel transmission towers.

Steel Tower Corrosion and Wildfires

Cause & Effect

Camp Fire, the deadliest wildfire in California history, burned more than 150,000 acres and killed 85 people in 2018.[7] In 2019, PG&E filed for Chapter 11, succumbing to the increased liabilities stemming from wildfires, a direct result of electrical transmission line failures owned and operated by the utility. Since then, **wildfires have only gotten worse**.

Not only can failing steel structures ignite wildfires, but conversely wildfires can also cause steel structures to fail, due to the effects of high temperatures on the structures themselves. In the galvanizing process, steel is submerged in a bath of molten zinc to create a uniform protective barrier on its surface. Brushfire temperatures reaching between 1500°F and 2500°F, depending on concentration of fuel source, significantly weaken or strip away the zinc coating entirely, leaving the steel pole at greater risk of corrosion.

4. "US power outages jumped 73% in 2020 amid extreme weather events," SB Global. Retrived 7/12/21. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/us-power-outages-jumped-73-in-2020-amid-extreme-weather-events-62181994
5,7. "PGE owner of biggest US power utility files for bankruptcy," CNBC. Retrieved 1/19/21. https://www.cnbc.com/2019/01/29/pge-owner-of-biggest-us-power-utility-files-for-bankruptcy.html
6. "PG&E transmission lines caused California's deadliest wildfire," NPR. Retrieved 1/21/20 https://www.npr.org/2019/05/15/723753237/pg-e-transmission-lines-caused-californias-deadliest-wildfire-state-officials-sa

America's Grid Is at Risk

America's steel transmission structures are in increasingly poor condition, putting grid resilience at risk. Both transmission and distribution systems in the U.S. are in urgent need of expansion, refurbishment, and upgrading to support increased demand and counteract continued condition decline. While there's been an uptick in transmission investments, America still faces an estimated $35.4 billion investment gap through 2039, compounded by renewable energy generation needs over the coming decade.[8]

There are direct economic consequences to not addressing the problem: Underinvesting in the grid will lead to inefficiencies in the delivery of electric power that are projected to cause each U.S. household to lose $5,800 in disposable income on average from 2020 to 2039.[9]

8,9. Report: "Electric Infrastructure Investment Gaps in a Rapidly Changing Environment," ASCE (accessed 12/19/20) https://www.asce.org/uploadedFiles/Issues_and_Advocacy/Infrastructure/Content_Pieces/Failure-to-Act-Energy2020-Final.pdf

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T&D: A Backbone Bending

Nowhere is the decline in structural resilience more apparent than in the backbone of the T&D system – the millions of steel transmission structures across the U.S.

Once touted as a near-indestructible material requiring little or no maintenance, steel, it turns out, does have weakness: corrosion. Over time, the strength of steel structures diminishes due to corrosion, reducing their reliability and making them more prone to failure.

In addition, the initial protection applied to these structures during fabrication and construction has continued to diminish. Galvanization may age out in less than 30 years below grade, leaving steel vulnerable to corrosion after just 40 years or less in some underground environments.

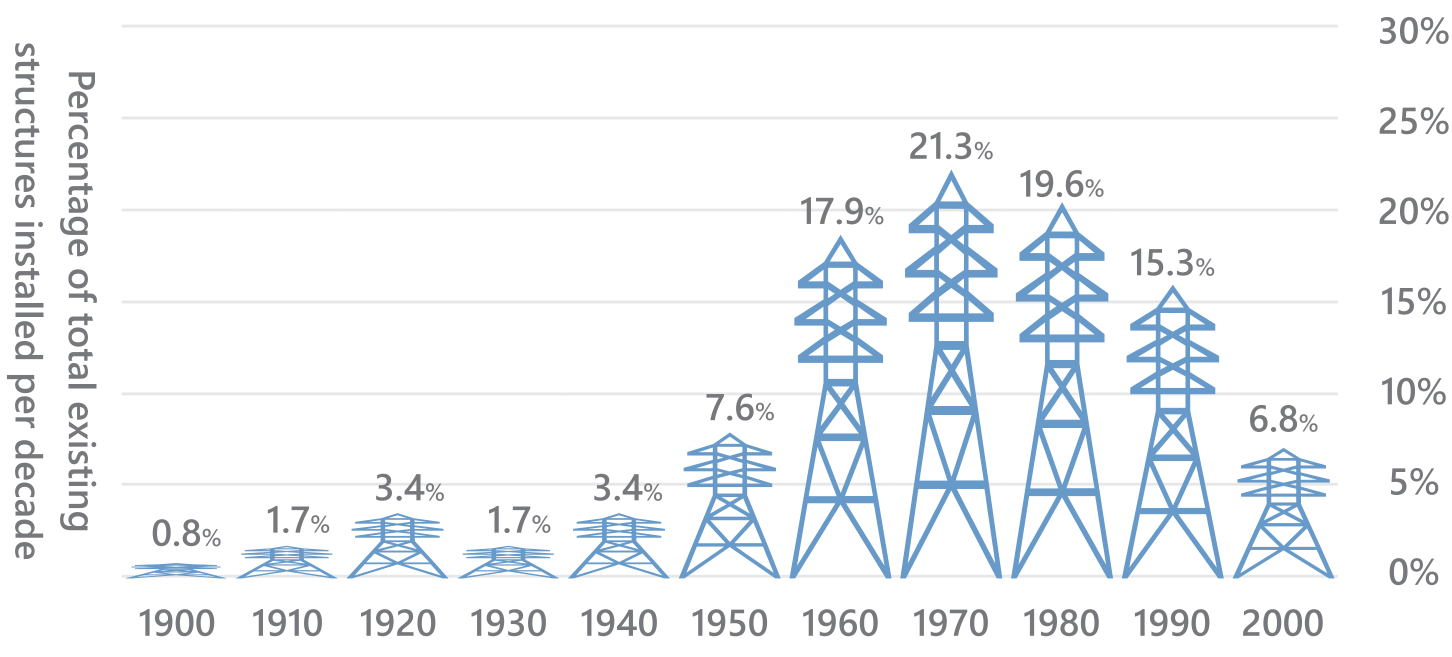
A major steel industry association claims the average life span of a steel structure is 60 to 80 years. In the U.S., the average age of a steel tower in service is more than 60 years old. Clearly, steel transmission structures are now showing their age.

Corrosion Wave Demands Attention

The power industry started using steel transmission structures about 75 years ago. The majority of steel poles and lattice towers were installed between 1950 and 1990. Today, these aged steel structures are reaching a point of degradation that puts the grid at risk, but they have yet to be assessed and addressed with proper remediation. (See figure below)

In our work of assessing steel structures for utilities, we have seen a wide array of disturbing issues like, for instance, towers with three of their legs so corroded that they are effectively standing on one leg. Without proper attention now, utilities may become overwhelmed by an increase of steel structure corrosion issues, and find themselves without the necessary resources to adequately revitalize a large percentage of their steel assets.

There are waves of aging steel structures that have yet to be assessed and addressed with proper remediation.



Source: Journal of Protective Coatings and Linings; Volume 27/Number 7; July 2010

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Reliability versus Resiliency

As our infrastructure ages, reliability, safety, cost management—and, most importantly, resilience—become the focus of increased scrutiny. Resilience, once considered a nice-to-have capability, is now being viewed by regulatory authorities as a categorical imperative.

But before discussing the role of resilience in the power infrastructure, let's define what we mean by reliability and what we mean by resilience.

Reliability is the ability of the electric power or telecommunications system to deliver expected service through both planned and unplanned events. Reliability represents the capability of the system to deliver consistent, predictable service on a day-to-day basis to its customers.

Resiliency, on the other hand, refers to the ability to bounce back and, in the longer term, the ability to stand up to tough circumstances. Resiliency is a measure of the system and its assets to withstand unusual forces and then recover quickly.

Grid resilience along with backup generation and storage is a priority for each and every utility: Asset owners need to know where their greatest risks lie, define what they are, and budget resources to address them. Achieving resilience involves a two-pronged approach. First, it calls for a systemic holistic perspective, rather than a piecemeal process; and second, it requires a cyclical and systematic program that can return measurable long-term results.

Osmose's approach to steel grid structure maintenance impacts the system as a whole, which contributes to the resiliency of the system and increases reliability.

> "Resilience and reliability concerns are increasingly driving infrastructure investment. While weather has always been the number one reliability threat, the number and intensity of disaster events and associated costs is accelerating."
>
> **According to the American Society of Civil Engineers' report, "Failure to Act - Electric Infrastructure Investment Gaps in a Rapidly Changing Environment."**

Building Resilience:
Why Reliability Is Not Enough

The grid is a complex system comprised of myriad subsystems including the many foundational structures that physically support it—and each of those structures represents a subsystem all its own. Supporting such a complex system requires a smart, systems-engineering approach. This is especially true for the care and management of the steel structures that are the cornerstone of an electric utility's transmission infrastructure.

Grid reliability, which the North American Electric Reliability Corporation (NERC) defines as a combination of grid adequacy (having sufficient generation to meet load) and grid security (having the ability to withstand disturbances), is a conceptually sound but incomplete framework for the nation's 21st century smart grid. Instead, the U.S. needs a grid that adapts to both large-scale environmental and unnatural events and remains operational in the face of adversity, minimizing the catastrophic consequences that affect quality of life, economic activity, national security, and critical-infrastructure operations. The concept of reliability must be augmented with a resiliency approach, one that looks at the grid not strictly as a flow of electrons but as a grid that serves, interfaces with, and impacts people and societies. Put another way, it is the consequences, not the outages per se, that matter.[10]

How do we build resilience?

- Start with a smart, scalable, and efficient remediation approach.
- Use a systemic and systematic technology-based approach to estimate and predict the future condition of steel towers and poles.
- Base assessments on an understanding of key corrosion variables, the nature of assets in place, and a database of actual steel structure performance.
- Develop a life extension program to reset asset life to a like-new condition instead of following a dead-end run-to-failure methodology.

10. Grid resilience, Sandia National Laboratories. Retrieved 1/22/21 https://energy.sandia.gov/programs/electric-grid/resilient-electric-infrastructures/

A Complete Approach: Analysis. Assessment. Mitigation. Restoration.

Having pioneered the practice of steel structure management for utilities, Osmose provides the best example of how to deliver sufficient stewardship—breadth of solutions, technical depth, and field excellence—to safely and efficiently manage this critical asset class.

And it begins with a key first step: Analysis.

Until recently, steel asset management programs relied on excavating every structure and applying a protective coating where corrosion was found. This method, while effective, was time-consuming and could rapidly eat up O&M budget dollars.

Now, digital innovation has enabled fact-based analysis of steel assets to prioritize the approach field staff takes to on-site asset assessment. Osmolytics® is a predictive analytics platform for steel corrosion that leverages our knowledge, circuit data, site conditions, and empirical data to provide solutions to help manage steel assets with greater foresight and certainty.

By making use of basic circuit information including structure type, age, and site soil characteristics, we can determine overall site conditions. With this information, we assign risk factors to prioritize specific circuits and enable the development of scalable intelligent methods to perform more efficient field assessment.

Accelerated Assessment

For utilities managing large concentrations of steel structures with limited O&M dollars, accelerated field assessment provides an alternative method that balances efficiency and accuracy in a pragmatic and cost-effective way. It draws on the extensive data in Osmose's analytics repository as well as the experience of our technicians, engineers, scientists, and corrosion experts, utilizing their knowledge to identify, prioritize, and solve issues to make utility infrastructure safer, longer-lasting, and more resilient while lowering the total cost of ownership.

One of the advantages of an accelerated assessment compared to a more comprehensive approach is speed. With an accelerated assessment, the utility can address three times or more the number of structures relative to a full-fledged approach. The burden on O&M resources decreases, as smaller teams doing partial investigative excavation can cover the system more quickly while still surfacing a majority of system defects. An accelerated assessment also provides a broad overview of where and how to prioritize resources and a more targeted approach to mitigating steel structure issues.

An accelerated assessment includes the following elements:

Visual Assessment – An above-grade visual assessment of all structures is made from ground line to the top of the structure for clearly visible defects.

Brush Removal – Brush is removed from around the structure to allow for proper excavation and assessment.

Excavation – A limited "partial" excavation is performed on the structure to expose the ground line area of the structure for visual examination. Additional excavation may be done when corrosion damage is indicated and steel thickness must be measured.

Structural Measurements – Steel thickness measurements are taken only where corrosion damage is evident.

Concrete Assessment – In addition to the corrosion assessment, and only where applicable, concrete foundations are evaluated by visual assessment.

Foundation Hardware – Additional foundation hardware such as anchor bolts and other items receive a visual assessment.

Environmental Measurements – Site environmental factors may be measured by indirect field assessment techniques to determine current corrosion conditions and for future corrosion potential.

Images - Inspectors may take images of pertinent structural conditions such as corrosion, mechanical damage, or other maintenance-related conditions.

Backfill - After excavation, structures are solidly back-filled and tamped around the structure.

Data Collection – All information collected is entered into a handheld computer while in the field.

Mitigation – No mitigation takes place in this accelerated approach.

Comprehensive Approach

If a utility is managing a relatively small set of steel assets and wants to institute a thorough program that can ensure structure soundness for 15 to 20 years, a comprehensive assessment provides the most practical solution. A comprehensive assessment involves fieldwork during which technicians assess the steel structures directly embedded in the ground. [See case study of a comprehensive assessment.]

The work involves excavating and evaluating the foundation, identifying issues, cleaning and preparing steel for protective coatings, and applying coating, and backfilling. Comprehensive programs are bespoke and tailored to meet client-specific needs. For example, a comprehensive program may include the following assessment elements depending on the structure types encountered, field conditions, and applicability.

Visual Assessment – An above-grade visual assessment of all structures shall be made from groundline to the top of the pole for clearly visible defects.

Excavation – Where applicable, structures passing the above ground visual assessment shall be excavated and cleaned to a depth of 18 inches below groundline. If any evidence of corrosion exists, an additional 6 inches will be excavated to a total depth of 24 inches below ground line.

Structural Measurements – Steel thickness measurements are taken with an ultrasonic thickness gauge, caliper, micrometer, or other similar measurement device according to the structure type and as determined appropriate by the contractor. Pit depths are measured with a pit gauge or similar device.

Concrete Assessment – Concrete foundations will be evaluated by a visual assessment and rudimentary hammer impact test.

Foundation Hardware – Additional foundation hardware components such as anchor bolts and other items are inspected, assessed, and assigned a condition rating.

Environmental Measurements – Site environmental factors may be measured by indirect field assessment techniques to determine current corrosion conditions and for future corrosion potential.

Images – Inspectors may take images of pertinent structural conditions such as corrosion, mechanical damage, or other maintenance-related conditions.

Mitigation – Depending on the structure type, location, and material, mitigation in the form of coatings and cathodic protection may be applied if the assessment warrants it.

Backfill - After excavation, structures are solidly back-filled and tamped around the structure.

Data Collection – All information collected is entered into a handheld computer while in the field.

Additional Task Items – These items may include ground wire repair, attachment of signage, and other work items as necessary.

Case Study: Comprehensive Assessment

A large regional electric utility retained Osmose's services to conduct a comprehensive assessment of its 40,000-plus steel structure assets. In the first phase of the project, we assessed 821 structures and determined that out of those 102 (or 12.4%) required immediate attention. The client decided to proceed with restoring and extending the assets' life, rather than waiting for the assets to fail and replacing them with brand-new steel structure.

Cost to **restore** the 102 steel structures:

$6,700 average per structure

$683,400 total

Cost to **replace** the 102 steel structures:

$87,000 average per structure

$8,874,000 total

Utility Savings: $8,190,600

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Continued Innovation

Osmose almost certainly invests more resources into operational innovation on behalf of its customers than any other grid structure services provider. Our R&D initiatives to improve utility steel asset management drive continuous innovation.

One recent Osmose innovation adds another level of thoroughness to the company's systems approach to steel structure management. SteelCalc™ is an advanced condition rating system that provides a groundline resiliency assessment based on the unique geographical and physical characteristics of the structure.

This new system takes analysis of steel structures beyond a basic examination of the extent to which a structure's supports ("members") are thinning:

- SteelCalc incorporates actual structure loading and utilization characteristics to prioritize members and structures, going beyond just section loss, to determine structure health. (Section loss is the amount of metal loss or deterioration at a given location due to wear and tear.)

- This innovation allows for a more objective prioritization of treatment, improved risk mitigation, and optimal use of capital for a utility's steel assets.

Conclusion

Regulators and customers are demanding greater resilience from electric utilities in the face of climate change and increasingly more extreme weather events. The challenge for utilities is to provide structural resilience, dependable reliability, and worry-free operations at a lower total cost.

The utility grid is a complex system comprising myriad subsystems. Supporting such a complex system requires a smart, systems engineering approach. This is especially true for transmission infrastructure: While the steel transmission structures appear to be a sturdy, enduring asset, they are actually vulnerable to a wide range of detrimental factors, from environmental conditions and increased loads to mechanical damage. Adding to the complexity, many of the threats to steel structures are hidden from sight and are often overlooked as a result.

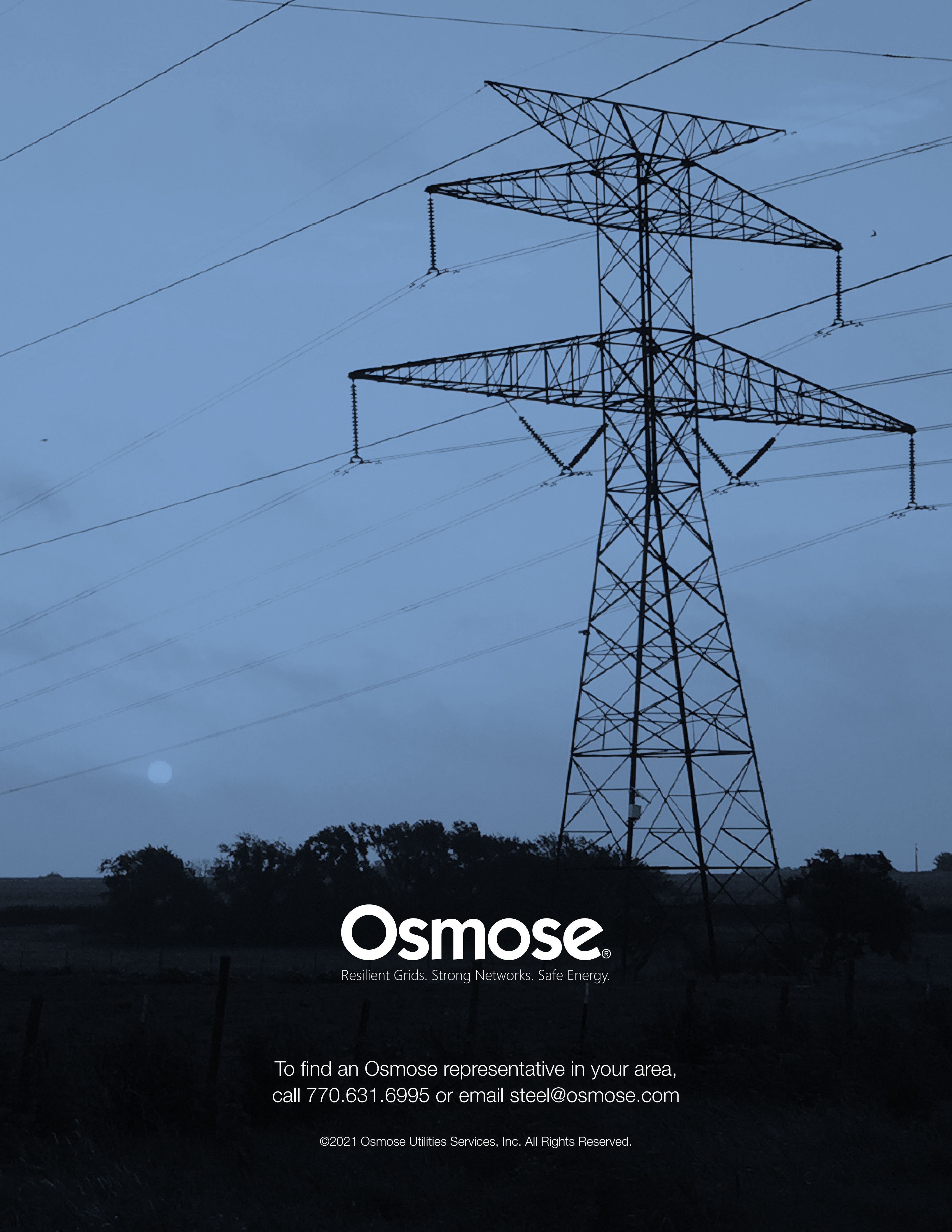
Utilities often lack the expertise or workforce to address the array of factors that can afflict steel structures and take a data-driven, integrated systems approach to managing these assets. As a result, many are playing with fire, operating at an excessive, sometimes unknown risk level and potentially facing an enormous expense to replace their steel structures.

Steel asset management is at the core of the Osmose business model. Since few utility companies employ large teams of corrosion science experts our job is, in part, to fill the gap. As a partner with electric and telecom utility companies, our work ensures safe, effective grid asset performance.

An accurate, consistent, and efficient systems approach to steel assets contains four major components: analysis, assessment, mitigation, and a restoration that includes engineering services. Osmose's approach—and the digital and process innovation that supports it—gives us unparalleled insight into the issues facing steel structures and allows us to develop smart restoration and mitigation solutions for compromised steel and concrete structural components. We literally can see inside of structures and identify what most utilities can't see: the corrosion that is otherwise invisible to the eye but is constantly active. As one famous singer put it, "…rust never sleeps…".

Osmose has restored and extended the lives of thousands of steel transmission structures over the past 20 years. That experience, and the extensive amount of steel and concrete degradation data we have gathered, informs our transmission asset management practices.

We pioneered fully integrated, systematic steel structure assessment and maintenance services for the utility industry. By doing so, we help provide solutions to manage the operation and maintenance of these assets so that you can focus on the long-term strategic issues facing your business.



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