WHITE PAPER

Revolutionizing substation maintenance practices to optimize reliability

Maintenance strategies
'Smarter' assets are evolving

For both utilities and industrial facilities, substations are keystone assets. When there's an issue at a substation, the resulting problems can be widespread and significant. In the quest for greater reliability and more efficient operations, traditional approaches to maintenance are increasingly falling by the wayside as substation owners join the revolution and adopt more predictive maintenance approaches. The demand for improved system reliability is also significantly increasing.

The maintenance revolution has been underway in industry for many years. Both process and manufacturing facility operators have embraced the seismic shift from traditional maintenance practices to a very different and far more effective approach. Today the revolution has grown to include utilities and other organizations engaged in power generation, transmission and/or distribution.

The revolution is the movement from cycle, time, or usage based maintenance to a predictive maintenance approach grounded in actual need rather than arbitrary schedules. The revolution is being propelled by the ever-increasing number of more intelligent devices that self-monitor critical asset health attributes and automatically report that information to facility operators.

These smarter devices – with the ability to "see, hear, and feel" – provide information that, combined with test and inspection data, enable substation owners to implement a far more efficient and effective maintenance strategy, with greatly increased asset reliability. The ISO 55000 asset management standard underscores the criticality of understanding asset condition and risk of failure, classifying the availability of that knowledge as a best practice.

Respondents to a recent global survey of 220 utilities put asset management ahead of other business efforts, with 52% saying it is a high priority. In the same survey, 55% of respondents said concerns about asset management are more important today than 12 months ago. Maintaining asset health through appropriate maintenance is central to an effective asset management strategy.

This white paper begins by comparing traditional maintenance strategies with the evolving strategies enabled by today's smarter assets. It goes on to lay out the reliability, cost, and other benefits of a more predictive maintenance model.

Triggers for maintenance activity

Car manufacturers long recommended oil changes every 5,000 miles and tire rotations every six months, with fine print that the interval be shortened based on harsh use or conditions. But it's intuitive that this arbitrary maintenance schedule made little sense. Whether your car was driven gently in a mild climate or saw harsh duty in severe weather, the maintenance advice was the same. Many, probably most, consumers wasted money on unneeded service; others neglected service that would have extended vehicle reliability and life.

It might seem logical to adjust maintenance schedules based on the age of the equipment. When looking at substation high voltage breakers and transformers, for example, surely older assets are more prone to failure and therefore require additional attention. Surprisingly, not so.

The Hartford Steam Boiler company provides equipment breakdown insurance for a variety of devices, including transformers. In their actuarial calculations related to transformers, they studied

94 insured failures to identify risk factors. Their study concluded that asset age is a poor indicator of potential failure. Other factors provide far more reliable indications of pending problems.

"We performed the same kinds of analysis but studied over 10,000 transformers," says Craig Stiegemeier, Director of Technology, Transformer Remanufacturing & Engineering Services North America for ABB. "We found exactly the same thing; age alone is not a good indicator for pending transformer issues or failure."

If duration of use and age of equipment are poor triggers for maintenance activities, surely cycles or rotations are better indicators. Again, not necessarily. The type and design of the asset, its maintenance history, operating environment, and other factors may each provide a better trigger. But, as will be pointed out, the most reliable trigger for maintenance action requires consideration of multiple factors.

Drivers for more effective maintenance
The increasing urgency to find more efficient and effective approaches to maintenance is the result of several long-term trends.

- **Aging infrastructure:** Many assets related to power distribution are very long in the tooth. A 2015 report found that 70% of transformers are 25 years or older and 60% of circuit breakers are more than 30 years old.[1]
- **Aging workforce:** The engineers and technicians responsible for maintaining those assets are also aging. Over half of the current utility workforce will be eligible to retire in the next six to eight years, and 72 percent of energy employers are having difficulty finding quality replacements.[2]
- **Flat operations & maintenance spending:** Despite an increased need for maintenance, 57% of utility companies plan decreased or flat O&M spending.[3]

Maintenance is one of the largest controllable costs

A predictive approach squarely addresses these issues by making better use of limited maintenance budgets by focusing attention on actual issues. Dispatching crews to substations to determine if repairs are required is, for the most part, incredibly wasteful; crews typically find nothing wrong. Armed with health data from substation assets, crews can be dispatched only when something actually requires attention. This approach greatly reduces the burden on ever-shrinking crews.

Regarding cost reduction, maintenance is one of the largest controllable costs in most industrial facilities, including substations.

> Traditional, break-fix maintenance can cost up to 10 times more than a predictive strategy.

In addition to reducing costs, predictive service boosts reliability by identifying potential issues before they progress to the point where the asset fails or goes offline.

Step-by-step solutions for substations of every size
Few organizations make the leap from old to new maintenance strategies in a single jump. An incremental approach is more easily taken and more logical. Facilities can adopt the lowest-cost steps first, or begin by implementing solutions focused on their most critical assets. When those smaller steps are taken with the final desired maintenance system in mind, every step moves the organization closer to their goal. Early implementations can be integrated into the larger, future solution.

As these implementations occur, substation owners advance along a continuum of increasing capabilities.
- Capture a baseline (health snapshot)
- Use existing data and incorporate analytics
- Advance to asset health automation
- Add sensors and monitoring

Each of these steps in the migration to a fully evolved maintenance system will next be investigated.

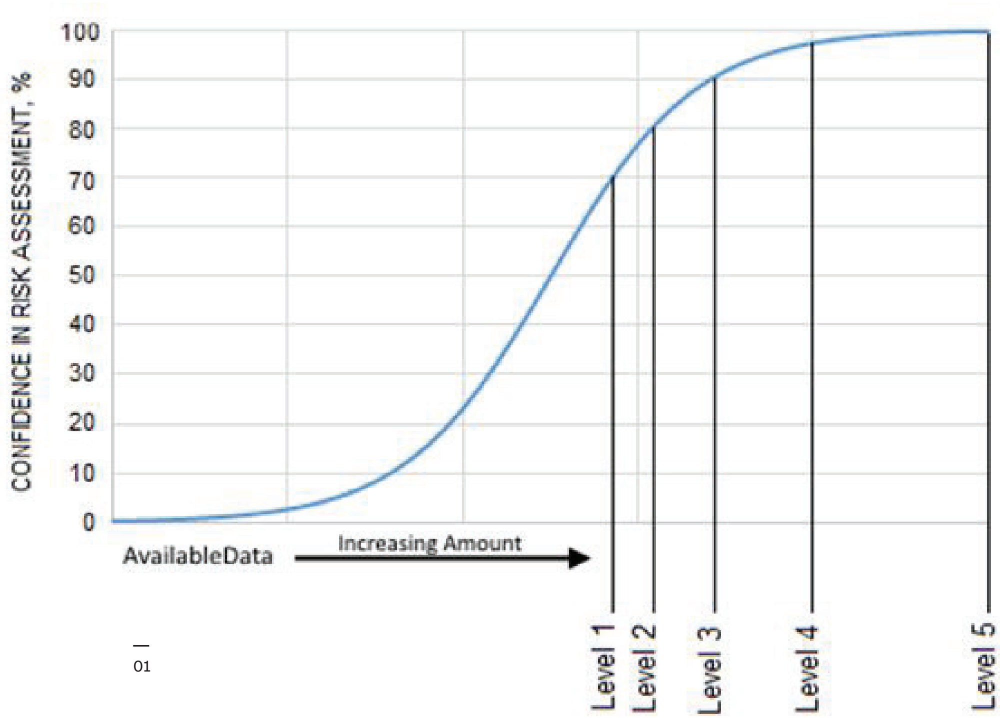
Capture a baseline (health snapshot)
The first step is to determine where you are now. An accurate snapshot of your current status regarding asset health will provide valuable guidance in future activities. It also provides a reference point that can be used to evaluate the effectiveness and return on investment of your substation maintenance modernization efforts.

Capturing the baseline condition typically entails a thorough visual inspection. Findings are documented and photographed, and existing documentation inventoried. Careful analysis of the condition and importance of the equipment, the service and operational history, as well as the availability of spare parts and maintenance competences allows risk level assessments at the component, system, and substation level.

Most organizations have some data related to key substation asset health and feel that provides the needed reliability assessment. Not so. A baseline analysis adds factors beyond basic asset health. The visual inspection, for example, provides invaluable observations about infrastructure like device foundation, as well as the physical condition of related devices, like cooling systems.

In addition to asset condition, the analysis also begins to consider and document the risks associated with asset failure and the importance of the assets to the system it supports.
This information will let you begin to better prioritize maintenance tasks.

Capturing baseline data is a one-time activity on the path toward more effective maintenance. It becomes the benchmark by which the changing health and the impact of your maintenance efforts can be evaluated.



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01 Risk of failure confidence based on available data

Use existing data and analytics
The next step involves optimizing information from existing data which, when combined with analytics, can continuously measure asset health. Every organization already captures information about some assets. In most cases, though, the data resides in silos and is difficult to correlate. Individual employees or departments set up systems to collect the data they need, creating asset information pockets or silos.

This information can reside in various repositories:
- Databases
- Historians
- SCADA systems (supervisory control and data acquisition)
- Spreadsheets
- Condition monitoring devices

This data builds on the baseline data, providing additional insights regarding asset health and increasing greater confidence in maintenance related decisions. Using transformers as the asset class, the following graphic highlights the increase in risk assessment confidence as data is added. Most utilities will collect Level 1 and Level 2 data which results in 70% confidence in the risk assessment using this data. Not a bad start.

Level 1 – Nameplate information, full DGA and oil quality parameters.
Level 2 – Level 1 + loading, power factors, accessory information.
Level 3 – Level 2 + physical condition, protection condition and history.
Level 4 – Level 3 + comparative data, design info, through fault info, reclosing practice, environmental risks and spares.
Level 5 – Level 4 + special test results, geomagneti cally induced current susceptibility.

Far greater benefit can be realized through analytical tools that convert the data you collect today and will have tomorrow into a holistic, on-going asset health profile.

Given the volume and complexity of the data, finding meaning is possible only through analytics. These applications sift through the data to identify and prioritize risks and enable preemptive maintenance, with substantial increases in reliability and support for the shift to a more condition based maintenance approach.

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02 Shifting role of data vs. human input in maintenance activities
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03 Breakdown of maintenance practice approaches

Using algorithms based on industry standards and experience, the software continuously assesses asset health to detect emerging problems before they pose a major risk. In addition, prescriptive analytics can identify issues, propose the best corrective action, and establish a response timeframe.

Armed with the output from these analytical tools, maintenance managers can make decisions based on a highly refined and prioritized list of potential maintenance activities. At this phase in the process evolution, wasted maintenance effort is virtually eliminated; almost all activity is directed at assets with impending problems.

Advance to asset health automation
People will always be a crucial part of the maintenance picture, but at the apex of the maintenance revolution, their role is reduced and changed. Some of this reduction is by necessity and some by design. As already mentioned, the ranks of skilled technicians continue to shrink and finding replacements is a challenge. There are simply fewer techs, so alternatives to human-based activity are needed.

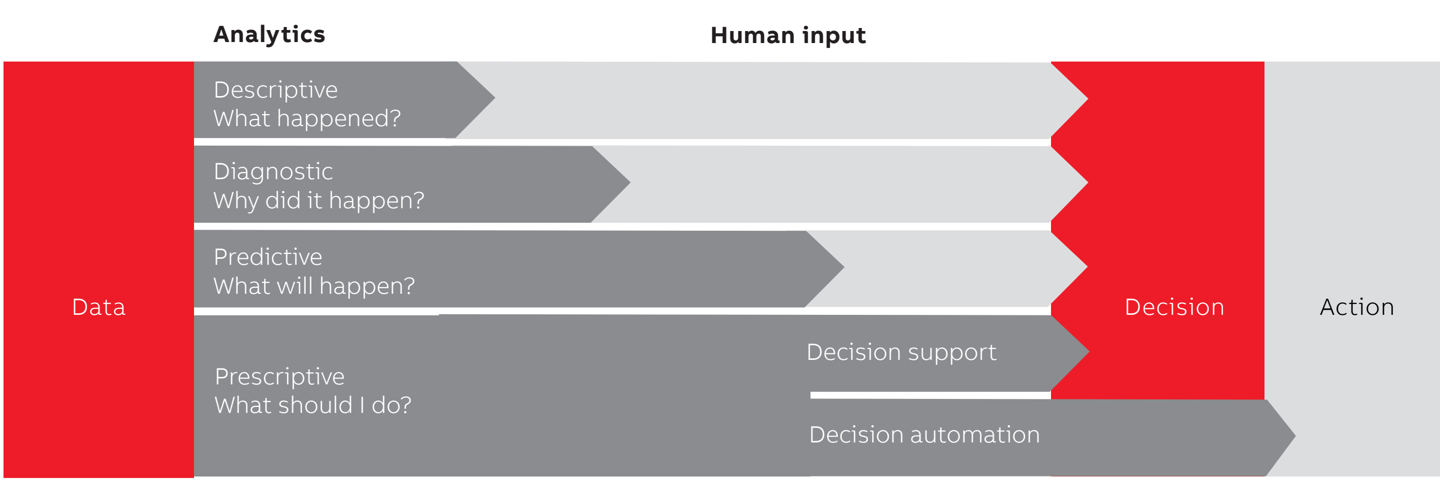
The other reduction is by design. Maintenance teams have long relied on the veteran who has been around so long that he is intimately familiar with probable asset issues and has the knowledge to expediently resolve them. As both older assets and veteran techs are increasingly retired, an automated approach to assessing asset health and determining corrective action becomes increasingly beneficial.

Once the organization is comfortable with the prescriptive analytics generation of a work request, details can be sent to the Enterprise Asset Management (EAM) system to create a work order.

Automation of maintenance needs assessments and work planning is likely to provide increasingly superior results compared to humans. In addition, having information at the fingertips of the maintenance personnel gives them the ability to analyze the situation before a truck rolls. If a sensor is sending erroneous data, for example, the data error would be flagged in the software, avoiding an unnecessary dispatch.

As illustrated in the graphic developed by Gartner (Figure 2), human input continues to wane and the tech's role shifts to implementation of required maintenance actions.

Most maintenance managers are gaining familiarity with the concept and benefits of predictive maintenance, but there are other less well known advanced maintenance approaches. One is reliability or risk centered maintenance. It takes predictive or condition based maintenance and adds another layer of intelligence based on the substation design and importance of each major component in the system. It not only evaluates the current health of the asset but also its criticality. A minor issue on a critical asset will be given priority over a serious issue on a secondary or tertiary asset.



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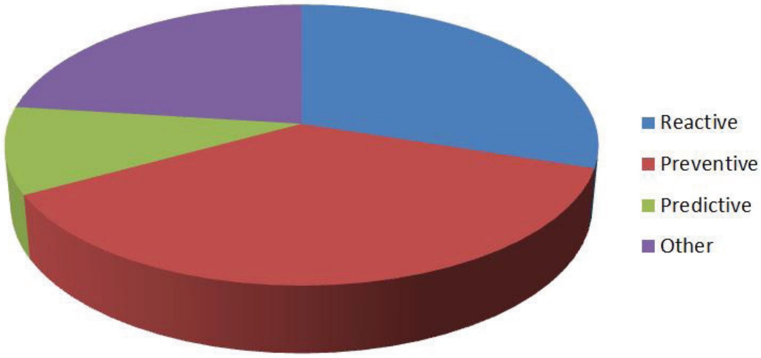
02 Source: Gartner (February 2015)



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The next step in the evolution of asset management is prescriptive maintenance. In this environment, maintenance is not only predicted by systems, but the course of action is prescribed automatically. An ARC Advisory Group report states that with a prescriptive (beyond predictive) maintenance strategy, unplanned downtime will approach zero.

A recent survey shows that for most substation owners there remains a long road ahead in their evolution to higher levels of maintenance management:

- 30% are still reactive, running to outage/failure before repairing
- 37% are now preventive, performing service on a fixed cycle or time interval
- 10% have advanced to predictive, monitoring for potential issues and responding to them[4]

Add monitoring via online sensors
Early digital cameras provided relatively grainy but usable images. The technology advanced to deliver incredibly sharp images. In the same way, the view of your assets will lack sharpness in the early phases of your maintenance evolution. As you add more inputs and data, your view of asset health will come into sharper focus.

Advancing to the next level requires the addition of online sensors to provide regular feedback regarding key asset health attributes. This initiates the flow of a continuous data stream. The sensoring of industrial devices and ability to interconnect them are keystone tools in what's referred to as the 4th industrial revolution or Industry 4.0.

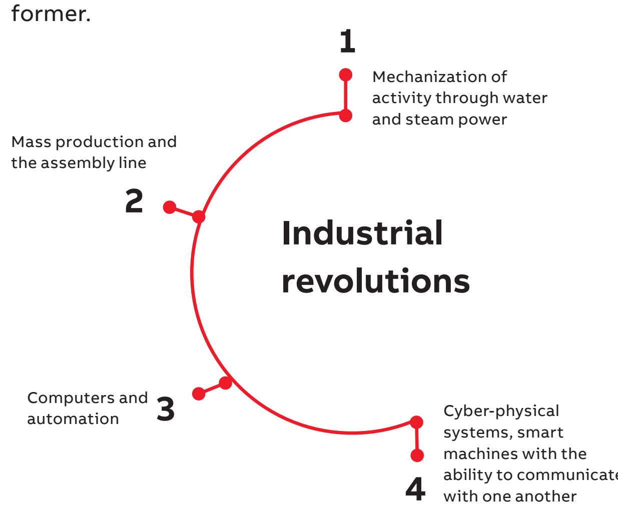
Industrial experts equate the fourth revolution with the Internet of Things (IoT) - devices that range from door locks to refrigerators, and from circuit breakers to transformers. These "things" are equipped with sensors and, increasingly, computing power and software.

It is more than just IoT that connects devices. Now there's even a service and people dimension added to this evolution called the Internet of Things, Services and People (IoTSP). Devices have been communicating with each other for years, but IoTSP extends the communication from intranets to the internet via cloud computing and mobile communications. IoTSP creates as-yet unimagined opportunities for increased device integration, control, and health monitoring.

Almost all new substation devices arrive, or are available with, integrated sensors. Older, installed assets can be readily upgraded with this capability. It requires a relatively small investment and only about a half-hour, for example, to add monitors to a standard breaker. It requires no major redesign to start acquiring up-to-the-minute data on breaker health and status. The asset owner can opt to monitor a variety of parameters: number of operations, opening/closing time, number of false-current operations, contact wear, heat signature, inactivity timer, compartment temperature, auxiliary power quality, and more.

In transformer sensors, design engineers have capitalized on recent, significant advancements in chemistry that provide insights regarding the condition of the transformer based on oil and gas analysis. Feedback on cooling-oil condition, including water percentage, dissolved gasses, and temperature, provides early and actionable warnings of potential transformer issues.As a rule of thumb, substation operators can typically justify adding online monitoring to their assets up to a cost of 10% of the asset's replacement cost.

An added and valuable benefit of incorporating sensors is cost avoidance. North American Electric Reliability Corporation (NERC) regulations include steep fines to utilities for unplanned outages. Avoiding even a single fine can offset the cost of adding a full complement of sensors to a transformer.



Evolve your maintenance approach

The benefits of evolving
Evolving your maintenance approach by incorporating data, analytics, and automation enables more effective use of precious maintenance resources and dollars, and ensures higher substation reliability. This reliability gain is especially valuable considering that many of the assets on the grid were deployed more than a half century ago.

The average life cycle of a power transformer is 40 years, while many installed assets are 50 or 60 years old.

Increased urbanization and the growing adoption of renewables are placing new and unforeseen demands on these vintage assets.

Beyond maintenance, facility managers have much better data on which to base capital spending decisions. With a clearer picture of an asset's health, it's possible to extend its life and avoid replacement costs with a higher level of confidence.

Yet another benefit is a reduction in compliance and environmental risks through a reduction in catastrophic failures. Every leg of the power network – generation, transmission, and distribution – is under increasing regulatory scrutiny. Failure to comply with power provision requirements can result in expensive fines. The costs, both environmental and financial, of a catastrophic transformer failure can also be significant.

Joining the revolution
The revolution is underway. We are well along in the transition from mechanically focused to digitally focused maintenance. There remains an honored place for seasoned techs who, both literally and figuratively, know the long-time assets under their care inside and out. But the day of the well-worn tool belt on the hips of veteran maintenance techs is giving way to more sustainable, more effective, and more efficient data-driven methods.

It is never too late or too early for substation owners to start their journey and join the revolution. As shown in Figure 1, it begins with capitalizing on the information you already have and building on that foundation. For the most part, organizations are initially embracing condition based maintenance in their high voltage equipment. It's clear, though, that over time they will be managing their entire networks via this approach.

The move toward condition based maintenance is a strong trend in high voltage circuit breakers. The number of maintenance teams doing five and 10 year checks continues to dwindle. Today, facility owners want to know the actual condition of a breaker so they can determine when it truly needs service. That health data won't be gathered via a visit to the breaker. Sensors, whether incorporated in the breaker when installed or added as a retrofit, will transmit the data back to their operations' area.

The revolution will be accelerated by the classic combination of advancing technology coupled with substantial decreases in its cost. Organizations will increasingly accelerate the shift toward increased online monitoring of assets and more condition based maintenance. They will have a clearer view of asset conditions which will, in turn, supporting optimized maintenance decisions, better controls on operations and capital spending, and enhanced asset reliability.

Shifting power demands, aging assets, increased renewables penetration, additional regulations, and other factors are combining to amplify the demands on maintenance organizations. Adequately meeting those demands will require nothing less than a revolution in your approach to maintenance.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