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A Practical Guide for Evaluating Maintenance Modernization Options

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Introduction

The economic crisis that began in 2008 forced many organizations to reduce capital expenditures. As a result, budgets for in-house maintenance teams, responsible for maintaining critical electrical and HVAC systems, were reduced. That same economic crisis pressured organizations to find ways to reduce operational expenditures without decreasing productivity. Uninterrupted operation had to somehow coexist with safety, security, reliability and extended equipment lifetime.

The downside of this untenable position was that the lack of maintenance planning became more prevalent. Practices such as one-shot maintenance, no response time commitments from vendors in case of emergencies, and lack of a predictive maintenance contingency plans set critical assets such as facility electrical systems at risk. For many organizations, this period of risky behavior has either already resulted in unanticipated downtime, or worse, will soon result in a costly shutdown.

The 2008 economic crisis forced many organizations to cut budgets for in-house maintenance teams.

Studies have shown that electrical equipment failure rates are 3 times higher for components which are NOT part of any scheduled maintenance program.

The question is not if the failure will occur, but when. Studies have shown that electrical equipment failure rates are 3 times higher for components which are NOT part of any scheduled maintenance program (as compared to equipment which is part of a service plan).[1]

Cost of downtime can average $5,600 per minute, which extrapolates to well over $300K per hour.[2] But this is just an average. In some industries like financial brokerage the cost of downtime can reach up to $6.8 million per hour with core manufacturing industry downtime cost reaching $1.6 million per hour.[3] Research reveals that more than two-thirds (67%) of breakdowns can be avoided through formalized maintenance service planning.[4]

The time is right to evaluate maintenance modernization

Now that economic conditions have generally improved, a reassessment of maintenance planning is in order for those organizations wishing to remain competitive in a growth environment. Analysts and operations executives agree

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that unless an organization can, at a minimum, sustain the current level of performance, it's bound to fall behind, losing any competitive edge and risking its business. In today's fast-paced, technology-driven world, it's even harder to stay competitive while maintaining performance levels.

Equipment needs to be maintained regularly in order to ensure that the infrastructure operates under favorable conditions.

From an operational perspective, sustaining performance means creating an environment that at least maintains current production levels, with efforts focused on two aspects:

- Support: The ability to apply resources to prevent and resolve issues, keeping the facility in an operational state.
- Maintenance: An ongoing effort to ensure assets perform as intended at the lowest operating cost.

Consider the following real-life situation: As a result of a trend by utility companies to deliver higher and higher voltages from the grid (like recent moves in the US to expand service from 5kV to 15 kV) many organizations with older transformers are having to replace that equipment. In addition, some organizations' equipment is 30-40 years old and is being operated at 120-125% of capacity. The operational condition of overcapacity, equipment age, and, in some countries, an increase in utility voltage service, are all strong drivers for formulation of new, more modern maintenance plans.

Each day, businesses increase workload demands on their building or factory physical infrastructure (i.e., water, air, gas, electrical and steam systems). Unfortunately, these core infrastructure systems may not have been originally designed to support such increased loads. The principal reason for electrical system failure is lack of maintenance. This equipment needs to be maintained regularly in order to ensure that the infrastructure operates under favorable conditions.

Performance and life expectancy of physical infrastructure is impacted by environmental conditions, overload conditions, and excessive duty cycles.

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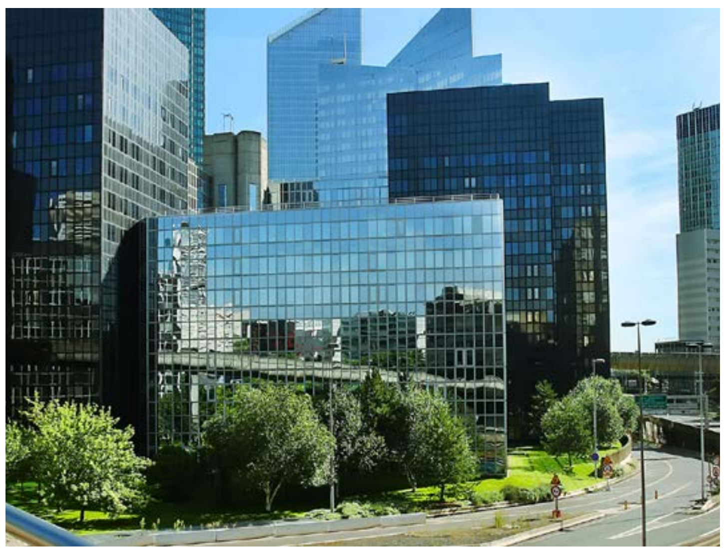
This reduces the possibility of breakdowns and enhances safety.

Performance and life expectancy of physical infrastructure is impacted by environmental conditions, overload conditions, and excessive duty cycles. Even when equipment has not been in operation for a long time, a strong possibility exists that it will require proper maintenance before it can be placed in service again.

Impact to the business

Within many industries today, high uptime of systems is a key influencer of revenue and customer satisfaction. Three important critical success factors need to be addressed in order to achieve system availability and customer satisfaction goals:



As the business world becomes more connected, the need for maintenance modernization investments is increasingly crucial.

- Active audits of infrastructure assets and their operational performance
- A linking of business benefits to the maintenance of a "always on" power infrastructure
- An optimized maintenance approach that makes sense to those executives who approve the maintenance expenditures.

This reference guide offers recommendations for identifying and addressing each of these issues and reviews the various strategies involved when undergoing a maintenance modernization process. Besides evaluating different types of maintenance approaches, holistic program planning and techniques for associating business value to maintenance modernization are also discussed.

Takeaway: As the business world becomes much more connected, the need for investment in maintenance modernization has increased due to aging equipment infrastructure and the high costs of downtime.

Formulation of a Maintenance Plan and Program

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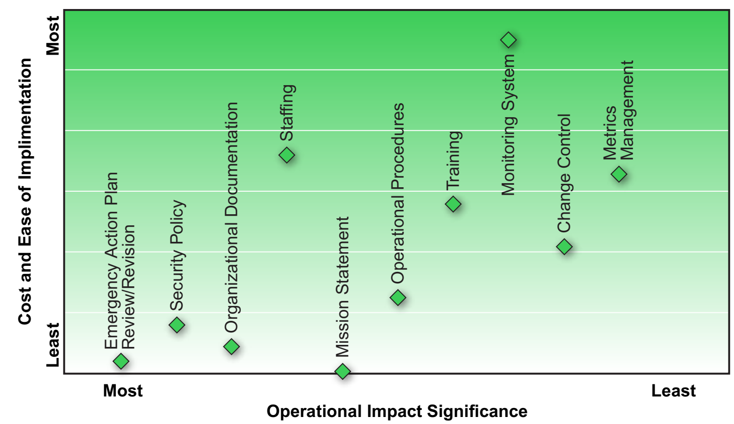
The reliability of core physical infrastructure systems like power, motors and drives varies greatly from site to site and from business to business. Operations teams work with dissimilar quantities and qualities of electrical equipment, support different mission critical processes, and pursue diverse maintenance strategies. Nevertheless, it is prudent to take into account the specific issues of a site and determine how reliable the system is and how reliable it needs to be. In all likelihood, most organizations have gaps in their infrastructure maintenance practices. As a result, Total Cost of Ownership (TCO) of equipment may rise as instances of downtime increase.

Formulation of a maintenance plan need not be a time consuming or frustrating task. Experience shows that if the right issues are resolved in the right order by the right people, vague requirements can be quickly translated into a detailed plan. Maintenance plans are often poorly communicated among the various business stakeholders within the organization. Decision makers are presented with proposals that are described in excruciating technical detail, yet still appear to lack the information they need to make good business decisions.

The initial steps of the planning process should focus on ensuring a shared understanding of the most important capabilities of the physical infrastructure systems to be maintained and the cost/benefit analysis. This system concept should involve decision makers capable of determining high level objectives and making early tradeoffs between performance, cost, and safety. This approach avoids the problem of key stakeholders not being aware of “the plan” and the cost associated with the introduction of new approaches (such as predictive maintenance techniques).

The early planning should focus on establishing a consensus. This ensures that high level decision makers focus on the most important decisions early and do not get drawn into discussions of details.

Below is an example of some important priorities and how they compare in a cost-to-operational impact context. Similar graphics for evaluating trade-offs can be generated to compare cost, safety, and performance considerations.



Source: Schneider Electric white paper, “Facility Operations Maturity Model for Data Centers”

System vs. component-based maintenance

An effort should also be made to avoid building a maintenance plan around separate components. Instead, planning should focus on a system-wide maintenance perspective as this will enhance overall performance. Here’s why:

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Formulation of a Maintenance Plan and Program (cont.)

Overall *system* reliability is only as good as its weakest link. Operations personnel can easily be misled if they focus on the reliability statistics of individual components. This false sense of security increases the risk of unplanned systems downtime. Consider the following examples:

- Assume a simple electrical system configuration consisting of a transformer that is 90% reliable and switchgear that is 90% reliable. Together this mini "system" really only guarantees a reliability of 81%.
- Or assume a system consisting of a transformer at 90% reliability, switchgear that is 90% reliable, and a distribution panel at 90% reliability. This system's reliability is only 73%.
- Or, even more alarming, a transformer at 90%, switchgear at 70% and a distribution panel at 70%. Such a system would equate to 44% reliability.

Why is the system reliability always significantly lower than the individual component reliability? Reliability is a property of an electrical power system that describes the likelihood that the system will operate or perform as designed, constructed, and intended. Reliability is determined from the combination of failure rates of individual components and the configuration of the power system to which they are applied.

Formulation of a maintenance plan need not be a time consuming or frustrating task.

Planning should focus on a system-wide maintenance perspective as this will enhance overall performance.

The notion of reliability is more of a mathematical probability than an actual physical condition. Electrical reliability is measured by its trouble-free time. For example, if a piece of equipment is designed and intended to continuously operate "X" years and it does, it is 100% reliable to "X" years. After that point in time, if there is an occasional breakdown, the reliability beyond the stated time is less than 100%.

Lowered reliability, especially in the realm of electrical systems, increases the risk of both employee safety and of downtime-related lost business productivity. Reliability gets worse over time if no action to improve reliability is taken. Therefore, it is prudent to build reliability enhancement investments into the annual operational expense (OPEX) budget.

Formulation of a Maintenance Plan and Program (cont.)

Such a budgetary line item should include following three essential elements:

- Electrical infrastructure assessment (evaluating the state of affairs),
- Recalibration of maintenance strategy (last year's strategy may not be relevant to this year's requirements), and
- Upgrade of low reliability assets (upgrading equipment that may be on the verge of failing).

Electrical reliability is measured by its trouble-free time.

Once the *system* view is agreed upon, the next step should include a determination of which of the components within the system are the most critical (those that will need the most comprehensive form of maintenance available). Devices in the middle of the criticality range may be placed on a preventive schedule. The least critical devices may only require a break/fix approach. The overriding question that needs to be answered for each of the components is "What impact does the loss of this individual component have on the entire system?" Below is an example of common electrical and HVAC components and the levels of maintenance usually required. How critical these devices are to the facility depends upon the overall system design and can be determined via an audit process.

Device	Internal components requiring maintenance	Relative level required
Transformers	Tightness, torque of connections	Low
PDUs	Tightness, torque of connections	Low
UPSs	Fans, capacitors, batteries	Medium
Ventilation/air conditioning	Belts, air filters, piping connections, compressor, fan motors, pumps, coils	High
Humidifiers	Drain, filter, plugs, water processor	High
Transfer switches	Switch components, firmware, torque	High
External storage (e.g., battery banks)	Torque, connections, electrolyte/acid levels, temperature levels	High
Fire alarm system	Valves, flow switches	High
Chillers	Oil pressure levels, gas levels, temperature settings	High
Generators	Fuel filter, oil filter, hoses, belts, coolant, crankcase breather element, fan hub, water pump, connections torque, alternator bearings, main breaker	High

Maintenance program elements

Within a comprehensive maintenance support program, factors that influence the performance of critical systems should include:

- A preventive maintenance program to reduce the risk of premature failure
- Condition monitoring to get early warning of impending problems
- Fast access to spare parts to make repairs
- Redesign of procedures to speed asset repairs and reduce impact on production
- Performance tuning to ensure a reasonable load on the asset
- Access to resources with the skills and training to diagnose and repair the asset

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Formulation of a Maintenance Plan and Program (cont.)

In addition, a plan should be established for new devices that get installed and that require maintenance and services. Since many of these new devices will come delivered with "smart" capabilities from the factory, it may be easy to integrate them into the predictive maintenance aspect of the maintenance plan. Or, if the predictive maintenance aspect is taking on a more significant role in the overall plan, some existing devices may get upgraded in the field in order to include them in the predictive maintenance network.

For enterprises that operate multiple facilities, a detailed maintenance program promises even greater return on investment since it enables a broader view of maintenance and equipment performance. This allows comparisons to be made among facilities and teams. The sharing of such data propagates best practices and allows stakeholders to adjust their corporate maintenance planning so that unplanned downtime events are eliminated.

It is prudent to build reliability enhancement investments into the annual operational expense (OPEX) budget.

In addition, data coming in from monitoring and control systems such as Building Management Systems (BMS), Factory Automation Systems (FAS), Building Automation Systems (BAS), Digital Control Systems (DCS) and System Control and Data Acquisition (SCADA) systems can be combined with advanced analytics capabilities in order to enrich the maintenance program. By providing accurate information about facility issues and then ranking them by how they impact the business, sound maintenance investment decisions can be made.

Takeaway: Planning is an important first step to maintenance modernization. Plans should be built on a system perspective as opposed to an individual component perspective.

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Techniques for Evaluating the Asset Base

Facility managers may be unaware of the current reliability state of their equipment unless maintenance and test results on all equipment are complete and readily available throughout the equipment's service life.

If documentation is unavailable or outdated, management may consider state of readiness assessment performed by a professional engineer. This assessment determines the present state of systems and associated equipment, its functionality, and its reliability relative to the present needs of a facility's functions and operations.

A thorough and effective assessment should undertake the following steps:

- Process understanding and risk analysis
- Equipment status assessment and reliability analysis
- Criticality index and competency evaluation
- Plans creation and conclusion meeting

If a power systems assessment is required, for instance, assessment should be performed by a registered professional engineer with in-depth experience surrounding the design, operation, maintenance, safety, and reliability of AC and DC power systems and equipment. During an assessment, a facility's risk is determined by a combination of the following four factors:

1. The impact of a power event on critical business processes
2. The safety hazard threat to electrical workers
3. The probability of a power event occurring
4. The ability of the organization (or supporting vendors or partners) to quickly correct the negative effects of the power event.

The maintenance professional should observe the environment (circuit breakers, installation practices, cabling techniques, mechanical connections, load types) and alert the owner to the possible premature wear and tear of components. He should also point out factors that may have a negative impact on system availability (i.e., possible human error in handling equipment, higher than normal temperatures, presence of gas in transformer oil, and corrosion). A maintenance visit should also include an evaluation of outside environmental factors that can impact performance (e.g., snow, water, corrosive fumes, dust, explosive atmosphere, lightning).

If documentation is unavailable or outdated, management may consider state of readiness assessment performed by a professional engineer.

One of the outputs of the audit will be a determination of how maintenance priorities are set. Components that are close to end of life will be identified. A common rule of thumb for electrical

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Techniques for Evaluating the Asset Base (cont.)

infrastructure equipment is to consider upgrading if the component in question is over 15 years old. However upgrade planning should not be random. Shut downs should be avoided if possible and the upgrade plan should be developed around equipment performance data. Stakeholders should determine whether the components in question support critical or non-critical functions. If critical, the reliability and integrity of that equipment should be preserved at all costs.

A common rule of thumb for electrical infrastructure equipment is to consider upgrading if the component in question is over 15 years old.

Other components will be assigned a replacement schedule based on age and operating environment. In some cases, older equipment can be upgraded by substituting old parts for new ones. In the case of low and medium voltage switchgear, older circuit breaker assemblies can be directly replaced with brand new ones. During the upgrade, the existing switchgear equipment structure is left intact. The new direct replacement circuit breakers are designed to fit into the existing cubicle with little-to-no downtime since there is minimal (if any) outage to the equipment bus.

When equipment is obsolete and no spares are available a

A maintenance visit should also include an evaluation of outside environmental factors that can impact performance.

“Retrofill” solution exists. This solution, involves modification of the internal circuit breaker cell to accept the new circuit breaker. In these cases, a bus outage is required for the modifications to take place. The retrofill approach also works in switchgear, including both low and medium voltage scenarios.

Such audits will provide operations staff with an idea of how much budget should be allocated to sustain existing assets and to provide for the maintenance of newly installed equipment. Also, the proper mix of break/fix, preventive and predictive maintenance can be ascertained. Elements such as equipment age, environmental stresses, criticality of equipment, and utilization, will serve as the determining factors in influencing the types of maintenance approaches selected.

Takeaway: Assessments and audits play a critical role in defining the scope of work and investment that will be required to meet the modern maintenance goals of the business.

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Types of Maintenance

Over time, equipment can break down for several reasons. One is mechanical failure. Another is the environmental conditions of the site. Human error also plays a factor (the less humans have to touch the equipment, the better). But in deciding on how to formulate an up-to-date maintenance strategy, how much maintenance is enough? Any what type of maintenance should be performed?

Maintenance approaches generally fall under three broad categories: reactive, preventive and predictive. Below is a brief overview of these three types of maintenance approaches:

Reactive maintenance - In a reactive approach (also known as corrective-based or break/fix maintenance) support is only brought in to address an unanticipated problem or emergency. This means that stakeholders wait until equipment falters or fails completely before initiating corrective action. If a component breaks down, a technician is called in to service it. This approach is not advisable for any components that are linked in any way to critical systems. Although reactive is the highest risk and most costly (over the long run) of the three maintenance approaches, it is, ironically, the most common approach utilized.

Despite the importance and expense of maintaining operational efficiency, most building owners rely on reactive maintenance programs for their equipment.

Maintenance approaches generally fall under three broad categories: reactive, preventive and predictive.

Despite the importance and expense of maintaining operational efficiency, most building owners/operators — some 55% in the United States[6] — rely on reactive maintenance programs to care for their equipment. In fact, referring to reactive maintenance as “maintenance” is a misnomer; it should really just be called “repair.” By waiting until actual failure, operators ensure that repair costs will be at a maximum and that there will be interruptions in service while the repairs are being made.

Both costs and unplanned downtime can be reduced by substituting reactive maintenance with preventive maintenance, in order to reduce the number of faults within complex parts or systems.

Preventive or “scheduled” maintenance is a very common proactive maintenance method. This type of

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Types of Maintenance (cont.)

maintenance approach is characterized by routinely performed maintenance (regardless of the equipment's condition). In some cases, maintenance may be unnecessary, but is nevertheless performed on a regular time schedule. Preventive maintenance is a less expensive option than reactive maintenance but more costly than predictive maintenance. A preventive maintenance approach yields a less risky, less cost approach when compared to reactive maintenance but is still not optimal as a solitary approach to maintenance.

Predictive or condition-based maintenance is another proactive maintenance approach that is scheduled. But that schedule is not based on time intervals. Instead, the results of diagnostic evaluation drive the maintenance. Like preventive maintenance, predictive maintenance is based on the tenet that a proactive approach is better than a reactive one. However, instead of making repairs based on a predetermined calendar schedule, the predictive approach makes repairs based on the actual condition of the equipment.

While reactive maintenance is the most popular approach, the highest performing facilities overwhelmingly use preventive maintenance and rarely utilize reactive maintenance.[7]

A preventive or "scheduled" maintenance approach is characterized by routinely performed maintenance performed on a regular time schedule.

Zeroing in on predictive: The new wave of maintenance planning and execution

Advances in "Internet of Things" (IoT) technologies and the proliferation of open Ethernet connectivity protocols have allowed for the affordable proliferation of monitoring sensors. This has opened the door to innovations in maintenance planning and execution. Whereas preventive maintenance tasks are completed when the machines are shut down, predictive maintenance activities are carried out as the machines are running in their normal production modes.

For example, in a traditional approach, machines are stopped or devices are shut down in order for maintenance people to go in and check the state of the equipment. This might happen four times a year. In a predictive environment, the equipment is monitored on a regular basis. "Vital signs" are kept track of. If an uptick in temperature begins to manifest itself, a detailed diagnostic is performed and a calculated estimate based on past history is projected. That estimate recommends the best time for when that machine or component will require a fix (prior to breakdown). Thus, instead of four interruptions to component uptime in a given year, that device may only have to be taken off-line once to implement the fix. This

Types of Maintenance (cont.)

helps to minimize costly interruptions to process systems uptime.

The predictive approach holds other advantages over preventive:

- Maintenance costs are reduced by 50 percent
- Unexpected failures are reduced by 55 percent
- Mean Time Between Failures (MTBF) increases by 30 percent
- Machinery availability increases by 30 percent[8]

In a predictive scenario, when operating conditions indicate a developing problem in a critical asset, an alert allows decision makers to plan maintenance prior to failure. Maintenance interventions are forecast and launched when alerts indicate that a predefined wear threshold has been reached.

To enable such responses from the equipment in question, sensors need to be installed in devices, switchboards, and installations. Many of the new devices that get shipped to customers now have such sensors pre-installed.

> Maintenance interventions are forecast and launched when alerts indicate that a predefined wear threshold has been reached.

A migration to a predictive maintenance scenario is not an "all or nothing" approach. Instead, it is common for organizations to practice all three of the primary maintenance methods (reactive, preventive, and predictive) in a hybrid fashion. As the equipment base evolves and is updated over time, more of the predictive elements can be added, and the more risky, costly reactive elements can be phased out or minimized.

All of the product performance data gathering is supported by a maintenance information system (Enterprise Asset Management), sometimes integrated with plant ERP. The system helps maintenance staff to plan for the most convenient intervention time, spare parts management, and other associated field service activities.

An example of how predictive maintenance can work

In industrial environments, variable speed drives (VSDs) often perform predictive maintenance activities. In fact, VSDs can be converted into "service-oriented drives" (SOD) so that plant uptime can improve. The intelligence within the VSDs estimates and projects equipment condition over time and uses probability formulas to assess downtime risks.

Most VSDs are installed within a "chain" of other electromechanical devices (such as transformers, circuit breakers, motors) or mechanical devices (gear box, mechanical transmission). These devices have a predictable behavior allowing their maintenance to be planned. Together these form a "driveline."

In an SOD scenario, VSDs minimize their own downtime

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Types of Maintenance (cont.)

and are also used as smart sensors for the entire driveline (monitoring motor torque temperature, main voltage, and load energy consumption and working from established sets of rules for when these components can be expected to fail). The system issues warnings when parts are likely to wear out and when warranties are about to run out. The SOD concept allows anticipative behavior algorithms to drive maintenance timing decisions (performing maintenance not too early and not too late).

> Reliability centered maintenance represents a strategy focused on outcomes and determines what should be done to ensure that an asset operates the way the user intended.

Reliability-centered maintenance: The optimal approach to lower cost and higher availability

Whether reactive, preventive or predictive, most maintenance strategies are often associated with maintenance of individual components. As we have seen, system reliability is more important than component reliability.

This brings us to the most comprehensive approach to maintenance: **reliability-centered maintenance (RCM).** This approach takes a systems view as opposed to a component view. It integrates preventive maintenance, predictive testing and inspection, and run-to-fail maintenance techniques. An ongoing process, reliability-centered maintenance gathers performance data to improve equipment design and enables management to make more informed future maintenance decisions.

Within an RCM implementation, all maintenance approaches are used, but the predominant strategy used is predictive. A typical configuration would peg a reactive method for 10% or less of the install base, with 25 to 35% supported by a preventive approach and 45-55% predictive.

RCM represents a strategy focused on outcomes and is the process utilized for determining what should be done to ensure that an asset operates the way the user intended. RCM is the capstone of a fully integrated maintenance program and can't be sufficiently deployed without a repeatable process for the foundational maintenance practices. This includes using a predictive analytics solution in support of predictive maintenance.

Takeaway: Look for the optimal blend of maintenance strategies that meet reliability and availability requirements at the lowest cost.

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Methods for Managing Maintenance Resources

The type of maintenance approach an organization selects impacts how maintenance support is resourced. Organizations can choose to source their maintenance support internally or may decide to rely on product manufacturers or third parties.

Internal maintenance teams on the wane

An internal maintenance model is difficult for most organizations to support. Some very large companies and government facilities might have the resources to completely manage their own service and maintenance plans. Most facility staffs, however, will find it challenging to find, hire, and train the necessary people within the constraints of their budget.

Recent market conditions have created an environment where maintenance teams are often understaffed and, as a result, are behind in the execution of their maintenance plans. Such working conditions make it difficult to implement the improvements that building and factory stakeholders expect. Although this situation is not the same for all facility maintenance staffs, most are faced with a three-pronged challenge when it comes to maintenance and operations:

1. The cost of maintaining the building plant keeps going up and budgets are tight
2. Individuals in building and factories want more modern services, but the maintenance teams don't have the tools or time to give it to them
3. The building energy costs are high, but no one can get organized enough to figure out how to lower those costs

Performing maintenance when conditions warrant (using a predictive maintenance approach) requires less labor and provides a means to mitigate the aging workforce challenge.

Another challenge that many organizations face is an aging workforce and the difficulty hiring replacements willing to work in an equipment maintenance setting. With the combination of fewer people and continually aging assets, more effective maintenance practices are required. Performing maintenance when conditions warrant (using a predictive maintenance approach) rather than periodically (preventive) requires less labor and provides a means to mitigate the aging workforce challenge.

If predictive maintenance is desired, the data analysis capabilities to support such an approach are not easy to build internally. First, a facility must possess a system capable of gathering large amounts of diverse data on all aspects of building and equipment performance (like a building management system). Second, the kind of analysis

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Methods for Managing Maintenance Resources (cont.)

software required is not standard in BMS solutions, and in fact requires special expertise by professionals who are skilled in its use.

Some facilities may find it more economical and flexible to outsource the implementation of their maintenance plans. For facilities wishing to take the next step to a smart service plan using analytics, it's even more likely that third-party help will be needed.

> Facilities may find it more economical and flexible to outsource the implementation of their maintenance plans.

Evaluating outsource of maintenance scenarios

Depending on the scope of operations, most facilities will find it less costly to hire a third party vendor who already has the expertise on-board and can leverage best-practice experience from many engagements.

However, care must be taken when enlisting third party support. The provider(s) selected should act as an extension of the company's own staff and work closely with the facilities department to provide the needed planning guidance, equipment expertise and qualified personnel.

The following points should be considered during the third party vendor evaluation process:

- **Previous experience** - Does the provider have experience with this type of facility? Education campuses, government buildings, life science facilities, industry — all these building types present their own special challenges.
- **BMS and analytics capabilities** - Even if a building owner/operator doesn't need these capabilities now and only wants a manually implemented maintenance plan today, it may be worthwhile to choose a vendor who offers a broad range of technology and expertise in case they are wanted in the future.
- **Coverage area** - Does the provider cover the territories for all facilities? A company with many facilities will find it more effective and economical to deal with one large maintenance contract provider, rather than many smaller ones. Therefore, a global company will probably want to find a global maintenance partner.
- **Contract flexibility** - Every enterprise and facility is different and requires its own maintenance contract. The contract should offer options for length, commitment, responsibilities, etc., and these options should meet budget limitations and business goals.
- **Provider authorization to perform work** – It has to be determined whether the provider selected is authorized on the type of equipment that requires maintenance without voiding its warranty. Certain manufacturers have very strict guidelines as to who can perform the maintenance work on warrantied equipment.

Methods for Managing Maintenance Resources (cont.)


Manufacturers package maintenance contracts that offer hotlines, support, and guaranteed response times.

Maintenance by vendor/authorized 3rd party vs. unauthorized 3rd party

Manufacturers package maintenance contracts that offer hotlines, support, and guaranteed response times. Manufacturers also maintain thousands of pieces of equipment across all geographies and are able to leverage tens of thousands of hours of field education to further improve their maintenance practices and enhance the expertise of their staffs. Data gathered by the factory-trained field personnel is channeled to the R&D organizations so they can analyze the root cause of breakdowns.

The manufacturer's R&D groups analyze the data and build needed hardware and software improvements into product upgrades that then form the basis for support via flexible maintenance methods. This global exposure also allows for manufacturer-based service personnel to maintain a deeper understanding of both component and wider system issues, a knowledge that they can apply to both troubleshooting and predictive analysis.

Risks of an unauthorized third party approach

Most third party maintenance companies are local or regional in scope; they tend to work on fewer equipment installations. As a result, their learning curve may be longer regarding technology changes. Since they have few direct links to the manufacturer and manufacturing sites, most unauthorized third-party maintenance providers have difficulty fulfilling an escalated level of support. Many problems they encounter are "new" because they don't have the benefit of leveraging the global continuous improvement maintenance data gathered from manufacturer installations all over the world.

Many operations teams keep a supply of spare parts for critical equipment, but what effort is made to ensure that those parts are kept at current revision levels, upgraded to new technology, or even maintained? Some vendors offer programs to manage spare parts for their clients, even to storing them in controlled areas with guaranteed response times.

New ways to access expert support

Tools such as a QR code (quick response code), a type of 2D bar code that is used to provide easy access to information and technical support through a smartphone,

> Most unauthorized third-party maintenance providers have difficulty fulfilling an escalated level of support.

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Methods for Managing Maintenance Resources (cont.)

help to link the asset to the diagnostic experts. These people are trained and certified to address issues that surround commissioning, diagnostics, spare parts selections, troubleshooting, and preventive/predictive maintenance operations.

One example of how such a process works in the real world is illustrated by the following chain of events as it pertains to variable speed drives:

When a large tornado had passed through an area of the mid-western US, part of the roof of a machine room within a manufacturing facility had been taken out. As a result, five variable speed drives controlling pumps in the facility had failed as heavy rain poured down on them. A local electrical distributor happened to have the same type of drives in stock and, the day after, maintenance personnel were sent in to install them.

However, the maintenance team had never started up such drives before. Since the drives had never failed, no one had experience in generating a proper start up. Fortunately, a QR code was displayed on the front face of each drive. By scanning the QR code, the maintenance personnel were directly connected to the hotline of the drive manufacturer. In less than half an hour, the experts on the remote help line were able to accurately define the drive's parameters and to start the drives up to the proper specification.

Tools such as QR codes provide easy access to information and technical support.

When setting up remote technical support, on site or remote operations intervention conditions have to be pre-defined and agreed to among the users and the providers, particularly when it comes to critical operations.

As software becomes more integrated into operational systems, the task of maintenance becomes even harder – for new staff members as well more experienced personnel. Businesses can leverage their vendors' resources to take advantage of their knowledge and experience not only with their products, but also with complex applications. Nowadays, suppliers provide phone and online access to certified remote technical support and field service engineers. Outsourcing of diagnostic and troubleshooting activities to outside experts has become more of a sensible option.

Takeaway: As critical systems become more complex, outsourcing of maintenance becomes a more cost-effective option. Care must be taken to partner with qualified vendors.

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Selling Maintenance Investments to Executives

Maintenance is often viewed as a necessary evil or an impediment to production. But when it is presented as part of the overall business performance equation, organizations show a willingness to invest.

Facilities and operations staffs have an important role to play in terms of supporting the goals of the executive leadership through the introduction of innovation, including maintenance innovation. Maintenance costs account for almost as large a percentage of a facility's operating budget as energy expenses. But usually this money is spent inefficiently with a reactive "wait till it breaks" approach. A proactive, predictive maintenance approach coupled with analytics can reduce a facility's maintenance and energy costs by up to 20%.[9]

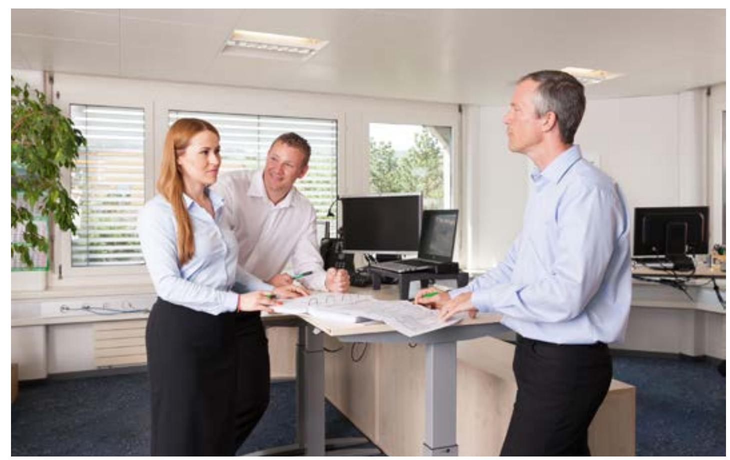
A key challenge facing maintenance department personnel is how to achieve buy-in from executives for the funding of their maintenance plan, particularly if maintenance is a fixed budget item and the maintenance needs have changed (which they do every year). The critical success factor is the ability of facilities and operations staff to communicate how sound, modern, diversified maintenance planning and implementation will enhance business value.

In preparation for any meeting with executives where the subject is project funding, facilities personnel should consider the following steps:

- Step 1: Record the number of electrical breakdowns that the organization has encountered over the last several years and their impact in terms of both cost of outage and lost productivity. Quantify the amount of money spent on correction of the issues through on-demand maintenance. The question of how to quantify savings is an important one. The expected ROI of a smart service plan can be calculated directly from the facility's data. This helps to justify investment to upper management.
- Step 2: Contact equipment manufacturers and task them with proposing a service plan that can be customized to the nature of the business. The proposed service plan should guarantee emergency on-site intervention and delivery of spare parts so that corrective action can be performed as soon as possible in case of a breakdown.

Maintenance project justification

Improved physical infrastructure maintenance plans have to translate into improved uptime which then has to be converted into impact on cost reduction, faster turnover, and/or higher return on investment. Executives often express frustration that subordinates lose them in detailed discussions surrounding spare parts management, insulation deterioration, humidity readings, and vibration



The critical success factor is the ability of facilities and operations staff to communicate how sound, modern, diversified maintenance planning and implementation will enhance business value.

Selling Maintenance Investments to Executives (cont.)

analysis. Oftentimes those discussions end with facilities and operations teams failing to acquire the funding they need to modernize their maintenance practices.

The following maintenance-related business drivers provide the basis for the business case:

Maintenance costs account for almost as large a percentage of a facility's operating budget as energy expenses.

- Revenue generation – Systems uptime improves equipment availability so production can meet its schedule and service levels can match or exceed customer expectations – which directly effects customer satisfaction and revenue.
- Balance Sheet - When assets last longer, the company retains cash and avoids using it to purchase replacement assets. Conserving cash improves the financial ratios used by Wall Street to measure the value of a company. Annual TCO is lower because the useful service life of equipment is longer
- Profit & Loss - Maintenance effectiveness, particularly in the asset-intensive industries in which maintenance is a significant cost, impacts the P&L statement. Improved maintenance effectiveness can help reduce unnecessary maintenance or prevent unscheduled downtime and the related labor, material, and equipment losses.
- Risk - Either intense competition or regulatory compliance drive executives to carefully manage risk. The goal of safety and risk management via a sound maintenance program aligns with this concern.

The "facilities to executives" language problem is compounded by the fact that investments in physical infrastructure are often invisible or gradual. For example, many electrical systems are hidden in power rooms and drives, motors, pumps and valves are hidden in basements or above ceilings. Predictive maintenance systems that manage the performance of all these assets are unseen by most of the organization's employees. Yet this "behind the wall" innovation builds profit through operational efficiency, improved uptime, and connectivity-inspired business productivity gains.

When selling more advanced maintenance approaches such as predictive maintenance, facilities and operations personnel need to emphasize these three points:

1. Highlight the practical business benefits of the maintenance plan being proposed.
2. Explain the side benefits of how innovation helps build competitive advantage through enhanced asset performance.
3. Emphasize that deploying innovation is not a one-time, one project benefit and discuss future improvement potential.

Facilities management selling strategies

Facility and operations staff need to also communicate the

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Selling Maintenance Investments to Executives (cont.)

cost of operating facilities in a reactive mode (as opposed to preventive and predictive modes). The break/fix approach tends to be the most expensive approach and also represent the highest level of risk for shutdown and business interruption. Downtime costs of several hundred thousands of dollars per hour are not uncommon in most industries. The indirect effects of downtime such as lost revenue from cancelled services, legal liability, damaged reputation, loss of customer satisfaction, or loss of market share also need to be factored in.

To avoid these worst case scenarios, facility teams need to build proposals that reflect an investment prioritization roadmap that allows executives to make the right maintenance planning decisions. Maintenance proposals should include the following touchpoints:

To transform from a reactive or preventive strategy to a predictive approach, organizations may need to earmark funds to implement and support new software platforms capable of capturing data on the actual condition of systems and equipment.

- Investment returns
- Demonstrated reduced risk
- Resources required
- Metrics to be deployed to show return (e.g., uptime, asset longevity, cost control, yield/quality, safety)
- Roles and responsibilities of those involved

Improvements in maintenance execution will improve ROI in several ways. Access to real-time data across systems reduces the time it takes to diagnose and fix issues and provides new insights into the various system components that work together. This creates opportunities to improve and optimize overall operations. An integrated maintenance program that involved the right partners with the proper mix of maintenance approaches makes it easier to identify best practices or areas that need improvement.

In order to transform from a reactive or preventive strategy to a predictive approach, organizations may need to earmark funds to implement and support new software platforms capable of capturing data on the actual condition of systems and equipment. Facilities staff may need further training, and perhaps additional staff would need to be hired. These factors obviously require a larger budget than the assumed "no problems" budget of reactive maintenance (i.e., where the planned expense is essentially $0).

Whether in-house or outsourced, incorporating analysis and prioritization drives the initial maintenance program costs higher. All of these factors will depend heavily on the size and culture of the company that is managing the facility, but the startup costs are not negligible. However, as with the perceived savings in reactive maintenance, this supposed higher expense is an illusion. The return on investment for

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Selling Maintenance Investments to Executives (cont.)

predictive maintenance is realized several times over.

Nevertheless, this higher initial cost presents a challenge for some organizations, since a predictive maintenance program requires buy-in and approval from upper management. The biggest hurdle will be changing the organizational culture to look at maintenance in a new way.

> Improved physical infrastructure maintenance plans have to translate into improved uptime which then has to be converted into impact on cost reduction, faster turnover, and/or higher return on investment.

Also, practical examples can help facilities teams to illustrate the point. Below is an example of how a predictive maintenance approach saved one company millions in potential lost revenues:

The asset in question was a 110MW steam model turbine with seven bearings (including generator bearings). According to the asset maintenance records, over one year this turbine demonstrated sporadic isolated issues, followed by an escalating condition that eventually resulted in the shutdown of the unit. The maintenance personnel identified turbine bearing vibrations and took corrective action. Upon completion of the maintenance, a similar cycle of sporadic issues began again, in addition to the introduction of new problems.

This unit's raw historical data was then analyzed with an up-to-date predictive analytics tool (in this case, Schneider Electric's Avantis PRiSM® tool). The results were significant. Had a predictive asset analytics solution been in place, plant personnel would have received early warning that turbine thermal expansion issues were developing and becoming chronic over the year. Through a modeling exercise, the tool was able to detect the fault patterns with early warnings six months prior to failure. The model showed that the bearing vibrations were a symptom while thermal expansion issues were the primary cause of the problem. Proactive remedial maintenance would have corrected the thermal expansion problem before it led to bearing vibration issues and the shutdown of the unit. The result would have been significant savings in maintenance costs as well as additional generation sales due to increased unit availability. Estimated savings in this case are in the millions of dollars - a result of 35 days avoided downtime offline and associated repair costs.

Such examples, and the savings that can be realized are driving the adoption of analytics for facility maintenance. As a result of improved technologies and decreasing implementation costs, predictive approaches to maintenance are expected to grow by 20% annually worldwide over the next few years.[10]

Takeaway: Any proposals presented to executives surrounding expenditures on maintenance modernization will need to be tied to business value.

New Tools for Maintenance Personnel

Most facility maintenance managers and technicians would agree that their jobs, over time, seem to be getting more complex. These days, building and industrial maintenance personnel are expected to be familiar with a broad range of products and to also understand how these products impact other connected devices. They are also tasked with producing detailed reports, so that facility management can track important equipment performance and uptime data.

Without proper servicing, the energy consumption of power distribution, HVAC and lighting infrastructure can increase dramatically—as much as 10 to 20% as the system slowly goes out of adjustment. As facilities modernize and as infrastructure becomes more automated and connected, maintenance planning and execution become critical success factors for rapidly servicing equipment and maintaining uptime.

Despite this high pressure work environment, relief is on the way for maintenance personnel in the field. Some new, relatively inexpensive tools are now becoming available that make the task of managing equipment maintenance much easier… and it all starts with a mobile device.

Without proper servicing, the energy consumption of power distribution, HVAC and lighting infrastructure can increase dramatically—as much as 10 to 20% as the system slowly goes out of adjustment.

From tedious to simple: The power of connectivity

Imagine a field engineer tasked with performing scheduled maintenance on some electrical systems. In a traditional environment and under normal conditions (if there ever is such a thing) he or she would have to locate the part that needs to be inspected or fixed, schedule some time to perform the maintenance, perform the proper diagnostics, administer the fix, test for proper function and then write up the report and submit to interested stakeholders. This work takes hours of tedious coordination, multiple phone calls, and sitting down once the work is finished to write a report.

And this detailed work often comes at the end of a tiring day when the field engineer's brain is already spent.

Now imagine a simple app on a smart phone that is designed with one priority in mind: simplification of maintenance operations in the field. It's a cloud-based tool that remotely monitors the status of all the connected assets under management. The field engineer and his management team has access to:

- Operation history to demonstrate that the job is done and to comply with asset maintenance regulations

New Tools for Maintenance Personnel (cont.)

- A maintenance plan to remember all the tasks
- A documentation repository that provides relevant information such as user and maintenance guides, single line diagrams and drawings

Here is how this tool works:

A digital logbook for each asset is integrated with a GPS, and informs stakeholders the location of the equipment that requires attention and traces maintenance activities in real time. If desired, each asset operation log can be customized to include voice memos, notes, photos, and measurements. A planning and task reminder associated to the asset logbook allows access, via smart phone, to a pre-defined maintenance plan. This information is then automatically accessed by any pre-approved peers and managers at any time, so that field engineers don't have to constantly report back to their managers. And best of all, this tool, which has gathered this data over the course of the day, produces a maintenance report in one click. That means the field engineer no longer has to sit down to write out information on forms describing what work was done and which equipment was worked on.

Most facility maintenance managers and technicians would agree that their jobs seem to be getting more complex.

Such tools allow maintenance personnel to create a collaborative community which includes team members, customers, and other interested parties. Therefore, information like digital logbook history and maintenance plans can now be shared. Equipment status and problem/resolution information can be communicated in real time through chats with colleagues and customers.

These apps can also be connected to predictive monitoring systems so that instant alerts and early warnings can be send out before any downtime or failure occurs. New pieces of equipment, when they come on line, can easily be added to the inventory. The more these tools are used, the more efficient the entire maintenance operation becomes.

Data management has become a key success factor in the maintenance modernization scenario. In order to succeed in cutting costs and reducing downtime, stakeholders need the ability to execute the following tasks:

- Gather data about the facilities
- Interpret that data through comprehensive and simple to use dashboards,
- Convert dashboard information into actions that save money and improve facility performance

Architecting such a data driven infrastructure from the ground up is costly, however. Fortunately, new, affordable services are available that allow organizations of all sizes to address these challenges.

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New Tools for Maintenance Personnel (cont.)

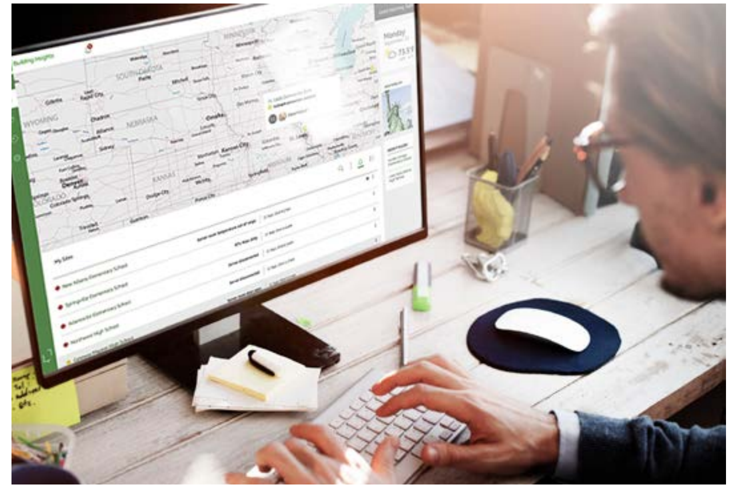
One example is a new service called [Facility Insights] (a Schneider Electric offering). Here's how it works:

First a site assessment is conducted and a proposal delivered to the facilities team. Meters are then installed to collect the relevant building physical infrastructure data. The information is sent to a cloud platform that drives the display of the data. Certified experts analyze that data, and then deliver detailed savings recommendations.

Examples of how such a tool can be applied include timely prioritized maintenance (what equipment is experiencing or about to experience faults), asset performance (what is working well so that best practices can be shared with other facilities), and reduction of energy costs (shift to a less expensive utility contract, efficient lighting controls, more efficient approach to HVAC).

Those who have utilized such tools identify the following benefits:

- Maintenance cost reductions of up to 8% [11] – The tools allow for planning and management of maintenance from any location. Maintenance work is also performed at the right time. All maintenance events on all equipment are tracked. Fault detection and diagnostics capabilities allow for a migration to predictive maintenance.
- Downtime reductions of up to 9% [12] – As a result of the active data gathering, various building sites can now be benchmarked. Abnormal conditions on equipment are identified ahead of time so unanticipated breakdowns can be avoided. Tenant activities and appropriate cost allocation are easier to manage.



Data management has become a key success factor in the maintenance modernization scenario.

Comprehensive reporting (monthly, year to date, yearly consumption, daily consumption, zone and usage consumption) powered by analytics allow for accurate reviews of progress.

- Energy savings of up to 18% [13] – These tools are capable of detecting abnormal consumption such as wasted energy, over heating or over cooling and water leakages. By interpreting utility contracts, the certified experts can propose plans to cut costs and to avoid power factor-related consumption penalties. Energy performance indicators can first be defined and then tracked so that effective improvement plans can be put into place.

The flexibility of predictive tools

Predictive asset analytics software allows for operations and maintenance personnel to be more proactive in their work. For example, instead of shutting down a section

New Tools for Maintenance Personnel (cont.)

of a power plant immediately, a problematic situation can be assessed for more controlled outcomes. Loads can be shifted to reduce asset strain or the necessary maintenance can be scheduled during a planned outage. The software tools allow for better planning which in turn reduces maintenance costs. Parts can be ordered and shipped without the need for expensive rush charges and equipment can continue running while the problem is being addressed. Maintenance windows can be lengthened as determined by equipment condition and performance. Other benefits include increased asset utilization and the ability to identify underperforming assets.

Other savings can be realized when avoided costs such as loss of power, replacement equipment, lost productivity, and additional man hours are considered. The power of predictive analytics tools is that they transform raw data into easy-to-understand and actionable insights that result in improved availability, reliability and decision-making.

Architecting a data driven infrastructure from the ground up is costly. Fortunately, new, affordable services are available that allow organizations of all sizes to address this challenge.

Predictive analytics tools allow personnel to visualize actual and expected performance of an asset including detailed information on ambient conditions, unit loading, and operating modes. Operations personnel become knowledgeable regarding where inefficiencies exist and what the impact is on financial performance. They can gauge the future consequences of the actions and decisions they make in the present. Risk assessment becomes a more exact science and the potential behaviors of each monitored asset and can be used to better prioritize capital and operational expenditures.

Knowledge capture is another benefit of the predictive analytics tools. In an environment where transitioning workforces are becoming more prevalent, knowledge capture ensures that maintenance decisions and processes are repeatable. Therefore, when experienced personnel leave the company, their years of accumulated knowledge remain available to incoming staff.

The reliability and efficiency improvements that accrue through the use of predictive asset analytics software also result in increased customer satisfaction rates. Consumers can experience more reliable service with fewer outages because utilities have the insight needed to avoid potential equipment failure and forced outages.

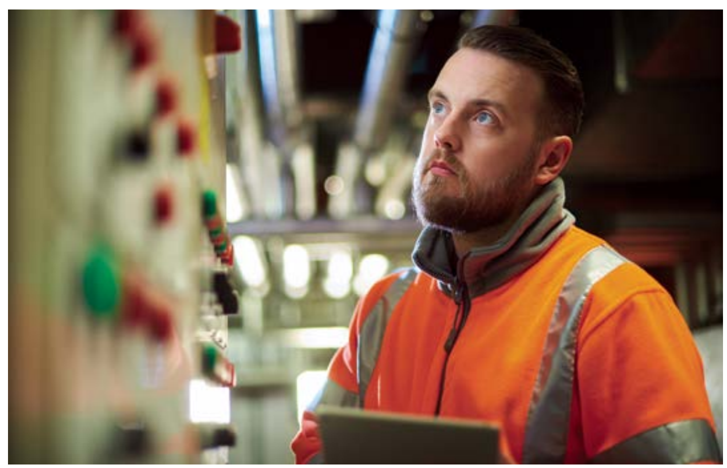
Takeaway: New tools now make it much simpler to manage an installed base of equipment that support reactive, preventive, and predictive maintenance methods.

Dealing with Hazardous Maintenance

Certain types of maintenance involve inherent risk to the maintenance personnel in and around the equipment (medium-voltage electrical distribution switchgear, for example). In such cases, safety standards need to be strictly enforced and detailed process and procedure should be adhered to by senior experts.

As in the case with switchgear, those performing the work must exercise caution and strictly follow recommended NFPA 70E procedures such as:

- Understanding all the possible sources of electrical energy supplied to the switchgear being maintained. This includes, but is not limited to, reviewing the most current electrical drawings and sources of energy to the switchgear.
- Properly disconnecting all the identified sources of electrical energy.
- Isolating these sources and make a visual verification that sources have been isolated. This can be done via switch viewing windows or by withdrawing a circuit breaker from its cell.
- Applying lockout/tagout designation to devices according to an established policy developed by the owner or organization performing the maintenance.



Certain types of maintenance involve inherent risk to the maintenance personnel in and around the equipment. Safety standards need to be strictly enforced and detailed process and procedure should be adhered to by senior experts.

- Verifying that electrical energy is absent from areas that need to be worked on. This can be accomplished with an appropriately rated voltage detection device used to test voltage differences between phase-to-phase and phase-to ground. Before and after each test, the voltage detector should be tested to determine correct operation.
- Properly grounding the conductors in the area of switchgear being maintained with devices rated for the available fault current in order to create an “equi-potential zone,” as described in OSHA 1910.269(n)(3), in which maintenance personnel may work.[14]

Additional areas of risk

Another source of risk during maintenance is electromagnetic energy storage in equipment connected to the power system. The promotion of renewable power sources, uninterruptable power supplies (UPS) and power quality devices have increased the number of sources of energy on modern electrical distribution systems. Renewable energy, generators and battery systems complicate distribution systems, and can make securing all sources of energy difficult.

Microturbine and UPS systems, which are becoming more prominent in critical power applications,

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Dealing with Hazardous Maintenance (cont.)


Renewable energy, generators and battery systems complicate distribution systems, and can make securing all sources of energy difficult.

can transfer unexpected energy onto the system while switchgear is under maintenance. Power factor correction capacitor banks that have not been properly discharged can pose a danger in switchgear being maintained. Automated generator systems or power transfer switches can energize switchgear in unforeseen power loss scenarios. Lengthy, medium-voltage cable runs will hold capacitive energy that can be suddenly released to de-energized switchgear during maintenance or mechanical testing procedures. These sources, plus more common incidents such as dropped tools, initial construction errors or misread electrical drawings, illustrate that the possibility of incidental energization of switchgear while under maintenance is quite possible.

Implementation of grounding switches at the switchgear design phase can address many of these concerns.

Automated generator systems or power transfer switches can energize switchgear in unforeseen power loss scenarios.

Safety enhancements decrease the risk to workers. Interlock schemes help protect workers from grounding into live parts, and live line indicators act as a visual safety indication. The intuitive design of integral grounding switches decreases the likelihood of human error by eliminating additional dangerous steps during the manual grounding process. The largest benefit is removing the need to expose personnel to energized equipment by grounding current carrying elements before panels or covers are removed. Implementing switchgear with integral grounding switches shows a dedication to safety and high-quality switchgear maintenance.

Takeaway: Extra precautions need to be taken when performing potentially hazardous maintenance. Product designs can often enhance worker safety when maintenance needs to be performed. However, limiting risk of injury by outsourcing this type of work to experts is likely to be the most prudent step.

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Conclusion

Organizations can transform and modernize their maintenance strategies by leveraging data and predictive asset analytics to gain the greatest return on every single asset. New predictive asset analytics software tools can allow asset owners to monitor critical assets for the purpose of identifying, diagnosing and prioritizing impending equipment problems — continuously and in real time.

However, a mix of reactive, preventive and predictive maintenance is recommended, especially for organizations that have traditionally relied on a reactive-only maintenance philosophy. Predictive maintenance is just one piece of the puzzle and it requires upfront investment in infrastructure in order to begin the process of predictive analysis. Over time, predictive approaches can be phased in to support some of the more critical elements that impact the overall reliability of the system.

Leading infrastructure vendors like Schneider Electric can assist in providing long term maintenance planning based on the specific needs of the organization. This can include branching out from reactive maintenance to both preventive and predictive approaches. For organizations more advanced in their maintenance planning, guidance can be provided for establishing a comprehensive Reliability-centered maintenance (RCM) program.

Predictive maintenance is just one piece of the puzzle and it requires upfront investment in infrastructure in order to begin the process of predictive analysis.

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Additional Resources

Schneider Electric's Service Plans

"Understanding How Predictive Analytics Tools Benefit Power Utility Asset Management."

"7 Predictive Maintenance Technologies That Enhance Power Equipment Reliability."

"How Service-Oriented Drive (SOD) Deployments Improve VSD Driveline Uptime."

"Understanding Maintenance Contracts and Requirements for Low Voltage Power Distribution Equipment."

"Real-time Maintenance Execution"

Footer Notes

[1] HSB (2010): Recommended Practices for EPM.

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[3] Network Computing, the Meta Group and Contingency Planning Research

[4] Hartford Steam Boiler Claims Data (2010).

[5] Westray, P. (2013). Electrical Preventative Maintenance (EPM)

[6] "Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency," Federal Energy Management Program, U.S. Department of Energy, August 2010

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[8] ARC Advisory Group, "Condition-Based Maintenance Improves Uptime and Lowers Costs", November, 2014

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[10] "Business strategy: Analytics and data management for Smart Buildings," IDC Energy Insights, November 2012

[11] Manufacturer Publication, CIAT and Trane

[12] The Service Council publication

[13] Navigant Research publication

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