Life Is On | Schneider Electric

Benefits of shifting from traditional to condition-based maintenance in electrical distribution equipment

by Arnaud Rivals

Executive summary

As businesses become more connected and digital, the need to rethink maintenance strategies intensifies due to increased business continuity risks and higher downtime costs. Technology trends such as the Internet of Things (IoT) and big data now make it much simpler to plan and manage an installed base of electrical distribution equipment and to cost-effectively combine preventive and predictive maintenance techniques.

This white paper explains the power of condition-based maintenance and how it addresses modern electrical infrastructure reliability and availability requirements.

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Introduction: The impact of digitalization

New words like digitalization, digital service, and connectivity are increasingly used in industry, especially in the electrical distribution domain.

Digitalization is using digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.[1]

Digital service is commonly described in two ways:[2]

1. It is a service that is delivered via the internet or electronic network
2. It is automated and requires little to no human intervention

Connectivity is the ability of a computer, program, device, or system to connect with one or more others.[3]

As digitalization acceleration spreads across global manufacturing environments, the number of IoT devices worldwide is forecasted to triple from 9.7 billion in 2020 to more than 29 billion in 2030.[4] One of the areas poised to benefit the most is electrical distribution equipment maintenance.

Traditional maintenance strategies have lacked insight into the actual condition of low-voltage (LV) and medium-voltage (MV) distribution assets. They have failed in the challenging mission of preventing downtime. Moreover, some owners of electrical distribution equipment haven't performed maintenance at all, while others consider the equipment "maintenance-free" because, in some cases, it has functioned without incidents for years.

But this traditional maintenance approach has grown too risky, particularly when an **unscheduled power outage can lead to cascading disruptions**. In addition, the **threat of unplanned downtime increases exponentially due to the asset's age, particularly if there's** no proper maintenance. Among Fortune 1000 companies, for example, the average total cost of unplanned application downtime per year is $1.25 billion to $2.5 billion. A single hour of downtime now costs 98% of firms at least $100,000, and 86% of businesses say one hour of downtime costs $300,000 or higher.[5]

The main function of modern electrical distribution systems is to help **provide business continuity and reliability** through a stable and predictable supply of electricity. But the consequences of system defaults go beyond just high cost; they can generate long electrical downtimes and physical damages. Additional challenges, such as overcoming the **lack of skilled personnel** and the increasing pressure on operations managers to **improve operational efficiency** and contribute actively to their business **sustainability goals**, make it difficult for operations and maintenance teams to manage their network effectively.

1 Gartner Glossary
2 Schneider Electric, What are digital services?
3 Cambridge dictionary
4 Lionel Sujay Vailshrey: "Internet of Things (IoT)-statistics & facts, August 2022
5 ITIC, "Hourly Downtime Costs Rise: 86% of Firms Say 1 Hour of Downtime Costs $300K", May 2019

For these reasons, a solid maintenance strategy should be implemented by analyzing how and where more recent maintenance approaches, such as **predictive and condition-based maintenance**, make sense. On the other hand, selecting a trusted services provider with deep knowledge and skilled technicians who can support you throughout your equipment's lifecycle to modernize and/or maintain them through a services plan is crucial.

Benefits of a proper maintenance strategy

According to IDC, 38% of companies reported events resulting in production losses. However, according to the same research, the adoption of digital services is still below expectations, representing roughly 30% of the companies interviewed.[6]

Updating or upgrading power systems maintenance plans that reflect the new reality of digitalized operations provide **five important benefits**:

1. **Safety and electrical equipment preservation** – Plant managers must adopt all technical and economic measures available to minimize the risk of unplanned events that can harm personnel, assets, and/or the business. Today, 70% of facilities operate with complex electrical systems, often leading to equipment damage and unplanned downtime.[7] Structured maintenance approaches focused on circuit breakers, designed to minimize the risk and severity of electrical system-related accidents or process breakdowns, are a good first step.

2. **Service continuity** – With many businesses relying on the 24x7 availability of their information technology (IT) and operations technology (OT), proper maintenance plans emerge as a competitive asset. Research reveals that more than 67% of breakdowns can be avoided through formalized maintenance service planning.[8]

3. **Energy-efficient equipment** – Electrical equipment that is not maintained is not as energy efficient as well-maintained equipment. Over time, normal wear and tear cause component stress, resulting in diminished energy efficiency and higher overall carbon emissions. An effective maintenance program will be very important in energy management practices.[9]

4. **Efficient spare parts management** – Spare parts alone can amount to half the total maintenance costs. Substituting a "break-fix" maintenance approach with a more modern, pragmatic, and lower-risk one can reduce these costs. An effective maintenance program will help reduce the breakdown of equipment and will provide better insight into spare parts management.

5. **Lower total cost of ownership (TCO)** – Considering the significant capital expenditure (CapEx) costs of installing new equipment, it's important to keep electrical distribution equipment running well for as long as possible. A planned maintenance program will help increase the useful life of the equipment and avoid premature replacement. Instances of emergency interventions, which often coincide with higher spare parts and labor costs, will also be reduced, resulting in lower operating expenses (OpEx).

6 IDC Whitepaper: Maximize Business and Operation Resiliency through Services
7 IDC Whitepaper: Maximize Business and Operation Resiliency through Services
8 Schneider Electric White Paper compares on-demand vs. service plans for electrical maintenance programs. 2017
9 Backlund S., Thollander P., Palm J., and Ottosson M. Extending the energy efficiency gap, pages 392–96, 2012

Maintenance approaches

Maintenance plans have evolved since the infusion of intelligence in electrical equipment, joining the three maintenance approaches described in this document.

We will not consider the corrective maintenance, or run to fail, which means no regular verification and maintenance are carried out on the equipment. It's generally intended for equipment whose repair costs are low, with a mean time to repair (MTTR) not resulting in a significant loss of production and associated costs; that's why it's not included in this paper.

The three main maintenance approaches

Below are **three of the main approaches to electrical distribution equipment maintenance** that owners often deploy:

1. **Predetermined maintenance**
   Predetermined maintenance is a preventive type carried out at established intervals, often referred to as calendar-based maintenance. It is a scheduled activity consisting of a series of systematic actions based on the assumed operating conditions and expected life of the assembly and its components.

   Compared with corrective maintenance, predetermined maintenance enables the planning of interruptions for maintenance, thereby minimizing the costs associated with loss of production and allowing power to be available to the connected loads when expected.

2. **Condition-based maintenance**
   Condition-based maintenance (CBM) is a preventive maintenance method that monitors the condition of equipment to determine which maintenance tasks need to be carried out and when.

   Compared to predetermined maintenance, condition-based maintenance permits some flexibility in the scheduled maintenance. It may require additional sensors in the equipment. Based on the data available, the time interval between two interventions can be reduced or extended as necessary. For low-voltage switchgear and control gear assemblies, the maintenance required can be based on one or several parameters, for example, the number of mechanical operations, the number of over-current trips, loading, ambient environment data (temperature, dust, salt content in the atmosphere, etc.), current harmonics.

3. **Predictive maintenance**
   Predictive maintenance is an advanced form of condition-based maintenance that enables developing faults to be analyzed and helps predict future consequences and time to downtime events. It determines when to schedule proper maintenance and which decisions should be made when the equipment's end of life gets closer.

   Predictive maintenance generally reduces maintenance by limiting it to only what is necessary for the device's actual working environment. Generally, predictive maintenance relies upon the following:

   - Multiple sensors in and around the device with frequent (hourly, daily) data reporting to a central processor.
   - Some form of a microprocessor uses the data from the device sensors and algorithms applied to simulate and trend aging, based upon the actual live operating conditions of the device, to estimate the remaining time before downtime occurs and the need for maintenance.

Which one is right? The answer is "hybrid."

Throughout its working life, electrical equipment should undergo appropriate maintenance. Subject to the manufacturer's recommendations, maintenance of equipment can be **predetermined, condition-based or predictive, or a combination of two or more types of maintenance.**

Predetermined maintenance should be organized based on inspections supplemented with operational checks followed by an examination. The inspections and checks should be of such frequency to ensure that no undue damage or excessive wear has been sustained in the course of operations since the last maintenance action.

Examinations should be conducted to determine whether there is any need for reconditioning of the contact systems, lubrication and adjustment of mechanisms, or insulation deterioration. The appropriate interval for the examination should be determined from the outcome of inspections or operational checks or be based on the manufacturer's recommendations, considering operating duty, environmental conditions, and the potential effects of downtime events. Inspection and testing of insulation should be undertaken during the examination.

Condition-based maintenance is similar to predetermined maintenance, except that the interval between maintenance is determined based on operating parameters. Compared with Corrective/Reactive (Break-fix) methods, preventive maintenance savings can reach 12-18%.[10]

This is because unplanned downtime and maintenance make inroads into productivity and profitability. For example, maintenance and downtime account for 25-30% of the total lifecycle cost of a pump.[11]

Predictive maintenance is less arbitrary as it relies on advanced analytics and aging models applied at timely intervals and predicts the necessary maintenance and when it must be carried out.

The **selection of the right maintenance approach** will depend on various factors influencing the proper mix of these approaches. These variables include:

- Budget
- The severity of downtime
- Age of the system
- Criticality of specific assets, among others

The site manager must weigh the options and select a maintenance strategy that is the ideal fit for their operation.

Today, many organizations are moving beyond reactive and preventive maintenance and adopting more condition-based and predictive maintenance practices, moving to a proactive approach.

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10 Frost & Sullivan, "Data-driven Asset Performance Management White Paper," 2020

11 Frost & Sullivan, "Data-driven Asset Performance Management White Paper," 2020

Migrating to condition-based and predictive maintenance might require the installation of dedicated **sensors that provide real-time and trended data** for key characteristics within electrical distribution equipment.

This data is gathered by a maintenance information system (sometimes referred to as “enterprise asset management”), which can be further integrated with a plant-wide enterprise resource planning (ERP) system. Over time, maintenance interventions can be forecasted and launched when programmed alarms (online monitoring of selected parameters of equipment’s core items) indicate that a predefined wear threshold has been reached.

With a well-designed predictive maintenance system, cost reductions can be achieved through better management of resources and spare parts, providing equipment integrity and process reliability audit, optimizing equipment obsolescence management, and predicting when a downtime event is likely to occur.

Maintenance optimization with a condition-based approach

When it comes to maintenance periodicity, each manufacturer recommends a specific schedule.

In normal environmental conditions, the recommended manufacturer maintenance is performed every three years for LV/MV equipment and transformers. This is based on the knowledge of the Schneider Electric Installed Base and historical maintenance experience. This recommendation is valid for any industry and geography. For example, at Schneider Electric, there’s a holistic approach at the site level, not at the asset level.

This maintenance periodicity shall be reduced depending on environmental conditions, where one parameter might influence the whole performance, from normal to severe, as mentioned in **Figure 1**.

Figure 1

Time-based maintenance recommendation

Environmental Factors	Normal all criteria to be fulfilled	Severe from one criterion checked
Temperature Average annual around/out of the switchboard	T° < 35°C	T° > 35°C
Humidity Relative	H < 85°	H > 85°
Salinity Site distance from seaside and room with no protected atmosphere	Low salt mist D > 10km	High salt mist D < 10km
Dust Level further to filtration and/or ventilation present	Low dust level or Filtration and/or ventilation	High dust level and No filtration or ventilation
Impact on maintenance cycles		
Equipment Low-Voltage Medium-Voltage Transformer	T = 3 years	T = 2 years

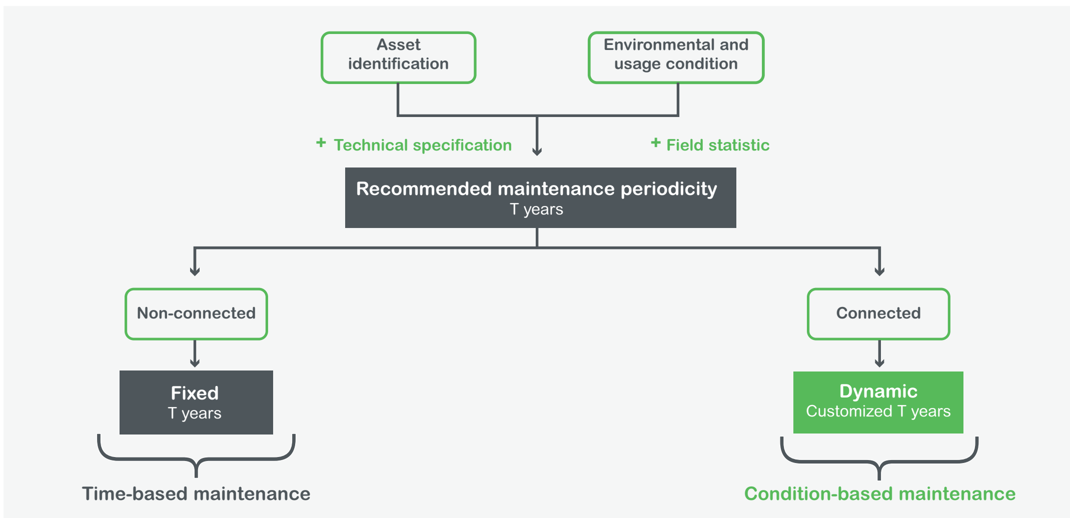
Optimization of maintenance intervals (periodicity)

Breakthroughs in IoT, big data analytics, and cloud connectivity influence how electrical asset maintenance intervals (maintenance periodicity) are fine-tuned. Now digitizing, collecting, and analyzing product-specific information (e.g., equipment age, maintenance history, environmental characteristics, and usage of condition data) makes it possible to optimize maintenance periodicity.

It is valuable for maintenance organizations to reduce shutdown periods and save money on operations expenses. The recommended maintenance periodicity remains fixed and predetermined if the electrical equipment is not monitored. But when sensors are installed, or the device is network connected (i.e., if sensors are native) in this same electrical equipment, it's possible to benefit from analytics to dynamically extend maintenance periodicity when condition-based or predictive maintenance is deployed, as explained in **Figure 2.**

Figure 2

Extension of maintenance periodicity



But how does it work?

First, let's understand better why we need **sensors in the equipment** and how it impacts the value of condition-based maintenance.

Asset remote monitoring

New remote monitoring tools help address potential maintenance issues before they result in unanticipated downtime by delivering, at the right time, detailed performance information to the people who need it. For example, if thorough diagnostics can be performed remotely before a service visit, the problem's root cause and potential consequences can be ascertained ahead of time. This allows the service team to quickly locate the equipment requiring service and minimizes the time needed to perform the maintenance.

The Oil & Gas industry has been successful in deploying this kind of approach. Equipping their electrical distribution devices with **intelligent sensors** that gather data, service representatives know when and how to service equipment ahead of time. Since these devices are connected, they send the data to a cloud repository, which is then correlated and analyzed on servers. The output of that analysis enables better, faster process decisions that help reduce costs and drive efficiencies.

Consider the example of electrical systems that support pump jacks in an oil field. Traditionally, oil companies regularly scheduled crew visits (every six months or so) to the pump jacks to ensure they were running. This was an expensive process. Often parts would get replaced whether or not they needed replacing. Certain pump jacks would malfunction (and may have been malfunctioning for quite a long time). Others would begin to malfunction shortly after repair crews left. There was no way to monitor their behavior.

New digital solutions now allow these pump jacks and their electrical support systems to record data locally so operational history can be accessed remotely. The data collected by a local system is submitted to the cloud irregularly (except when the pump starts to experience distress). Instead of waiting for a crew member to come around, an artificial intelligence (AI) engine allows these systems to send an alert. This new approach reduces losses by limiting pump jack downtime and boosts the operational efficiency of the repair crews.

When you're planning to digitize your electrical operation, **step 1 is to equip your critical assets with proper sensors**, and that can be done in three ways:

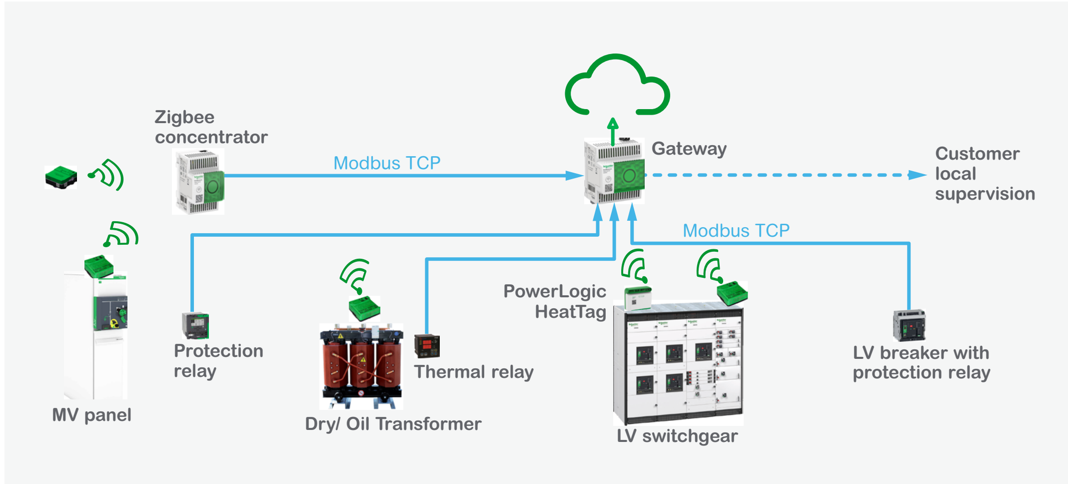
- If the electrical equipment is fairly new, the sensors will likely be native to the equipment.
- If the equipment is older, you may need to upgrade it by installing sensors.
- If the equipment is close to the end of life, you may need to modernize it and take this opportunity to install products with native sensors.

Sensors gather relevant data and send it to the cloud, which is analyzed and makes it possible to identify any potential anomalies in the equipment performance, **see Figure 3**. The three most important sensors for your electrical equipment are:

- **Wireless temperature and humidity sensor:** enables the continuous environmental condition monitoring of an enclosure (de-energized surface), such as a switchgear cabinet. The measurement features both the temperature of the surface in contact and the Relative Humidity, allowing MV and LV switchgear users to optimize predictive maintenance by avoiding conditions of deterioration due to moisture and pollution.
- **Wireless thermal sensor for continuous condition monitoring:** enables the continuous thermal condition monitoring of all the critical connections made on the field, such as cables, withdrawable circuit breakers, and busbar connections, helping to reduce risks for operators and equipment, prevent connection damages, minimize unscheduled downtime of critical installations, and optimize maintenance costs.
- **Detection of overheating cables sensor:** smart sensor, able to analyze gas and particles in the switchboard and alert before any smoke or insulator browning occurs. This sensor helps detect cable deterioration due to improper tightening torque or continuous vibrations, surfaces damaged by corrosion, excessive pressure, friction, fluctuations between cold nights and hot days, or low and high current.

Figure 3

The role of sensors



Advanced analytics toward predictive maintenance

Therefore, maintenance decisions can now be made based on data collected from the field, gathered from the maintenance history of thousands of components installed worldwide. Advanced analytics, also called **the maintenance index (see Figure 4)**, greatly increases the accuracy of decisions made and lowers the risk of performing maintenance too early (unnecessary cost) or too late (unanticipated downtime).

Figure 4

Maintenance Index

Interpretation of the "Maintenance table"
About the Maintenance Index value:
1. No action is needed. Scheduled maintenance date is confirmed
2. The maintenance plan has to be reviewed with the support of Schneider Electric experts
3. The maintenance date of the asset has to be scheduled in the next 2 years
4. The maintenance date of the asset has to be scheduled in the next 12 months
5. Maintenance activity has to be re-scheduled with high priority

The Maintenance Index indicates if maintenance has to be preponed for each asset vs. the initial date to avoid potential downtime and/or premature aging. A Maintenance Index can **extend the maintenance cycle up to 5 years** by continuously monitoring the connection to the cloud assets and performing an analysis based on stress, wear, and aging indicators, which allows **for dynamically controlling the date of the next recommended maintenance**. Moreover, end users can see their maintenance schedule in a dashboard and receive alarm notifications.

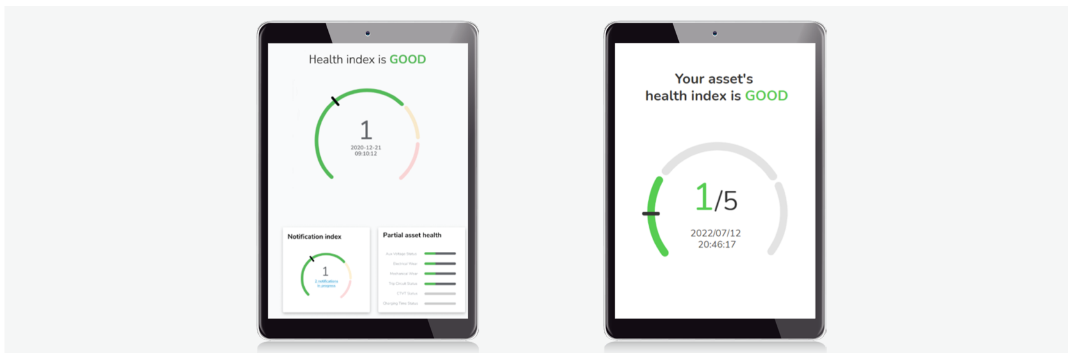
But what can make a real difference is the combination of this index with a remote expertise team that analyzes the data and contacts the end user to propose, when necessary, to reschedule the maintenance, plus an on-site services expert team that performs the maintenance with higher efficiency and more relevant insights thanks to analytics.

At the same time, this index is fed by additional data, including the Site Health Index, which estimates site risk based on the criticality and health of all the monitored assets:

- The criticality of each asset is defined by the customer, taking into account the potential electrical downtime impact on this process
- Based on field data and advanced analytics
- 24/7 monitoring accessible via mobile app and web portal
- Alarm notifications
- One Asset Health Index for each connected asset plus one overall site Health index considering the asset's criticality and health status (**Figure 5**)

Figure 5

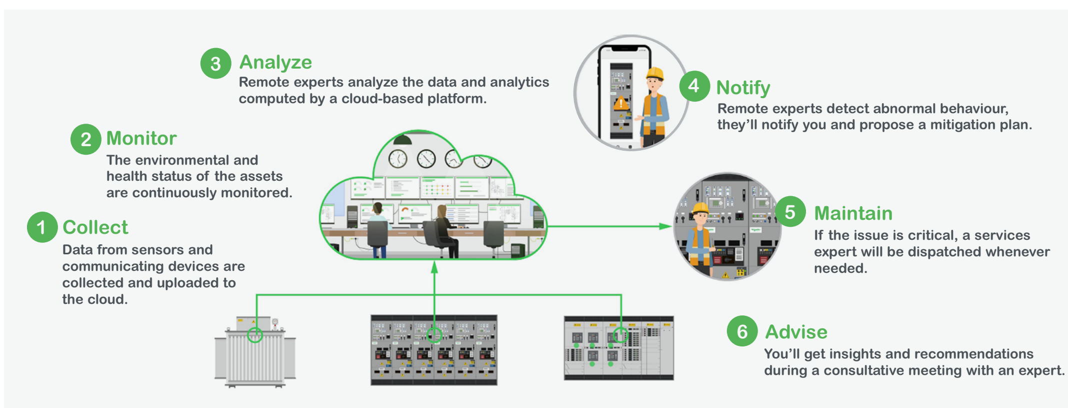
Example of Health Index by Schneider Electric



In this maintenance approach, supported by a **service plan**, assets under management can rely on a combination of on-site and digital services, from collecting the data from sensors to an advisory layer, as explained in **Figure 6**.

Figure 6

How to optimize asset management

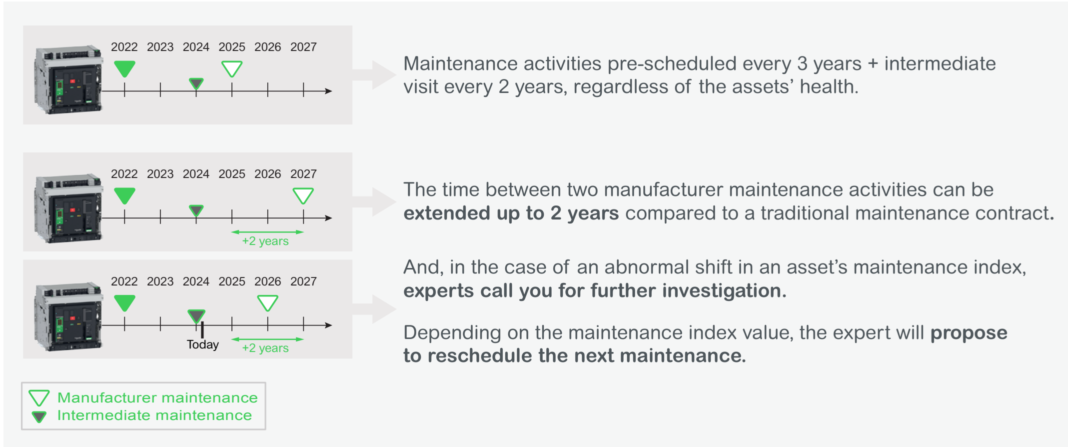


As shown in **Figure 7**, with condition-based maintenance, the time between two manufacturer maintenance activities can be extended up to 2 years compared to a traditional maintenance contract.

A remote expert will alert you for further investigation if there is an abnormal evolution of an asset's maintenance index. Depending on the maintenance index value, the expert will propose to reschedule the next maintenance to avoid downtime.

Figure 7

Maintenance timeline



What are the benefits of condition-based maintenance? According to internal studies:[12]

- **Up to 75%** of minimizing unplanned downtime
- **Up to 40%** of maintenance activities and planned downtime can be reduced with a strong financial impact
- **Up to 25%** lifetime extension can be reached

According to IDC, over 25% of companies interviewed could not accomplish their sustainability objectives.[13] By performing maintenance based on the condition of the assets and remote monitoring, there are savings in the carbon emissions related to dispatch services and the maintenance team. Besides, by monitoring the health of the equipment and anticipating potential issues, its performance is optimized, its lifetime is extended, and operation efficiency is increased.

Use cases

Maintenance programs are shaped through audits that determine the criticality of each component to the overall system. The audit will determine whether reactive, preventive, condition-based, or predictive maintenance is best for that particular component. Users can optimize spending by taking a "hybrid" approach while simultaneously lowering their downtime risks.

In essential industries like Food & Beverage, steep demand spikes place manufacturers in a position where a slowdown or halt in operations cannot be tolerated. For example, within dairy-producing operations, milk production from cows is ongoing. If plants are forced to cease operations, incoming milk will have to be discarded, resulting in regrettable waste of an important food asset and a corresponding negative impact on profitability.

Machine assets are taxed beyond typical limits, and provisions must be made to minimize downtime despite equipment breakages. In such cases, digitalization solutions that enable predictive maintenance help limited staff to focus on the most at-risk assets and plan repairs before any major.

Disruption to operations occurs. Companies can extend the lifetime of their equipment by measuring its condition with IIoT sensors. Companies can delay a repair beyond the standard period if it is not warranted. According to McKinsey, such improved condition monitoring typically reduces maintenance costs by 10-15%.[14]

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12 These percentages are non-contractual and are based on Schneider Electric's experience and expertise for the main root causes of electrical downtime observed and for which Schneider Electric has developed solutions.

13 IDC Whitepaper: Maximize Business and Operation Resiliency through Services

14 McKinsey, "Coronavirus: Industrial IoT in challenging times," April 2020

Despite that, as mentioned previously, the adoption of digital services is still low, less than 30% compared with traditional on-site services.[15] This means there's still a way to go to shift from corrective or calendar-based to condition-based or even predictive maintenance that combines on-site with digital capabilities.

For example, **Nestlé Nescafé**, in its largest soluble coffee factory in the world, in Mexico, which produces 1 million jars of soluble coffee, operates 365 days per year and cannot afford any downtime, but unfortunately, they have experienced this in the past several unplanned that caused production to falter, representing $52,000 per hour. But the determinant factor that made them rethink their maintenance strategy was a single disruption in April 2020: A short circuit inside an unmonitored section of the main substation resulted in a 14-hour shutdown, costing Nestlé approximately $588,000. Because this section wasn't connected, engineers weren't alerted that equipment was at risk. So, they have decided to move from reactive maintenance to a predictive approach by modernizing their production equipment with sensors and subscribing to a service plan that has allowed them to: avoid three stoppages per year, get real-time remote visibility on the asset's health, ensure business continuity, and increase operational efficiency.[16]

When a company has a calendar-based maintenance strategy, like **LafargeHolcim Maroc**, the world's largest cement maker providing construction materials for the building and infrastructure sectors, moves to a condition-based approach with digital capabilities, they can benefit from:

- Increased service continuity
- Reduced downtime
- Increased worker safety
- Optimized maintenance costs
- Improved monitoring to help prevent equipment from rapid aging

That's what has been achieved by modernizing critical assets and a predictive/condition-based approach that enables maintenance optimization with real-time insights into the condition of their electrical equipment, anticipating potential issues, and reducing costs.[17]

How to start the transition of maintenance strategy

The first step is to work with a trusted services provider with deep energy management and automation expertise to audit the existing electrical distribution network. Then, based on the audit, the experts will provide several recommendations to modernize equipment (if necessary) and update your maintenance plan based on your needs and requirements.

For those ready to undertake the maintenance strategy upgrade journey, several short-term actions are recommended:

- **Within the next month** – Identify initial areas within the enterprise that can benefit from the potential cloud-based maintenance remote monitoring services. Begin to seek out vendors that have emerged as digital diagnostics and performance-monitoring marketplace leaders.
- **Within the next six months** – Secure funding for low-risk and high-return projects. During this time, begin to assemble a team of interested stakeholders.
- **Within the next year** – Implement a digital maintenance pilot. Track expenses and quantify benefits during the pilot and test period—leverage vendors to fill in knowledge gaps where required.

15 PTC, Digital Transformation Report, 2018
16 Nestlé Nescafé Customer Success Story
17 LafargeHolcim Maroc Customer Success Story

Conclusion

Innovation in maintenance strategies creates business value in multiple ways. With remote monitoring of electrical equipment, **fewer on-site visits** are required, safety can increase, and people, equipment, and goods are better protected. Further, system availability enhancements through **consistent performance monitoring** help to avoid costly situations when emergency repairs are required. When issues are identified early, the potential damage presented can be mitigated to help electrical distribution equipment run safely for longer periods. In addition, when downtime can be scheduled instead of unanticipated, labor and spare parts costs are much lower, and stress levels among staff decrease.

Now's the time to embrace the benefits of big data and IoT to drive long-term electrical infrastructure reliability and availability.

Resources

How thermal monitoring reduces the risk of fire more effectively than IR thermography
White Paper

New gas and particle sensing technology detect cables overheating in LV equipment.
White Paper

About the author

Arnaud Rivals is the global offer manager of maintenance services for electrical distribution at Schneider Electric. In addition to his current position managing the electrical distribution maintenance services portfolio, he has broad experience in customer satisfaction and B2B marketing across industrial sectors. He holds both Master of Electrical Engineering and Master of Business Administration degrees.

Contact Us

For feedback and comments about the content of this white paper:

Energy Management Research Center
dscs@se.com