The Future of Remotization in the Electric Power Industry

A white paper by the GSEP Digitalization community
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Introduction and Context

Introduction

Climate change and greenhouse gas (GHG) emissions are a great concern shared by most organizations in the world today. Electric utilities are not blind to this reality. Furthermore, they are a major player in the expected evolution from today’s mainly carbon-based economy toward a green and sustainable carbon-free economy in two different ways: 1) current electric generation activities in many jurisdictions account for a significant portion of global GHG emissions; and 2) electricity will be a major vector of transformation that may positively replace a large part of actual fossil fuel usage in final end uses as the generation mix evolves to reduce the world’s carbon footprint. This important shift in final usage will support a growing demand for electricity while, at the same time, we will see an impressive penetration of renewable generation introduced in the grid. This major evolution will require an important transformation of the electric utility business.

In order for electric utilities to play the critical role they are expected to in this evolution, they will need to adapt and take advantage of many new technologies. Among them, remotization and reliance on many new digital technologies is seen as a strategic imperative that will greatly contribute to the adaptation of utilities to new economic realities and constraints. Remotization can greatly improve the efficiency of electric utility operations. It will allow electric utilities to improve the way assets are operated and maintained, how decisions to replace them are made and how construction sites are managed. Remotization has potential applications in almost every segment of the utility business, from generation plants, hydroelectric dams, transmission lines and substations, to the distribution grid and customer premises.
This paper aims to present the opportunities provided by the deployment of remotization technologies in the electric utility business. The current and future context of utilities is presented in order to gain a better understanding of the coming challenges that will drive change. Potential applications and expected benefits reveal the multiple possibilities seen by utility experts. Use cases will show how remotization is already a potential reality in many applications, and a vision of the future will establish that this is just the beginning. Then, drivers for the adoption of these technologies, as well as barriers, will be discussed. A quick review of the ecosystem that will be needed to address challenges in order to develop technologies and make deployment a reality is presented. Since the underlying purpose of this paper is to get outside actors interested and willing to contribute to the development of remotization technologies applicable to the electric utility business, the conclusion will highlight the importance of collaboration in the interest of rapid success.

Context

The electric system is a critical part of the modern economy’s infrastructure. It provides comfort for home users, lighting and air conditioning for commercial and institutional buildings, and mechanical capabilities for industries. Customers expect reliability and affordability without knowing exactly what electric power is. In fact, people never really use electricity; it is just a necessary vector to provide them with light, heat, hot water, fresh air or images on their screens, what they really need! Electricity is a given, at least in advanced economies, and developing economies generally aim to achieve this same goal.

However, concerns about climate change and greenhouse gas (GHG) emissions are now shining a light on the electricity business. On the one hand, the fact that about 65% of global electricity\(^1\) generation is based on important GHG-emitting technologies shines the spotlight on our business and causes stakeholders to announce their will to drastically reduce GHG emissions. On the other hand, the growing use of new technologies which generate green electricity from wind or solar and with almost no GHG emissions, positions electricity as the perfect vector to replace fossil fuels in many final end uses.

\(^{1}\) 2018, IEA.
This trend will increase the demand for electric power across society and industry. But the rollout of variable and intermittent renewable energies will result in more unstable power supply markets and greater difficulty for energy suppliers to manage and balance the grid.

All these changes put electric utilities in turmoil. What used to be a conservative business building new capacity based on load forecasts several years in advance, approved by regulators or state governments, is now changing its mindset to become a flexible customer-centred business in interaction with a number of players. In some countries where the use of electricity is rapidly expanding, utilities need to quickly build a totally new electric system. In others, new technologies are being rolled out amid legacy equipment that may still be there for several decades to come. All future grids are expected to integrate distributed and centralized generation from different partners, and we will see increased interaction between utilities, customers and aggregators, and probably among customers as well.

Electric utilities are at different point today. Some have already taken a few steps in advance of the previously described transformation, for different reasons. The generation mix is also different depending on resource availability, so different generation technologies are used. So urgency may be different from one electric utility to another, but they will all need to improve their flexibility and their efficiency in the future, probably sooner than later. Remotization can really help to achieve these objectives.

The next section describes remotization, presents different applications and discusses the potential benefits of remotization.
What is remotization?

Remotization can take many forms. In essence, it is any means of allowing decisions to be made and actions to be undertaken at a distance. As such, the SCADA\(^1\) system, which has existed for years in all electric utility businesses, can be considered the first step in remotization. However, in the near future, there will be a world of new possibilities thanks to digitalization, which will give access to an incredible amount of data, as well as robotics, artificial intelligence and so on. All these technologies will allow system operators to be aware of what’s going on in the electric system, not only by having access to more data, which could quickly overwhelm individuals, but by having valuable insights into the situation thanks to big data analytics, and robots and drones able to conduct inspections on their own.

With such technologies, abnormal situations would be detectable as soon as they occur and could be addressed before they deteriorate to a point where more damage could occur or, even worse, workers could be injured.

Thus, remotization can be defined as any means that allows system operators to be aware of a situation without being physically on site, or any means that allows system operators to act at a distance to inspect, verify, correct, measure or operate apparatus, devices or equipment. They could be thousands of kilometres away for some applications, and just a few metres away in other situations where those few metres keep them safe or give them access to locations that would be unreachable by a person without special equipment or significant effort.

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1. SCADA: Supervisory control and data acquisition, a computer system for gathering and analyzing real-time data.
Potential benefits

Remotization could bring many benefits to the electric power industry, from day-to-day system operations to major refurbishments and new construction and maintenance activities. It should improve many aspects of utility operations, including:

**Worker safety**

Remotization will improve safety and health awareness at work. It will bring to the field new applications of digital technologies and tools to ensure full situational awareness, monitor critical infrastructure and improve safety. Moreover, remotization is expected to redefine the scope of work; how is done, by whom and where, and it will also provide an important safety barrier to prevent miscommunication and incidents. In the event of a disaster, drones and mobile devices can be used to quickly collect information and investigate the extent and state of the damage. This information can then be applied to safely achieve a faster recovery. It can also increase the safety of lone workers by providing real-time health and activity information to a remote support room. Finally, in the case of potential contagion such as the current COVID-19 pandemic, remotization can significantly reduce the risk of workers’ exposure to airborne viruses.
Operational efficiency

O&M activities can reach a new level of performance through the implementation of remote solutions, which eliminate the repetitive and manual part of the utility process, and introduce new processes that add greater value. The quality and productivity of operations can be enhanced through the utilization of artificial intelligence (AI) and the Internet of things (IoT) in a wide range of fields, such as the automatic processing of routine tasks, and remote inspection and monitoring using drones and sensors. Remotization may also reduce unproductive travel time for utility employees needing to access remote facilities or dense urban locations where street traffic may be a concern.

Environmental impact

The use of technologies allowing for remote action and monitoring will support efforts to reduce CO₂ emissions, since more process and maintenance operations could be performed remotely by centralized specialists. In addition, remote monitoring allows for asset management and optimization at scale, introducing new solutions to successfully lead the shift to renewable energies and reduce fuel consumption.

System reliability

Grid stability can be enhanced in substations, supporting the growing complexity of grid management required by the growth of distributed generation, renewables, electric vehicles and storage capacity.
Activities that could benefit from remotization

Many activities in the electric power industry could benefit from remotization, including:

- **Operations in large facilities** (e.g. HV lines, PV plants), where drones could be used to monitor and detect anomalies and to automatically assess completed tasks in plants under construction.

- **Monitoring applications for IoT environments**, providing manufacturers with crucial operational and technical insights (edge processing and data analytics).

- **Predictive maintenance**: Remote collection of operational and quality data from equipment, and analysis and correlation of data with service operations to predict future malfunctions and process drift. Benefits include more efficient existing and new systems, lower maintenance costs and fewer breakdowns, thereby optimizing equipment effectiveness.

- **Remote commissioning and startup of new power plants and substations**

- **Specialized support** for daily operations carried out remotely leveraging on virtual reality and/or collaboration tools (e.g. training, support during emergency events).

- **Remote recognition** of risk behaviours via artificial intelligence.

- **Remote safety surveillance and fire detection**

- **Remote cameras combined with artificial intelligence-based image analysis and recognition technology** can be used to identify defects such as foreign body hang-ups, rust, oil leaks or dangerous hot spots in the underground cable junction room.

- **Interventions on or shutdowns of live high- or medium-voltage equipment**, eliminating the risk of dangerous power reestablishment after interventions and reducing the number and/or duration of equipment shutdowns, avoiding/reducing customer power outages and increasing asset availability.

- **Remote visits to inspect** power plants and substations.

- **Remote visits by suppliers** who need to carry out activities on the premises.

- **Remote visits to monitor the progress of work** during construction or other projects.
Potential applications and benefits

➤ **Inspection of transmission power lines:** Instead of a crew to run an inspection, the use of drones significantly reduces the duration of the inspection and reduces risks and dangers; this can be accomplished safely in a matter of minutes.

➤ **Using drones for distribution line inspections** for vegetation control to better define real needs may make it possible to restrict work to the sectors that need it most.

➤ **Distribution line power outages:** Drones may take less time to identify failures, especially when distribution power lines are not visible from the street, and make it possible to send a crew directly to the site of the problem, reducing work time and returning power to customers sooner.

**Further ahead**

Looking further into the future, we can imagine autonomous multi-purpose airborne and land-based robots and a large fleet of deployed sensors. These will offer wide coverage across the system for most major assets. Yet there will still be a need for a quick response to outages and emergencies, and for the assessment and repair of certain electrical equipment. Robots will be our emergency first responders, helping us to reduce our response time and lead time to the initial assessment of a situation. We can imagine a fleet of autonomous robots of various types, able to flex and perform different activities, depending on the situation. The flexibility and multi-purpose capabilities of these platforms are expected to be critical, since, although single-purpose, single-activity robots requiring human intervention may work, they are not expected to achieve the cost/benefit value required for the company and our customers.
This section presents some real applications of remotization. Some are demonstrations or pilot projects of technologies ready for commercialization, while others are an early rollout of new equipment or new concepts applied to utility facilities. These use cases show the benefits of remotization in different forms:

- Use of **extensive organized monitoring** in the United States to prevent unplanned failures and related damage.
- Deployment of **smart substations** in China to reduce manpower and improve the quality and efficiency of substation operations and maintenance.
- Use of **satellite images and AI** in Europe and South America to perform public lighting censuses.
- Use of **drones** to measure the electrical resistance of transmission line splices in Canada.
- Use of **AI and images** to increase safety on construction sites and in power plants.
- Use of **robots** to assess the durability of an aging aluminum conductor steel-reinforced (ACSR) cable on high-voltage lines.
- Patrol with **smart glasses** in Japan.

All those cases could be replicated in most utility around the world.
Use Case

Monitoring of large transmission level substation power assets

In the United States, American Electric Power (AEP) has standardized the deployment of online partial discharge, online dissolved gas analysis and bushing monitoring devices for different levels of transmission substation high-power transformers and shunt reactors (138 to 765 kV). This standardized monitoring package is composed of commercially available components from several different vendors.
These monitoring devices, and the data and alarms that they provide in real time, have been integrated into AEP’s internal communication and information gathering systems, to leverage their capabilities for near real-time (4-12 hour) notification and response to critical asset health monitoring alarms. As currently configured, when the monitors detect sudden changes or increases in certain parameters beyond the configured limits, alarms are received by the appropriate personnel, who follow defined processes for review and confirmation of the measurements, followed by an assessment with the appropriate subject matter experts.

As required, and following the recommendations of subject matter experts, decisions can be made by transmission system operators to remotely remove the equipment from service in a controlled manner for field inspection while isolated. In addition to the increased real-time awareness of the state of the assets, the information from the monitoring packages is guiding decisions to defer and reprioritize some maintenance activities that were previously strictly time based.

Since 2012, AEP has installed over 400 monitoring packages on transmission substation transformers and shunt reactors. This monitoring has replaced or deferred some of the condition assessments that were previously exclusively performed by personnel in the substation on a minor/major maintenance schedule that gave a sense of their current condition once every six months or more, and could at times require an outage of the asset under review. With this level of frequency of measurements and assessments, it was rare and difficult for AEP to identify an asset in a state of imminent risk of failure.

The management of these devices and the data and alarms that they provide, and their integration into internal processes and information gathering systems have allowed AEP to effectively manage over a dozen imminent equipment failures. The estimated value of the avoided site cleanup costs, collateral damage and repairs, and the accelerated time to asset repair and restoration have been estimated at over $40 million to date. Of course, the safety benefits to field personnel working near the assets are beyond measure.
In its journey to build this monitoring infrastructure, AEP learned a hard lesson in the early days, when it failed to fully integrate and commission all of the communication and data flows from the monitoring equipment to the information gathering systems, prior to the energization of a new asset. Unfortunately, this led to a missed save (the asset failed within 72 hours of its initial energization). Since then, all monitoring devices have been fully commissioned prior to the energization of new transformers and reactors.

Some of the information gathered from monitoring devices is relatively new to AEP. Interpreting it has required the close collaboration and assistance of vendors and subject matter experts. AEP continues to work toward and would like to explore more advanced analytic approaches to interpret the information and ensure a more automated and intelligent interpretation of all of these signals, with the ultimate goal of having clearer and faster response times to detected anomalies.

New processes and clear roles and responsibilities had to be developed and continuously revised when the first group of online sensors was deployed in order to ensure that the key stakeholders in the organization could quickly obtain and understand how to review and respond to alerts generated by the online asset monitors. This has been critical, since experience has shown that several indicators of a high risk of failure may only be present or noticeable for less than 12 hours before an asset fails.
State Grid of China Corporation (SGCC) proposed a new pilot project involving the construction of nine smart substations in seven provinces in China starting in 2019. China’s first 200-kV smart substation, Gehu Substation in Jiangsu Province, was fully up and running in May 2020.
The total investment in the digital transformation of Gehu Substation is about 80 million yuan (about US$12 million). The whole substation is equipped with 96 digital meters with long-distance data transmission function, 198 wireless intelligent sensors such as temperature and humidity sensors, smoke and immersion state sensors, and more than 140 HD cameras, to collect electric equipment status, identify environmental changes and analyze the operating status of the substation in real time. The company is also looking to install odour sensors to identify changes in the electronic components.

The renovated Gehu Smart Substation has a variety of smart functions, such as full awareness of device statuses, one-button switching operation controls, active warning of problems on devices, robotics all-round monitoring, smart capturing of human behaviours and collaborative operating of main and auxiliary equipment.
Gehu Smart Station has liberated manpower and effectively improved the quality and efficiency of substation operations and maintenance. The station has built a smart inspection system combining remote online inspections and robotic on-site inspections. With the help of robots, the system replaced traditional manual on-site inspections and upgraded the original 30-day cycle of manual comprehensive inspections to daily remote online inspections.

Robots can work in a live environment, and workers can remotely control them to inspect the equipment. In most cases, workers no longer need to work in dangerous environments. It makes people safer and makes routine inspection more efficient.

Artificial intelligence-based image recognition technology is used to identify 17 types of defects, such as foreign body hang-ups, rust and oil leaks. It has played a visible role during the coronavirus crisis: more than 20 bird’s nests threatening the safety of power grid operation were identified in the first inspection after returning to work.

The traditional manual switching operation was replaced by single-key automatic operation, operation time was reduced from 60 minutes to 20 minutes, and personnel is now safer. Manual infrared temperature measurement has been completely replaced by machines.

In the future, there will be no workers on site; robots/drones or other smart devices will maintain the smart substation. Workers will go to the substation only when necessary. Since many substations are far away from the city, this can save costs.
Use Case

Machine learning algorithms applied to satellite images

The goal of the project was to design machine learning algorithms and satellite imagery analysis to:

- Increase the efficiency and effectiveness of the public lighting census
- Improve safety, since no human operations are required on site
- Detect relevant districts to focus upselling of new lighting poles (low brightness in high-density population districts)
Public lighting poles have generally been manually censused through the use of electronic GPS tools and an on-site human workforce. To do that, operators must perform the following two steps:

1. Reach the installation base of the next lighting pole
2. Save the position of the lamp post using a professional GPS tool

Collecting and saving coordinates requires less than 1 minute for a practised operator, who can also introduce human error. The second step, moving to the next location, is the most critical step, and can last up to three times longer, leading to a massive increase in operational costs.

An Enel X e-city challenge posted on the Open Innovability platform on August 5, 2019, sought solutions to reduce the cost of maintaining public lighting systems. Less than a year later, the prize-winner has reached a technical partnership agreement to work jointly with the Enel X team to develop a new solution and a proof of concept focused on demonstrating the accuracy and economic benefits of satellite imagery analysis to address the lighting pole census. During the setup of the solution, the remote mapping service was established by applying machine learning algorithms to street topology open data and nightly images acquired from the Chinese satellite Jilin-1.

Use Case  Machine learning algorithms applied to satellite images
With this complex setup, Enel X is now able to generate accurate data for the updated street lamp census map, status of street lamps (lights on or off), bulb technology (LED/HSP) and brightness correlation with population density by providing useful information at the decision-making level.

The high-definition nightly satellite images had to be acquired on a cloudless night. Once acquired, the night satellite data images were processed through both supervised and unsupervised machine learning algorithms, which leverage on street topology open data to detect and recognize public lighting points only.

The results were then compared with Enel X ground through data to verify the achieved accuracy which, in the end, produced an outstanding result of 90% of lighting poles recognized within a distance of 3 metres from the ground truth data.

The AI & satellite solution was fully validated to scale up to more than one million lighting points (LPs), proving to be 89% faster and 75% cheaper than the previous censusing solution, and generating significant savings on the target census costs.

Use Case  Machine learning algorithms applied to satellite images

Cities chosen for the demonstration.
Another benefit to report is the fully remote workforce formed by small teams that worked remotely throughout the entire project. The remotization feature of this solution made it possible to work non-stop during the COVID-19 pandemic.

In its journey to build this monitoring infrastructure, Enel X learned the potential of massive asset census capabilities by using machine learning algorithms applied to high-definition satellite images, as well as their limitations.

Since satellite acquisition, processing and data collection have a fixed base cost, the most relevant limitations faced during the setup of this solution were the size of the area and the density of the lighting points within the area to be censused.

The general rule to understand how much this technology is useful in lighting point recognition is that the wider the area and the denser the lighting points, the greater the economic benefit.

Other challenges to consider when this technology is taken into account are:

1. **Weather conditions.** Even a small cloud can introduce noise into the satellite image data. Clear skies are essential during satellite acquisition, so the weather must be taken into account in the project planning phase, because it can easily add to the total amount of time needed to conduct the census.

2. **Obstructions.** Items like trees and buildings can partially or totally hide the light emitted by lamp posts. This problem can introduce false negatives, which can be partially resolved with additional satellite acquisitions.

3. **Reflections.** Items like car windows and reflective coatings can introduce noise into the data acquired by satellite, which does not have a huge impact on the final accuracy, but deserves to be mentioned.
Use Case

Measuring transmission line splice electrical resistance using drones

The electrical resistance of transmission line splices can increase over time. This can cause overheating that can further damage the line and restrict the current limit.
Use Case  Measuring transmission line splice electrical resistance using drones

It is possible to see the phenomenon using thermal inspection from the ground, but the period of time when the current is strong enough to allow such inspection is limited. When the power line current is not strong enough to allow for thermal inspection, contact measurements need to be taken using a probe which measures splice electrical resistance. The probe is installed on a pole handled by a lineman who must perform several measurements on and near the splice. But in order to reach a splice, the lineman must climb the tower or use a bucket truck.

The Hydro-Québec research institute has developed a drone called the LineDrone, which is able to land on an energized power line up to 315 kV and, once on the line, travel to the target splice thanks to its motorized wheels. It then takes electrical measurements using its motorized embedded probe.

In 2020, a LineDrone was deployed to test the drone for R&D purposes and to provide Hydro-Québec’s Transmission Group with critical splice measurements. The electrical resistance of more than 250 splices were measured. LineDrone has been used for regular planned power line inspections and for special projects (for example, to validate the possibility of increasing power line maximum operational current).
Use Case  Measuring transmission line splice electrical resistance using drones

This technology has many benefits:

**Increased safety:**
- no climbing
- no work in proximity to energized lines

**Speed of inspection compared with climbing or the use of a bucket truck**
- 10-minute ground deployment in the vicinity of splices
- 5 min/splice (fly, travel and measurements)
- 10-minute demobilization

**Access to hard-to-reach areas:**
- compared with climbing: access to junction splices (away from the tower)
- compared with the use of a bucket truck: off-road six-wheel vehicles, rough terrain, snowmobiles

**Ease of deployment.**
- two operators only
- no need for the network operator to put in place special safeties, since the on-site operators are not exposed to electrical danger

Many challenges have been overcome in deploying this solution. First, the reliability of a drone around a 315-kV line needed to be tested in a controlled laboratory environment and then in real conditions in the field. Then, linemen needed to be trained and qualified in piloting commercial drones in advance of the deployment. In the near future, increased wind resistance will make it possible to use this technique in a wider range of weather conditions. In the longer term, autonomous navigation for pilot assistance and for long-distance flights will improve the possibilities of this solution.
Use Case

Use of artificial intelligence to improve safety on construction sites and at operating power plants

This use case describes the use of artificial intelligence to identify risky behaviors at construction sites and power plants, thanks to cameras installed on site and computer vision algorithms.
Use Case  Use of artificial intelligence to improve safety on construction sites and at operating power plants

Enel Global Power Generation will use the solution to provide real-time notifications of critical events and will have complete reports on the go for further analysis. The application will first be tested at three different sites in Spain, using the fixed installation of more cameras in the same working area. Use cases will cover both renewable power plant construction sites and operating power plants.

Currently, safety events are reported by supervisors or workers on site. This method cannot cover all possible events because it is dependent on the physical presence of people at the site. Moreover, it is impossible to have a bird’s eye view to evaluate all possible corners of the site.

A software layer was superimposed on camera video streams and in real time to evaluate conditions, collect data and issue notifications where required for all selected use cases for each visual area. After an initial training period, the algorithms will learn specific conditions and will be capable of identifying risky behaviors at sites. The software will run on a computer board located onsite to reduce communication bottlenecks, while aggregate information will be sent to the cloud infrastructure.

The expected benefit of this solution is an increase in the number of safety notification events to improve training, inspection and corrective actions on site.
Use Case  Use of artificial intelligence to improve safety on construction sites and at operating power plants

Specific benefits:

- Increase the number of safety event notifications/report selected use cases
- Encourage people to take precautions
- Increase multiple and contemporaneous area coverage by same supervisor
- Reduce time between events and activation of safety procedures thanks to real time notification and early detection of dangerous situations
- Simple integration in future sites

Some barriers need to be addressed in order to deploy this solution:

- **Artificial intelligence reliability**: Training and adaptation to different environments are a critical phase. Different kinds of field of view and environmental and lighting conditions can create new challenges at every installation.
- **Industrial Law and Data Protection**: Every time cameras are installed at a work site, an alignment with country references on the topic of industrial law and data protection must be done.
- **Acceptance**: A solution like this must be integrated into the normal working process with the specific involvement of workers, along with an explanation of the proper use of the solution and the benefits everybody will receive.
Use Case

Corrosion detection in aged aluminum conductor steel-reinforced cable (ACSR) using robots

The protective zinc layer on the inner steel core of ACSR tend to get thinner and thinner over time.

LineScout with LineCore sensor on a 315-kV line over the Saguenay river, Quebec, Canada, June 2020.
Corrosive environments in certain areas, such as polluted sectors around industrial complexes, coastal salty air, or near high-traffic roads that get de-iced during the winter, will tend to accelerate this degradation. When this situation is overlooked to the point where no more zinc layer exists, actual steel corrosion occurs, reducing the overall strength of the conductor.

The typical way to assess this condition is to take out samples from the lines, and to analyze them using destructive methods. However, since some spans will be more affected than others, taking samples in each of them for destructive assessment is not an option. Furthermore, the sample is usually taken out at the most accessible location (near the tower), and not where aging is most active (near the lowest point in the span).

Based on the eddy current testing method, Hydro-Québec developed LineCore technology to assess the progression of zinc thinning. The unit is battery operated, transmits its data directly to the ground in real time, and is very compact and lightweight, so that it can be mounted on several remotely operated robotics solutions: from a simple motorized version that cannot cross any obstacles on the line, except splices; to LineScout\(^\text{1}\) technology, with its ability to cross obstacles and realize multi-span inspections; to the latest LineRanger\(^\text{2}\) technology, which is dedicated to long-distance efficient bundled configuration inspections. Lastly, it can be mounted onto LineDrone, HQ’s custom drone technology presented previously, which can land on energized conductors.

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LineCore technology was used extensively to assess the inner condition of several 50-, 60- and 70-year-old sections of line up to 765 kV. One of them is a 2.5-km stretch of line that was to be reconstructed to a higher voltage level, but only in five years. Since it was built in an industrial setting, near chemical plants and refineries, it was suspected that the conductor was corroded inside (as were most of the steel towers). LineCore was deployed on about 15 spans, by LineScout and other means, and it was found that the zinc protective layers were still present, and the line could be safely operated until its expected end of useful life. Few spans were actually directly above the industrial sites, and signs of corrosion were spotted very near to the adjacent highway.

The entire evaluation described above took about two and a half days in the field. When compared with the time required to take samples of the line, including all the different steps (lowering the conductor, releasing its mechanical tension, cutting a specific length, compressing two mechanical joints and reinstalling it), it is obvious that the advantage is not necessarily that it is a time-saving option. The key advantage is in both the quantity and the quality of the information collected. Having access to the entire length of conductor, not just the one cut length, provides the real figures required to make actual decisions. Also, it is now possible to survey the same line again and monitor the effects of time, for example in 2, 5, or 10 years from now. Finally, it is likely that the most important advantage is the fact that no splices, which are prone to aging faster than the conductor itself, are added to the network.

The remote method also has safety benefits, since the line crew is less involved in higher-risk activities and handling. This method also allows for easier access to specific areas such as directly above highways, waterways or fields during crop season. But the single most advantageous aspect is the benefit of postponing the capital investments required to refurbish or rebuild a line before it reaches its actual end of life, which could easily amount to several million dollars.

Since reliability is very important, all the robotic platforms were extensively tested by the R&D team. But several installations were done previously, some of which did not turn out as expected. One of the lessons learned was to involve the design team as much as possible in the first field deployments.
Use Case

Patrol with smart glasses

Kansai is dealing with a decreasing number of employees, but needs to maintain the quality of its work. Remotization applied to substation patrols has been tried lately, and is seen as a solution to maintain quality operations with fewer of employees.
Substation patrols are required for gathering data sets in order to observe operating trends and continuously monitor abnormalities.

Those patrols present some challenges:

1. The number of substations that can be patrolled by a person in one day is limited.
2. The quality of work varies because of different skill levels.
3. There is a risk of personal injury because workers are holding computers as they walk.

A remote monitoring system has been built. The system involves deploying one young patroller with smart glasses on site so that an experienced patroller in an office can patrol substations by video from different sites at the same time. The experienced patroller can give instructions to the young patrollers as appropriate in order to ensure quality.

The benefits of this system are as follows:

4. The number of substations that can be patrolled in one day has increased.
5. The quality of work is stable because of equivalent to an experienced employee patrol.
6. Patrols have been safer because patrollers are not holding computers as they walk.

Trials have been completed in limited areas. Deployment to other areas is currently under consideration.
The use cases presented in the previous section are just a few examples of the useful applications of remotization in the electric utility business. Although this is just the beginning, it is possible to see all the possibilities of remotization in the near future. And a crisis like the COVID-19 pandemic will act as an accelerator for implementing such solutions in day-to-day operations. An attempt to decrease social contact between workers in the first months of the pandemic resulted in many solutions for reducing the number of people in one place and demonstrated the ability of large businesses like utility companies to evolve and adapt to new realities. This painful experiment should result in a shift from a conservative approach to a more open-minded one, and increase the speed of evolution.

The electric utility environment is also rapidly changing, with distributed generation being implemented everywhere on the planet, bringing down the cost of electricity generation, but also bringing many new players into our industry, from residential customers to large aggregators. These new players come from different backgrounds, do not fear change, and will quickly adapt to customer expectations. That will put pressure on conventional utilities to reduce costs and increase efficiency. At the same time, growing expectations from customers and less tolerance for power outages will require that electric utilities improve their services. All these trends are pushing toward a wide-scale adoption of technologies that will meet these objectives.

We see remotization as an important part of these solutions, which will bring utilities into the world of tomorrow. Digital solutions, such as sensors, and images from fixed cameras or cameras mounted on robots, drones or even satellites, will provide a world of data. Digital intelligence will improve operational efficiency by replacing frequent inspections, avoiding undesirable events and allowing for a quicker response to such events. It will also improve asset management, since more data will give better
insight into the expected end of useful life of equipment. It may take some time, since much of the equipment used in the utility business has a long replacement cycle, but as new equipment replaces older pieces, there will be new ways of making decisions, relying at least in part on digital learning. This will centralize decision making and reduce the need for crew travel and the number of highly qualified personnel at each generation site, which may become critical, since the number of generation sites may increase with the rollout of new renewables.

Autonomous robots and drones may also come soon. Thanks to developments in autonomous vehicles, autonomous robots and drones could be used in many applications. They could replace visual inspections of substations as seen in one of the use cases, but they could also be used for many other kinds of inspections: fault detection on distribution lines or underwater inspection of power dams, solar parks and construction sites. Robots can also do dirty jobs and improve worker safety, which is always a priority for utilities.

Finally, remotization will allow us to operate in a totally different way. Replication of the current way of doing things is only the first step toward all the potential applications of remotization. Soon after the first rollout, new ideas of how we can build, operate and maintain equipment and how we can deliver value to our customers will follow. This will probably require an influx of people with different backgrounds such as digital intelligence and other sciences.
Drivers and barriers

Many industries today are undergoing a process of digital transformation, exploring new technologies and revising internal processes. These novelties are enabling the remotization of many activities that previously needed human physical intervention. Moreover, the remotization process of work activities has been accelerated by the health emergency caused by the COVID-19 pandemic, which is changing our approach to day-to-day activities in every industry.

In this section, we will take a look at the main drivers that enable remotization and the barriers to their effective adoption that industries face.

Drivers

Digitalization and globalization are changing the way people live and work on a fundamental level, driving the growth of the remote workforce and the automation of many activities.

In many industries, remotization has been enabled by new technologies and scientific progress, such as:

- New telecommunication capabilities (e.g. 5G, satellite constellation) and increased computing power density and storage, all at an affordable cost
- The availability and effective adoption of cutting-edge solutions (e.g. augmented reality, virtual reality, sensors, wearables, IoT devices)
- Data mining using artificial intelligence to exploit data for predictive maintenance or to inform business decisions
Drivers and barriers

These technological drivers make it possible to fully connect the workforce and the infrastructure easily and affordably. Moreover, the increasingly cutting-edge development of these technologies in industrial environments provides access to user-friendly equipment.

The introduction of digital technologies across the industry not only opens up the way to new applications and use cases, as seen in the previous paragraphs, but also sustains numerous benefits from a business, organizational and safety point of view.

Regarding economics and business aspects, remoting activities such as site visits, inspections, training and specialist support means introducing a more efficient and sustainable way of working. We continue to see impressive results with respect to the efficiency of operations thanks to reduced reaction time, as well as a reduction in travel costs and time and in the cost of maintaining physical offices.

From a safety point of view, minimizing human intervention and coordinating operations remotely (e.g. using drones to monitor critical infrastructure, sensors for asset inspections, AR for remote training and safety walks) help avoid mistakes and reduce the number of personnel on site, resulting in a reduced risk of injury.

Activity remotization also has a positive impact on the environment and city sustainability thanks to a decrease in traffic and transport infrastructure congestion, with a consequent reduction in CO₂.

Remotization has a major impact on work organization and operating models. On the one hand, automating repetitive and manual tasks has simplified the activities of employees, who can now focus on high added value accomplishments with more stimuli for creativity and productivity. On the other hand, it has introduced major flexibility in day-to-day activities, resulting in an enhanced work-life balance. Finally, changing the way we work and, eventually, the types of duties means enhancing people’s skill sets, which will enrich the industry’s cultural heritage.

Finally, regulation can also benefit from remotization. With growing investments needed to renew utility assets, savings will be needed both on investment and operating costs to maintain the price of electricity. The deployment of remotization technologies, accompanied by data analytics, contributes to both. In some jurisdictions, there has been a shift from investment-based retribution to performance-based retribution. This will put pressure on utilities to reduce investments and operating costs to maintain or improve their benefits.
Barriers

Remotization is a challenge for all types of industries. In this section, we will look at the main barriers to its adoption.

Although the introduction of new technologies constitutes a strong motivator, it can bring with it barriers related to both the adoption of technology and the maturity of the systems into which it must be integrated.

Many technological standards have been introduced over time that do not identify a unique framework that integrates different systems or platforms. As we are well aware, integration between multiple systems in complex IT environments can be very demanding. In this sense, it is strategic to reduce the differentiation from site to site and target the development of standardized or integrated platforms. For remotization to work, cheap and fast connectivity is the key. A barrier to overcome is the resetting of connection issues (e.g. at home, on-site connectivity), taking advantage of the spread of 5G and of the satellite constellation (e.g. Starlink, LeoSat, OneWeb).

Major utilities expect to master digital for most activities to reduce costs and generate new revenue streams. However, the effort and budget involved in switching to fully digital operations and maintenance are significant. Perceived costs and the skills required to support and maintain the collection of remotization technologies can also be seen as an obstacle.

The lack of availability of adequate tools (hardware, software, equipment) and the digital maturity of utilities can also constitute a barrier to remotization. These can be rather low, especially in operational business units (e.g. blue collar), both in terms of technology awareness and the management of digital transformation. This could delay the effective adoption of digital tools for all on-site operations. From a work organization perspective, it means introducing new skills and ways of working, and leveraging adequate reskilling and training plans in both technical skills and cultural growth. This entails an investment in terms of effort, time and money, not only to define training plans but also to define change management actions. Resistance to change is a big challenge that all utilities must overcome, because employees may find it difficult to understand their new or changing role in the industry ecosystem or may feel they are being replaced by technology. Consequently, it is critical to define an appropriate digital approach integrated with company strategy, and to create a roadmap with prioritized digital capabilities to be developed and value to be realized. This strategic vision must be shared within the entire company to avoid silos between departments.
Finally, the lack of excellent technical personnel may not be satisfied with the reskilling of internal resources, requiring a hiring plan.

From a safety perspective, employers must provide and maintain a working environment that is safe and without risk to the health of employees, as far as is reasonably practicable. With the arrival of new remotization technologies, we reduce the risks to which employees are subjected, but we are also confronted with new ways of working. It is therefore essential to define new health and safety practices and procedures to identify and mitigate risks or hazards that may arise in the workplace.

Another barrier to take into account is the regulation aspect. Many local laws can create obstacles and jeopardize remotization because too many constraints must be taken into account to bring a viable product to different markets. An important tool to be adopted at the global level could be a standard for remotization levels using a sort of classification system, as has been done for autonomous vehicle systems.
Remotization solutions development and implementation provide opportunities for many different types of contributors along the value chain from opportunity design to operation. Certainly, for the transformation to be successful, the wide-scale involvement of the different actors is needed. New ideas will generally come from interaction with people from different organizations and with different expertise and backgrounds.

Some of the main actors usually involved in opportunity identification, idea generation and initial development (e.g. proof of concept) include:

- The open innovation ecosystem (e.g. incubators, innovation hubs, R&D centres, startups)
- Thematic communities and Industry bodies (e.g. IEEE, CIGRE, IEC, EPRI)
- Technology vendors
- Universities
- Utility labs
- Equipment, sensor, robot and drone manufacturers
- Utility suppliers

During the solutions development and industrialization phase, the main actors are:

- Equipment, sensor, robot and drone manufacturers
- Software developers
- Utility suppliers and partners, including system integrators and technology vendors

Finally, during the deployment phase, the main actors are:

- Engineering firms
- Utility employees, such as engineers, workers, information technologists, unions and executives
- Solution integrators
- Utility regulators
- Technical schools and other training institutions

Moreover, it is useful to involve the following during the entire process:

- Final users, to ensure adoption and usability
- Cybersecurity and health and safety departments, to mitigate risks and ensure compliance
As world concerns evolve, so do utility customers, and so must utilities. Climate changes due to greenhouse gas emissions is a reality, and electric power utilities have the opportunity to play a major role in the transformation of the economy. However, in addition to their new responsibilities, they will still have to reliably, efficiently and affordably deliver electric power to customers. In order to do that, they will need to adapt the way they build, operate and maintain their assets.

Remotization provides many benefits for the electric power industry: it improves worker safety, increases operational efficiency, reduces environmental impact and enhances system reliability. It can be applied at almost every step, from generation to end uses, in different types of generation plants, in dense cities and in remote areas. Many applications are already possible, use cases have been shared, but the future should bring many more possibilities. Of course, there are some barriers that need to be addressed, but serious drivers will support the rollout of new remote technologies sooner than later.

We will soon see a world of new possibilities brought about by quick developments from various manufacturers. As the Internet of things (IoT) knocks on our residential home doors, propelled by new startup companies that didn’t exist of few years ago, there will be many new players that can offer new solutions for the electric power industry. Current suppliers will also play an important role in the design and rollout of new solutions. By sharing our vision, we hope to promote the development of new technologies that will help to accomplish our mission today and in the future.

In order to succeed, we will need to partner with a large ecosystem of solution developers, manufacturers, suppliers and integrators. Regulators and governments will also need to be on board to allow us to move quickly. Only this type of collaboration will allow us to expedite this evolution in order to overcome the challenge we are facing.
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