Four key technologies for a stronger, smarter and greener distribution grid

Ushering in the next generation of electricity grids with digital substations and smart field devices

HITACHI ABB POWER GRIDS

Enabling a stronger, smarter and greener distribution grid starts here

Introduction

The electric power industry is undergoing a major transformation driven by three key megatrends:

1. Decarbonization
2. Digitalization
3. Decentralization

Each of these megatrends brings its own set of challenges that are disrupting established business cycles and practices. Some of these shifts, such as the integration of renewable energy sources into electric grids, are fundamental changes that have far-reaching implications across the entire sector. Other challenges, like data-driven solutions that can lead to new efficiencies and revenue streams, require businesses to adopt new skill sets and ways of looking at the economic landscape to take advantage of the new technologies.

The speed of development and complexity of emerging technologies can pose additional challenges to system operators when deciding what solutions to choose.

Despite the scale and pervasiveness of the transformation, one thing is certain: The transition to a smarter and greener distribution grid is no longer a choice.

To be successful in the transition, utilities and distribution system operators (DSOs) need a framework to help guide investment and decision making across their organizations – from the field to the boardroom.

THE THREE Ds

Decarbonization is the reduction of carbon dioxide emissions using low carbon power sources, thus reducing the output of greenhouse gases into the atmosphere.

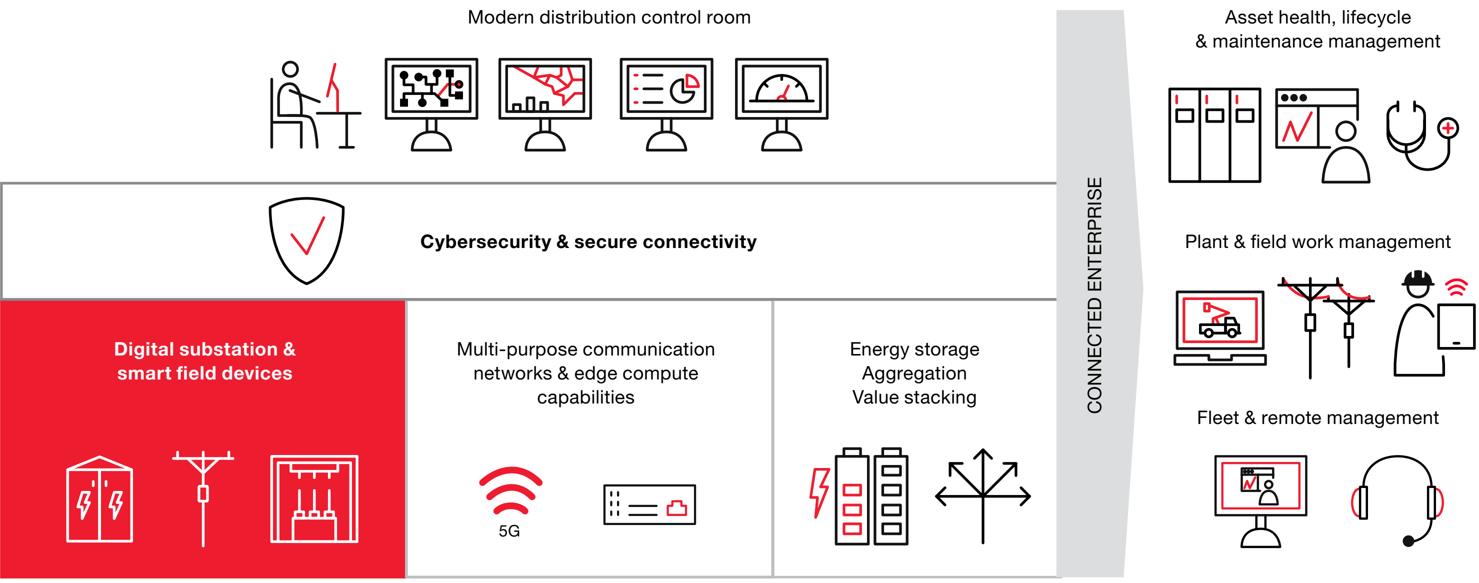
Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities.

Decentralization of the power grid refers to drawing power from multiple, localized energy networks and sources, often to facilitate the influx of power from renewable resources

To that end, Hitachi ABB Power Grids has identified six key investment areas that can act as a framework for that purpose:

1. Digital substations and smart field devices
2. Multi-purpose communication networks and edge compute capabilities
3. Energy storage, aggregation, value stacking
4. Asset health, lifecycle and maintenance management
5. Control room solutions
6. Cybersecurity

This paper focuses on the first building block: Digital substations and smart field devices. Within this investment area, application of four technologies will be instrumental to meeting the imminent challenges posed by the megatrends and ushering in the next generation of electricity grids.



Automation can help mitigate key challenges faced by utilities

1

Extending automation to the secondary distribution grid

Extending automation to the secondary distribution grid can greatly improve situational awareness and help alleviate some of the key challenges distribution companies face, allowing for greater visibility into the distribution network, advanced distribution management, and reduced investment costs.

3

Enabling data-driven operations

Solutions that enable data-driven operations help utilities overcome the challenges associated with digitalization and the increasing complexity of the power grid. Armed with the right data at the right time, utilities can dramatically improve operational efficiency and effectively combat outages.

2

Developing self-healing networks for grid performance

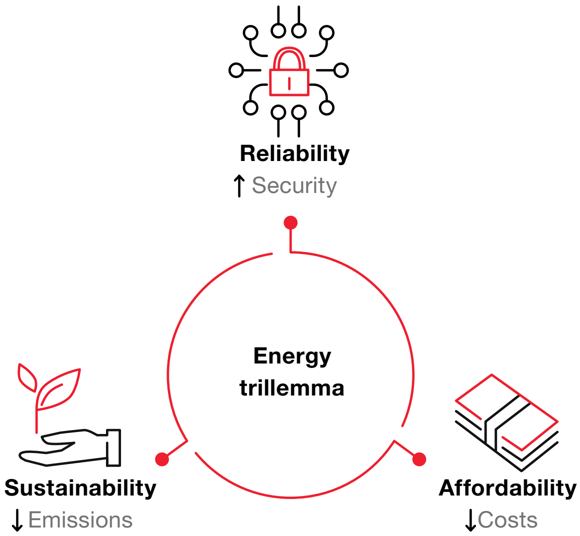
With self-healing networks, problems within the grid are discovered and resolved using automation technologies. A field-installed decentralized automation solution decreases operational failures and simplifies monitoring and control for control center operators. Automatic network reconfiguration is more secure and dependable.

4

Using line voltage regulation to integrate renewables

Compared to lengthy and expensive grid upgrades, line voltage regulation offers a cost-effective alternative for bringing renewables into the fold. With line voltage regulator, the voltage can be “recalibrated” so that renewable energy can be fed into the existing distribution network without disruption.

Automation: The first building block of tomorrow's grid



One of the main benefits of extending automation to the secondary distribution grid through digital substations and smart field devices is providing situational awareness for DSOs, allowing them to literally see the content of their network.

Automation will play a central role in making the electrical grids of tomorrow smarter, more efficient, and more reliable. Extending automation to the secondary distribution grid brings multiple benefits for DSOs such as increased visibility in the distribution networks, advanced distribution management as well as cost savings on investments and operation.

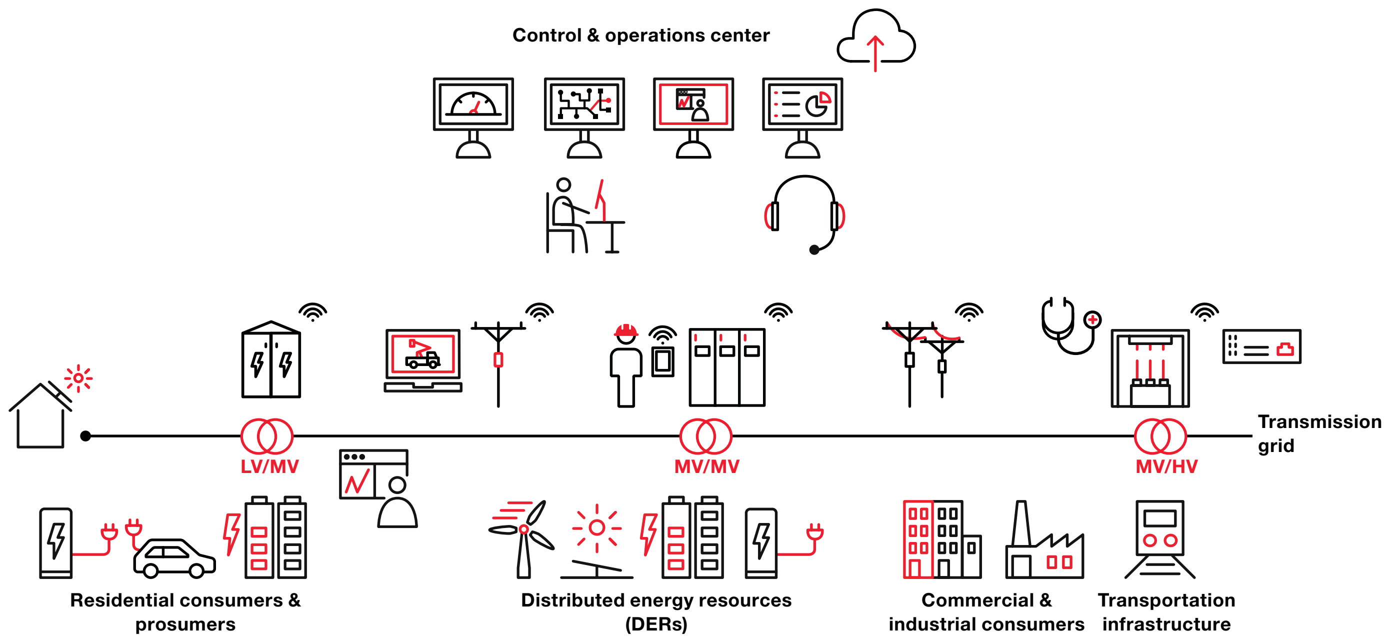
The primary drivers for extending automation into the secondary distribution grid are the increasing penetration of distribution generation from renewable sources of power, both on utility and non-utility scale, the electrification of transportation, as well as fluctuating peak times due to the increased number of consumers like electric vehicles and home battery systems. However, there is also a growing pressure to meet regulatory requirements combined with increasing customer demand for a continuous and reliable power supply. To meet all these requirements, DSOs are often faced with the challenge of making a compromise among reliability, sustainability, and affordability. It can also enable utilities to change their business processes.

Utilities can transform their business processes by sharing information across the entire enterprise, thus improving cooperation and increasing effectiveness of customer delivery.

By converting the information from analog to digital format, it is possible to provide asset data for advanced analytics or remote management at high levels, which enables the migration from asset focus to system level analysis.

Extension of automation into the secondary power grid can help alleviate the enormous strain electrical grids face from the emergence of multiple renewable energy sources that are being fed into the grid. Smart automation devices can be used to stabilize voltage control for grids as power from photovoltaic installations, wind turbines and other distributed energy resources (DERs) gets integrated into distribution systems.

Automation can also help DSOs save costs on investments by reducing downtime and grid failures. Natural or component failures in the power distribution network can be caused by multiple sources such as falling trees, overhead lines falling to the ground, or poor insulation of isolators. Data from EU countries indicate that, on average, more than 70% of these types of incidents occur in the medium voltage part of the network. To reduce monetary loss from failures and duration of outages, DSOs have to find a solution and grid automation has the potential to dramatically reduce downtime.



Digital substations and smart field devices enables automation in the secondary distribution grid and thereby provide situational awareness for DSOs, allowing them to see into the network.

One way to limit unplanned downtime is by moving overhead cables underground. While undergrounding is effective, it is expensive and comes with a host of logistical and scheduling issues. On the other hand, network automation solutions help reduce the number and duration of outages no matter where the lines are located. Feeder-based fault detection isolation and recovery (FDIR) is an automated process performed in the secondary substation that enables a rapid response to a troublesome feeder and substantially reduces the number and duration of failures in the distribution network. Reducing outage rates enables DSOs to improve key reliability metrics like system average interruption duration index (SAIDI) and customer average interruption duration index (CAIDI). These performance improvements go a long way toward reducing penalties and increasing end customer satisfaction.

Enabling automation: applications in the distribution network

Grid automation relies on software applications that can be divided into two broad categories: basic and advanced. Basic applications include functions such as system monitoring, control, measurement, and protection. Advanced applications encompass Volt VAr optimization support, current fault detection in the medium voltage networks and automatic network for VAr configuration, medium and low voltage broken conductor detection, transformer low voltage monitoring, as well as applications like utility interface for distributed generation connected to the distribution grid. These applications help reduce energy losses through enhanced observability and fault awareness.

Case study
Secondary grid automation in Bern, Switzerland

In a recent project, Hitachi ABB Power Grids' remote terminal unit was chosen to solve the problem in the low voltage network in a rural area near Bern, Switzerland. The distribution grid is operated by BKW, one of Switzerland's largest energy companies. Namely, with the installation of a new solar plant of 134 kW, where a maximum fluctuation of +/- 10% is allowed to ensure power quality, voltage limits within the low voltage network were violated. Introduction of RTU540 with a monitoring function enabled a controlled adjustment of the line voltage.

For this case, a pilot solution was developed featuring remote access and controls running over a virtual private network (VPN) tunnel via the public communications network starting inside the RTU540. This enabled BKW to improve the power quality with distributed energy resources on its network and avoided high-cost spending on a new transformer and rewiring the low voltage network with higher rated cables. The installation also provided BKW with a secure VPN, and helped the company save on operational costs as it was able to monitor and control the voltage, load situation, and temperature of the line voltage regulator remotely.

Self-healing networks: Increase grid reliability and responsiveness

DSOs need reliable solutions that allow them to meet the many challenges faced in daily network operation. They seek to reduce downtime, improve fault detection capabilities, and improve product availability, while trying to strike a balance between cost and quality.

Another important deliverable is fast fault detection and network restoration following fault clearance. This is a general requirement to reduce SAIDI and SAIFI while also ensuring power quality by maintaining voltage and frequency values within a defined range. Furthermore, to ensure a stable and available supply of electricity, network operators must adhere to regulatory codes while in distribution.

With the introduction of self-healing networks, problems inside the grid are detected and remediated through automation tools. Field-installed decentralized automation solutions reduce operational failures and make monitoring and control easier for the control center operator. When compared to manual network reconfiguration by service personnel, automatic network reconfiguration is safer and more reliable. RTU automation controllers are central to the types of solutions that satisfy all those requirements. They are designed from the ground up to allow DSOs to communicate securely over all network types, and include: FDIR, detection of broken conductors and blown fuses, and automatic re-energization.

Fault Detection Isolation Restoration (FDIR)
Rapid fault detection and recovery of the network are universal requirements, not only to reduce SAIDI and the system average interruption frequency index (SAIFI), but also to ensure power quality while maintaining the voltage values and frequency within a defined range. To achieve maximum flexibility, it is desirable to use a decentralized approach. By implementing IEC104 bi-directional communication, the peer-to-peer communication bandwidth requirements can be minimized. Generally, IEC104 provides monitoring information for the SCADA system and sends commands in the other direction. The address can also be changed, which enables communication between RTUs in the form of the so-called horizontal communication. If changes or errors occur in the network, this information can be distributed directly to all RTUs at the next or the same level.

Broken conductor and blown fuse detection
Overhead line defects can be discovered with the use of broken and blown fuse detection. The longer the overhead lines, the more detailed the inspection and awareness of flaws are required. Detecting blown fuses in the top-mounted feeder and inspecting the equipment is a high-risk, time-consuming procedure. The safety of the network is critical in secondary distribution grids. A broken conductor that is electrified might result in a life-threatening condition. To ensure the safety of workers and networks, DSOs must quickly and effectively identify defects caused by broken cables and conductors.

Open circuits, such as energized broken conductors, encounter faults with a high impedance and an imbalanced load. If not identified, this will result in significant infrastructure damage. A blown fuse in one of the substations takes a long time to locate, especially when multiple customers are linked behind each fuse in the case of an RMU, a cabinet with numerous fuses and low voltage. For example, for a supermarket with a cooling system, a blown fuse can cause major damage on weekends or at night.

Automatic Transfer System (ATS)
ATS is an application that allows the changeover from a main source to an alternative power source. When triggered, the ATS switches from main source to alternative one or the other way around. The switch happens automatically without switch operation by the service personnel or network operator. An automatic switch allows a retransfer to a re-energized and healthy main source of power. To create ATS functionality, a redundant network structure is needed, together with motorized switches, and voltage measurement in each

DSOs need to ensure fast fault detection and network restoration following fault clearance which is a general requirement to reduce SAIDI and SAIFI

incoming feeder. The ATS's important purpose is to lessen the impact on business caused by unstable power supply. The transfer is not flawless, but the restoration time is supplied in seconds, minutes, or hours and is not reliant on the knowledge and availability of the individuals doing the operation.

In order for ATS to work a redundant network structure, motorized switches, and voltage measurement in each incoming feeder is needed. The ATS is activated by a protection relay, identified by a 500 CVD voltmeter and undervoltage detection. ATS can also be used for manual transfer of operations.

Case study
Autonomous FDIR

The skyrocketing power demands of the Pudong district of Shanghai epitomize the growing need for flexible and quick power distribution systems that can serve fast developing markets in China. To respond to these needs, Hitachi ABB Power Grids has introduced 500CVD21 multimeter to help connect additional customers, making grids more adaptable and flexible.

The multimeter obtains the senses required for autonomous fault detection, isolation, and recovery. In practice, this means detecting a fault and working with other RTUs to isolate the broken link and restore power to the remaining network. The procedure takes less than 15 seconds, and once the defect has been isolated, an update can be sent to the SCADA system for a comprehensive examination and dispatch of a repair crew. Each RTU is only capable of detecting its own local flow, but it maintains a network map and communicates with other RTUs. The communication is based on IEC 61850 industry standard.

The solution enables the region to have a robust infrastructure, keeping more customers connected for longer periods of time with the fast power restoration capabilities ensured by Hitachi ABB Power Grids' RTU500 series. The series has demonstrated ability to achieve five-nines (99.999 percent) reliability.

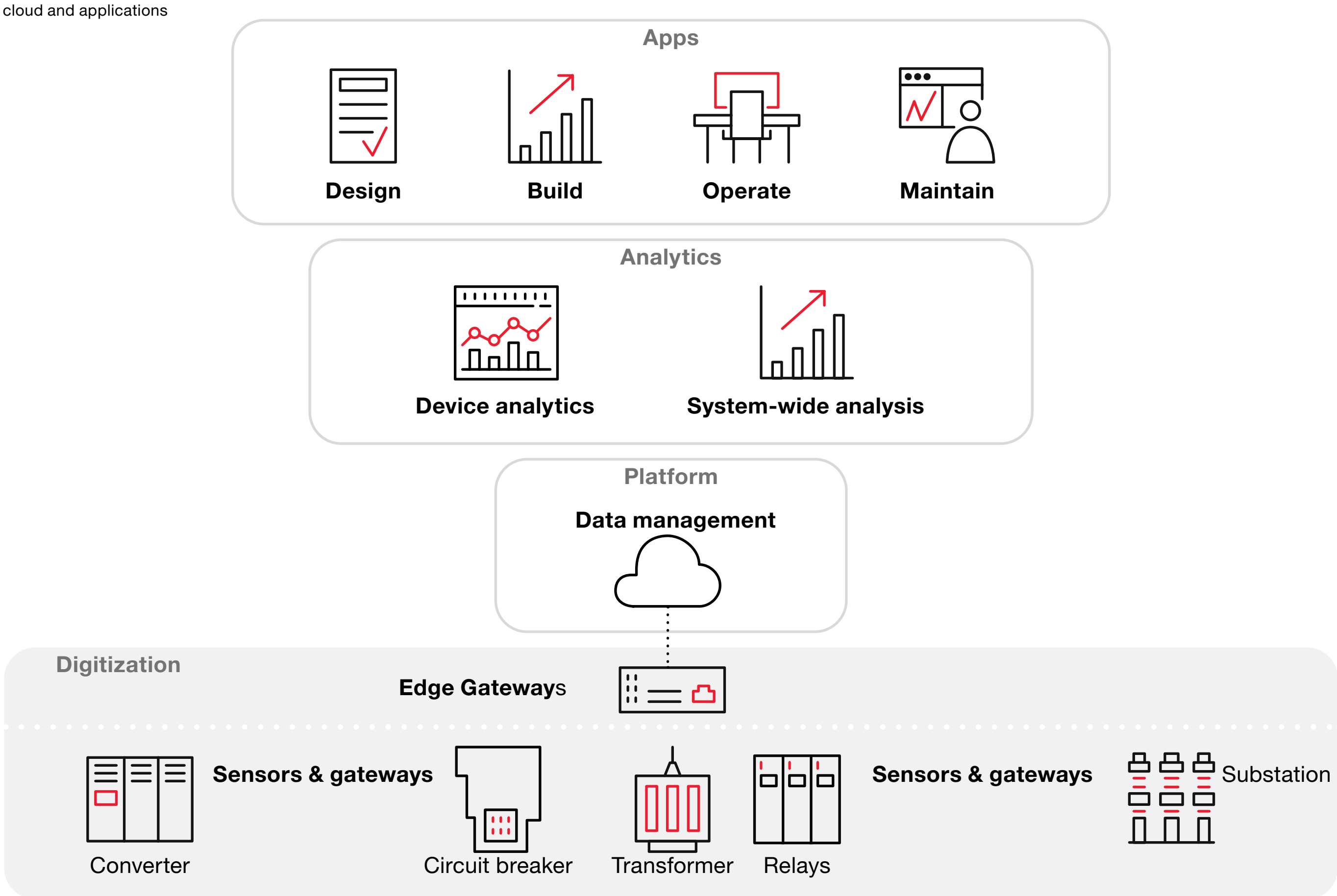
Data-driven operations:
Extracting value from your assets

Digitalization provides a unique opportunity for organizations to make their business more reliable and efficient by integrating more and better data into the decision-making process. However, digitalization always involves processing large amounts of data and trying to decipher which data is useful and operable and which is not. This can be quite demanding, especially if your data is coming from different sources. The main challenge facing the utilities is managing different types of multi-vendor data systems, which can lead to increased costs and workload.

With the increasing complexity of the power grid and the rapid digitization of various systems, it is becoming increasingly difficult for DSOs to identify the right data to be used. In data-driven operations, operators often have to use multi-vendor monitoring systems, making it difficult to exchange information between them after installation. Similarly, extracting value from data from these systems and creating new business models and outcomes is difficult.

For example, where there are workforce management systems, supervisory control and data acquisition (SCADA) systems, and asset management systems installed by different vendors, it is difficult to share information and simplify processes between them. Additionally, having multiple disjointed systems can limit DSOs ability to extract value from data across all systems, further weakening the operator's ability to create new business models and results.

Making data actionable by bringing the field data from sensors to the cloud and applications



Such isolated or island systems make it more difficult to automate operations. To overcome these challenges and support an organization's complex data processing, Hitachi ABB Power Grids has developed a four-staged approach that consists of:

Digitization: The feed level where digitally enabled devices produce relevant data for O&M processes.

Platform: Cloud platform connected via edge gateway to the feed level; ensures safe transfer and storage of data to a centralized place.

Analytics: The available data can be used for analytics of separate devices and/or the entire system.

Applications: The collected data and analytic information can be brought into applications tailored for different kinds of processes.

The concept uses a field-to-boardroom approach to bring data from sensors to the cloud and applications with a real perspective to support the organization's use of the data and make this data actionable. The system has been built with cybersecurity at its core both when it comes to individual products and software applications as well as the way systems are delivered to clients.

One of the solutions that can be used is system device manager (SDM) that collects data from network automation equipment. This kind of solution manages and collects data. The data comes from the disturbance recorder from substation automation systems in the power system and it is sent to a relevant enterprise.

Line voltage regulation: Bringing renewables into the fold

Line voltage regulation uses active VAr management to regulate the voltage in the feeder

The use of line voltage regulators to integrate renewable energy sources is a more cost-effective solution than grid expansion or reinforcement. The line voltage regulator restores the voltage to a more conventional level, allowing for the injection of a greater amount of renewable energy into the grid. By utilizing the line voltage regulator, the voltage can be “recalibrated” to allow renewable energy to be integrated seamlessly into the existing distribution network.

The extra voltage goes into the grid and can affect the grid to increase or decrease the voltage. In the case of high amount of wind and sunlight, the reduction of the grid voltage happens. Otherwise, when there is no wind or sun, and energy consumption increases, the voltage of the last meter or the last kilometers of the network increases, so there is full voltage and full power available. The voltage drop can be regulated by customers with mobile units. Voltage management can adjust voltage and no longer represents a limiting factor.

Case study
Line voltage regulation in rural area

Line voltage regulation was put to the test in a real-world scenario, when an 8.8-megawatt photovoltaic farm was erected in a rural area. Following an examination of three scenarios, there was only one option for connecting the feeder. The first scenario involved extending a cable. If 10 km of new cable with greater cable diameter were installed, the power at the site 10 km away from the transformer station could be increased by up to 50%.

Another way was to use active VAr management. The line capacity was raised by 25%, allowing this device to be installed with a capacity of up to 5 MVA. If the voltage drop is regulated with an active unit, the active volt management is only limited by the capacity of the cable. Voltage is regulated through volt management, and voltage no longer represents a limiting factor. The LVR installation took four months, with the typical voltage set point of 21 kV.

Enabling a stronger, smarter, greener grid

Application of automation and intelligent solutions in the substation enables a stronger, smarter, and greener distribution grid.

It can become stronger with feeder-based FDIR that helps reduce the frequency and impact of outages, while predictive and condition-based maintenance enable the grid to maximize asset uptime and optimize its lifecycle. This leads to better decisions on CAPEX and OPEX budgets.

With Hitachi ABB Power Grids' self-healing networks based on the RTU500 series, operators can slash outage times by up to 81% through efficient detection and isolation of faults. This not only saves money, it also improves reliability indices and customer satisfaction.

Deployment of automation technology for both greenfield and the retrofit projects allows system operators to see inside the grid in real time and make faster, smarter decisions upon disruptive events. Hitachi ABB Power Grids' SDM600 System Data Manager and solutions offer DSOs a holistic platform to collect and analyze data, enabling them to plan smart maintenance activities and investments, as well as optimize asset lifecycle. The digitalization-focused TXpert™ ecosystem includes asset performance management capabilities that can provide operators with prognostic information and give actionable maintenance recommendations.

Finally, with the increasing amount of power generated from renewable sources, and multiple producers feeding into the grid, operators are faced with a risk of large voltage variations. Instead of investing huge amounts of capital into network upgrades, a quick and cost-effective solution can be found in line voltage regulators (LVR). Through LVRs, operators can opt for greener alternatives to network upgrades that enable greater penetration of power generated from renewables, helping decarbonize their operations with lower investments.

Discover more information to digitize your grid.

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