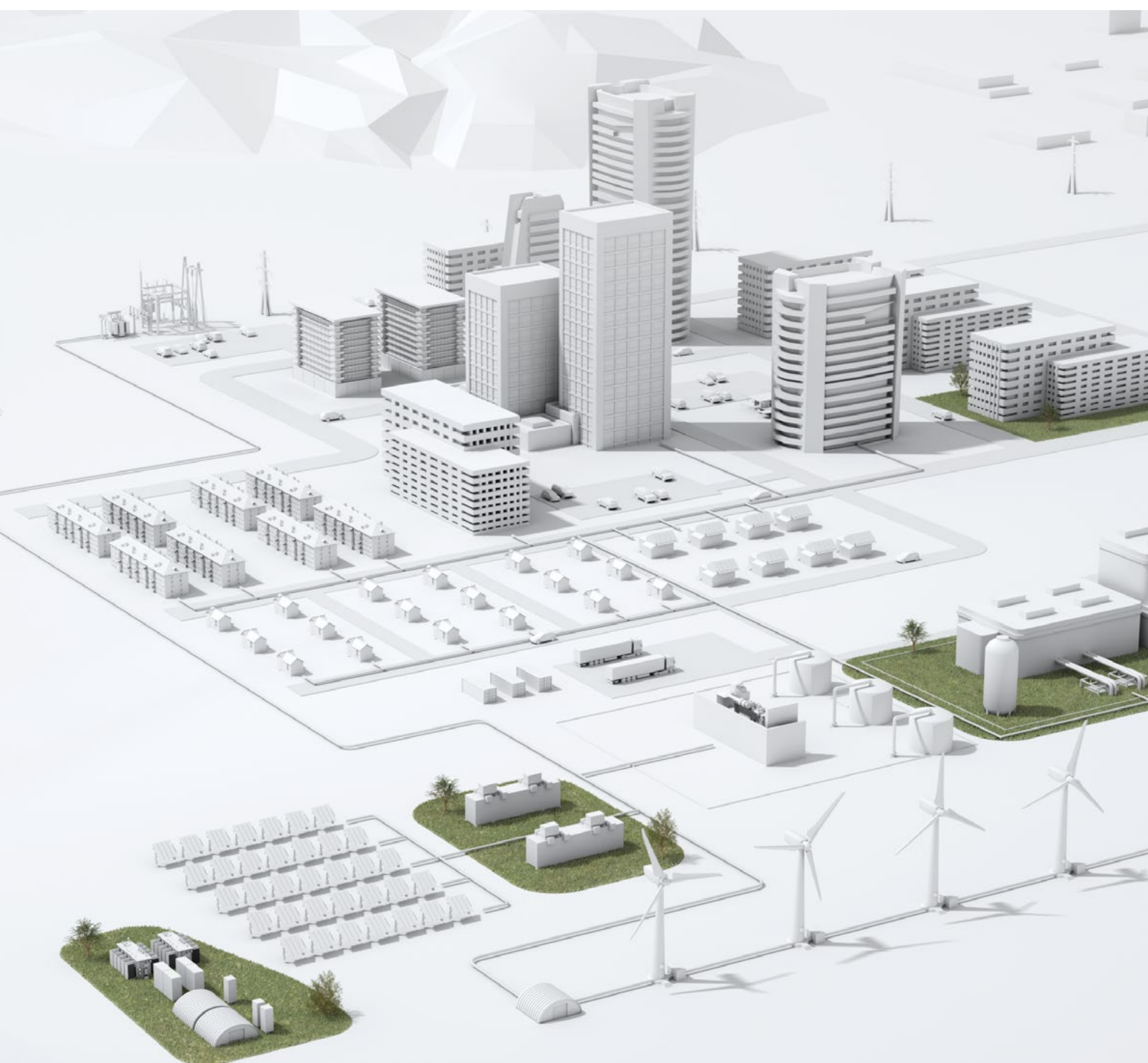

Microgrid solutions

Delivering resilient power
anywhere at any time



Innovative and flexible solutions for today's energy challenges

The global energy and grid transformation is creating multiple challenges for the power industry. In developed countries these include ensuring the availability of resilient power across increasingly complex grids with an ever-growing number of diverse, distributed energy resources and a high penetration of renewables. For emerging countries there is the need to provide access to cost-effective, reliable and high quality electricity in remote locations. These challenges continue to create significant opportunities for the development of innovative and flexible technologies and solutions. Microgrids are a particularly attractive solution.

Microgrids can integrate multiple distributed generation sources including conventional diesel and gas, and/ or renewables such as solar photovoltaic (PV), wind, hydroelectric, tidal and even thermal schemes like combined heat and power (CHP), together with energy storage. The microgrid provides the overall control to coordinate these resources to meet the requirements of industrial, residential or consumer loads.

Microgrids are best known for delivering electricity to communities or industrial operations in remote or inaccessible areas where it is too costly or difficult to provide a grid connection. However, grid-connected microgrids are now taking on a new role in developed areas of the world to ensure continuity of supply in the event of potential grid faults and emergencies. The ability of microgrids to seamlessly separate and isolate themselves from the main grid when needed is an increasingly important feature.

Microgrids can offer:

- Reliable access to power for locations where the grid is unreliable or where there is no grid
- Resilient power that protects cities and industrial operations against power disruptions of any duration from fractions of a second to prolonged outages
- Deferral of grid investments by helping to meet peak demands or increased loads
- Cost effective ancillary services that support power quality
- Optimized use of renewable energy and reduced consumption of fossil fuels

Unmatched expertise in microgrids

ABB has unmatched expertise in the design and construction of off-grid and grid-connected microgrids with well over 30 global installations across a range of applications serving remote communities, islands, utilities and industrial campuses. We have distilled more than 25 years of experience into our portfolio of technologies that enable microgrids to balance and optimize generation and demand to provide reliable power for their connected loads. Flexibility, modularity and scalability are the core of our microgrids philosophy. This enables ABB to deliver everything from products and standardized packages through to fully engineered systems. The main elements in ABB's microgrid portfolio are:

Distributed control systems

A specially designed network control system uses distributed agents to control and integrate all the various microgrid elements such as power generation resources, multiple loads, energy storage devices and the interface with the main grid. This provides intelligent, efficient power management with the ability to make a seamless transition from grid-connected to islanded operation, and back again. The result is total continuity of customer supply since the microgrid responds immediately to the changing operational needs of the local and extended grid.

Modular integrated energy storage systems

For energy storage and grid stabilization in microgrids, ABB has developed a range of standardized, modular and scalable systems that provide effective 'plug and play' solutions for all applications. This compact, containerized approach ensures fast and easy transportation, installation and commissioning. Our energy storage systems are designed to integrate seamlessly with customer or utility control systems. They help stabilize power networks against fluctuations in frequency and voltage caused by variable renewable sources or microgrid loads.

'All-in-one' solar microgrid solutions

ABB's 'all-in-one' solutions provide the main microgrid elements, such as the PV inverter, batteries, power converter and protection and control systems, in a container that is delivered to site fully factory tested and ready for connection to the PV panels. This approach enables the

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01 ABB's
Microgrid
capabilities

fastest possible installation and commissioning to deliver rapid access to power in remote areas of the world, making it particularly suitable for village electrification projects. The solutions can also work in parallel with existing generators, weak grids or even grid expansion projects to ensure a fully future-proof solution.

Advanced power distribution and protection

As an industry leader in power products, grid connection and integration solutions, ABB offers a full range of protection, control and measurement solutions for microgrids. This includes switchgear, transformers, circuit breakers, substations, protection and control and measurement and monitoring. ABB's new generation components, such as our latest low voltage circuit breakers, are taking the next step in simplifying the cost-effective creation of microgrids by embedding key microgrid functionalities.

Remote asset management and data analytics

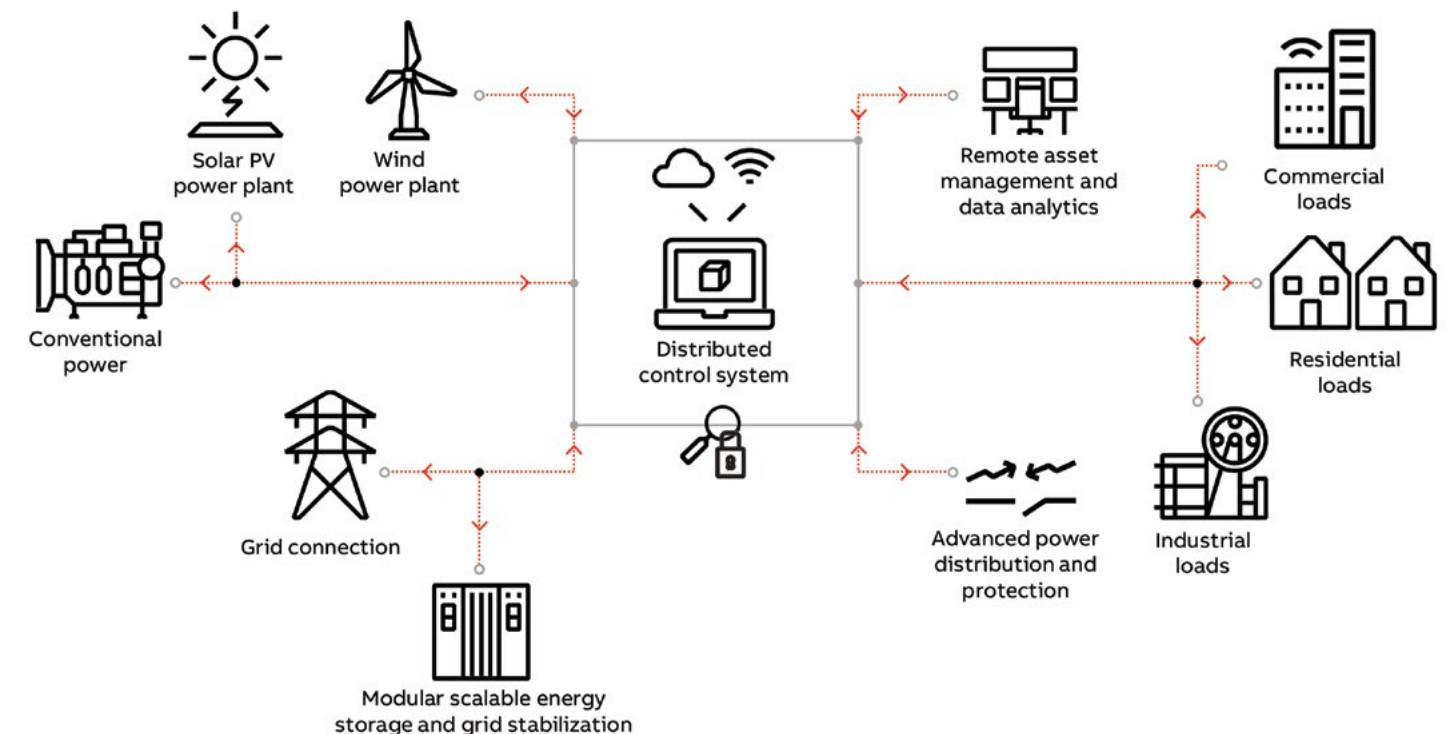
ABB's cloud based remote operation and monitoring tool offers a comprehensive solution to increase productivity, improve energy efficiency and reduce operational costs. ABB's expertise also includes detailed data analysis to optimize the operation and to protect the customer's return on investment.

Consultancy and system planning

ABB provides its microgrid customers with detailed consultancy and system modeling services right from the initial conceptual design and feasibility study stages. This includes a thorough analysis of the operational goals, business cases, available resources and specific site and network challenges. Customers therefore can have total confidence that their microgrid is a perfect match for their technical and economic needs, not just now, but for well into the future.

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We are a leading provider of microgrid products and solutions that offer a complete end to end approach from initial consultancy through to remote operations and maintenance. This covers intelligent automation and control, energy storage and grid stabilization, EBoP (electrical balance of plant) and advanced protection technologies to enable microgrids globally.

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Resilient independent power with or without grid connection

Microgrids integrate distributed energy resources and loads to ensure that they operate in a completely controlled and coordinated way. They can support a main power grid or be completely off-grid. A grid-connected microgrid can also transition seamlessly into 'islanded' mode, operating as an independent self-sustaining energy system.

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02 Grid-connected microgrids ensure resilient power despite disruptions from the main grid supply.

Islanding is an increasingly attractive capability in developed markets with well established grids, where there are rising concerns about the resilience, stability and quality of the power supply. There is also growing interest in this capability in developing countries where weak grids can suffer from frequent power interruptions. Not only can microgrids help keep the lights on in day to day operation, they will deliver continuous power in case of a planned outage, fault or natural disaster.

Microgrids can also enable utilities to defer investment in expansion or upgrading of the main grid. In addition, the capability for smarter control of the distributed energy resources within a

microgrid creates new value propositions for the provision of ancillary services vital for grid stability or for peak shaving/load shifting for economic optimization.

For industrial customers microgrids deliver enhanced resilience for mission critical installations be they a data center, food processing plant or mine. They also give them improved self-sufficiency and control over their own power supply, reducing overall energy costs.



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03 Off-grid microgrids deliver grid quality power while enabling fuel and emissions savings.

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04 ABB's all-in-one village electrification solutions enable cost efficient access to reliable power.

Grid quality power for off-grid installations

ABB's modular solutions are designed for quick and easy deployment that provides fast access to grid-quality power for rural communities, islands or remote industrial operations where there is no grid available. Typically, this is at lower cost and with lower environmental impact than fossil fuel generation or extending the grid.

The main commercial drivers for off-grid microgrids are typically fuel independence and lower levelized cost of electricity (LCOE). ABB adopts a generation-agnostic approach that optimizes the microgrid operation regardless of the generation mix, enabling savings on both fuel costs and emissions.

Another important driver is access to a robust and reliable power supply. ABB's off-grid microgrid solutions effectively manage and balance renewable energy sources such as solar PV or wind with fossil fuel generation in accordance with loads and energy storage to ensure grid stability. They incorporate frequency and voltage control, control of spinning reserve, active and reactive power supply, peak shaving and load leveling, load sharing between generators, and fault current provision.

Microgrids are future-proof, with the flexibility to expand to accommodate new power generation sources and consumer loads. And they are grid-connection ready and compatible with grid standards should the possibility arise for connection to a grid.

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Ensuring the maximum return on investment in microgrids

ABB has developed a range of lifecycle management, consulting and integration services that enable our customers to achieve the maximum return on investment in their microgrids, from the initial design concept and on throughout long service life.

Consulting

ABB offers consultancy services throughout a microgrid project with the goal of finding the optimal solution that maximizes the value of the assets and financial investment.

The main elements of our consultancy services are:

- Feasibility studies and simulations
- Grid studies
- Renewables engineering

Remote services for operation and maintenance

ABB's service concept extends well beyond the simple solution of day to day problems to help support and improve strategic operation. The goal is to help customers operate their microgrids at the highest possible levels of capacity, flexibility, reliability and operational security, and to extend the plant life cycle. ABB's solution is an Operation and Maintenance (O&M) service tool that combines an effective maintenance program with a system that monitors all parameters related to production. The result is increased productivity, improved energy efficiency and reduced operation costs.

This enhanced vision of service works 365 days a year, 24 hours a day, providing predictive, preventive and corrective maintenance, process analysis and support from skilled staff, remote diagnostics, and remote operational control. Together with ABB's local presence across the globe, our customers can rest assured that the trouble-free operation of their microgrid is secured.

Integration into utility operations and energy markets

The global trend from centralized generation to more distributed and varied types of energy systems means that microgrids are becoming increasingly visible within regional and national energy systems. ABB's Information

Technology/Operational Technology (IT/OT) integration strategy bridges the gap between the microgrid operation (the OT realm) and the business decision making (IT) realm for effective integration within utility operations and energy markets. This strategy is based on advanced communication network infrastructure including fiber optic industrial Ethernet and wireless solutions, together with protection and control technology that enables smart grid applications such as advanced metering infrastructure (AMI) and distribution automation.

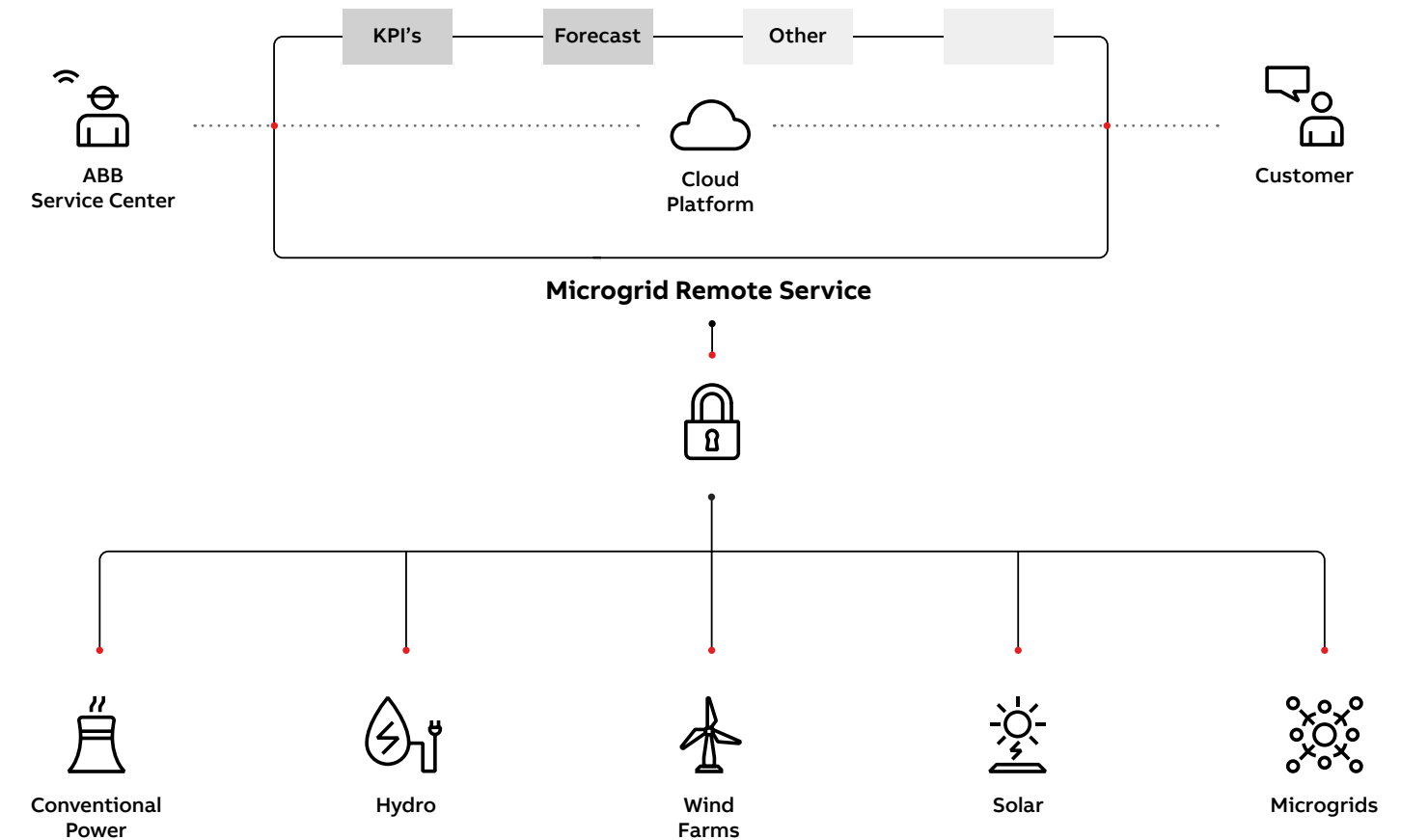
Energy portfolio management (EPM)

ABB's energy portfolio management offering consists of advisory consulting services, market intelligence data services, and software. This provides simulation, forecasting, optimization and market communication for both traditional and distributed asset portfolios. We enable customers to optimize their microgrid asset performance based on economic or environmental criteria for the next 5 minutes or the next 50 years.

Real-time control and management of distribution operations

ABB's Network Manager ADMS (Advanced Distribution Management System) is an integrated software platform that enables utilities to optimize the safe and efficient management of their complete distribution network. ADMS integrates with the control system of utility-owned, grid-connected microgrids in both interconnected and islanded modes to provide monitoring and control, network analysis, network optimization and outage management capabilities.

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05 ABB's microgrid solutions, delivering resilient power anywhere at any time

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