Microgrids

The mainstreaming of microgrids using ABB technologies

CELINE MAHIEUX, ALEXANDRE OUDALOV – For years local power generation has been the standard form of delivering power to islands, remote communities or industrial sites. However, several factors, including power supply reliability, environmental concerns and economic constraints, are forcing energy service providers and end customers to take another look at self-powered, grid-independent alternatives, such as microgrids. Microgrids can now incorporate renewable power, reduce costs and enhance reliability. Today they can also be used as black start power or to bolster the grid during periods of heavy demand. As a result, microgrids are increasingly being adopted. Significant cost reductions of renewable distributed generation such as solar photovoltaics (PV) and wind, along with the development of efficient energy storage technologies and the availability of affordable wide-area communication infrastructure, have helped make microgrids more feasible. ABB continues to develop technologies that are redefining the electricity supply chain.

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A microgrid is considered an integrated energy system consisting of distributed generation, storage and multiple electrical loads operating as a single, autonomous grid either in parallel with or "islanded" from the existing utility power grid. By this definition a microgrid may be made up of many different generation and storage mixes and grid connectivity formats, as well as cover a vast range of sizes. Therefore, microgrids can look very different. A typical microgrid may have a structure and components as shown in → 1. This definition allows for several classes of microgrids that are defined by the type of customer served, the motivations for building and the region of the world in which they are operating → 2.

Title picture
Microgrids are mainly targeted for remote areas and islands, often integrating renewable energy sources.

In many respects, microgrids are smaller versions of a traditional power grid. However, microgrids differ from traditional electrical grids by providing a closer proximity between power generation and power use, resulting in increased power supply reliability. Microgrids also integrate renewable energy sources such as solar, wind power, small hydro, geothermal, waste-to-energy, and combined heat and power (CHP) systems.

Microgrids differ from traditional electrical grids by providing a closer proximity between power generation and power use.

A microgrid control system performs dynamic control over energy sources, enabling autonomous and automatic self-healing operations. During normal or peak usage, or during a primary power grid failure, a microgrid can operate independently of the grid and isolate its local generation and loads without affecting the grid's integrity. Microgrids interoperate with existing power systems and information systems and have the ability to feed power back to the grid to support its stable operation.

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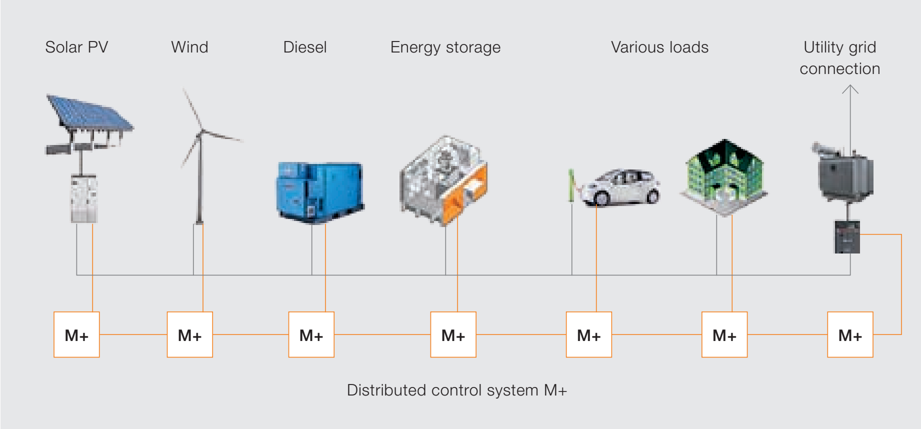
1 Typical microgrid structure and components



Successful installations

ABB's modular and scalable microgrid integration platform is a result of state-of-the-art technology development and practical experience obtained during more than two decades of designing and building microgrids worldwide. The ABB microgrid solution includes two key elements. Firstly, ABB's network control system solution, Microgrid Plus, which uses distributed agents controlling individual loads, network switches, generators or storage devices to provide intelligent power management and efficient microgrid operation. This solution is teamed with ABB's PowerStore™, which is a flywheel- or battery-based grid stabilization technology that enables high penetration of renewable power generation by providing synthetic inertia and grid-forming capabilities.

Combining these technologies allows 100 percent peak penetration of renewables in wind-diesel and solar-diesel power systems, maximizes fuel savings and enables the microgrid to automatically connect to or disconnect from the utility grid without interrupting critical loads.

A few notable examples of successful installations of ABB's microgrid technology illustrates its solutions and its value to customers.

Marble Bar

The world's first high-penetration, solar photovoltaic diesel power stations were commissioned in 2010 in Nullagine and Marble Bar, in Western Australia. The projects include more than 2,000 solar modules and a solar tracking system that follows the path of the sun throughout the day → 3.

PowerStore grid-stabilizing technology and the Microgrid Plus power management solution ensure that the maximum solar energy goes into the network by lowering diesel generation down to the minimum acceptable level or switching it off completely. When the sun is obscured, PowerStore covers the loss of solar power generation as the Microgrid Plus system ramps up the diesel generation ensuring the network has an uninterrupted energy supply. The solar energy systems generate over 1 GWh of renewable energy per year, supplying 60 percent of the average daytime energy for both towns, saving 405,000 L of fuel and 1,100 t of greenhouse gas emissions each year.

Microgrids have the ability to feed power back to the grid to support its stable operation.

Faial Island

In 2013 ABB commissioned a microgrid control solution that enabled the island of Faial in the Atlantic Ocean to add more wind energy to its power mix without destabilizing the network. Faial is one of nine volcanic islands in the Azores, about 1,500 km from the mainland. The island of 15,000 inhabitants has an electricity network that operates as a self-con-

2 Key microgrid drivers per class and region

	Europe	North America	Latin America	Asia Pacific	Africa
Commercial and industrial	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply		Reliable & secure power supply	
Government institutions and campuses	Environment	Cost, Reliable & secure power supply		Reliable & secure power supply	
Community	Environment, Cost	Cost, Reliable & secure power supply		Cost, Reliable & secure power supply	
Remote villages	Cost	Cost	Cost	Electrification, Cost	Electrification, Cost
Islands	Environment, Cost	Environment, Cost	Cost	Cost	
Remote mines and constructions	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply
Military		Cost, Reliable & secure power supply			

Electrification Environment Cost Reliable & secure power supply

tained microgrid, powered by six oil-fired generators producing up to 17 MW of electric power. The local power utility, Electricidade dos Açores (EDA) has installed five wind turbines as part of its effort to boost capacity by more than 25 percent and minimize environmental impact on the island, where tourism is an important industry → 4. The Microgrid Plus control system calculates the most economical configuration, ensures a balance between supply and demand, maximizes the integration of wind energy and optimizes the generators so that the entire system performs at peak potential. The integration of wind energy combined with ABB's innovative solution saves an estimated 3.5 million L of fuel per year and has the potential to reduce annual carbon dioxide emissions by around 9,400 t.

SP AusNet

A microgrid with a battery energy storage capacity of 1 MH / 1 MWh as well as 1 MW diesel generator power is a pilot project for SP AusNet's electricity distribution network in Victoria, Australia → 5. The battery system and smart inverter are the primary energy source, while the diesel generator acts as backup to extend the capacity available. Scheduled to be completed by the end of 2014, the system will comply with the distribution grid codes when grid connected, transition into island mode when the network controller gives the command, and switch back to grid-connected operation without any power supply interruption. ABB's scope of supply includes the design, engineering, construction, testing and supply of the ABB PowerStore-Battery System and a 3 MVA transformer to be integrated with the diesel generator. The plant is managed by ABB's Microgrid Plus control system and implemented as a transportable power station consisting of seven outdoor containers and kiosks.

Looking forward

The microgrid market is rapidly developing, with commissions occurring around the world in a variety of application segments. Microgrids are shifting their focus from technology demonstration pilot projects to commercial projects driven by solid business cases. A recent Navigant Research report has identified over 400 microgrid projects in operation or under development globally.[1] The same study forecasts that the global annual microgrid capacity will increase from 685 MW in 2013 to more than 4,000 MW by 2020. North America will continue leading the microgrid market and the Asia Pacific region will likely emerge as another growth area by 2020 due to the huge need to power the growing populations not served by a traditional grid infrastructure.

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Footnote

1 "Microgrids Global Market Analysis and Forecasts Report," Navigant Research, Boulder, CO, Dec. 2013.

Energy storage plays an important role in microgrid stabilization and in renewable energy time shifts that bridge peaks of power generation and consumption.

3 Marble Bar microgrid in Australia

4 Wind-diesel microgrid on the island of Faial, in the Azores

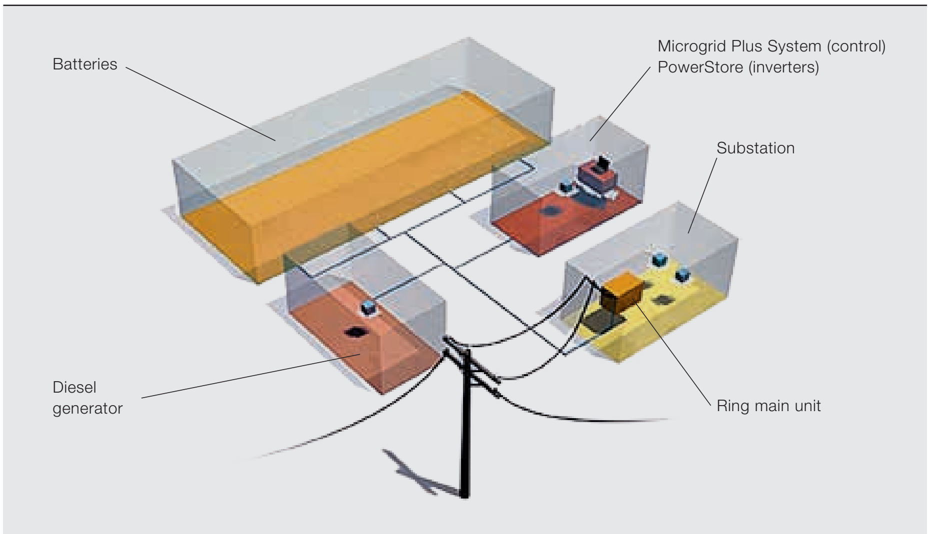
As the microgrid market continues to evolve, ABB is developing new technologies to address the challenges still being faced. Though surmountable, the challenges are varied and complex.

Energy storage

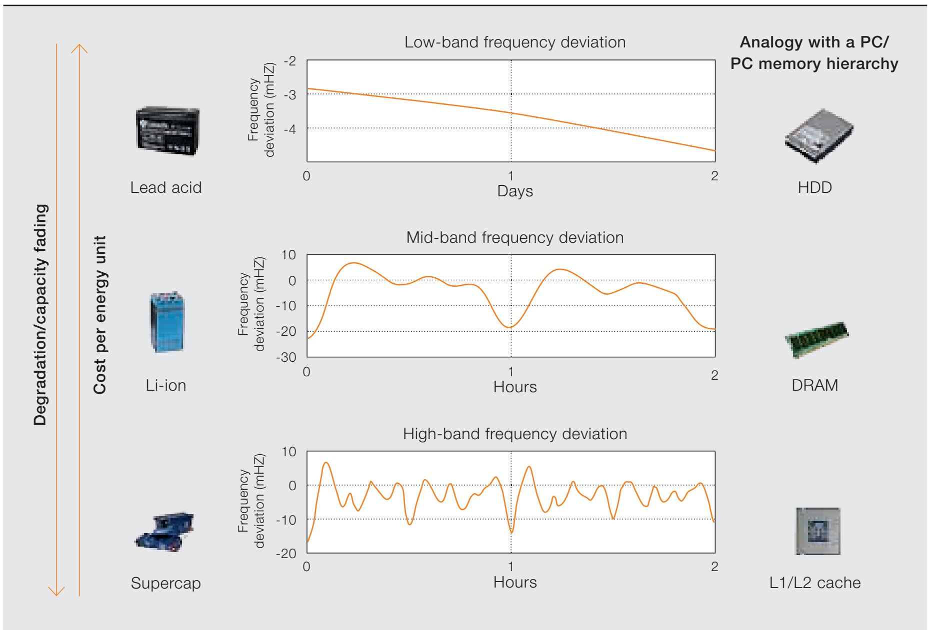
Energy storage plays an important role in microgrid stabilization and in renewable-energy time shifts that bridge peaks of power generation and consumption. Yet the two functions require very different technologies for energy storage.

The microgrid stabilization apparatus must provide a very fast response while possibly being called several times per minute. This results in high power output but very small stored energy. However, with renewable-energy time shifts the system should be capable of storing energy for a few hours to bridge the peaks of energy production and consumption. In order to meet these different requirements a hybrid system design with a combination of underlying storage technologies with different performance characteristics (cycle life and response time) may be the better choice → 6. A hybrid energy storage system will combine the benefits of each storage media and will have a lower total cost compared with the individual units. ABB is analyzing the advantages and disadvantages of such a system and developing control solutions for the technology.

5 Schematic diagram of SP AusNet microgrid, Victoria, Australia



6 Hierarchy of hybrid energy storage and its analogy with computer memory functions



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Protection system

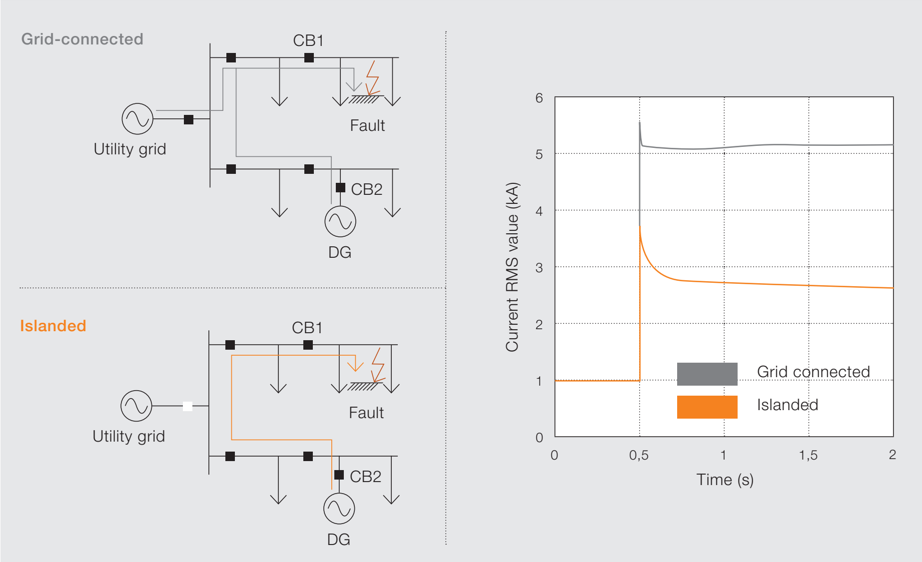
A protection system must respond to utility-grid and microgrid faults. With a utility-grid, fault protection should immediately isolate the microgrid in order to protect the microgrid loads. For the fault inside the microgrid, protection should isolate the smallest possible section of the feeder.

Problems related to selectivity (false, unnecessary tripping) and sensitivity (undetected faults or delayed tripping) of a protection system may arise because the level of short-circuit current in the islanded operating mode of a microgrid can drop substantially after a disconnection from a utility grid → 7. ABB is researching different approaches on how to deal with this problem – either with grid automation devices or by using a dedicated fault source.

When a microgrid is protected by IEDs (intelligent electronic devices) that support multiple setting groups, the settings can be switched in real time according to the actual state of the microgrid based on the preset logic. Frequently microgrids can be protected by fuses, which have been dimensioned based on fault current levels supplied by the main grid. In this case at least one local energy resource must deliver a fault current high enough to ensure sensitivity and selectivity of protections. Such a fault current source will detect a short circuit based on a local or remote voltage measurement

An accurate forecast of available renewable energy and loads (both electric and thermal) will play an important role in the economic dispatch of a microgrid.

7 Fault current level variation in grid-connected and islanded modes



and rapidly release a large amount of energy generating the required level of current to blow a fuse.

Energy management

Thermal loads usually represent a considerable part of total energy use by end consumers. There is a large potential for cost savings particularly with regard to combined heat and power (CHP) systems, which allow consumers to realize greater efficiencies by capturing waste heat from power generators. It is also much easier and cheaper to store thermal energy compared with electric energy. Therefore, coordination between thermal energy storage and other thermal sources, and between thermal and electrical systems must be considered for cost-effective microgrid energy management. ABB is working to develop an energy management system with this functionality. An accurate forecast of available renewable energy and loads (both electric and thermal) will play an important role in the economic dispatch of a microgrid.

Tools for modeling

How a system is modeled is of great importance during all phases of development – from the conceptual design and feasibility study through construction and testing of the microgrid project. For example, when an existing diesel-based backup power supply is extended with a large amount of fluctuating renewable energy resources, stable operation of the microgrid cannot be guaranteed. In order to optimally dimension a grid-stabilizing device such as PowerStore and to tune its control parameters, the dynamic behavior of legacy diesel gensets has to be known. Usually an accurate dynamic generator's response is evaluated during field trials followed by a process of tuning the parameters of all controllers causing delays during the commissioning phase. But this situation will be avoided once a microgrid controller is developed that can learn about a response of a controlled unit (eg, an old genset) and share this information with other controllers for automatic tuning of their parameters.

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Further reading
ABB Renewable Microgrid Controller MGC600, http://new.abb.com/power-generation/microgrids-solutions