Deep Dive on **Microgrid Technologies**

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In the wake of Superstorm Sandy, a microgrid kept the lights on for more than for the more than 60,000 residents of Co-Op City in the northeastern section of New York City. In addition to providing greater resilience than the conventional power grid, microgrids have also been recognized as a key strategy for improving energy efficiency, deferring or avoiding capital investments in new transmission and distribution infrastructure and mitigating cyber security risks. In the aggregate, these forces are moving microgrids from the margins into the mainstream of America’s energy economy. This is the third eBrief in a three-part series on microgrids describing the key regulatory, financial and technical issues affecting microgrid projects. The first eBrief described the regulatory issues likely to affect a microgrid project, including the risk of violating franchise laws and the possibility that the microgrid will be subject to economic regulation under state utility law. The second eBrief described several key considerations for evaluating the potential economic benefits and financial structures of a microgrid. This eBrief focuses on critical technical issues involved in pursuing microgrid projects using a system-level approach that ensures a holistic approach to microgrid planning. The first section of this eBrief considers potential technical requirements of a microgrid project. The second section surveys the three principal types of components that comprise a microgrid. These components are combined in the design process to successfully achieve the project’s technical requirements.
Technical Requirements

As a general matter, all microgrids are distribution networks that interconnect a set of embedded generation assets dispersed within a specific geographic area. One of the critical advantages of a microgrid is that it can be designed to meet the technical requirements of specific customers. For example, many microgrid customers require levels of reliability significantly higher than what is provided by the centralized power grid. For example, microgrids can be designed to support critical infrastructure when emergencies and natural disasters cause outages on the centralized grid. The ability to provide continuous power to support essential public services depends upon appropriate design measures that ensure the microgrid can readily serve critical loads during times of need. To this end, the necessary design parameters should be incorporated when developing microgrids for critical infrastructure resiliency.

The first step in developing a microgrid project is defining the microgrid’s technical requirements. In other words, what must the microgrid be capable of doing in order to deliver the value or values desired by the customer? The technical requirements for a microgrid project flow from the answer to that question. A systems-level perspective drives the selection of technology platforms and individual components for a microgrid project based on their functional and performance attributes. Standards and protocols like the IEEE 1547 and IEEE 2030 provide overarching constructs for the microgrid design process.

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The systems-based approach to the design process allows for selecting the optimal scale and technology type of generation components, for managing cost efficiency by balancing the application of redundancy and hardening, and for defining a weighted set of metrics used to assess the criticality of loads.
Platform Technologies

A microgrid encompasses multiple interacting components spread across a defined geographic space. The components are connected and monitored with advanced sensing, control and communications technologies and can be configured to meet the needs of a variety of dynamic load types and operate under a range of grid conditions. At a minimum, these components include: a transfer switch to separate the microgrid from its adjoining utility and connect to self-generation, a generator to supply power in autonomous mode, interconnecting cables and an end-user load. Microgrids must integrate several technologies and components to achieve the required platform functionalities within a set of infrastructure constraints. Like the macrogrid, microgrids include a wide array of power generating technologies, distribution infrastructure components and control systems. The components of a microgrid can be broken down into three categories: infrastructure, generation and controls.

Infrastructure Components
Common infrastructure components include automated relays, automated switchgears, transformers, inverters and uninterruptible power supply systems. These components must be configured to provide safe and adequate service based on the requirements of the surrounding utility distribution system, which are typically either network, radial or loop distribution systems. Automated grid components are key hardware components that execute the Microgrid controller’s command to connect or disconnect the microgrid from the main network at times of grid disturbance. A microgrid’s ability to “island” generation and loads simultaneously can provide a higher level of reliability than that provided...
by the traditional electric grid. At the same time, the infrastructure requirements of a microgrid capable of islanding may be more complex and costly depending on the type of surrounding utility distribution systems.

### Interconnection Technologies

Microgrids must meet certain specifications before they can interconnect with the local utility’s distribution grid, which are based on the previously described IEEE 1547 and 2030 standards. In addition to protecting the distribution grid from potential power quality and safety problems, interconnection technologies are designed to capture the full spectrum of value streams created by microgrids. Interconnection technologies include network protectors, inverters and similar devices. A network protector is a device that automatically connects and disconnects its associated network transformer from the secondary network. An inverter is an electrical device that converts direct current (DC) to alternating current (AC). Inverters convert DC produced by generators to AC using a system of switches that synthesize the DC waveform into an AC waveform. Wind turbines and solar panels commonly use inverters to interconnect with the (AC) electric distribution system.

### Monitoring and Controls Components

An integral piece of the microgrid is the intelligent, automated control that connects the various Microgrid systems together and optimizes their management. A microgrid’s control system is critical for integrating the system’s components – generation, power distribution and loads – in the manner required to achieve the project’s technical requirements and optimize operation. Microgrid control solutions allow Microgrid operators to intelligently manage and control distributed energy resources for reliability, economics and power quality while connected or disconnected from the grid.

The control solution must be able to interface with local utility systems, including Energy Management Systems (EMS), Distribution Management Systems (DMS) and Supervisory Control And Data Acquisition (SCADA) systems, to ensure that the utility and microgrid control systems interact efficiently and...
reliably. The software will likely be deployed at the control center or at a remote site and use standard utility communication protocols like DNP to communicate with any other grid components. The software should follow industry standard advanced cyber security requirements and meet NERC CIP requirements for a control center deployment. Solutions can be found that are “operator-free” which do not require traditional 24-7 monitoring.

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IEEE 1547 & 2030

The Institute of Electrical and Electronics Engineers (IEEE) develops technical standards and establishes best practices for the electronics, computing and electric power industry. The IEEE is developing two sets of standards that apply to microgrids. The IEEE 1547 set of standards establish technical requirements for the interconnection of distributed resources to electrical power systems. The IEEE 2030 set of standards provide an interoperability reference model and knowledge base for developing microgrids.

Consolidated Easy-Use SCADA: complete SCADA functionality for secure, reliable and efficient operation. The user interface provides clear and easy-to-operate user environment.

Load Forecast: utilizes historical load data as well as seasonal weather conditions to forecast load profiles within the microgrid over hourly and weekly intervals. Interfaces to local building automation, metering systems, SCADA systems and more provide the load profile data to develop a complete load forecast.

Generation Forecast: optimization allows each microgrid owner to determine at an aggregate level whether to optimize generation dispatch based on economics or emissions or a combination of the two. A variety of robust weather forecasting systems are
supported to forecast renewable generation production in order to balance the generation to the load forecast.

**Generation & Load Management:** regulates the real power output of the generating units within the microgrid to maintain the desired frequency and voltage when in island mode and to maintain net interchange with the external grid when in grid connected mode.

**Load Shed:** performs shedding or disconnecting of loads when requested by an operator or automatically during disturbance conditions (such as islanding) to maintain system stability. The loads are virtually ordered according to predetermined priority schemes. Thus the sequence of events can be controlled and the most important loads remain connected.

**Data Archiving:** a Historical Information System (HIS) to provide a solid and reliable archive to store power system historical data.

Optional, advanced features could include:

- Market Participation
- Fast Load Shed
- Control Center Redundancy
- Advanced Cyber Security

Advanced functionality in the microgrid control solution can enable microgrid operators to participate in energy markets by intelligently managing their own power generation with visibility into the power needs of the grid. Operators can plan power generation based on energy market price forecasts from 15 minute to hourly increments up to day-ahead or seven day-ahead horizons. This allows microgrid operators to achieve full economic value from the microgrid while maintaining their traditional base load needs.

Monitoring is also an important consideration for microgrids. A microgrid operator may want to monitor a wide range of potential parameters, including voltage, frequency, real power, reactive power, current, switch status points and relay status points. In many scenarios, monitoring is required for control and/or synchronization purposes. For example, voltages may need to be measured at multiple locations to detect when to disconnect the microgrid from the macrogrid and determine when conditions on the macrogrid are suitable for reconnecting.

A robust control architecture is needed for dynamic optimal management, communications between subsystems and demand management.

**Generation Assets**
Microgrids can use electricity generated from a wide range of power technologies, using both renewable and non-renewable energy resources as fuel. The portfolio of generating technologies selected for a specific microgrid, which might include renewable-energy resources, combined heat and power, energy storage systems or many other technologies, present different cost-benefit scenarios. Some examples are discussed below.

**Solar Photovoltaics**
Solar photovoltaic technologies convert solar radiation...
into electricity. Solar DG refers to small-scale, on-site electricity generation for homes or small businesses. Falling technology costs, grid-independent solutions, tax incentives and financial innovation have reduced the capital costs of solar PV systems and in turn accelerated customer adoption rates. Solar PV rarely produces enough power to meet all of a customer’s electricity needs and if an off-grid or “island” mode is required of the microgrid, a significant amount of traditional fossil fuel based generation will be required to provide stabilizing energy.

**Combined Heat and Power**

Combined heat and power (commonly known as co-generation or CHP) is an integrated system of one or more technologies designed to capture heat typically wasted in the generation of electricity and use it to meet the heating, cooling or other needs that would otherwise require additional consumption of electricity. CHP systems can use a wide variety of prime movers to generate electricity, including fuel cells, microturbines, reciprocating engines and Stirling engines. While most CHP systems rely on natural gas as a fuel source, they also often use different forms of biomass as fuel. CHP typically drives significant energy efficiency savings and can range in size from 1MW to hundreds of MWs.

**Energy Storage**

Energy storage technologies include electrochemical devices that convert electricity into chemical energy and then reverse the process for the provision of power (i.e. batteries). They also include devices that convert electricity to potential mechanical energy (compressed air, pumped water), to be reconverted to
electricity when required. There are several promising energy storage technologies for microgrid applications including advanced lead-acid, lithium-ion, flow and sodium-sulfur batteries. While battery prices are expected to continue to drop in pricing, currently there are limited regional applications where battery cost justifies the investment.

**Summary**

Selecting the optimal technologies is critical to the success of a microgrid project. In particular, a robust, front-loaded design process that encompasses steady state and dynamic state studies is vital to selecting the optimal generating technologies and system components for a microgrid.

When selecting a Microgrid vendor, be sure to evaluate their skills at not only the overall Microgrid design and system stability studies, but their capabilities to successfully integrate the entire system – both existing and new components regardless of technology provider. This will ensure your system operates as designed.

Lastly, it is extremely important to design the Microgrid control system during the planning stage to ensure the complex networks of power generating and distribution components are designed to deliver the expected benefits – both financially and operationally. The controls system must maintain system stability, optimally balance supply and demand and respond in real-time to changes conditions on the central power grid. Microgrids that operate during severe weather events or in the wake of natural disasters should also be designed with control capabilities needed to mitigate any potential safety risks. Anyone considering a microgrid must be careful to select project partners with strong track records in the microgrid space and proven abilities to integrate components from multiple vendors.

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**About Siemens**

The Siemens Energy Management Division offers an end-to-end portfolio of products and solutions to develop intelligent energy networks for forward-thinking utilities, municipalities, military bases, large industry, cities, and commercial customers. Siemens' turnkey Microgrid capabilities pull together financing, consulting, advanced grid technology, generation assets, O&M, and an adapted supervisory control and data acquisition system sized for microgrid management, all within a comprehensive systems integration package. The company offers a broad microgrid business model approach based on the concept of design, build, operate, and maintain, with financing options supported by Siemens Financial Services. For more information visit [www.usa.siemens.com/microgrid](http://www.usa.siemens.com/microgrid)