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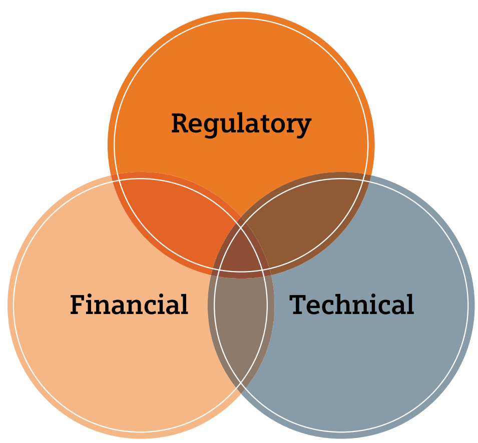
Microgrid Start Up: A Guide to Navigating the Financial, Regulatory, and Technical Challenges of Microgrid Implementation

Intelligent Microgrids – Feasibility And Planning

On October 29th, 2012, Superstorm Sandy slammed into New York City's shoreline. In the days and weeks that followed, the New York City Subway system and all but one of the road tunnels entering Manhattan were severely flooded, entire neighborhoods were decimated and millions of customers in New York City and on Long Island lost power – many for days and weeks. Microgrids kept the lights on at New York University in Manhattan, Princeton University in New Jersey, South Windsor High School in Connecticut and Co-op City in the Bronx during Sandy storm and its aftermath. In addition to providing greater resilience compared to 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. The following eBrief is the first in a three-part series describing the key regulatory, technical and financial issues affecting microgrid projects. This eBrief describes 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. In addition, the eBrief provides strategies for avoiding these pitfalls in order to realize the maximum value from a Microgrid.

Figure 1: Expertise Required for Pursuing Microgrid Projects – All Three Are Equally Critical to Success



Anatomy
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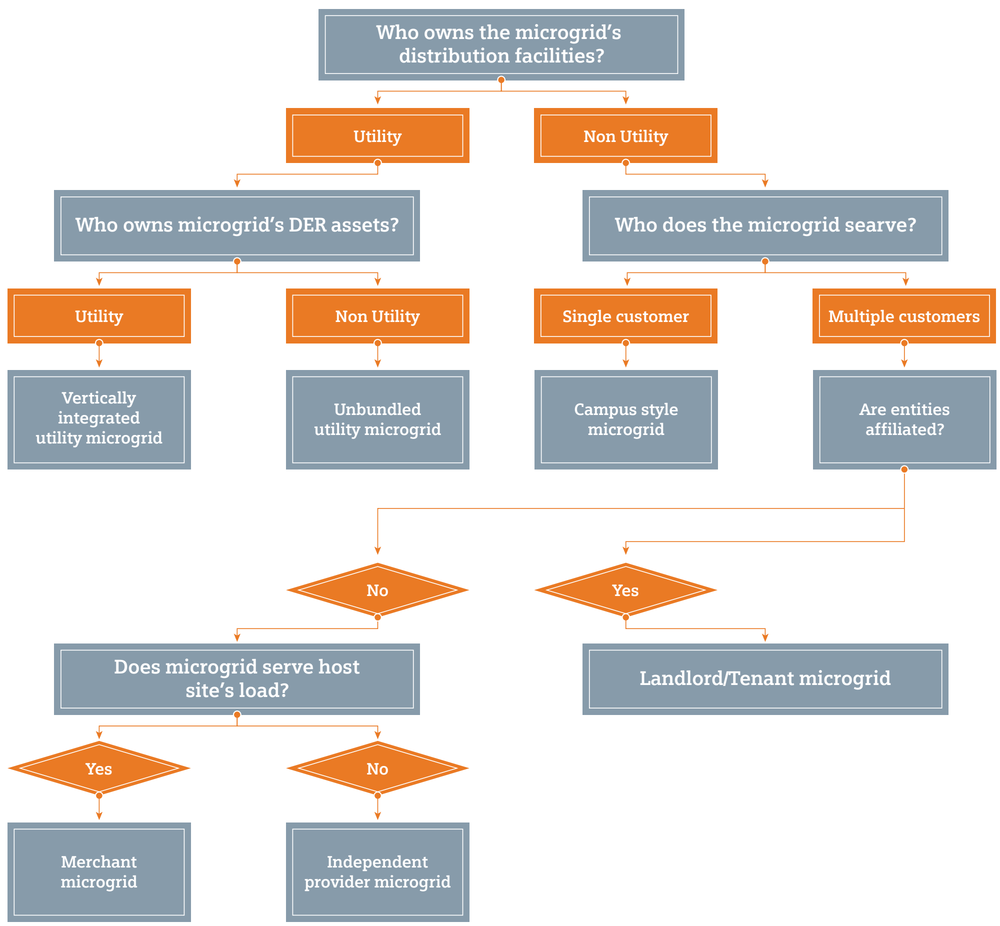

Regulatory Issues

- How do consumer protection laws affect microgrid owners?
- Do metering laws limit the ability to sell electricity from the microgrid?
- How does "the right of the way" rule affect microgrid location selection?
- Are microgrids eligible to participate in demand response or similar DSM programs?
- Are microgrids eligible for state/local incentives?
- Are emissions regulations outpost based? Is air modeling required?

directly. Most states, instead, have extended the regulatory standards and protocols used for regulating traditional distributed generation to microgrids in some shape or form. These states are addressing ambiguities in the traditional regulatory scheme as applied to microgrids on a case-by-case basis.

Is it legal for one or more customers to build and operate a microgrid in a given area? The answer may depend on how effectively the microgrid developers have tailored the project to comport with the applicable legal and regulatory requirements in that area.

Microgrids have a legal right to exist in many states, but the legality is almost always contingent on several stipulations. In particular, local and state regulations may require the microgrid's owners or operators to be the primary consumer of the electricity the system generates, be physically located on or contiguous to the site where power is generated or serve only a limited number of customers. Complying with these stipulations may be more or less complicated depending on the specifics of local regulation. For example, in Georgia, customers are not considered contiguous if they are separated by an easement, public thoroughfare or utility-owned right-of-way. Despite these issues, several states like New York and Connecticut are promoting deployment of microgrids through incentive programs and by initiating regulatory proceedings to resolve concerns about franchise encroachment.

Crossing the Street: Franchise Rights

A prospective microgrid faces considerable uncertainty with regard to where and how it can be built and operated under the existing regulatory environment.

- *Utility and regulatory limitations may impair functional access of a microgrid's ability to serve buildings nearby if power supply lines cross a street or public right of way. A robust analysis of the ability to serve contiguous properties and cross rights of way is critical for microgrid projects.*

Microgrids that cross a public right of way (e.g., for moving transmission or distribution facilities over public streets) may trigger multiple regulatory requirements under state and local law related to franchise rights. A microgrid that distributes power and/or thermal energy across a public street may

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violate the franchise rights granted to an incumbent utility. A franchise represents a contract between a company or service provider and a local municipality or state government. Franchises are granted for specific geographic areas and remain in place for a limited number of years.

Although franchise rights can be exclusive, monopoly is not an essential feature of a franchise. For example, in New York State, franchise rights are not exclusive. Many municipalities permit narrow encroachments into existing franchises by granting right of way permits, revocable licenses, revocable consents and similar instruments. For example, New York City granted New York University a revocable consent to install and operate a microgrid system in Manhattan that technically violated the local utility's franchise rights by distributing electricity and thermal energy across a public right of way.

It is critical to resolve any uncertainty aboutthe legal treatment of a microgrid under existing franchise law prior to pursuing a microgrid project, especially if it is located within the service territory or franchise area of an existing utility. In many cases, the mere threat of litigation is enough to derail small enterprise from pursuing a potential microgrid project.

State regulatory bodies are realizing that out-of-date regulatory rules are limiting Microgrid adoption and are working to change regulation. States such as New York, Connecticut, and Minnesota have allocated funding and started conversations on how best to change the state regulation to allow for Microgrids to be adopted. Regulators realize the significant value that microgrids can provide to their constituents and have begun efforts to accommodate them within the existing regulatory paradigm. Given the customer-centric focus of microgrids, more and more utilities and utility regulators are starting to appreciate any opportunities they may have to collaborate with customers considering a microgrid project. Engaging utility regulators as early as possible can also help customers identify any specific challenges that may affect their planning for a microgrid project.

Microgrids have a legal right to exist in many states, but the legality is almost always contingent on several stipulations.

Utility Regulation

Another equally significant regulatory risk affecting microgrids is the potential that it will be regulated as a public utility by the state utility commission. If a proposed microgrid is considered to be a public utility under state law, it will face far more significant barriers to implementation. For example, the New York State Department of Public Service establishes the rates that utilities charge customers for providing service and has significant control over the utility's financial operations. Utilities are also typically required to comply with various reliability standards and consumer protection laws.

Microgrid developers can avoid the risk of utility regulation by assessing the applicable legal framework rigorously at an early stage of the project. In particular, this assessment will involve careful consideration of the applicable legal definition of a "public utility," That definition will determine whether a microgrid owner or operator is subject to regulation by the state utility commission?

Like franchise rights, the statutory definition of a public utility varies – often significantly – from one state to the next. For example, in South Carolina, the public utility commission has jurisdiction over the sale of electricity such that anyone who sells electricity is regulated as a public utility. If the owner of an apartment building sold electricity produced onsite by solar panels to one of the building's tenants, the owner would be considered to be a public utility.

Risk Mitigation Strategies

Microgrids create conflicting pressures on utilities and regulators. Understanding these pressures – and knowing what strategies are effective for managing them – can be critical to a project's success. For instance, regulators across the country have different notions of what a microgrid is and how it might operate, and their opinions may depend on how the microgrid concept is framed. When framed as a small independent power producer, a microgrid may yield a different reaction than when it is framed as a large distributed generator, or placed in the context of energy services or demand management.

It is critical for microgrid owners to understand the utility relationship and associated regulatory access processes. Both microgrid owners and microgrid project developers have to realize that utilities are one of the important stakeholders involved in any microgrid project. Utilities are not necessarily an obstacle to microgrids. On the contrary, the more forward-thinking utilities are extremely supportive. They recognize the added value, diversity, and specialized services that can be provided by microgrids. However, the utility must pay for the installation, operation, and maintenance of the external power supply system. To remain in business, they must continue generating value for shareholders. The inability to recover capital invested in equipment that utilities were obligated to install as a regulated monopoly could impede this objective.

It is critical for microgrid owners to understand the utility relationship and associated regulatory access processes. Utilities are not necessarily an obstacle to microgrids.

The traditional utility is more likely to perceive microgrids as a direct economic threat in markets where electricity revenue is based principally on volumetric sales of electricity in kilowatt hours. It is important to fully understand the tariff conditions in the regional market and to assess macro market conditions that allow for purchase or sale of electricity to the grid.

Long after a microgrid has been constructed and begun operations, the local inter-connected utility still provides the microgrid with important and beneficial services most of the time. In establishing inter-connected generating capability, the microgrid-utility relationship necessarily becomes more complex and requires a higher degree of communication than a simple provider-recipient relationship.

For decades, institutional and commertial buildings and campuses have addressed their need for uninterruptible power by installing local generators. Most engines powering these generators are rated to operate for only a few hours. One could argue that microgrids are already in operation when the local energy supplyer is not able to provide energy due to weather or other causes. To help stakeholders embrace this de-centralized generation approach: microgrids could be viewed as a UPS system rated to operate continously and reaching beyond the facility that houses it.

Key engagement strategies

- Establish a team of trusted advisors with expertise in regulatory, technical and financial aspects of energy projects and with strong track record for completing projects successfully
- Engage stakeholders – including regulators and utilities – in front-end discussions
- Include utilities and other stakeholder groups in design and implementation of microgrid project
- Be open/transparent/factual/honest ■

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Microgrids have the potential to play a significant and positive role in promoting a cleaner, more resilient energy infrastructure. Microgrids' proximity to customers makes them less susceptible to distribution grid failures. In the wake of Hurricanes Sandy and Irene, several microgrids continued to supply electricity and thermal energy without interruption. By enabling the use of locally sited renewable energy resources such as solar, biogas and geothermal energy, microgrids may diversify a customer's or microgrid owner's energy portfolio, mitigating price volatility and potentially reducing its environmental footprint. Microgrids may also lower a customer's total cost of energy.

Growing awareness of these benefits has galvanized considerable -interest in deploying microgrids as a primary or supplemental source of heat and power. This is the second eBrief in a three-part series on microgrids. This eBrief describes several key considerations for evaluating the potential economic benefits and financial structures of a microgrid. In most cases, the decision to invest in a microgrid is based upon a two-part evaluation process.

The first part evaluates the bankability or financial viability of a microgrid project by (1) conducting a rigorous analysis of applicable utility rates and (2) developing an investment pro forma based on the rate analysis. The second part of the investment process involves selecting an ownership model and a financing structure for implementing the project. This process should be executed before detailed technical designs are developed to ensure the project is financially viable.

Bankability

Microgrids almost always require an initial capital investment. The amount of capital required can vary widely depending on the specific circumstances of a microgrid project. Similarly, the source of the capital may also vary for different projects. In some instances, third-parties may provide the capital needed to construct the microgrid. In other cases, the customer may provide the capital. The capital may be provided by more than one source.

Microgrids are considered to be financially viable or "bankable" when they yield an acceptable return on this investment. "Bankability" of a microgrid project means it creates sufficient energy cost savings and/or generate revenues to carry financing costs typically over a period of time. In practical terms, microgrids create financial value by reducing a customer's total cost of energy and/or create additional revenue streams. A robust analysis of the cost savings and/or incomes created by a microgrid is essential to estimating the project's return on investment.

Microgrid customers will typically pay for electric service based on a different rate for grid-sourced power than the rate they otherwise would pay.

The rate of return (ROR) expectation could vary for different investors. Depending on the risk profile, large corporations are unlikely to commit funds to support early-stage investments with RORs below 12%. Third-party equity investors typically expect a ROR of at least 15% or more, depending again on the project risk profile. Lower returns are acceptable for investments made later in the development cycle of a project when the project is much more matured and the risks have been substantially mitigated.

Several financing vehicles are available for funding a microgrid. An investment feasibility analysis is a critical part of evaluating the advantages and disadvantages of these financing options for an investment in a microgrid.

The financial Analysis is an essential step to understand a microgrid's "bankability". Equipped with the results, the customer will be able to make informed decisions about the tradeoffs of different financing options for funding a microgrid project.

The Financial Analysis consists of two principal steps. The first step is to analyze how utility rates are likely to affect a customer's total cost of energy in the future. This exercise estimates the cost savings created by a microgrid. In some cases, the calculations need to consider how much income a microgrid can generate. The second step involves selecting an ownership structure based on the customer's risk preferences.

Utility Rate Analysis

Most microgrid customers are unlikely to disconnect completely from the electric grid. In most cases, microgrid customers use the grid to supplement power produced by the microgrid during periods of peak demand or use the grid as backup when the microgrid is unavailable (e.g., due to maintenance). Microgrid customers will typically pay for electric service based on a different rate for grid-sourced power than the rate they otherwise would pay.

Because utility rates can significantly affect the economics of a microgrid, potential investors in a microgrid project commonly conduct a rigorous analysis of utility rates as part of their due diligence. This analysis is highly technical and requires financial expertise as well as experience with utility tariffs.[1]

Microgrids interconnected with the conventional grid may be required to pay standby rates to the local distribution utility similar to the stand-by rates that apply to baseload generators. Standby rates are designed to capture the distribution utility's cost of supplying services to users. These users consume power provided by the conventional grid for supplemental power such as when an on-site generator or microgrid is offline for scheduled or un-scheduled maintenance. The term "standby rate" is often used as shorthand to describe various rate structures designed for customers with onsite, non-emergency generation.

The services provided under standby rates include one or more of the following:

- **Backup service:** serves a customer load that would otherwise be served by onsite generation during unscheduled outages of the onsite generation
- **Supplemental service:** customers whose onsite generation does not meet all of their needs, typically provided under otherwise applicable full service tariff
- **Scheduled maintenance service:** price of grid-sourced power used by microgrid customers during scheduled maintenance outages
- **Economic replacement power:** electricity at times when the cost of producing and delivering it are less than that of the onsite source

Standby rates include three distinct charges: customer charges, contract demand charges and daily-as-used demand charges. The customer charge is designed to recover certain fixed costs (e.g., metering expenses) that do not vary with energy use and shows up on the customer's bill as a fixed monthly charge. The contract demand charge is designed to recover variable costs associated with providing electric service to the customer and only applies when the customer's consumption of power from the conventional grid exceeds some pre-determined threshold during a given time period. When consumers exceed their demand threshold, they are subject to penalties in the form of a surcharge equal to between 12 to 24 times the monthly demand charges for all excess usage. The daily-as-used demand charge is designed to recover the costs of distribution infrastructure required to serve the system's peak demand. The daily-as-used demand charge is based on the customer's daily maximum metered demand during peak-hour periods on the macro system.

Standby rates are different in each utility territory and may make the economic case for a Microgrid prohibitively expensive. For example, "demand ratchets" can have adverse financial consequences for onsite generators.[2] A thorough financial analysis should be completed using anticipated demand data to understand what expenses may be occurred during Microgrid operation.

Preparing Project Pro Forma

Developing an investment-grade project pro forma comes after the initial financial analysis as it requires a robust understanding of utility rates and reliable historical data on customer's demand profiles. In addition, the pro forma should take into account of operating profiles, local and state incentives, fuel costs, service costs, depreciation, taxes and several other relevant inputs.

Unlike energy efficiency or distributed generations projects, evaluating the economics of a microgrid project poses several unique challenges. For example, in most states, government incentives are generally designed for individual generators and individual customers. Microgrids link one or more generators to multiple users. Similarly, incentives are typically structured for specific market segments – e.g., municipal, commercial or residential. For example, net-energy metering may be available for residential customers but not commercial customers. Microgrids may serve customers in more than one market segment simultaneously. This level of complexity is exactly why investment grade project pro-forma is required when planning and developing a microgrid project.

Financing Issues Vary By Market Segment: Hospital Example

It is important to point out here that not all market segments face the same financing challenges. Take hospitals as an example. Hospitals are among most energy-intensive facilities in the United States, consuming about 2.5 more energy than the average commercial building every year. The cost is staggering. Hospitals spend over $10 billion on energy annually and often accounts for about 2% of a typical hospital's operating budget. So are the environmental consequences. A 2007 study estimated that health care accounted for 8% of all U.S. greenhouse gas emissions.

Capital budgeting decisions made at hospitals oftentimes constrain efforts to reduce energy costs and greenhouse gas emission. Energy investments rarely make the "A" list of capital projects undertaken at a hospital. Traditionally, hospitals have financed energy efficiency projects as on-balance sheet capital projects with the proceeds of conventional taxable and tax-exempt debt structures such as bank loans, financing leases and bond financing. Such structures impair hospitals' debt financing capacity and are included by rating agencies and lenders in their credit scoring criteria. Given a choice between capital projects for revenue producing patient care assets and projects that may create energy savings, hospitals are less inclined to pursue the latter. There are, however, still other financial options available could be considered more favorable when financing a microgrid project at hospitals. For example, transaction structures that eliminate debt capacity and address credit evaluation concerns may increase the likelihood of energy efficiency projects being pursued at hospitals.

It is imperative to recognize the market segment a microgrid is serving. This way, it can be ensured that financial issues facing this specific market segment are taken into account during the microgrid project "bankability" due diligent process.

Ownership Models and Financing Vehicles

After developing a robust financial pro forma, customers can begin evaluating the advantages and disadvantages of different ownership structures and financing vehicles. Decisions about ownership and financing arrangements frequently affect the project's underlying economics. In many cases, ownership and financing structures may significantly strengthen a microgrid's return on investment. For this reason, it is critical to consider multiple options before making a final choice.

Ownership Models

- **Direct Ownership:** Retain control over all aspects including financing, build, own, operate and maintain. Offers greatest potential return, but also creates largest risk for owner.

- **Joint Ownership:** Retain ownership, but only finance the project. Third party agrees to develop and operate microgrid. Transfers share of returns from owner to third party in exchange for third-party assuming some of the risk.

- **Third-Party Ownership:** Outsources financing, development, O&M and ownership. Significant risk transfer from customer to third-party, but latter also gets primary share of potential returns.

At minimum, the following factors should influence customers' selection of an ownership structure:

- Risk tolerance
- Required rate of return
- Access to low-cost capital
- In-house technical expertise
- Business strategies
- Institutional objectives – e.g., sustainability goals
- Accounting treatment
- Tax implications

Structure	Potential Advantages	Potential Disadvantages
Equity	No impact on debt profile	Potential future capital constraints
Debt	Fast, drawable options	Higher rates, on-balance sheet
Operating Leases	Tax benefits, low transaction costs	May require on-balance sheet
Capital leases	Tax benefits, low transaction costs	On-balance sheet

Financing Vehicles

A growing number of financing options are available for developing a microgrid project. The basic mechanics for a few of the more common financing options are discussed below. However, financing is an especially dynamic part of the microgrids industry. New and innovative financing vehicles are constantly emerging in the marketplace, making it even more critical for customers considering a microgrid project to select qualified partners.

Like most things, decisions about ownership and financing almost always entail tradeoffs. The advantages and disadvantages of each ownership model and financing vehicle are likely to vary in significance for differently situated customers.

Power Purchase Agreements (PPA)

Under a Power Purchase Agreement (or, PPA), the customer agrees to buy all or a portion of the electricity generated by the microgrid for a specified term. Under the PPA model, a third-party developer either owns or leases (from its investors) the microgrid and is responsible for operating and maintaining it for the duration of the PPA term. In addition to shifting the O&M responsibilities from the customer to a third party, a key advantage of the PPA structure is that the third-party owner is on the hook if the microgrid fails to perform as expected. The typical PPA only requires customers to pay for power if it is actually generated. If the microgrid does not produce power, the customer will pay nothing.

At least initially, the price customers pay for electricity purchased under the terms of the PPA is typically the same or less than the price the customer would otherwise pay the utility for regular service. Over time, however, the PPA price commonly increases by anywhere from 1% to 5% annually over what is typically a 20-year contract term. Because PPAs shift performance risk and maintenance responsibilities from customers to a third party entity, the PPA is a commonly used financing options for distributed generation projects as well as microgrid projects.

Leases

In this third-party-ownership structure, a leasing company owns the microgrid and leases it to the customer (the lessee) over a period of years. During the term of the lease term, the customer is responsible for operating and maintaining the microgrid and is allowed to consume all of the electricity it generates. In exchange for this use of the system, the lessee makes a series of recurring lease payments to the lessor (these payments must be made regardless of how well the microgrid performs). Two types of lease structures are used to finance energy generation projects, namely capital leases and operating leases. The accounting and tax implications are different for each type of lease.

In addition to the two basic types of lease agreements, leasing structures have also been developed for specific customer segments. For example, an Enhanced Use Lease (EUL) is a financing vehicle designed for customers in the public sector. An EUL allows state

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or local government entities like a public hospital to lease underutilized assets like a cogeneration plant to a third-party developer in exchange for cash or in-kind consideration. In the event of an emergency, an EUL agreement temporarily returns control of the asset to the government entity as necessary.

Energy Savings Performance Contracts (ESPC)

An Energy Savings Performance Contract (ESPC) addresses the first-cost barrier to microgrids. The ESPC requires no upfront capital from the customer. The contractor provides the capital needed to implement the project. The contractor only recovers their capital investment if the project generates cost savings. As a result, an ESPC is designed to be cash-flow neutral. In other words, the amount of monthly energy savings is supposed to be at minimum equal to the monthly payment needed to finance the improvements.

Customers are more likely to consider an ESPC if they have capital constraints or limited available cash. In addition, customers that lack in-house technical expertise may prefer to outsource the operations and maintenance of the system to a qualified third-party. Finally, many ESPCs guarantee the projected energy savings. If the savings are less than initially projected, the contractor will reimburse the customer for the difference.

Summary

Decisions about ownership and financing are frequently among the most complex customers must make in the microgrid development process. Making the right decisions is critical to the success of a microgrid project. The due diligence process described in this other eBrief is essential to selecting the optimal microgrid financing vehicle for a specific customer or group of customers. ■

[1] Standard & Poors, *Will Securitization Help Fuel The U.S. Solar Power Industry?* January 23, 2012.

[2] A "ratchet" clause sets peak demand charges based on the highest average peak demand in one demand interval during the past year. Ratchet clauses can affect an entire year of utility bills based on a single 15-minute period of high demand.

Deep Dive on Microgrid Technologies

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.

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.

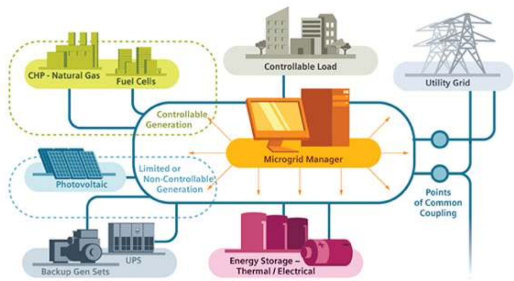
The systems-based approach to the design process allows for selecting the optimal scale and technology type of generation components, for managing cost efficiency by balancing the application of redundancy and hardening, and for defining a weighted set of metrics used to assess the criticality of loads.

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.

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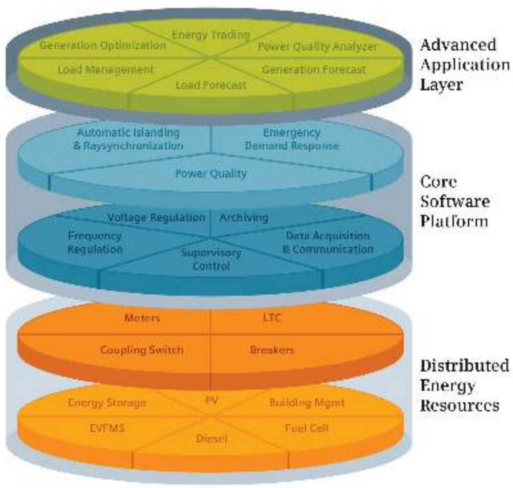
The control solution must be able to interface with local utility systems, including Energy Management



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.

Microgrid operators can choose from a variety of control solutions with varying levels of functionality and design. A major design decision is required between a centralized control solution that offers a management system based on existing utility control solutions or decentralized control solutions with more reliance on distributed field devices. In addition, a decision to invest in advanced functionality should be made based on the microgrid operating plans and economics. Standard microgrid control functionality will include the following:

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

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.

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.

Renewable Energy Technology	Typical module capacity sizes
Small hydro	1–100 MW
Micro hydro	25 kW–1 MW
Wind turbine	200 Watt–3 MW
Photovoltaic arrays	20 Watt–100 kW
Solar thermal, central receiver	1–10 MW
Solar thermal, Lutz system	10–80 MW
Biomass, e.g. based on gasification	100 kW–20 MW
Fuel cells, phosphoric acid*	200 kW–2 MW
Fuel cells, molten carbonate*	250 kW–2 MW
Fuel cells, proton exchange*	1 kW–250 kW
Fuel cells, solid oxide*	250 kW–5 MW
Geothermal	5–100 MW
Ocean energy	100 kW–1 MW
Stirling engine	2–10 kW
Battery storage	500 kW–5 MW

*Fuel cells frequently rely on natural gas, but are considered to be renewable in many states because they do not use combustion to generate electricity.

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 MW's.

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. ■

About Siemens

Siemens is a global powerhouse focusing on the areas of electrification, automation and digitalization. One of the world's largest producers of energy-efficient, resource-saving technologies, Siemens is a leading supplier of systems for power generation and transmission as well as medical diagnosis. In infrastructure and industry solutions the company plays a pioneering role. As of September 2014, we had 343,000 employees in more than 200 countries. In fiscal 2014, they generated revenues of €71.9 billion from continuing operations. Siemens USA reported revenue of $ 22.2 billion, including $ 5.2 billion in exports, and employs approximately 46,000 people throughout all 50 states and Puerto Rico.

Siemens' Energy Management Division is one of the leading global suppliers of products, systems, solutions, and services for the economical, reliable, and intelligent transmission and distribution of electrical power. As the trusted partner for the development and extension of an efficient and reliable power infrastructure, the Energy Management Division provides utility companies and industries with the portfolio that meets their needs. This includes facilities and systems for microgrids and the distribution power grid level, smart grid and energy automation solutions, power supply for industrial plants, and high-voltage transmission systems.

The Division develops innovative solutions which cope with the new challenges our energy systems worldwide are facing. This includes a growing range such as the efficient transmission of bulk volumes of green power over long distances, enabling dedicated power exchange between power grids, and connecting renewable energy to main grids.

A leading portfolio of products and solutions are available to develop intelligent energy networks for forward-thinking utilities, municipalities, military bases, large industry, cities, and commercial customers. Siemens' Microgrid capabilities include financing, technical infrastructure consulting, advanced grid technology, generation assets, operation and maintenance, and more.

Siemens' Microgrid strength lies with their suite of Microgrid control solutions. From basic to advanced functionality, Siemens Microgrid control solutions provide the power of proven utility SCADA platforms with the innovation of advanced optimization and forecasting. The suite enables a multitude of customized solutions for smarter infrastructure grids and introduces opportunities to further stabilize systems, develop new business models and optimize energy trade.

For more information visit www.usa.siemens.com/microgrid