The business case for microgrids

White paper:

The new face of energy modernization

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SIEMENS

1. Executive summary

The utility industry is in the midst of grid modernization efforts that ramped up in large part following the Northeast Blackout of 2003. The massive blackout, a wake up call to utilities and consumers alike, compounded the concerns about climate change, the burgeoning population and scarcity of natural resources. The blackout spurred the industry to aggressively pursue a more intelligent power grid.

At the same time, energy consumers became more concerned about their local power quality and efficiency of the system. Local brownouts are a nuisance and have driven consumers to take greater responsibility for their electricity supply – particularly industries and communities with a critical need for reliable power. Investments in energy efficiency, renewable generation and power monitoring and control systems increased, often resulting in a diverse and disparate array of installed technologies.

The Siemens vision is to integrate these technologies into automated microgrids that connect seamlessly with the main grid, and may be grid independent when needed. The result is a solution that enhances reliability, efficiency, security, quality and sustainability for energy consumers and producers alike.

Microgrid value proposition

- Efficiency: Lower energy intensity and distribution system loss
- Reliability: Near 100 percent uptime for critical loads
- Security: Enable cyber security and physical security
- Quality: Stable power to meet exacting consumer energy requirements
- Sustainability: Expand generation to renewables and cleaner fuel sources

This paper summarizes the vision, benefits, strategy, and business considerations of microgrid solutions.

2. Microgrids defined

A microgrid is a discrete energy system consisting of distributed energy sources (e.g. renewables, conventional, storage) and loads capable of operating in parallel with, or independently from, the main grid. The primary purpose is to ensure reliable, affordable energy security for commercial, industrial and federal government consumers. Benefits that extend to utilities and the community at large include lower greenhouse gas (GHG) emissions and lower stress on the transmission and distribution system.

The core of a microgrid will be one or more small (under 50 MW) conventional generation assets (e.g. engines or turbines) fueled by natural gas, biomass or landfill methane. When connected to the main grid, microgrids will rely on a mix of power generation sources depending on the metric to be optimized (cost, GHG, reliability). Specialized hardware and software systems control the integration and management of the microgrid's components and the connection to the utility. (Figure 1)

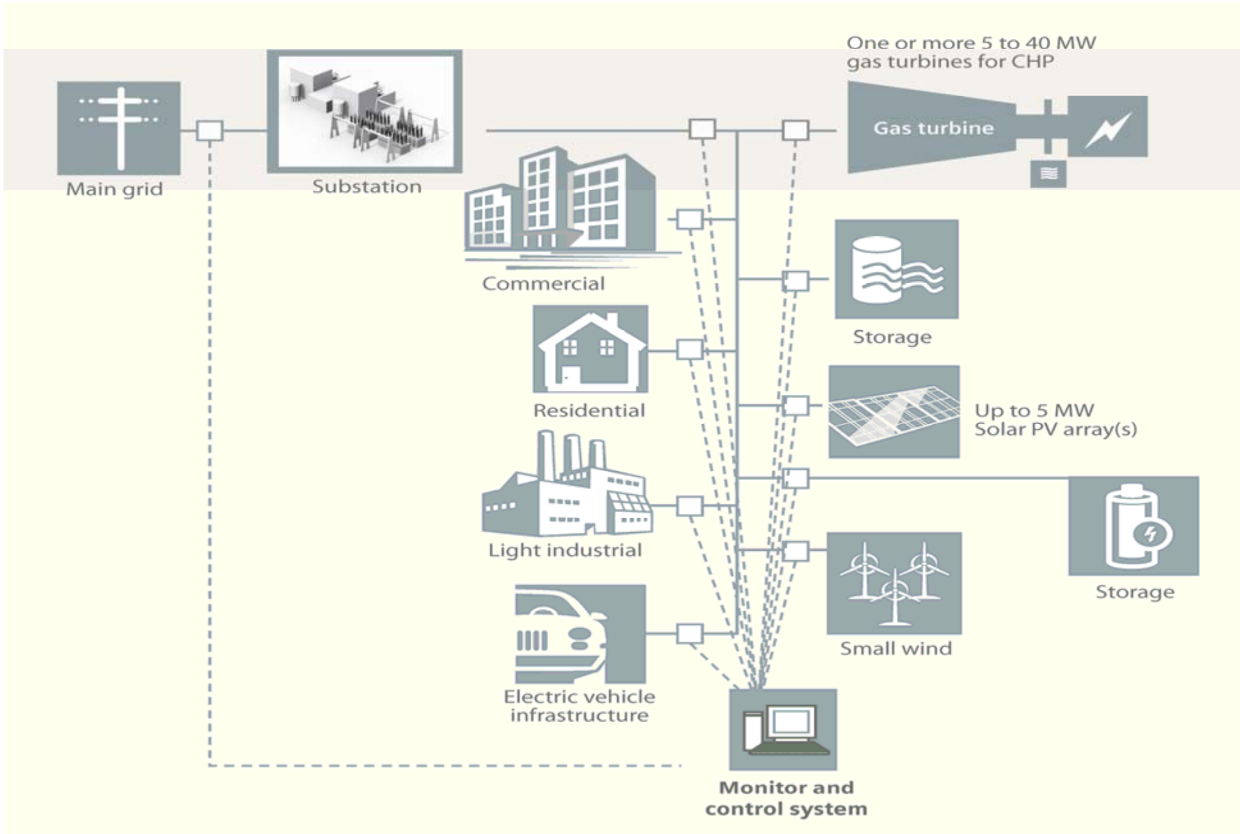

Figure 1: Physical view: the individual elements will vary, but in most cases a turbine will be the central component of a microgrid.

3. The microgrid vision

A microgrid includes generation, a distribution system, consumption and storage, and manages them with advanced monitoring, control and automation systems. The critical first step of pursuing a microgrid solution is a permanent reduction in consumption (electricity, water and gas). This will give the consumer near-term cost savings driven by measured and verifiable conservation measures.

A fully-developed microgrid has the capability of automatically disconnecting and operating independently from the main grid. For example, if a storm disrupts energy service from the main grid, automated controls will reduce non-critical loads (selected lighting, HVAC systems, etc.) and the microgrid will distribute power from on-site generation and storage for an extended period of time. When the main grid is back online, the microgrid will automatically reconnect, recharge energy storage, and ramp down on-site generation as appropriate. Microgrids will have approximately 20-25 percent of their on-site power generation be from renewable technologies integrated with thermal energy storage and electric battery storage if cost competitive.

4. Market drivers

The key factors influencing the emergence of microgrid solutions are the vulnerability of energy infrastructure to cyber threats, growing energy demand, the need for reliable and secure power, and external incentives.

Cyber security

As the reliance on modern communication technology increases (wireless, cloud computing, etc.), power systems are vulnerable to cyber attacks and hackers (e.g. online advocacy groups like Anonymous). In some specific customer segments, such as the military and research labs, there is significant value in a secure network.

Growing demand

The population is growing rapidly and more electricity is being used per person, increasing congestion and stress on the physical grid and on the utilities tasked with managing it. In addition, the locations of demand growth are unbalanced, which poses a challenge to maintaining the reliability of the system.

Reliable and secure power

Certain commercial and industrial environments have a critical need for a constant power supply and cannot afford brownouts or blackouts – research labs, data centers, semiconductor manufacturing and infrastructure deemed critical to national security. For example, research labs conducting trials may require a certain temperature and air quality to have the results compliant with the FDA; climatologists in San Diego studying one-of-a-kind ice cores from the Arctic will lose ancient history if the cores melt; and data centers that process millions of financial transactions daily require constant power to ensure the flow of capital.

Incentives

Government incentives for energy efficiency, renewable power generation and electric vehicle infrastructure all stimulate investment in advanced energy infrastructure.

5. Benefits to energy consumers

Reliability

Energy consumers have very high expectations for reliable, high quality electricity but they don't expect to pay a lot. They need the lights to stay on, production lines to keep running and energy costs to be low. Increasing the amount of on-site energy (generation and/or storage) with a microgrid solution reduces the risk of a catastrophic power loss and may lower costs.

Efficiency

Lowering consumption is the fastest way to impact energy costs. A first step is creating transparency throughout the system with advanced metering to drive savings – "what gets measured gets managed." Implementing other technologies, such as energy efficient lighting, variable frequency drives (VFDs) on motors and chiller/boiler upgrades, will further improve energy efficiency. Increasing the amount of on-site generation has the added advantage of minimizing transmission and distribution line losses – as much as seven percent of electricity generated (EIA estimate, 2008).

Security of supply

Energy supply is vulnerable to acts of terrorism, natural disasters and other risks. Increasing the amount of on-site generation in conjunction with appropriate physical and cyber security measures is a risk mitigation strategy.

Sustainability

A growing number of organizations place a higher value on renewable energy generation and are committing to long-term targets, regardless of the expected time to recoup the investment. For example, a university may want to serve as a "living laboratory" for environmental engineering and technology developed by its students and researchers, or a manufacturer may want to increase its Dow Jones Sustainability Index score by reducing GHG in their production processes.

6. Evolution of energy modernization

Implementing a microgrid solution will involve four phases: demand reduction, on-site generation and storage, advanced controls and automatic grid independence (Figure 2). Each phase is not completely distinct, nor must they be implemented in sequence – there are areas of overlap. Generally, a customer that follows this path will have the lowest lifecycle cost. More mature and economic technologies will be implemented first, and newer technologies, which may not yet have very favorable cost/benefit ratios, will be implemented later.

Demand reduction

Reducing an installation's electricity, natural gas and water consumption requires a change in customer behavior combined with the implementation of conservation measures. Some examples of widely commercialized solutions include programmable thermostats, occupancy sensors, efficient lighting, building envelope improvements, chiller and boiler upgrades/retrofits, VFDs for HVAC units, building management systems and advanced metering. The cost savings that result from conservation measures can be leveraged to fund advanced on-site generation and storage solutions. While electricity conservation is the primary focus of this phase, water conservation will improve project payback.

On-site generation and storage

Implementation and integration of on-site generation (renewable and conventional) and storage solutions is the next level of microgrid development. The goal is to deploy power generation that is cleaner (lower GHG) and more efficient for the end user than what is generated by the main grid. Renewable, on-site electricity generation options include solar photovoltaics and small wind turbines. Given the relatively low cost of natural gas and efficiency of modern combined heat and power (CHP) solutions, end users can deploy small gas turbines (under 50 MW) to provide an economically viable generation capability. To lower the total carbon footprint, locally produced biomass or methane from landfills can be used as fuel for the turbines instead of natural gas. Storage of energy, whether thermal or electric, may be high- or low-tech. Batteries, flywheels, compressed air and pumped hydroelectric storage are among the more high-tech (and higher cost) options. Relatively low-tech storage solutions include chilled water or ice storage. Electric vehicles offer another alternative for energy storage. Although experts are split on the feasibility and business case of using electric vehicles as storage, what is universally accepted is the attraction of recharging vehicles at night – when the demand for electricity and the cost of electricity is lowest.

Advanced controls

Control systems such as distribution supervisory control and data acquisition (SCADA), building management and demand response are all parts of an intelligent microgrid network. As the percentage of on-site renewable generation approaches around 20 percent of the total power supply, the control and optimization of the power system becomes a significant challenge. Centralized transparency into all devices, from the power generation assets to the devices that consume electricity, enables proactive management of the power system. With automated monitoring and controls, power system supply and demand can be optimized and balanced in real time and faults can be quickly detected, isolated and repaired. Advanced controls allow systems to operate based on performance metrics such as economics, carbon footprint or reliability. Advanced demand response systems enable automatic peak load shedding and participation in the energy markets (where allowed by local regulations) – a key revenue generating opportunity. In addition, storage assets can be automatically deployed to sustain mission critical loads. The key challenge is the integration of the disparate systems to optimize the total system.

Grid independence

A fully evolved microgrid is the culmination of the previous three phases and the ability to operate independently from the main grid for an extended period of time. Automated controls know when, how and why to be grid independent, or connected to the main grid. Grid independence can be accomplished in two ways. First, if the microgrid has internal combustion engines with reactive power compensation within the system to provide voltage and frequency regulation, the power system can connect or disconnect via relays, switches and breakers – this is the more developed method and commercially available today. Alternatively, the microgrid generation and storage assets can connect to the main grid via a series of inverters, allowing for more advanced control of power in both directions between the main grid and the microgrid.

Reduce demand

- Building management system
- Lighting retrofits
- HVAC upgrades
- Building envelope improvements
- Usage transparency (advanced metering)

On-site generation and storage

- Gas turbines <50 MW
- Diesel generators
- Integration of storage
  - Thermal
  - Electric
- Integration of renewables
  - Solar PV
  - Small wind
- Electric vehicle infrastructure

Advanced controls

- Demand response programs
- Balance system supply and demand
- Optimization of power system based on performance metrics (economics, carbon footprint, reliability, etc.)

Grid independence

- Automatic connect and disconnect from main grid to meet specific performance outcomes (economics, carbon footprint, reliability, etc.)

Figure 2: The microgrid technology evolution ranges from strategic energy efficiency measures to full grid independence.

7. What drives a consumer to consider a microgrid solution?

Microgrids are not for every type of end user. The investment can be significant. The simple payback will likely be more than 15 years, but for certain organizations it is well worth the cost.

Reliable and secure power system

Hospitals, universities, refineries, pharmaceutical manufacturing, data centers and the military are dependant on having a continuous, uninterrupted supply of power. Today, these organizations maintain on-site generators (mostly diesel) for emergencies because even a modest loss of power can have negative consequences. The automated controls in a microgrid will better balance the demand in the system with a supply of energy from backup generation, the main grid and local storage assets.

Physical and cyber security

Some federal installations, particularly the military and security agencies, place a high value on physical and electronic security. Hacking sponsored by governments or online activists (e.g. Anonymous) adds an additional degree of risk and the need for an advanced, secure power system solution.

Planned transformation

Organizations in growth or transformation mode are ideal candidates for a microgrid solution. Expanding a university, building a new factory or the military's base realignment and closure process (BRAC), which consolidates personnel onto fewer, expanded bases, are good candidates for microgrid solutions. In each case, there will be a significant increase in baseline energy consumption. Similarly, a planned replacement of on-site power generation is a perfect time to consider future power system needs and conduct a lifecycle cost assessment to determine the best path forward.

Regional drivers

Government regulations and incentives that affect the microgrid business case are at the local, state, regional and federal level.

- Local: The Database of State Incentives for Renewables & Efficiency (www.dsireusa.org) provides an expansive and dynamic list of local, state, utility and federal incentives and policies that support green energy initiatives.

- State: Certain states have established renewable energy targets or Renewable Portfolio Standards (RPS) for power producers, making some degree of renewable or alternative fuel adoption mandatory.

- Regional: Independent system operators (ISOs) and regional transmission organizations (RTOs) vary on whether and how energy consumers may participate in energy markets. When consumers are allowed to participate, it opens up a new revenue stream for consumers who can sell electricity back to the main grid.

- Federal: Compliance with current and future EPA regulations is a significant opportunity for cost avoidance. Diesel generators must be permitted and are limited in their run time due to pollution concerns – a point in favor of integrating a higher portion of renewables and/or natural gas turbines. The New Markets Tax Credit, which is relevant when an efficient generation source is installed in a low income or disadvantaged location, can reduce the out-of-pocket costs for the project. In the future, depending on the political climate, a national carbon market is possible, which will be a revenue opportunity for those organizations that can verify their carbon reduction.

Altruism

Organizations with a strong commitment to green energy and a vision of a sustainable future are likely to invest in renewable power generation and microgrid solutions. These groups may harbor concerns that the main grid faces reliability risks or are concerned about the environmental impact of fossil fuel generation. They will choose to reduce their own consumption and dependence on the main grid at almost any cost.

Microgrid candidates

- Continuous power requirement
- Security requirements
- Planned transformation
- Regional drivers
- Altruistic consumers

8. Microgrid investment vs. payback

One of the biggest hurdles to the adoption of microgrid solutions – the end user return on investment (ROI) – can be managed by tailoring the solution architecture and project implementation schedule to the end user's requirements. Energy and water conservation measures are the quickest way to realize project payback, and they can be combined with simple demand response programs (outsourced to an aggregator or managed internally) to improve ROI. A fully developed microgrid with demand reduction, on-site generation and storage, advanced controls and grid independence capabilities will likely be reserved for large energy consumers with a critical need for reliability and the patience for a longer payback.

For an installation with an average load of 40 MW (roughly the size of Fort Knox, Kentucky), the estimated investment and results are estimated to be:

Investment	
Investment via energy savings [1)]	$110 million (incl. ~$30 million of renewables)
Investment via capital outlay	$40 million (incl. ~$30 million of renewables)
Total investment required [2)]	$150 million
Results [3)]	
Energy savings achieved	15% (~6 MW of permanent load reduction)
Renewable generation deployed	14 MW (cost ~$60 million, see above)
Financing term of energy savings	24 years (assumes a 6% interest rate)
Note: Investment includes advanced controls, cyber security and grid independence capability	
[1)] This investment will be paid back via energy savings	
[2)] Does not include revenue potential from demand response programs	
[3)] Expected water savings are not detailed here, but water conservation measures are included in the total investment required	

The above estimate includes the measurement, verification, operations and maintenance required to ensure the demand reduction measures (electricity and water) are implemented. The estimate does not include the potential revenue benefits of selling electricity back to the utility through demand response programs, state level incentives or carbon trading (if applicable). This revenue potential will vary greatly depending upon the state and region.

Advanced controls, automatic grid connect/disconnect and storage technologies are expected to decline in cost as they are more widely adopted, which will lower the investment numbers shown above.

Example microgrid investment benefits

- Improved energy efficiency of installations
- Integrated renewable power generation
- Supply and demand balancing
- State-of-the-art security solutions for critical infrastructure protection
- Self-sustaining power generation, particularly for critical loads and systems
- Safe, easy-to-operate and modular solutions that may be upgraded as required
- Turnkey solutions from trusted leaders in technology integration

9. Partner approach to implementation and management

Microgrids are not a do-it-yourself project, even for organizations with deep electrical and mechanical engineering expertise. Microgrids have multiple power, operations management and control system components from diverse vendors that must be integrated and optimized for interoperability and security. The right team of software, hardware, systems integration and consulting partners will ease the design and implementation process.

Key areas for partnering

- Microgrid management software
- Hardware for connecting to the main grid
- Power system design and modeling
- Renewable energy project development and financing
- End user change management programs

10. Conclusion

A microgrid is the end state of an energy modernization effort that will take two to five years to implement at an installation (corporate park, military base, university campus, etc.). The benefits will accrue to the end user, utility and the public overall. External research points to strong growth opportunities and the need for this technology; however, the challenge is execution. Like other Smart Grid solutions, microgrids will continue to improve as new technologies are commercialized. Advancements to the hardware that enables automatic grid independence and the systems integration that enables automatic control of the entire power system are some of the innovations currently underway. End users who place a high value on continuous access to reliable, secure power and want a high level of control over their energy supply and demand should look closely at a microgrid solution and its potential to secure energy independence.

11. Author bio

Robert Liam Dohn is a project manager responsible for developing the microgrid business within Siemens. Prior to joining Siemens in 2008, Liam was a Captain in the United States Marine Corps and worked at GE in the lighting and low voltage electrical distribution businesses. He studied finance at the University of Virginia and has an MBA from London Business School.