

Microgrids Are For Real

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In the past few years, Microgrid developments have grabbed the attention of various utilities and industries as a key part of system hardening and Smart Grid implementation. This is to enhance the reliability of the electric grid, as well as the power quality – particularly for the purpose of providing backup power supply during system restoration as a result of blackouts or natural disasters. Given that, the discussion around microgrids does not seem to be solely a research and/or academic ambition anymore; rather recently, several industrial assemblages and utility-oriented events are widely organized around the specific topic of microgrids.



Two of such recent events include the Microgrid World Forum, held in March 2013 in Irvine, California [1], and the second Microgrids Summit, held in late April 2013 in Arlington, Virginia [2]. Additionally, without exception, all major North American and/or international power and energy conferences and symposiums (e.g., IEEE PES general meeting, IEEE T&D Conference, CIGRÉ, Distributech and Smart Grid Roadshows) have a number of panels and multiple paper presentations as an essential part of their agenda on the subject of Microgrid. To further emphasize, it is worth noticing the significant governmental funding and the support of several pilot projects in the last two years. Over \$600 million dollars is assigned by the U.S. Department of Energy (DOE) and the Department of Defense (DOD) in support of some 30 microgrid demonstration projects.

Figure 1 shows the relative locations of the present microgrid demonstration projects in the United States.

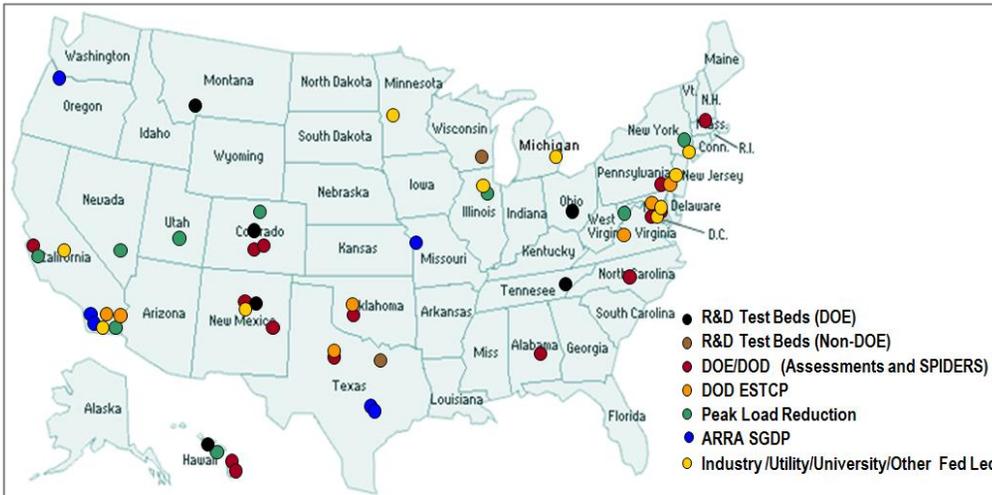
The major drivers for microgrid developments are:

- The debates on improving the resiliency and reliability of the interconnected electric systems in the aftermath of recent blackouts and devastating natural disasters (storms and tsunamis) from one end.
- A paradigm shift toward customer-owned distributed generation for active participation of end users in the development, enhancement and utilization of the energy delivery infrastructure from the other.

To name an existing precedent, Sendai Microgrid, one of the early pilot projects conducted by NEDO in Japan, survived the 2011 earthquake and managed to supply power to its customers (hospital, water treatment plan, nursing house and control center) during grid restoration [4].

For many utilities, thus, microgrids have become top choices in order to explore methods of improving power quality, as well as to provide power to customers during system restoration and maintenance periods. Based on the observations by the DG owners and also local users who have experienced major blackouts, many have raised concerns or questioned the inability of the existing and increasing amount of distributed energy resources (in the form of residential/ commercial Photovoltaic (PV) and wind generation systems) in serving the areas under outage and supplying power to local businesses. Aside from regulatory changes that are required to allow microgrid operations in the utility environment, several other technical challenges need to be investigated.

Figure 1 – Microgrid landscape in U.S. – Federal programs, institutions and the private sectors [3]



What is a Microgrid?

When it comes to the definition of microgrids, proposed definitions and/or terminology descriptions in the technical literature or public domain seem to be noncompliant. Some would even argue that a microgrid is nothing new and is just another buzz word. To position the

microgrids more clearly, at least for the purpose of this article, it is important to understand that an on-site, genset-based power generation system, and/or what is commonly known as an uninterruptable power supply (UPS), may not be qualified as a microgrid. Those systems could provide an alternative solution to the similar power outage issues mentioned earlier; yet, their applications are limited to the single purpose of local load supply that is just one of the many features of microgrids. The concept of microgrid extends beyond the electricity requirements and can consider heat and thermal energy needs of the users, as well.



Figure 2 - Left: Sendai Microgrid Energy Center (photo courtesy of H. Keiichi, NTT Facility) - Right: Sendai Microgrid during the 2011 disaster (photo courtesy of A. Kwasinski, U. of Texas at Austin)

According to the definition proposed by the U.S. DOE [3], A microgrid is an integrated system that includes multiple distributed generation units (alternative and renewable sources) serving clusters of loads and consumers. In other words, the key distinguishing characteristic of microgrids from other systems is the integration of renewable energy resources and loads through advanced controls (local and supervisory) to present the microgrid as a single, dispatchable entity to the rest of the grid. The microgrid is able to operate with the presence of the main grid (grid-connected operation) and/or in the absence of it (stand-alone operation).

The power management and energy exchange in a microgrid is performed among multiple energy providers and users in a coordinated and autonomous fashion. In essence, involvement of multiple generation sources, including the main utility grid and the distributed resources as well as the need for supplying power to customers with different levels of power quality and reliability expectations, are the major challenges in the design and operation of a microgrid.

Microgrid Architecture

Based on the applications and end users, microgrids are widely developed by utilities and private sectors (industries) or proposed for military purposes. Campus and community-based microgrids; however, have been the most attractive and cost-effective

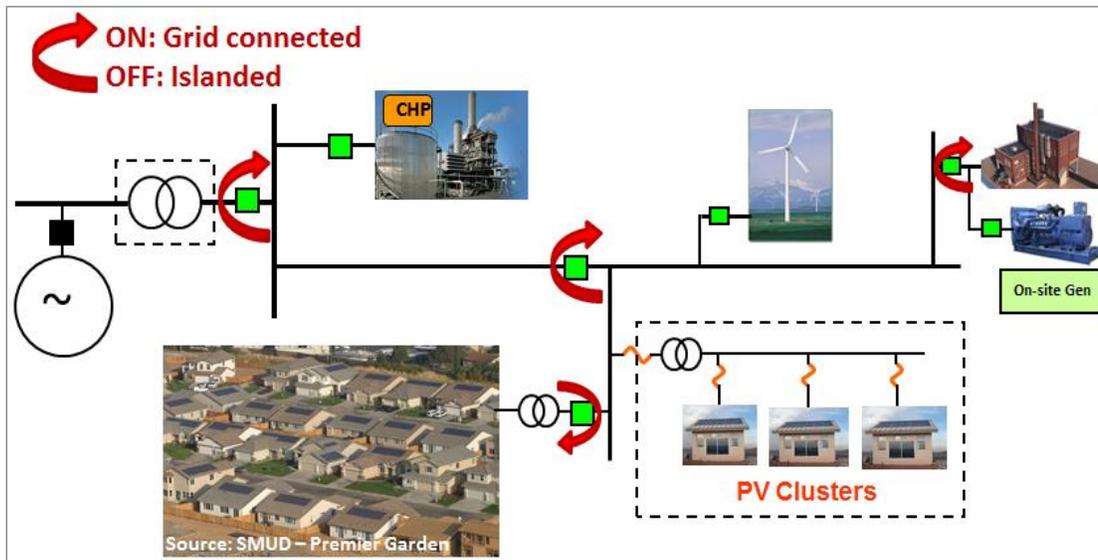


Figure 3 - Microgrid: An integrated system consisting of clusters of Load and Generation

applications built upon co-location of multiple facilities, while sharing a common energy infrastructure.

Yet, recent advancements in Smart Grid technologies and deployment have gathered much interest in several other types of microgrids, as shown in Figure 4, including:

- Utility Microgrid – An implementation owned and operated by the local utility incorporating part of a distribution feeder or an entire substation. The utility microgrid is used to locally manage load growth and integration of renewable generation, while providing ancillary services such as reactive power management, demand response and premium power quality for the utility benefit and meeting customer needs.
- Multi-facility (campus) Microgrid – An energy infrastructure comprising several commercial buildings and/or public facilities. A multi-facility microgrid may have a single or multiple Points of Interconnection (POIs) with the main utility grid. A well-known example is a microgrid built around a university campus or a military compound.
- Single-facility (residential/commercial) Microgrid – An individually owned and operated system to meet specific customer requirements. It may serve a residential application or small retail and commercial purposes. At commercial end, data centers and cellular communication providers have been implementing microgrids to secure cost-effective and high-quality power supply at reliability and security levels required for these systems.
- Remote Microgrid (mini-grid) – A system for electrification of isolated communities and non-integrated areas on geographic islands or hardly accessible regions. The microgrid architecture facilitates contribution of renewable resources to reduce fossil fuel consumption and development of a sustainable environment.

Key Technologies & Functions

Microgrid design and development is a multi-disciplinary area involving several emerging, advanced technologies consisting of:

- Advanced controls and protection systems – for real-time control and operation
- Precision sensors and high-resolution measurement devices – for real-time monitoring and health status update
- Resource forecasting and scheduling schemes – for system optimization and reliability enhancement
- Communication infrastructure – for automation, remote control and monitoring
- Next generation power electronics – as the interface media for distributed generation and energy storage apparatus, as well as power-conditioning systems (such as static switches, reactive power compensators, and active harmonic filters)

A microgrid has several modes of operation including: grid connected mode, islanding transition, stand-alone operation, re-synchronization and transition to the main grid after restoration. Each mode requires unique functionalities and an operation strategy. The control and protection methodologies are conceptually different for the two situations of the grid-connected and islanded operation.

In the grid-connected mode, the primary control objective is to optimize operation in terms of increasing the renewable generation contribution, reducing losses and improving voltage/reactive power profile in an effort to maximize power delivery to the grid. The voltage and frequency is dictated by the grid.

On the contrary, the islanding and stand-alone operation mode requires precise voltage and frequency control and fast-acting power sharing among the resources to maintain stability of the microgrid. After the disconnection from the grid, the short-circuit capacity of the islanded area is drastically reduced, which challenges the protection design.

Also, due to the incapability of the grid to supply reserve capacity requirements, energy storage unit and strategic demand response methods are applied to ensure the close balance between generation and load.

In addition to autonomous control strategies applied through individual resource controllers, typically, an overall supervisory controller or a Microgrid Master Controller (MMC) is required to coordinate the operation of multiple generation sources and to ensure power balancing and energy management. MMC would also play the role of the interface and data exchange with the utility and system operators for participation in the energy market and coordination of the operation with the rest of the grid. Resource forecasting to properly determine expected power from the intermittent resources (PV and wind generation), as well as monitoring the operational states of various components of the microgrid, are other functions of the MMC.

Experience & Service Offering for Microgrids

Quanta Technology experts are in the forefront of the microgrid development and technology advancement. Our practical experience and deep understanding of various microgrid applications come from involvement in the design, technology selection, field deployment and operational analysis of several utility and government sponsored projects. Quanta Technology experts have helped utilities and manufacturers develop functional specifications and define control requirements that led to enhancement of the existing products and facilitating planning and road mapping of the next generations of innovations.

Developing a robust design and reliable architecture that can survive harsh environment is our key value added offering. We support project development from the early stage of the design with extensive simulation analysis and transition to the laboratory testing of the prototypes and final products, as well as assistance during field deployment and performance evaluation. Quanta Technology has recently developed an autonomous controller and remote monitoring scheme for a microgrid application in collaboration with a utility in the western United States. The system is laboratory tested and is ready for deployment in the field.

References for further reading:

[1] Microgrid World Forum website: <http://www.microgridworldforum.com>

[2] The 2nd Microgrid Summit website: <http://www.infocastinc.com/events/microgrids13>

[3] M. Smith, "Overview of Microgrid research and development – US department of energy", Microgrid international symposium, Sept. 2012, Portugal.

[4] H. Irie, "Sendai microgrid – introduction and use case", July 2012, http://e2rg.com/microgrid-2012/Sendai_Irie.pdf

[5] International Microgrid Symposium website: <http://der.lbl.gov>

For more information regarding Quanta Technology's Microgrid capabilities, please visit our website www.quanta-technology.com or contact Farid Katiraei at fkatiraei@quanta-technology.com.

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