Metric #6: Load Served by MicroGrids

M.6.1.0 Introduction and Background

Microgrids may change the landscape of electricity production and transmission in the United States due to the changing technological, regulatory, economic, and environmental incentives. The changing incentives could allow the "modern grid" to evolve into a system where centralized generating facilities are supplemented with smaller, more distributed production using smaller generating systems, such as small-scale combined heat and power (CHP); small-scale renewable energy sources (RES) and other distributed energy resources (DERs). The development of new technologies in power electronics, control, and communications,[1] along with the combined values of heat and electricity through cogeneration, added reliability, security, and stability may offset the lower costs of centralized generation.[2]

A microgrid is an integrated distribution system with interconnected loads and distributed energy sources and storage devices, which could be as small as a city block or as large as a small city, and which operates connected to the main power grid, but is capable of operating as an island.[3,4] Key distinctions between a microgrid and distributed generation are its ability to be islanded with coordinated control, and that it contains more than one generating source.

In "Grid 2030," the Department of Energy sees microgrids as one of three cornerstones of the future grid.[5] Microgrids are seen as local power resources that are connected to the regional grid to provide distributed energy resources while managing local energy supply and demand.[6]

Microgrids will add three features to the electric system: efficiency (by combining heat and power); matching of security, quality, reliability, and availability with the end-users needs; appearing to the electric system as a controlled entity.[7] Microgrids using combined heat and power (CHP) can capture as much as 85 percent of the energy used in generating electricity by also powering heating and cooling

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[1]Lasseter R, A Akhil, C Marnay, J Stephens, JE Dagle, RT Guttromson, AS Meliopoulos, R Yinger and J Eto. 2002. *Integration of Distributed Energy Resources: The CERTS MicroGrid Concept* LBNL-50829. Lawrence Berkeley National Laboratory, Berkeley, California. Accessed November 13, 2008 at http://www.osti.gov/bridge/servlets/purl/799644-dfXsZi/native/799644.PDF

[2]Agrawal, P, M Rawson, S Blazewicz, and F Small. 2006. "How 'Microgrids' are Poised To Alter The Power Delivery Landscape." *Utility Automation & Engineering T&D*, August, 2006, Accessed November 4, 2008 at http://uaelp.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=260536&VERSION_NUM=2&p=22&pc=ENL

[3]Lasseter et al. 2002.

[4]Rahman, S. 2008. *A Framework for a Resilient and Environment-Friendly Microgrid With Demand-Side Participation*. Advanced Research Institute, Virginia Polytechnic Institute and State University, Arlington, Virginia. Accessed November 4, 2008 at http://www.ieee.org/organizations/pes/meetings/gm2008/slides/pesgm2008p-000334.pdf.

[5]DOE—U.S. Department of Energy. July 2003. *"Grid 2030: A National Vision for Electricity's Second 100 Years". Office of Electric Transmission and Distribution*. Accessed November 4, 2008 at http://www.oe.energy.gov/DocumentsandMedia/Electric_Vision_Document.pdf.

[6]Ye, Z, R Walling, N Miller, P Du, and K Nelson. 2005. *Facility Microgrids*. National Renewable Energy Laboratory, NREL/SR-560-38019. Accessed November 4, 2008 at http://www.nrel.gov/docs/fy05osti/38019.pdf.

[7]Marnay C, and R Firestone. 2007. "*Microgrids: An Emerging Paradigm for Meeting Building Electricity and Heat Requirements Efficiently and with Appropriate Energy Quality*. Lawrence Berkeley National Laboratory, LBNL-62572. Presented at the European Council for an Energy Efficient Economy 2007 Summer Study, La Colle sur Loup, France. Accessed November 4, 2008 at http://eetd.lbl.gov/EA/EMP/reports/62572.pdf.

systems. In comparison, central grid generation may lose up to 60 percent of the energy because of losses in transmission and venting heat into the atmosphere. In addition, microgrids can supplement power to the electric system by injecting power into the central grid during peak periods.[8] Microgrids can also achieve 99.999% reliability compared with 99.9% reliability for the centralized grid.[9]

A three-phase implementation path was recommended to the Department of Energy for the development of microgrids in 2005. During the first phase, pilot cases will examine the ability of microgrids to reduce costs of power and develop technologies to automatically connect/disconnect the microgrid from the central grid. Phase II pilot cases are expected to examine the security and resiliency of microgrids with higher penetration rates, and Phase III will examine a microgrid's ability to export power to central grid. Each phase will also address regulatory challenges. Phase I will seek to enhance retail competition while providing fair compensation to utilities for investment and services provided. Phase II will focus on cost recovery of security investments, while Phase III will emphasize transparency of costs to end-users, including real-time and environmental benefits.[10,11] The CERTS microgrid, a joint demonstration project funded by DOE and the California Energy Commission (CEC) is used to provide research and development experience on technical, business and regulatory issues associated with microgrids.[12]

There are few commercial examples currently operating as the commercial microgrid is in its infancy. Rahman[13] provides two microgrid examples. He describes a Wal-Mart store that has six 60 kW microturbines that provide cooling, heat and electricity. The system has an overall efficiency of 80 percent. In the second example, 4 Times Square in New York City has two 200 kW fuel cells, 15 kW of integrated PV panels and natural-gas powered absorption chillers/heaters that provide heat, cooling and electricity. Another example is the Mad River Park Microgrid (MRPM).[14] The MRPM connects five commercial and industrial facilities and up to 12 residences to multiple generation and storage devices. Yeager[15] discusses the microgrid installed at the Illinois Institute of Technology but gives no capacity values. There are many examples of microgrids at university, petrochemical, and Department of Defense (DoD) sites.[16]

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[8]PSPN—Penn State Policy Notes. 2008. *Reducing Demand, Promoting Efficiency Key to Defusing Electric Rate Increases.* Center for Public Policy Research in Environment, Energy and Community Well-Being. Accessed November 4, 2008 at http://www.ssri.psu.edu/policy/GeneralPolicyBrief_0415.pdf

[9]NC—Navigant Consulting, October 2005. *Microgrids Research Assessment Phase 2*. Accessed November 4, 2008 at http://der.lbl.gov/2006microgrids_files/Navigant%20Microgrids%20Final%20Report.pdf

[10]Agrawal et al 2006.

[11]Navigant Consulting 2005.

[12]DOE—U.S. Department of Energy. ca. 2006. *"Advanced Distribution Technologies & Operating Concepts: Microgrids." Office of Electricity Delivery and Energy Reliability*. Accessed November 4, 2008 at http://www.electricdistribution.ctc.com/microgrids.htm.

[13]Rahman 2008.

[14]RDC—Resource Dynamics Corporation. 2005. *Characterization of Microgrids in the United States: Final Whitepaper*. Accessed November 4, 2008 at http://www.electricdistribution.ctc.com/pdfs/RDC_Microgrid_Whitepaper_1-7-05.pdf.

[15]Yeager KE. 2007. "Facilitating the Transition to a Smart Electric Grid." Testimony before the House Energy and Commerce Committee. Accessed November 4, 2008, at http://energycommerce.house.gov/cmte_mtgs/110-eaq-hrg.050307.Yeager-Testimony.pdf

[16]RDC 2005.

M.6.2.0 Description of the Metric and Measurable Elements

The following three measures have been identified as important for understanding the number of microgrids and the amount of capacity they serve.

(Metric 6.a) the number of microgrids in operation. Microgrids must meet the definition in Section 1 above.

(Metric 6.b) the capacity of microgrids in MW.

(Metric 6.c) the percentage total grid summer capacity. This metric measures the impact these microgrids are having on the ability of microgrids to meet electricity-supply requirements of the entire grid.

M.6.3.0 Deployment Trends and Projections

Currently, approximately 20 microgrids can be found at universities, petrochemical facilities and U.S. defense facilities. According to RDC[17] the microgrids provided 785 MW of capacity in 2005. They noted additional microgrids that were in planning at the time as well as demonstration microgrids. RDC also noted that by examining the Energy Information Administration's database they could determine approximately 375 potential sites for microgrids if they weren't already microgrids. Outside of the petrochemical microgrids, there are no commercial microgrids in the United States.[18] Given EIA's net summer capacity of 906,155 MW and assuming no devolution of microgrid capacity from 2005, the percentage of capacity met by microgrids is about 0.09% in 2006.

Table M.6.1. Capacity of Microgrids in 2005 (MW)[19]

	University	Petrochemical	DoD
Capacity (MW)	322	455	8

Current projections and forecasts for microgrids are as follows:

- Navigant Consulting, in their base case scenario, projected 550 microgrids installed and producing approximately 5.5 GW by 2020[20] or about 0.5% of projected capacity.[21] Navigant[22] predicts a range of 1-13 GW depending on assumptions about pushes for more central power, requirements and demand for reliability from customers and whether there is an environmental requirement for carbon management.

[17]RDC 2005.
[18]PSPN—Penn State Policy Notes. 2008. "Reducing Demand, Promoting Efficiency Key to Defusing Electric Rate Increases." Center for Public Policy Research in Environment, Energy and Community Well-Being. Accessed November 4, 2008 at http://www.ssri.psu.edu/policy/GeneralPolicyBrief_0415.pdf
[19]RDC 2005.
[20]Navigant Consulting 2005.
[21]DOE—U.S. Department of Energy. June 2008. *Annual Energy Outlook 2008 with Projections to 2030***.** Energy Information Administration, DOE/EIA-0383(2008). Accessed November 4, 2008 at http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html
[22]Navigant Consulting 2005.

M.6.3.1 Associated Stakeholders

There are numerous stakeholders associated with microgrids, but the primary stakeholders (in no particular order) include:

- End users, including distributed-generation owners and customers, who need reliable, high quality power. Offsetting costs by selling excess power and/or heat has the potential to make programs more economical and attractive.
- Distribution-service providers who, depending on their size, location, and ability to integrate microgrid power production, as well as utilities and municipalities, could significantly benefit from integration of microgrid resources into their overall resource portfolio.
- Electric-service retailers
- Products and services suppliers of generation, control, and communications equipment that enable microgrid operation
- Policymakers
- Policy advocates, particularly environmental-policy advocates.

M.6.3.2 Regional Influences

Regional influences should not create many obstacles for this microgrid development. Potential regional influences are driven more by how stakeholders in different regions of the country will interface or integrate with one another, and how regional or state regulators in the utility and environmental areas will either support or hinder distributed-energy resource development. (See Metric 3 for differences in acceptance of interconnection standards.)

Microgrids can be favorable in remote places such as in Alaska and Hawaii, where significant periods of islanded operation can be expected. Microgrids with CHP may be of greater value in colder climates (northern states) or regions where heating and cooling requirements are significant.

M.6.4.0 Challenges to Deployment

Unfortunately, several barriers have been identified that may stifle the deployment of microgrid systems in the United States. As in other industries, regulatory barriers and their economic impacts are more significant challenges to deployment than the technical challenges. While there are several regulatory barriers, the business and financial challenges listed below are those with highest impact.

M.6.4.1 Technical Challenges

While the business and financial challenges are more significant, there are technical challenges to moving microgrid deployments forward. The primary challenges include:

- Interconnection—interconnection requirements must be resolved through standards such as IEEE 1547.4; otherwise seamless transitions will not occur.[23] Completion of the IEEE 1547.4 standard for

[23]Navigant Consulting 2005.

microgrid requirements is also needed.[24]

- Large-scale microgrids— as the interconnection points increase, large microgrids with multiple points of integration become more complicated to coordinate and protect.[25]
- Penetration level—the level of penetration could become an issue if the load served by microgrids becomes large enough that they are serving more than their own demand, and system events such as lightning strikes or other system failures cause the microgrid to respond by disconnecting from the regional grid leaving other dependent entities without power.[26]
- Security—some concern exists regarding the level of security, both physical and cyber, required for microgrids to be a reliable resource.[27]
- Power generation types—for alternative-energy resources such as renewable energy, fuel cells and microturbines, the lack of experience with system design and integration will provide technical challenges.[28,29]
- Power quality—power quality may be impacted by current IEEE 1547 standards, as microgrids may be forced off the grid when stability events occur. Power quality in the microgrid is a function of its size, impedance, and load level.[30]
- Intentional islanding—the transition between regional grid-parallel and isolated operation can leave microgrids without power for periods from seconds up to minutes. The impact on loads within the microgrid due to transient effects or disruption isn't acceptable. A more instantaneous transition is required.[31]

M.6.4.2 Business and Financial Challenges

The most significant business and financial challenge is making the business case for microgrids. A part of the business case includes ensuring that microgrids are not made infeasible by standby charges, interconnection policies that discourage or prohibit microgrids, and the loss of revenues faced by utilities as microgrids are deployed. But, the business case must also be effectively shown for the value of combined heat and electricity generation, added security, reliability, and power quality in order for investment to take place.[32] Significant challenges to the business case include:

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[24]IEEE. 2008. *1547 Series of Standards*. Institute of Electrical and Electronic Engineers. Accessed November 4, 2008 at http://grouper.ieee.org/groups/scc21/dr_shared/. (Last updated 12/21/2007).
[25]Ye, Z, R Walling, N Miller, P Du, and K Nelson. 2005. *Facility Microgrids*. National Renewable Energy Laboratory, NREL/SR-560-38019. Accessed November 4, 2008 at http://www.nrel.gov/docs/fy05osti/38019.pdf.
[26]Ye 2005.
[27]NETL—National Energy Technology Laboratory. 2007. "Barriers to Achieving the Modern Grid". Department of Energy, Office of Electricity Delivery and Energy Reliability. Accessed November 4, 2008 at http://www.netl.doe.gov/moderngrid/docs/Barriers%20to%20Achieving%20the%20Modern%20Grid_Final_v1_0.pdf
[28]Ye 2005.
[29]Navigant Consulting 2005.
[30]Navgant Consulting 2005.
[31]Ye 2005.
[32]Navigant Consulting 2005.

- Standby charges—charges assessed to end-users on their installed capacity if it isn't used solely for emergency purposes. Utilities use the standby charge to pay for the infrastructure necessary to serve the microgrid's load in the event the microgrid's generating capability becomes unavailable. These charges for rarely-used infrastructure are a significant economic barrier to microgrid deployments.[33,34]
- Interconnection—the policies and procedures that describe how power-generating capacity not owned by the utility will be connected and integrated into the power grid. Without national or regional policies and procedures, utilities can develop their own policies and procedures that discourage interconnection of power-generating capacity that they do not own or control.[35] (See Metric 3)
- Lost utility revenues—The way the U.S. utilities are regulated, they exhibit strong economies of scale that make competition from smaller, less-efficient suppliers significantly less economical. In addition, utilities have no financial motivation to look at grid innovations that reduce their sales. Utilities have commonly raised barriers to interconnection and self-generation and also discourage energy-efficiency investments because of the significant likelihood of a loss of revenue and profits.[36]

M.6.5.0 Metric Recommendations

The number and capacity (MW) of microgrids needs to be added as a sub-category of distributed generation where DG can be islanded and controlled to allow for the enumeration and quantification of microgrids.

[33]Hatziargyriou N. 2008. *"Microgrids: the Key to Unlock Distributed Energy Resources?"* Accessed November 4, 2008 at http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04505823.
[34]Venkataramanan G and C Marney. 2008. "A Larger Role for Microgrids," *IEEE Power and Energy Magazine*, pp.78-82. Accessed November 4, 2008 at http://eetd.lbl.gov/EA/EMP/reports/microgrids-larger-role.pdf
[35]Venkataramanan and Marney 2008.
[36]Venkataramanan and Marney 2008.