Energy Surety Microgrid™ Methodology

SAND2011-2190P

Sandia National Laboratories

ENERGY SURETY MICROGRID™ METHODOLOGY

1. DEVELOPER INFORMATION

A. PRIMARY SUBMITTING ORGANIZATION

Sandia National Laboratories

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B. Joint submitters

None

2. PRODUCT INFORMATION

Energy Surety Microgrid™ Methodology

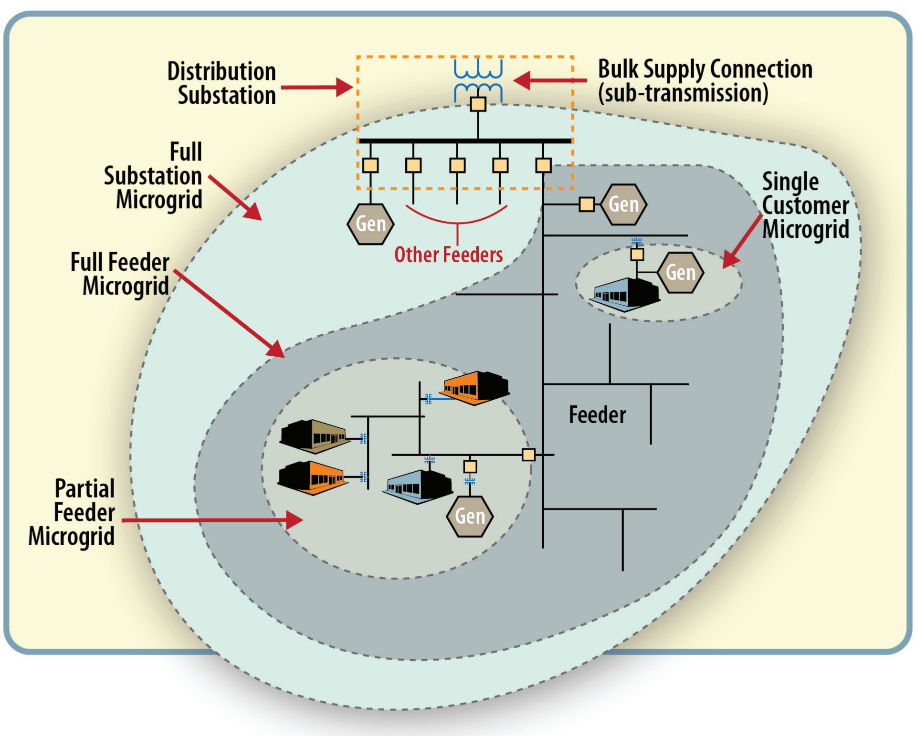

Figure 1: Energy Surety Microgrids can be deployed at many levels (from single customer to full feeder). All will play an important role in the electric grid of the future.

3. DESCRIPTION

Energy Surety Microgrid™ presents a new paradigm in the production of our nation's power—embracing "think globally, act locally," but utilizing an innovative practical approach.

4. PRODUCT FIRST MARKETED OR AVAILABLE FOR ORDER

The Energy Surety Microgrid (ESM) was first licensed on 26 May 2010.

5. Has this product or an earlier version been entered in the R&D 100 awards competition previously?

No

6. Principal Investigator(s)

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7. PRODUCT PRICE

The Sandia ESM methodology employs a comprehensive set of advanced computer modeling and evaluation techniques that produces a safe, secure, sustainable, reliable, and cost-effective microgrid design, tailored to meet specific customer requirements. Therefore, it is not possible to predetermine an exact cost. Licensing is negotiated with each partner on an individual basis.

Sandia's ESM methodology allows for the design and deployment of autonomous large-scale microgrids.

8. PATENTS OR PATENTS PENDING

This process is not patented. The framework and the approach have been trademarked.

9. PRODUCT'S PRIMARY FUNCTION

A microgrid is a localized group of energy sources, storage devices, and users. Small microgrids are already in existence. They normally operate while connected to the larger electric grid. Ideally, a microgrid could be disconnected from the larger grid via a single point of connection, allowing it to function autonomously when the larger grid fails. Sandia's ESM methodology allows for the design and deployment of autonomous microgrids of various sizes.

The ESM methodology directly links energy surety (safety, security, reliability, sustainability, and cost-effectiveness) with critical power needs. It does this by (1) assessing the energy needs for an area (for example, a military base) and how the capacity and reliability of those needs may vary dynamically over time; (2) assessing the existing and planned electrical infrastructure (for example, electrical distribution system, controls, renewable energy resources) for the area; and (3) designing a microgrid system that builds on the existing electrical infrastructure and integrates distributed energy resources (DERs)—which include back-up diesel generators, photovoltaic (PV) solar systems, small wind turbines, and electrical energy storage—into a local electrical distribution service area (that is, a microgrid) capable of supporting critical loads during a utility disruption. This integrated yet decentralized approach allows the "pooled" DERs to be managed much more intelligently, efficiently, and reliably than traditional back-up power schemes, which rely on back-up generators dedicated to individual buildings.

An ESM is a micro-version of the larger utility electric grid. It can generate and control electrical power output in a self-contained, localized area, thus ensuring that buildings and other facilities within the microgrid have the necessary power to maintain critical missions, even when the main electric grid experiences a failure. An ESM-style microgrid is illustrated in Figure 2.

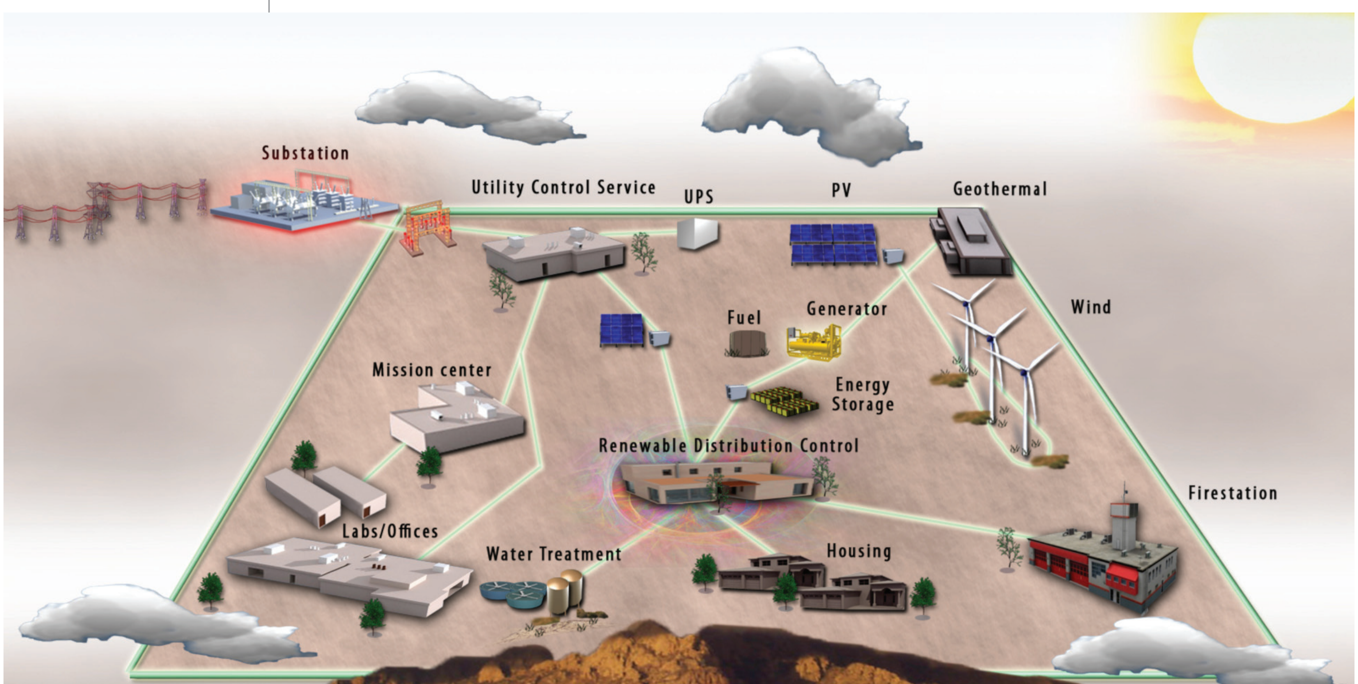

Figure 2: Energy Surety Microgrid.

The ESM methodology directly links energy surety (safety, security, reliability, sustainability, and cost-effectiveness) with critical power needs.

In addition, localizing electrical power generation and control in a microgrid will set the stage for future grid modernization. Because the ESM framework utilizes the integration of DERs into a microgrid, it lessens the need for the construction of large, distantly located electrical power plants, which can include large PV and wind farms.

Local control of microgrid resources enables smart grid functionality, including:

- Demand response (shutting down high-energy-use appliances such as air conditioners for brief periods during times when the demand for electricity is high)
- Intelligent interconnection and integration of small DERs, including generators, PV panels, and small wind turbines
- Net metering—the ability for the microgrid to sell back to the utility any excess power generated within its borders.

10. HOW DOES IT OPERATE?

The ESM methodology integrates existing electrical distribution system technologies, advanced computer modeling, and redesign of electrical grid devices (the "main control" switch). The integration allows the microgrid to operate in both islanded and grid-tied modes. That is, it can operate as part of the grid or separately, under its own power.

Currently, when the main grid loses power, many end-users rely on back-up generators for their emergency power supply. These generators are usually diesel-powered. In most cases, single back-up generators are dedicated to single buildings. In an ESM design, when the main grid goes down, the microgrid is physically disconnected (islanded) from the main grid and it automatically begins to produce the power needed to operate the critical missions within its domain.

One key method for producing the required power in the most efficient, reliable, and cost-effective way is to interconnect back-up diesel generators within the microgrid. If a single generator fails, interconnected generators can meet the demand, and because interconnected generators serve more than one building, they can be scheduled to run at full power, which is the most efficient operating mode for a diesel generator.

In non-ESM microgrid designs, when the main grid goes down the renewable resources on the grid, such as solar and wind systems, must be disconnected because the power they produce continues to feed into the grid, thus creating safety hazards for those working to repair the grid. Because the ESM methodology ensures that the microgrid physically disconnects from the main grid, renewable generation sources within the microgrid do not need to be disconnected. They can continue to produce power without creating a safety hazard.

The ESM methodology also has advantages when the main grid is up and running. In grid-tied mode, DERs such as solar or wind systems located within the microgrid can minimize dependency on utility-generated power. This results in decreased costs. And because microgrid customers can sell back to the utility any energy they produce, the utility's dependence on fossil fuel is minimized.

Recently, grid security has become a pertinent issue because of the danger of cyber attack. Cyber security is thus a salient ingredient of the ESM microgrid design process. The ESM methodology allows for the incorporation of cyber attack mitigation such as encryption, firewalls, strong password requirements, and other measures that enable command and control of the microgrid.

The ESM methodology is illustrated in Figure 3. ESM provides a framework for integrating distributed energy resources on a distribution level network.

ESM Methodology Flowchart/Activity Diagram

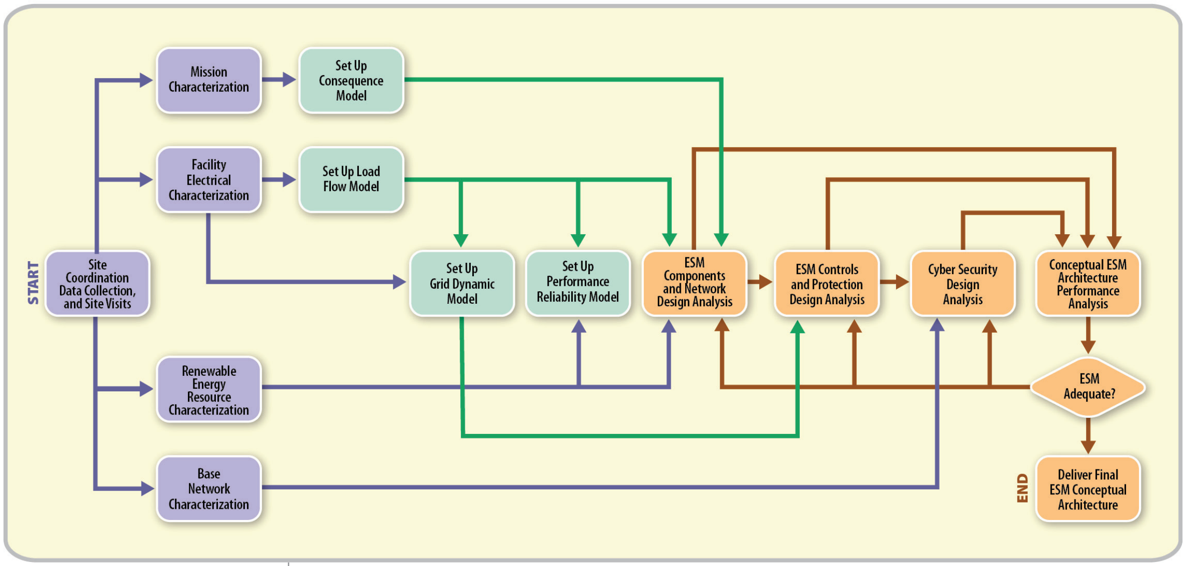

Figure 3:Energy Surety Microgrid methodology flowchart.

11. BUILDING BLOCKS OF OUR TECHNOLOGY

Three main building blocks of Sandia's ESM methodology provide the framework for microgrid designs:

- mission characterization
- modeling and analysis
- design and evaluation.

Mission Characterization Phase

Mission characterization starts with a site visit and data collection about the site's electrical infrastructure, mission operations, and energy surety requirements (safety, security, reliability, sustainability, and cost effectiveness). This step is followed by an assessment of available and planned renewable resources. The final element of this phase is an assessment of the existing and planned network infrastructure available for utilization in microgrid control.

The ESM methodology allows for the incorporation of cyber attack mitigation such as encryption, firewalls, strong password requirements, and other measures that enable command and control of the microgrid.

Modeling and Analysis Phase

In this phase, a consequence model is developed using PowerSim Studio 8 software, a dynamic simulation tool. This allows Sandia scientists to analyze and select the appropriate type and size of DERs to be implemented into the microgrid. Sandia developed this modeling tool using the principles of system dynamics, a proven methodology which employs scenario-based approaches and which allows end-users to perform trade-off analyses. Sandia's ESM consequence model produces quantifiable results that enable us to determine which DERs will work best within a given microgrid.

This consequence model provides the basic foundation for the microgrid design. The design is further refined using applications developed in MatLab software, including load flow analysis, dynamic grid analysis, and reliability assessment using Sandia-developed software.

Design and Evaluation Phase

In this phase we design the electrical network, protection, controls, and cyber security elements for the microgrid. We then assess the performance of the design architecture against the energy surety requirements. If the surety requirements are not met, then we iterate on relevant design parameters until a satisfactory design is achieved.

12. PRODUCT COMPARISON

The concept of a microgrid is not new. People living "off the grid" have essentially created their own microgrids. However, the installation of large-scale (megawatt and larger) microgrids at commercial and industrial levels is still in its infancy.

US Microgrid, Lockheed Martin, General Electric, and other large commercial entities, design microgrid technologies and integrate microgrids. Sandia's product is a framework of user requirements and design options that can be used by any of these commercial entities to integrate safe, secure, sustainable, reliable, and cost effective microgrids.

Sandia's ESM methodology offers three main advantages over current microgrid designs:

1. ESM microgrid design allows the microgrid to be grid-tied (that is, operated while connected to the grid, even augmenting the main grid with microgrid-generated power) or to be islanded (that is, operated completely independent of the main power grid).
2. ESM computer modeling utilizes extensive analysis capabilities to determine the most efficient, cost-effective, secure, and safest combination of DERs within the microgrid.
3. ESM risk assessment identifies the critical needs within a microgrid. If the main grid loses power, an ESM-designed microgrid will apportion power to those elements of the microgrid that are most critical. That is, the methodology identifies the missions that pose the most critical risk to security and safety, and it apportions the power accordingly.

TABLE 1. COMPARISON MATRIX

Sandia ESM Methodology	Other Microgrids
Functions in both grid-tied and islanded modes	Designed to function only when grid-tied or only when islanded
Sustains multiple day outages	Sustains several hour outage
Provides for a risk-based selection of critical loads	Entire load
Allows for high penetration of renewable energy sources	No renewable penetration
Efficiently manages DERs	Oversized generators
Ability to island in a timely manner	Incomplete islanding or no islanding
Minimizes cyber security issues	Cyber security threat is greater
Controls resources for optimized operations	Autonomous control or no control

IMPROVEMENTS OVER COMPETITIVE PRODUCTS

The ESM methodology is the result of many years of microgrid design experience. Sandia scientists have designed ten microgrids for military customers and are in the process of working with integrators to implement four others.

As shown in the table above, the ESM methodology not only allows a microgrid to operate when grid-tied or islanded, it also dramatically increases the time that a microgrid can operate in islanded mode. This is possible because of the risk-based assessment for determining critical loads.

Because the ESM methodology is a process and not a physical product, it can be applied to any existing or planned microgrid. Whether implemented in part or in full, Sandia's ESM methodology can result in improved microgrid efficiency.

LIMITATIONS OF OUR PRODUCT

The ESM methodology is not an off-the-shelf product; it still requires significant engineering expertise to implement. However, our goal is to make the methodology easier to use through training and improved software products so that it will become a common approach to designing microgrids for military and civilian applications.

13. PRODUCT USE

PRINCIPAL APPLICATIONS AND BENEFITS

The principal application of the ESM methodology is to ensure that critical applications have access to reliable, efficiently produced electrical power when they need it, no matter the condition of the main electrical grid.

In addition, the integration of ESM-designed microgrids that can provide energy back to the main grid will result in an energy infrastructure that is safer, more reliable, and more cost-efficient.

Whether implemented in part or in full, Sandia's ESM methodology can result in improved microgrid efficiency.

Electric utilities face a dilemma. They must be able to guarantee a supply of energy to all customers on the grid, no matter how high the demand. For example, on a hot summer day demand can peak. Even though this may only happen a few times a year, the utility must meet this high demand. Microgrids provide utilities with access to locally-produced electricity for meeting this demand. This results in significant savings for the utility; they no longer are required to generate power to solve the problem.

Utilities recognize that microgrid approaches like the Sandia ESM can result in smart grid "nodes" that will be the building blocks for the modernization of the US grid. These nodes handle all the interactions and communications necessary to balance energy use within the node itself by aggregating microgrid DER systems and implementing demand response only at the microgrid level. In the future, utilities will no longer be forced to communicate with thousands of end-users within the nodes, which is a costly data- and time-intensive effort. Instead, they will communicate at the node level itself and manage power accordingly. And, if the transmission grid goes down, ESM-designed microgrids can share resources among each other, making the distribution grid more reliable.

Sandia's ESM framework is recognized as a pathway to the most cost-effective and manageable method for the US to increase its distributed renewable energy generation. With the ability of universities, hospitals, military bases, and other installations to produce green energy locally, the need for constructing large, distantly located PV and wind farms will be significantly reduced, which will delay or even eliminate the need for constructing new transmission lines.

OTHER APPLICATIONS

The current application of the Sandia product is primarily for fixed military bases, but the implications in civilian applications are numerous. Hospitals, neighborhoods, large industrial complexes, and airports are only a few of the potential customers for this technology. Additionally, the ESM methodology is transferrable to mobile and deployable systems such as military forward operating bases and combat outposts.

14. SUMMARY

The Sandia ESM methodology employs a comprehensive set of advanced computer modeling and evaluation techniques that produce a safe, secure, sustainable, reliable, and cost-effective microgrid design tailored to meet specific customer requirements. It ensures that critical applications have access to reliable, efficiently produced electrical power when needed, regardless of the main electrical grid's condition.

Sandia's ESM framework is recognized as a pathway to the most cost-effective and manageable method for the US to increase its renewable energy generation. The ESM methodology provides end-users with the ability to produce green energy locally and sell excess power back to the utility.

By enabling the concept of the smart grid node, Sandia's ESM methodology can play a vital role in the modernization of our nation's electric grid.

15. AFFIRMATION

I affirm that all the information submitted as a part of, or supplemental to, this entry is a fair and accurate representation of this product.

Juan Torres

APPENDICES

APPENDICES

APPENDIX A: SUBMITTER INFORMATION

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APPENDIX C: LETTERS OF SUPPORT

COMMANDER, U.S. PACIFIC COMMAND
(USPACOM)
CAMP H.M. SMITH, HAWAII 96861-4028

February 23, 2011

R&D 100 Award Administrators,

U.S. Pacific Command (PACOM) understands that DoD's reliance on a fragile commercial grid to deliver electricity to its installations places the continuity of critical missions at risk. With the assistance of Sandia National Laboratories, we're taking proactive measures to overcome the many technical and operational difficulties required to ensure that military bases under our purview have the electrical power required to carry out critical missions where they need it, when they need it, and under adverse circumstances.

One method of meeting these challenges is the implementation of two energy surety microgrids in Hawaii, at Joint Base Pearl Harbor-Hickam and at Camp Smith. Both are part of the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS), Joint Capability Technology Demonstration (JCTD) in a partnership between the DoD, DOE, and DHS. **The role of Sandia National Laboratories in the design, modeling, and testing of these microgrids is vital to the success of the SPIDERS project.**

At Pearl-Hickam, the energy surety microgrid will encompass a small, but critical portion of the base. The microgrid designed by Sandia will not only provide secure backup power for this critical load, but will demonstrate how an existing hydrogen production system can be used for electrical energy generation, in combination with an onsite photovoltaic system. At Camp Smith, which hosts PACOM headquarters, the microgrid developed by Sandia will encompass the entire base. Photovoltaic systems will be integrated with cutting-edge electrical energy storage to ensure reliable, safe, and secure power. Cyber security will be a key feature at Camp Smith thanks to the assistance of Sandia. At both bases, backup generators will be configured to run optimally in the event of emergencies by integrating renewable resources, thus prolonging the duration of emergency power, reducing carbon emissions and ensuring greater reliability.

The technology, control systems, and operational procedures of the energy surety microgrids developed by Sandia will be incorporated into other DoD facilities; and with DOE as a major partner in the effort, lessons learned can be used for civilian applications. We believe that the applicability to both PACOM's mission and the nation's secure power needs makes the Sandia microgrid solution a strong contender for this prestigious award.

Sincerely,

GEORGE KAILIWAI III, SES
Director, Resources & Assessment

NORTH AMERICAN AEROSPACE DEFENSE COMMAND
AND
UNITED STATES NORTHERN COMMAND

24 February 2011

Interagency Coordination Directorate
250 Vandenberg Street, Suite B016
Peterson AFB CO 80914

Sandia National Laboratories
PO Box 5800
Albuquerque NM 87185

Dear R&D 100 Award Administrators

USNORTHCOM's homeland defense mission must have continuous and assured electric power. To that end, we recently partnered with USPACOM to propose a Joint Capability Technology Demonstration (JCTD) entitled "Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS). This proposed demonstration is a collaboration of DoD entities with the Department of Energy and the Department of Homeland Security. This interagency partnership speaks volumes about the pressing need that is being addressed: secure, reliable electrical power that will ensure critical missions can be carried out under any circumstances.

In the Fall of 2010, USNORTHCOM elicited the support of Sandia National Laboratories to develop a conceptual design for an energy surety microgrid for Fort Carson, CO. Under SPIDERS, this concept will be realized as an installed microgrid with all of the necessary hardware, software, control systems, and cyber security. The approach used by Sandia incorporates modeling and design efforts that ensure the final microgrid design is robust and optimized to reliably support our critical missions.

With its two megawatt photovoltaic array, Fort Carson actively supports DoD's efforts to embrace renewable energy. This renewable energy source will be part of an Energy Surety Microgrid that will combine electric vehicles for energy storage and distributed back up diesel generation that will assure continuous power when the microgrid is in islanded mode. The integration of this vehicle-to-grid technology, combined with a high penetration of solar generation, makes this project unique. Lessons learned here will be applicable to many of DoD's installations.

Our prior experience with Sandia assures us that their work in this area is both innovative and transformational. We feel confident that the SPIDERS JCTD can substantially advance USNORTHCOM's approach to energy security and enhanced mission assurance. With this in mind, I enthusiastically and wholeheartedly support Sandia's nomination for an R&D 100 award.

Sincerely

BERND McCONNELL, SES
Director

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National Nuclear Security Administration