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NATIONAL RENEWABLE ENERGY LABORATORY

MODELS & TOOLS

Continuously Optimized Reliable Energy (CORE™) Microgrid

The National Renewable Energy Laboratory (NREL) produces conceptual microgrid designs—plans for electrical generation and distribution systems capable of autonomous operation—that deliver reliable, economical, and sustainable energy.

We use a customized process for our conceptual microgrid designs called Continuously Optimized Reliable Energy (CORE). The CORE process is a systems-based design approach, evaluating all microgrid systems. These include utility interface, energy management, communications, controls, generation, load management, and others. Fundamental to the CORE process is to optimize key microgrid objectives to achieve reliable energy. These objectives are energy surety, economic value, and sustainability.

Design for Reliable Power

The CORE process focuses on designing for continuous operation to deliver reliable power. Our approach provides a comprehensive view of all load profiles for both islanded and grid-connected systems. This wide-range perspective supports a microgrid system design that fortifies continuous operation by accommodating changing load requirements. For example, we can design a flexible microgrid footprint to handle critical loads but that can expand to meet essential loads or adjust to drop loads unnecessary for basic operations, known as sheddable loads.

This phased design capability proves useful not only in technical design considerations but also in developing capital funding plans. Examining the continuous operation profile over time for a facility and identifying appropriate areas of energy optimization allow for long-term load and generation forecasting. This forecast also serves as a planning tool for future expenditures.

Additionally, using strategies developed through the CORE process, operators know whether a resource is in operation on a real-time basis, and there are no surprises regarding operability when the microgrid needs to draw from onsite assets during an unplanned outage.

NREL's CORE process focuses on delivering reliable energy that is economical, fortifies energy security, and draws from sustainable resources and strategies.

Areas of Expertise

- Energy analysis and resource assessment
- Baseline and scenario modeling for system power flow, dynamic, and stability
- Economic and technical analyses
- Testing at NREL's Energy Systems Integration Facility (with a 1-megawatt microgrid testing capability)
- Energy security value assessment

Benefits of the CORE Process

The CORE process offers many benefits, which include:

- Integrating the right systems and resources into 24/7 operations
- Optimizing for energy surety, economic value, and/or sustainability
- Enhancing fuel diversity
- Expanding and contracting systems to deliver energy for a variety of load coverage needs
- Allowing for gradual addition of components over time to accommodate funding, growth, or staffing constraints

The CORE process focuses on designing for continuous operation to deliver reliable power.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

What Is a Microgrid?

A microgrid is a group of interconnected loads and electricity generation. It can act as a single entity with respect to the grid or operate in parallel with or islanded from the grid. Common characteristics include:

- Autonomous operation from the grid capability
- Distributed generation sources, including conventional and renewable energy sources
- Load coverage to match energy security objectives and generation availability
- Dispatchable control
- Can be designed to serve one facility; a component of a substation; an entire substation, campus, regional area (such as a military base); or larger area.

What Generation Sources Are Used?

Generation sources include conventional sources like natural gas and renewable energy sources like solar, wind, and biomass.

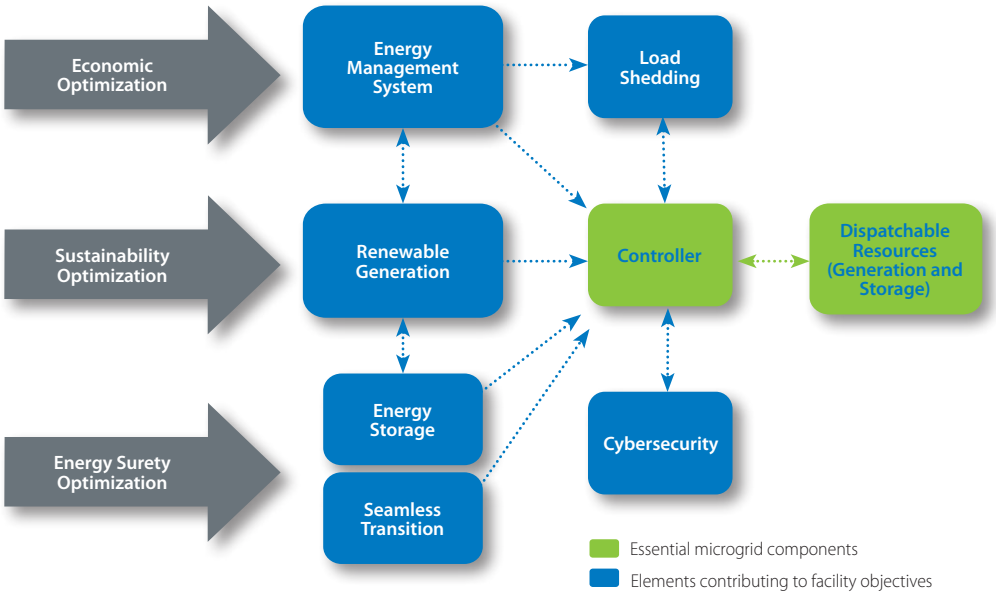
They are responsible for picking up load, regulating voltage and frequency, and maintaining stability during dynamic events such as changes in load needs.

What Is Microgrid Design?

The design of an optimally operated microgrid is a complex electrical engineering modeling challenge. It involves identifying appropriate energy-generation systems and pairing them with operational equipment. Then these components are synchronized precisely to deliver the right amount of energy when needed.

The dynamic nature of load changes requires intermittent generation sources and sophisticated modeling techniques that pull in concepts from both traditional transmission and distributed energy planning. The end result is a reliable energy generating and delivery system.

Microgrid Elements to Support Objectives



The goal of the CORE process is to produce a reliable microgrid optimized for economic value, sustainability, and/or energy surety.

Optimizing Key Microgrid Objectives

The CORE process incorporates continuous optimization of key objectives to achieve reliable energy. These objectives are economic value, sustainability, and energy surety. They are the three "core values" of the CORE process. A facility can choose to focus on one, two, or all three objectives.

Economic Value

To achieve optimal economic value from a microgrid, NREL experts make sure operations are efficient and systems and resources are wisely enlisted. For example, we can design a dispatch algorithm around market rate structure, generation costs, and operational considerations, so the capital investments of a microgrid can be offset by market opportunities to export power or ancillary services. We also help to incorporate effective energy management systems and smart load shedding schemes to maximize system performance.

Sustainability

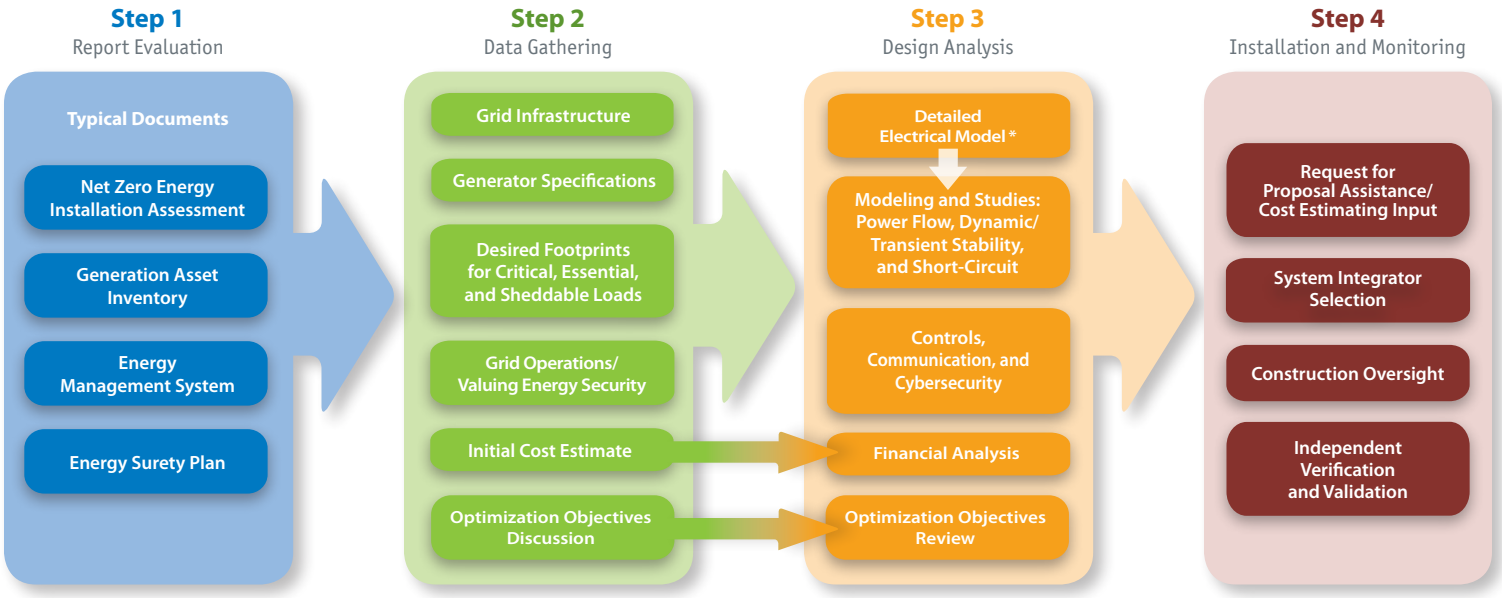
A sustainable microgrid produces few emissions by pulling from renewable energy sources and using energy efficient strategies. We identify the most effective ways to integrate renewable energy and energy efficiency into a microgrid system. By using renewable generation and energy storage strategies, microgrid owners can decrease fuel inventories, add redundant fuel sources, and reduce the microgrid carbon footprint.

Energy Surety

For many microgrids, energy surety is the primary objective, and NREL planners design microgrids that strengthen security. Often energy security is enhanced when energy storage is incorporated. Additionally, to ensure uninterrupted service to ongoing operations, we can plan for seamless transitions from one system to another. To support the business case of energy security, NREL can help to assign a value to electrical energy security at a site.

We deliver plans that achieve the appropriate balance between key objectives such as energy surety and economic value.

Microgrid Design Process



*Detailed electrical modeling is the foundation for microgrid design.

NREL's exacting process results in a conceptual microgrid design that produces and delivers reliable and economical energy.

The CORE Design Process

The CORE microgrid design process consists of four steps: report evaluation, data gathering, design analysis, and installation and monitoring.

Step 1: Report Evaluation

Evaluating reports and other information on proposed microgrid projects, such as net zero strategies and energy security plans, helps form a solid understanding of previous investigations. For example, a net zero energy installation assessment establishes an energy baseline for a facility and outlines a phased approach to reach net zero energy use by installing energy efficiency and renewable energy features. Having this information before designing a microgrid enables NREL designers to examine a long-term, comprehensive view of potential generation assets and possible load shedding opportunities.

Step 2: Data Gathering

An intense data gathering effort to collect detailed information on the grid infrastructure is a crucial step. This phase includes compiling a preliminary assessment of existing and potential generation sources; collecting, analyzing, and categorizing load profiles; and documenting the current procedures for grid operations and energy security. NREL experts use the collected data to form the basis for a detailed electrical model of the distribution system. This model represents the operational electrical infrastructure used to establish a baseline for the microgrid design. Gathering existing communications, control, and cyber security requirements are also part of this phase. Initial cost estimates are begun as well, providing guidance for design analysis.

Step 3: Design Analysis

The baseline model, developed from data gathered in Step 2, is used to produce simulation studies to assess the feasibility of different microgrid configurations, including "what if" scenarios. These simulations include normal islanded operational assumptions, as well as contingency questions (e.g., loss of load, loss of generation asset) that might be important for microgrid operability. We use the results from simulated scenarios to propose configurations that can support the identified load coverage objectives for the microgrid. Considerations for control, communications, and cybersecurity requirements are also included in proposed designs. These designs provide the foundation for performance specifications necessary for a system integrator to bid on installing the project.

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In addition to technical design considerations, cost considerations are included in Step 3. As part of the design configuration analyzed, we include a high level cost estimate for proposed designs. Cost information coupled with design functionality and operational priorities help to establish a priority ranking of microgrid configuration options.

Step 4: Installation and Monitoring

NREL experts support microgrid installation by assisting with request for proposal development, selecting the system integrator, and overseeing the construction phase. NREL can also monitor microgrid operations once the system is installed.

Supporting the fundamental goal of continuous optimization, this step provides the opportunity to verify design assumptions and validate performance of the system. By monitoring system performance under real-time conditions, the assumptions and contingencies used for modeling can be improved for future design work.

Validating the system performance also helps a facility to enhance metrics and improve operational procedures. A third-party verification is valuable, and NREL can serve in this role. Verification activities involve documenting whether the final design works as intended and conducting a subjective validation relative to the appropriateness of the design and efficiency with which the system integrator's design meets the client's system requirements.

CORE Process Examples

Marine Corps Air Station Miramar

NREL applied the CORE process to develop plans for a conceptual microgrid at Marine Corps Air Station Miramar (MCAS) north of San Diego, California. NREL analysts used CORE process Steps 1 through 3 to provide strategies for financing, installing, and implementing a custom microgrid for MCAS Miramar. Plans recommend a hybrid system, incorporating photovoltaics, jet fuel, landfill gas, energy storage, and natural gas.

U.S. Air Force Academy

We are working with the U.S. Air Force Academy in Colorado Springs, Colorado, to provide a conceptual microgrid design for its campus. Findings indicate the microgrid system may include a combined heat and power system in addition to energy storage and photovoltaics for this sunny location.

U.S. Air Force Academy in Colorado Springs, Colorado. *Photo from U.S. Air Force*

Microgrid Design Testing

NREL's new Energy Systems Integration Facility (ESIF) houses multiple laboratories for testing energy systems used in microgrids. Verification and validation of microgrids can be performed at our facility.

For more information about the ESIF, visit *www.nrel.gov/esi/esif.html.*

Energy Systems Integration Facility at the National Renewable Energy Laboratory in Golden, Colorado. *Photo by Dennis Schroeder, NREL 23402*

NREL's capabilities encompass the laboratory's full range of technologies, which span the energy efficiency and renewable energy spectrum. NREL staff members educate partners on how they can advance sustainable energy applications and also provide clients with best practices for reducing barriers to innovation.

NREL's mission is to be the leader in technology innovation and to advance renewable energy efforts around the world. Let NREL help propel your organization toward a more sustainable energy future.

For more information about NREL's energy systems integration capabilities, see our website at *www.nrel.gov/esi.*

To learn more or to take part in field tests, contact Julieta Giraldez, julieta.giraldez@nrel.gov, 303-275-4483.

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