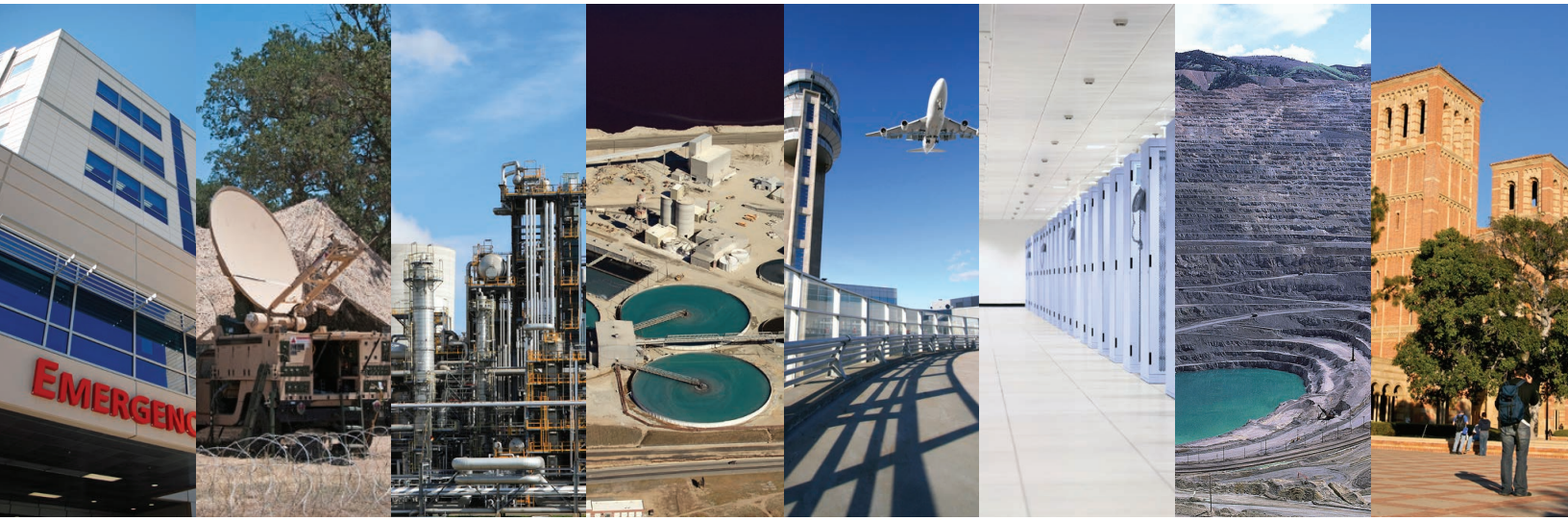
SEL Microgrid Systems

Reliable, Economical Power Delivery



Resiliency and reliability in all conditions.

- Intelligent control provides seamless islanding as well as comprehensive generation and load management.
- Front-end engineering design, development, testing, and commissioning expertise ensures implementation success.
- Built-in optimization reduces energy costs and emissions.
- Robust layered cybersecurity ensures secure operation.
- Scalable control system minimizes development costs.

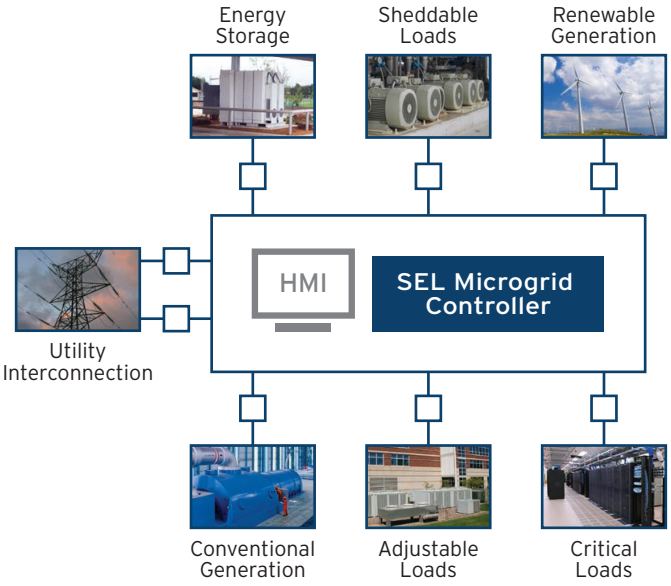
SEL

Providing Energy Assurance for Your System

SEL's microgrid control systems are reliable and secure solutions for maintaining uninterrupted energy delivery. They control and protect many types of distributed energy resources. SEL systems allow system owners to operate independently when islanded, ensuring a constant delivery of energy after the loss of a utility interconnection.

Microgrid capabilities provide benefits to numerous industries across multiple customer segments:

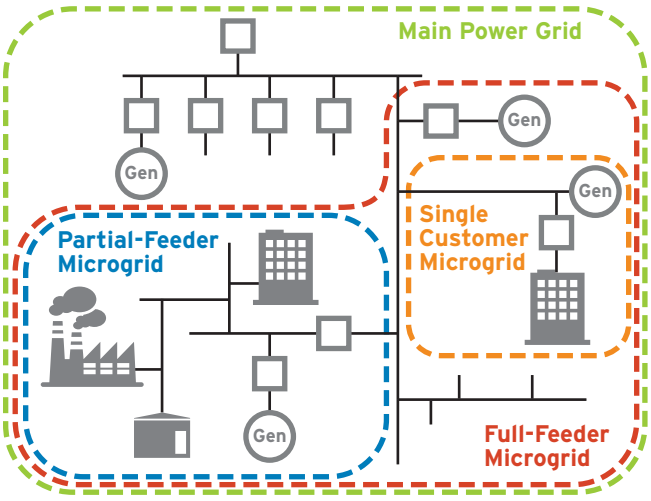
- **Keep the lights on.** SEL microgrids are characterized by their ability to seamlessly separate or island from the central grid, which ensures reliable and resilient energy delivery no matter the conditions.
- **Enhance system user economics.** SEL microgrids give system owners the ability to manage the amount of energy they generate locally or import from the utility.
- **Facilitate renewable energy integration.** SEL microgrids allow system owners to select or prioritize the best mix of local renewable and nonrenewable energy resources that can support local demand.



Incorporate All Assets—SEL microgrid control systems are capable of protecting and controlling many types of distributed energy resources.

Deterministic Control

SEL microgrid control systems combine dependable computing and communications, including adaptive relaying, synchrophasors, and cybersecurity, to provide high-performance microgrid control. Microgrids have low inertia compared to the larger macrogrid, which means they need relay-speed SEL microgrid controllers. Control algorithms and demand response need to operate much more quickly in order to preserve the load and generation energy balance, maintain system stability, and provide good power quality.



Islanding Configuration Possibilities—Within the microgrid, the SEL control allows one or more submicrogrids to operate, ensuring critical loads are always served.

The Intelligence Center of the Microgrid

At the core of every reliable SEL microgrid is a powerful controller that is able to respond to external data, such as real-time pricing signals and fast-changing system dynamics. This capability enables the controller to optimize the system's configuration based on the system user's priorities and real-time data. The fast, deterministic controller can operate at subcycle speeds, allowing it to reliably balance load with the available generation.

Controlling the energy balance in the microgrid system is one of the most difficult challenges for reliable microgrid operation. Because SEL's controller is able to operate at relay speeds, this can all be done seamlessly, which means processes stay online during islanding from the grid and resynchronizing to it. SEL controllers and systems allow the facility to stay online continuously, maximizing process uptime.

SEL microgrid control systems can combine microgrid and distribution automation control into a single controller. This maximizes a microgrid's value. Integrating these capabilities into a single controller results in a low-risk, cost-effective solution for the system owner. The integrated distribution automation capability allows network configuration within the microgrid because conditions that impact the utility grid can also impact the microgrid.

Adaptive Protection Schemes for Safe Operation

The integration of distributed energy resources and novel topologies embedded in microgrids challenges the characteristics of protection schemes in microgrids as compared with those of conventional distribution systems. Distributed energy resources located in microgrids can modify fault currents, change fault current flow paths, result in bidirectional power flows, and affect protective device operations. SEL microgrid control systems integrate adaptive protection schemes into the system to ensure that personnel and equipment are always protected, regardless of the network configuration. Adaptive protection allows different settings in the same relay to be used to optimize protection.

Synchrophasor Measurements for Enhanced Control

SEL integrates high-resolution, real-time synchrophasor measurement technology into the microgrid, providing more effective system control and operation.

Benefits of using synchrophasors:

- Fast, reliable system decoupling (island detection)
- Seamless resynchronization with grid
- Real-time measurements for improved control
- Improved understanding of system operation through direct phasor measurements

Maintaining Grid Stability

A microgrid's value is tied to its ability to maintain system balance while offsetting demand charges or giving system owners more operation flexibility. SEL microgrid control systems provide comprehensive generation and load management controls.

Generation Control Functions

- Automatic generation control maintains balanced generation and nominal frequency under all scenarios.
- Dynamic capability curve calculation constantly monitors the maximum capability of distributed generation.
- Voltage control system balances reactive power and maintains system voltage under all scenarios.

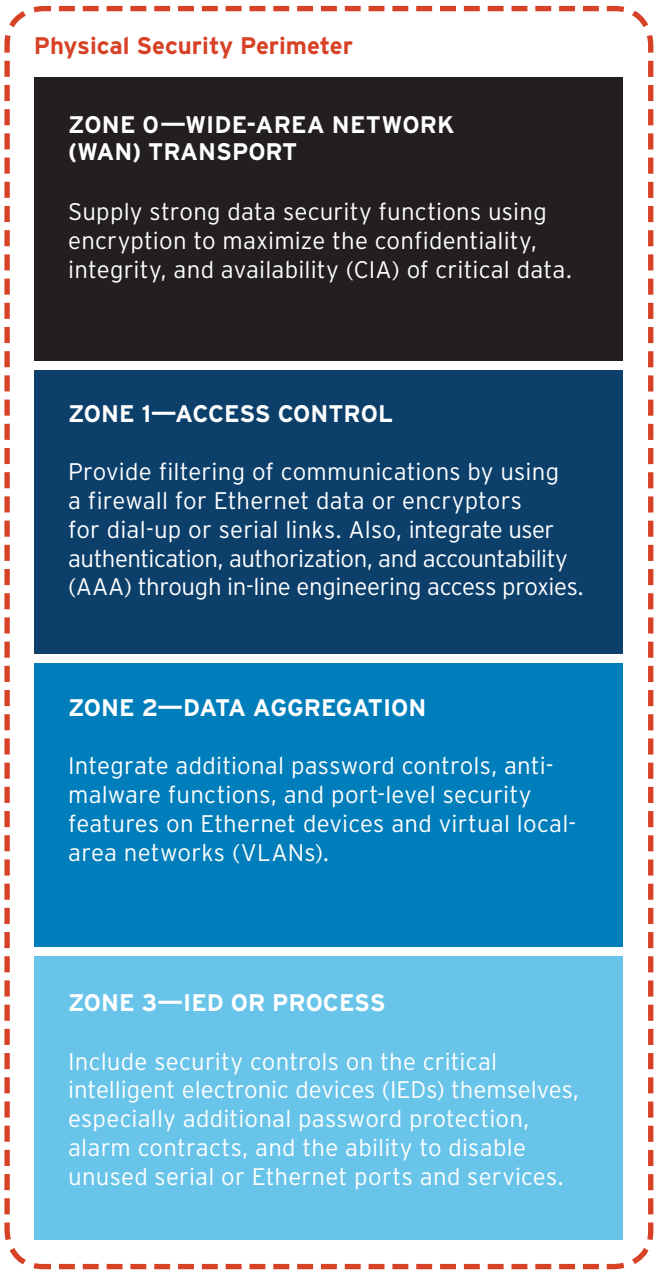
Load Management

- Prioritized high-speed contingency- and frequency-based load shedding sheds the load based on system configuration and operation.
- Peak shaving reduces the amount of energy purchased during peak hours when the charges are the highest.
- Load shifting eliminates demand peaks by precharging energy management systems or precooling a building to offset anticipated charges.

Robust Cybersecurity

Consistently secure operation is very important because microgrids are relied on during severe weather or emergency situations. The cybersecurity structure in SEL microgrids ensures resilient power to critical facilities and protects against malicious attacks. It provides the ability to control user access to different information throughout the system. Threats could be malicious and adversarial from outside sources or accidental internal errors.

SEL's defense-in-depth philosophy applies cybersecurity in a layered approach that maximizes reliability and minimizes the intrusiveness of controls on existing critical processes. Besides physical security, SEL implements four digital zones of defense in our systems.



Security System Overview—SEL microgrid systems use a defense-in-depth approach to guarantee information assurance and secure operation.

Ensuring Success

There are other factors that need to be considered when implementing a microgrid in addition to selecting the right components. SEL is able to provide many types of services that can support microgrid development, design, and implementation. These services improve the project's return on investment and ensure success.

Defining System Requirements

Front-end engineering design (FEED) is a critical step in the development of microgrid projects. The objective of a FEED study is to establish and define technical requirements, applicable standards, and project guidelines. This can be daunting for microgrid projects since there are few industry standards and regulations for microgrids; however, SEL has years of experience designing and implementing microgrids and is a trusted solutions provider to many utilities. Our FEED process reflects the client's project-specific requirements and helps prevent major changes, reduces risk, and addresses resource commitment during the execution phase.

Factory Acceptance Testing—All microgrid control systems are thoroughly tested and configured before shipment using hardware-in-the-loop testing.

Evaluating System Performance

SEL provides detailed system studies and Electromagnetic Transients Program (EMTP) simulations, which can be used to help system owners make decisions about their microgrid. These studies and simulations can be used to plan a new microgrid, evaluate an existing microgrid, or investigate a specific system vulnerability. Some of SEL's capabilities are:

- Transient and dynamic simulations
- Coordination studies
- Inrush current simulations
- Power flow studies

Thorough Testing for Reduced Downtime

All SEL microgrid control systems use hardware-in-the-loop testing during the design and testing phase. This ensures that the actual devices intended for use are tested in a controlled environment before shipment and are preconfigured to integrate with the system before they get to the field. Less field work leads to shorter commissioning timelines.

Transferring Knowledge

To ensure successful implementation, SEL provides comprehensive training for end users that includes onsite personnel training along with a complete set of materials and documentation. Advanced engineering training for ongoing system and configuration management is also provided. SEL offers 24/7 maintenance and support services from a single support phone number.

SEL Making Electric Power Safer, More Reliable, and More Economical

Schweitzer Engineering Laboratories, Inc.
Tel: +1.509.332.1890 | Email: info@selinc.com | Web: www.selinc.com

PF00344 • 20160202

WORLDWIDE 10 years WARRANTY