Africa's largest microgrid project in Equatorial Guinea's Annobon Province will provide stable, reliable, and consistent power supply to the island, advancing regional economic development. Photo courtesy of Eaton

Microgrid Solutions Sustain Power—Even when the Grid is Off

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Microgrid projects are integral to initiatives that aim to strengthen the economy, save lives during natural disasters, and make our energy supply more sustainable and our electrical power more secure. Microgrids increasing support more reliable, efficient and safe power for critical infrastructure in military, utility, healthcare, government, university, residential, and other applications.

The primary driver for microgrids is the ability to deliver reliable, clean power to critical facilities during an extended period by islanding or operating independently of the utility grid. A microgrid can better manage local power generation by providing optimal control, dynamic stability, and balance demand and generation on a small but critical scale.

Simply put, a microgrid is small-scale, local power grid that can operate either connected to the utility or independently. In remote areas, a well-designed and managed microgrid can operate as a standalone power grid. Microgrids that are connected to utility power can support all or some of the power requirements for extended periods of time when the grid is unavailable. When it is repaired, the system automatically reconnects itself to the utility for full-system power delivery.

Diesel generator sets, renewable energy resources, fuel cells, battery storage, natural gas generators, or combined heat and power typically power microgrids. Photovoltaic and battery technologies are economically viable and can provide sustainable electricity, fueling the growth for microgrid applications.

Design Challenges

A recent project on a military base in the U.S. demonstrates the ability of a microgrid to be isolated at will from the primary grid and achieve uninterrupted power delivery, independent of utility power. The application is designed to maintain mission critical and support functions regardless of the availability of the primary grid.

The project integrates a combination of solar, wind, and traditional backup generation sources in a microgrid that is isolated, intentionally or otherwise, from the utility grid. It demonstrates how a combination of variable renewable energy sources and traditional backup power generation resources can be managed through the use of intelligent controls to maintain power quality and reliability.

Creating a successful microgrid is challenging. It involves understanding basic system requirements, accommodating unique operating characteristics of generation sources, managing and prioritizing power requirements, and seamlessly interfacing with the utility grid. A structured approach to microgrid implementation gives us the ability to support critical infrastructure even in the event of a major power disruption.

Early on, an analysis of the system to define the goals and parameters of the microgrid operational characteristics is necessary. The evaluation forms the backbone of the infrastructure requirements and microgrid plan, minimizing long-term operating costs and initial investment by identifying exact system needs. In military applications, a goal may be to maximize the generation content from renewable resources, minimize fossil fuels, and provide secure, local power. Larger government facilities may elect to maximize electrical supply to critical loads at the lowest overall cost.

Establishing system requirements involves identifying critical loads and deciding on the infrastructure that must be operated under islanded conditions. These decisions become much more complex as the gap between available generating capacity and load requirements widens.

Each generation source has unique operating characteristics. For example, photovoltaics are highly intermittent power sources. Combined-cycle units require distinct start-up procedures before they can be counted on to produce steady electricity generation. Available local generation assets need to be analyzed holistically to achieve seamless operation.

Microgrids control the dynamic balancing of varying loads with available generation capacity to maintain system stability. This can be performed with pre-determined rule-based load shedding scheme for simple microgrid applications, while a more dynamic fast demand/response capability coupled with generation optimization strategies is often more suited for larger, more complex designs.

Extensive modeling and analysis needs to be performed to address the protection of the generation assets and subsystems. Fault studies and multiple protection devices are often required to create a robust protection system.

Islanding

A key feature of grid-connected microgrids is the ability to island. To do so, they need to be designed and proven "safe" to island while providing power to critical loads, and to ensure safety for utility linemen. This can be accomplished by using a proven microgrid anti-islanding scheme that is thoroughly tested. See figure 1.

Figure 1. Anti-Islanding Test—Microgrid Voltage and Frequency

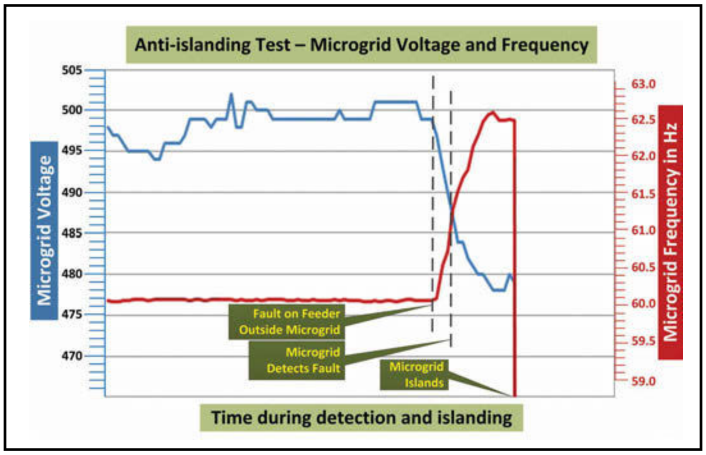

Figure 1 demonstrates microgrid controls developed for anti-islanding capability. Frequency and voltage deviation generated by the controller allows the protection relay to open the microgrid interconnection switch. This allows the microgrid to isolate from a faulted line and power loads within the microgrid while safely allowing service personnel to work on the faulted line.
Diagram courtesy of Eaton

System design and testing considerations

Microgrids are required to perform with a high level of reliability to achieve a robust system capable of performing the necessary control with high availability in harsh environments.

It is critical to carefully consider the hardware foundation that will form the control system and tap proven technology and products to support the system.

In microgrid applications, many of the control issues are focused on communications and the lack of an integrated systems approach to microgrid controls. Careful consideration needs to be exercised when selecting communication protocols and the data that is available for exchange. An open standard, plug-and-play communication system is essential.

Cybersecurity, password protection, and traceability are key considerations for microgrid applications, especially those serving critical government facilities and functions. Communications in military base applications often require Department of Defense Information Assurance Certification and Accreditation Process certification to communicate with existing infrastructure. Strong consideration should be given to microgrid system capabilities that will make this certification easier and meet utility connection cybersecurity as well.

Further, microgrids control a complex operating environment due to the number and types of generation and load assets. One solution is to require closed loop simulator testing to fully prove the system implementation prior to system shipment. This is the best method to evaluate operating scenarios and validate the safety of the controls.

The system's overall design structure should consider whether it will be easy to expand and change in the future or will considerable custom programming be required. The generation and load assets of microgrids tend to be dynamic as new options become available and load considerations change. Systems designed in a modular building-block fashion adapt well to change with minimal rework.

Safe, Reliable, Efficient, Sustainable

With the continuing proliferation of distributed energy sources, the grid will continue to become a much more dynamic electrical environment that will require ever-smarter apparatus, faster communications, and automation systems in order to maintain grid stability and power quality.

Apparatus in the distribution system will contain greater levels of embedded intelligence that will perform predictive diagnostics within itself and to each other, dynamically coordinate equipment safety settings, optimize system operation and efficiency, and successfully integrate renewable energy and battery sources to penetration levels not even imagined just several years ago.

The authors are members of Eaton's microgrid development team that is focused on leveraging the knowledge and expertise gained from the supply of numerous turnkey government and commercial microgrid installations.