Thought leadership
White paper

Customized microgrid at Fort Custer modernizes electric infrastructure and advances energy resilience

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Abstract

In 2015, the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) recognized the critical need for power system resiliency, soliciting environmental and energy technologies for demonstration and validation to improve energy security on military installations. A team was formed between Eaton, the Michigan Army National Guard (MI ARNG) and Consumers Energy under the leadership of Electricore Inc. The MI ARNG has a history of deploying state-of-the-art solutions to advance cybersecurity and energy resilience, presenting Fort Custer as the ideal candidate for deployment of a microgrid. Eaton developed an autonomous operating microgrid through the integration of a utility-compliant control solution with smart grid enabled switchgear and legacy generation. The project demonstrates the ability for microgrids to maintain continuity of critical power resources during extended outages and enable controlled export of excess energy.

Specific project requirements include:

- Utilization of existing assets to improve the economic feasibility of a microgrid
- Engineering of a cost recovery mechanism for exported power
- Investigation of the potential to share resources between Fort Custer and neighboring federal facilities

The Fort Custer microgrid project is being analyzed for potential replication to at least 100 sites throughout the U.S. where military bases are closely located, dramatically reducing the cost to advance energy resiliency.

This paper will examine the challenges associated with deploying the grid-connected microgrid power system and steps taken to help the DoD achieve a secure, reliable and easily replicable microgrid system.

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Project overview

A microgrid is as unique as the business, community or government institution that deploys one. The solution is not a "one-size-fits-all" but must be based on a scalable and replicable platform to minimize non-recurring engineering costs and maximize adoption throughout the DoD. By understanding ESTCP's needs and requirements, the project team needed to identify the applications and assets required to engineer the microgrid control framework.

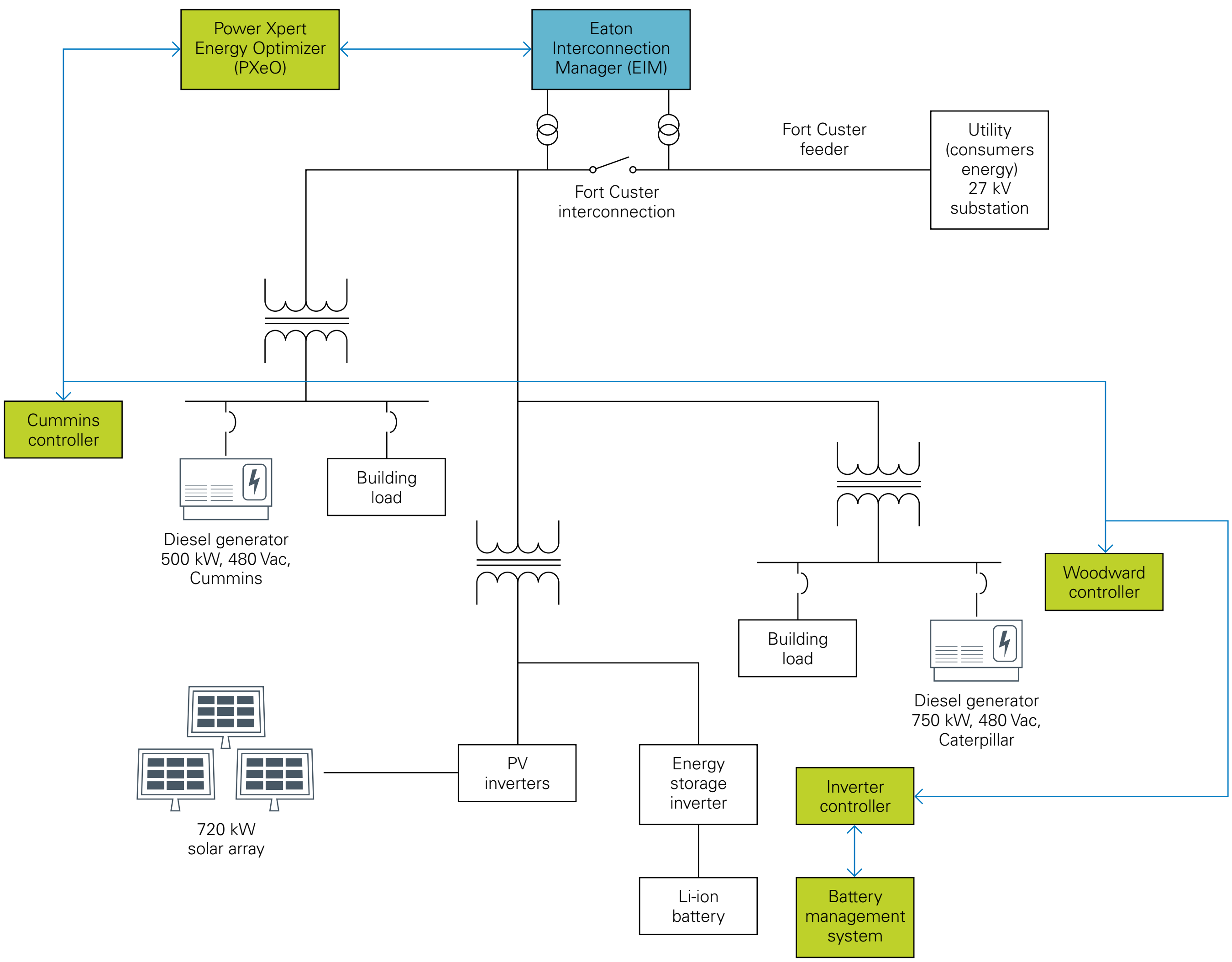
The microgrid solution required the management of a mix of geographically distributed energy resources across the facility. To build this microgrid, advanced control system expertise was required to integrate an existing solar photovoltaic (PV) plant, new energy storage assets and existing backup diesel generators for grid-connected operation.

The project team needed to establish these intelligent controls to create a centrally managed dispatchable generation hub that would serve as the power base for networked and utility feeder connected facilities. Fort Custer could operate this hub as a microgrid for managing diesel-based energy generation, renewable generation, demand and battery storage assets for power export.

Grid connection of the microgrid required extensive interaction with the region's utility provider and regulatory officials, as well as the development of new energy export approaches, policies and procedures. To demonstrate improved economic feasibility, the team developed the microgrid by maximizing existing assets.

Once the design and installation phases were complete, the project team demonstrated functionality and achievement of defined project parameters, including:

- Intentional islanding of microgrid from utility on base energy manager command
- Reliable power quality and ramp rate control for PV power transitions with support from energy storage
- Validation of high-penetration PV and control of PV power ramp rate for generator stability
- Controlled export of power to utility feeder for cost-effective generation for regulated energy markets, or to generate revenue through ancillary services in deregulated energy market



Project planning

Many questions can arise while exploring microgrid sizing and design options. No one size solution can fit all circumstances; rather, to understand each specific context, many factors must be explored, including the existing electrical infrastructure and generation assets, load profile and expected growth, utility rates, existing generation assets, and generator control capabilities.

The Fort Custer microgrid project involved integrating separately located energy assets from different manufacturers, with individual asset-level control requirements, to operate in a coordinated manner to establish a dispatchable microgrid. A primary challenge included how to design the microgrid around existing energy-resiliency assets, as extensive effort was required to modify existing backup diesel generators for dispatchable and grid-parallel operation. Additionally, interconnection between the utility and the microgrid system required hardware additions such as modifications to existing distributed energy resource assets for grid-connected operation and control.

The complete solution, including control elements, was built and tested in a virtual microgrid ahead of the installation. This virtual environment allowed the team to operate the system at the factory prior to the deployment phase, reducing costly and time-consuming commissioning and field changes, which only required controller fine-tuning.

Virtual microgrids, or hardware-in-the-loop simulations of complex microgrid systems, enable owners and project designers to understand the system as if the assets and devices were already connected. This demonstration informs how the system is configured and optimized during the design phase. The ability to adjust individual elements of the microgrid system before it is in place helps drive a better understanding of the system dynamics and feasibility—all based on data from the simulation. A virtual microgrid also gives owners confidence that the system will perform as expected, while providing the data needed to modify the design to optimize performance.

Insights from a virtual microgrid can be configured to specific requirements and application considerations, enabling pre-engineering and system configuration and optimization to save time (and money). Today, the microgrid controller can be pre-configured and mapped based on the feasibility study and virtual microgrid simulation to help avoid project delays and save time during the installation and commissioning phase.

For example, all distributed energy resources (DERs) were incorporated into the virtual microgrid design for Fort Custer. By including all of the individual microgrid components, including generators, solar PV, energy storage and inverters along with control input/output points, the approach considerably reduced field commissioning complexity and time—as the controller configuration and software was already validated in a simulation environment.

Accurate simulation results lead to more precise planning and management of the microgrid system, including its distributed generation and distributed energy resources. This allows projects to move more quickly and successfully, with confidence that they are optimized out of the gate.

The virtual modeling and simulations also provide Fort Custer with additional value for future facility operations. The effects of microgrid system expansion can be accurately modeled to determine the impact on standalone and grid parallel operation. Also, any new DER resources to be added at the facility can be modeled, allowing tuning and testing of the control algorithms prior to commissioning.

System design

The custom microgrid architecture consists of scalable commercial-off-the-shelf controllers, protection relays and switchgear suitable for grid interconnection and automation. The modular design was implemented using industry-leading substation and energy automation solutions that could efficiently be scaled to meet a wide range of applications, and adapt to evolving generation and load assets.

To improve economic viability, the system was engineered around existing generation resources with minimal energy storage investments. The project team utilized a legacy 1.25-megawatt diesel generator and 600 kilowatts of existing solar PV alongside traditional grid connection as the primary sources of incoming power.

A Battery Energy Storage System (BESS) was added to support the renewables and replacement switchgear to enable full substation automation. The application of scalable energy storage was intended to provide the advantages of microgrid stability and maximize renewable sources without the prohibitive cost of utility scale storage.

Replacing the manual switches at the point of utility interconnection with microgrid islanding controls and protection switchgear allows disconnecting of the microgrid from the 27-kilovolt utility feeder. This equipment can now support advanced energy automation capabilities. While grid-connected, the control performs balancing of the generation and load to ensure adequate export power availability, with an additional capacity margin for safety and stability.

Typical backup generators have limited protection and switching hardware and are not suitable for paralleling with the grid. Upgrades were made to the generator controllers and switchgear to ensure safe and reliable power export. The upgraded controls allow isochronous and base-load operations as well as load sharing by the generator. The controls also support a "fall-back" automatic transfer switch mode that allows the generator to support local electrical load when disconnected from the base distribution system.

Eaton applied its modular Microgrid Energy System control architecture to help Fort Custer easily adjust system performance to adapt to evolving generation and load assets. The platform includes repeatable generation module templates, pre-format load options, a suite of pre-engineered optimization strategies, standard displays and reports, and scale templates to help expedite the process of building a microgrid from the ground up.

At the core of the architecture is Eaton's Power Xpert® Energy Optimizer microgrid controller with advanced control algorithms to support system stability, shave peak demand, shift load and manage black starts. With this microgrid controller in place, the Fort Custer microgrid is able to automate renewable energy contribution, utility demand response functionality and proactive management of generation assets to maximize microgrid performance.

Further, the over-the-fence connection of the microgrid required extensive interaction with Consumers Energy to resolve right-of-way concerns. Compliance with interconnection, parallel operation and other regulatory requirements was fully demonstrated.

Testing and results

The customized microgrid infrastructure designed for Fort Custer has created a modular and scalable solution that can be applied to at least 100 sites throughout the United States where military bases are closely located. The ability to seamlessly island, control the demand to a set point, and even export excess energy onto the utility grid to support other loads on the regional distribution system can be used by the neighboring federal facilities or Consumers Energy to optimize grid stability and reliability.

The model also shows how utilizing existing backup power infrastructure to build a customized microgrid can dramatically reduce the cost to implement energy surety goals. A key accomplishment of the project was adding grid-connection support alongside advanced automation and control features to legacy diesel generator, solar PV and battery storage assets to maximize economic viability. During grid outages, the solar PV system is supported by energy storage to regulate local demand and even enable Fort Custer to support closely sited facilities. This over-the-fence powering capability can also help reduce the investment required for neighboring facilities to support mission-critical energy resiliency initiatives.

Further, the implementation of Eaton's microgrid control architecture allows military facilities with microgrid installations to participate in ancillary services while meeting their energy security needs. Microgrid operation was demonstrated in different modes using the developed control framework, including: islanded mode illustrating resiliency, grid-parallel mode (non-export mode) illustrating demand management and grid-parallel export mode for participating in ancillary functions. The demonstration involved a continuous 48 hours of islanded operation as well as 4 hours of grid-parallel operation of the military base with active management of the on-site resources to perform different functions.

1 Isochronous
2 Grid-following

Islanded operation

Generator 1 is operated as the isochronous generator while Generator 2 runs in the grid-following mode. PV output is dictated by its MPPT controls, and energy storage is primarily responsible for mitigating fast PV ramps. This demonstrates a reliable control framework and upgrades.

1 Grid-following
2 Grid-following

Grid-parallel operation

Both generators are operated in the grid-following mode. The dispatch settings of the generators are optimized for different scenarios, such as net zero export and demand response. The set points of the individual generators within the microgrid are also managed internally to utilize better fuel economy of different generator operations, without affecting the net export to the utility.

Demand response and ancillary services

Because of grid-parallel operation capability, Fort Custer can sell energy through an aggregator into the real-time and operating reserve markets and the developing demand response market. The value of the exported energy will be determined based on the $/MWh to monetize the available generation capacity from Fort Custer.

Further, the fully automated system is able to effectively ramp down power in 60 seconds when PV production is reduced during events such as intermittent cloud cover. For safe and reliable operation, the system has achieved compliance with IEEE® 1547 and ANSI C84.1 standards. The system also complies with MSPC R460.601–R460.656 for reliable grid connection and meets local interconnection agreements.

Key findings and project conclusion

Project findings prove the demonstration is able to effectively enhance power surety, energy resilience, distributed generation management and demand response, while contributing to the critical power needs of nearby military installations.

Research will continue to fully analyze the full monetization potential for exported power and return on investment for upgraded controls and substation automation components. One important consideration for future replication at similar sites includes compliance with regional environmental regulations. For example, the state of Michigan allows operating backup generators for extended duration. However, this extended operational time for diesel generators will be an issue for this technology implementation in other states with stricter EPA regulations. This may require larger renewables and battery capacity.

An additional challenge for future applications involves the depth of communication and coordination required between grid operators and microgrid operators, especially in the context of power export to nearby facilities and ownership of infrastructure and equipment. If nearby microgrid facilities coordinate with each other, they must keep in mind the electrical infrastructure separating their facilities is generally owned by the local utility, which will seek to mitigate risk to its own equipment. Eaton recommends the application of equipment protection measures such as fault detection and surge protective devices to help in this regard.

With a proven history of power system excellence, Eaton understands that each microgrid needs to precisely match and meet the goals of a specific project. Understanding the entire system and how all the microgrid components work together delivers a powerful advantage, especially when coupled with data-driven insights.

Eaton continues to invest time and resources to experiment with microgrid operations, with the goal of better understanding the unique feasibility, dynamics and requirements of each customer. Eaton has invested in a full-scale operational microgrid at its Power Systems Experience Center in Pittsburgh. Visitors can see an operational microgrid system and its testing laboratory, with access to a controlled environment that allows direct observation of microgrid performance, testing, demonstrations and training. Through this laboratory and an ongoing commitment to project success, Eaton provides an experienced partner that is dedicated to making microgrids work, with successful deployment of systems that meet and go beyond specific needs.

For more information, please visit
Eaton.com/microgrid

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