U.S. DEPARTMENT OF
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Office of
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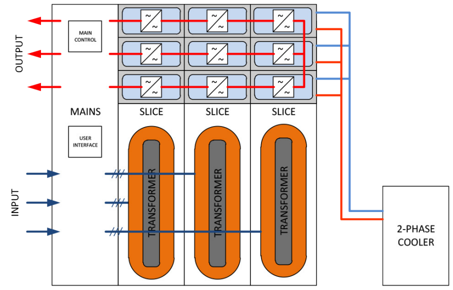
RENEWABLE ENERGY



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Left: Schematic view of an existing TECO-Westinghouse VersaBridge power converter module system with cabinet that houses the mains controller and three slice cabinets; each cabinet includes three power cubes, an isolation transformer , and slice controllers for the output and active front end controls. Right: A physical installation of a VersaBridge system. *Photo credit TECO-Westinghouse Motor Company.*

High Speed Medium Voltage CHP System with Advanced Grid Support

Combined heat and power (CHP) systems provide both electricity and heat for their host facilities. CHP systems have mostly saturated the large industrial facility market, where economies of scale and the required presence of technical staff make the deployment of large systems (greater than 20 MW electrical capacity) cost effective and practical. There remains, however, substantial room for growth of smaller CHP systems suited for small and mid-size manufacturing facilities.

In addition to manufacturing facility energy and cost benefits, the needs of the modern electric grid are also emerging as key drivers for further deployment of CHP systems. As intermittent renewable generation resources constitute a growing and increasingly significant portion of electricity generation, the need for dispatchable generation (i.e., sources of electricity that can be used on demand at the request of power grid operators, according to market needs) to maintain the stability of the grid grows. Many small and mid-size manufacturing facilities would be ideal hosts for flexible CHP systems that can provide needed grid services, while also providing an additional income stream for the facilities.

However, in order for CHP systems to seamlessly integrate with the grid and provide more advanced grid services, further technical development is needed. In particular, the current state-of-the-art in medium voltage, multi-megawatt power electronic systems does not support advanced grid functions. The development of advanced controls is needed for these CHP systems to be cost effective and able to respond to rapidly changing grid conditions.

This project aims to address this challenge by developing an innovative controls system that improves the grid integration of gas turbine-based CHP systems in the power range of 1 to 20 MW. These advanced controls will support the most stringent reliability requirements for manufacturing facilities, meet grid integration requirements through advanced grid support functions, and reduce overall interconnection challenges by decoupling the system from the grid. The project will also integrate advanced wide bandgap technology utilizing silicon carbide (SiC) materials into power converter modules to improve the system's power density and power quality for high speed applications.

Benefits for Our Industry and Our Nation

This technology is expected to provide increased reliability and efficiencies to small and mid-sized manufacturing plants by enabling facility microgrid operations that can buffer the impacts of severe weather events. The technology can also result in increased energy efficiency by operating the plant's CHP system at the optimum speed for the required power output.

In addition, having such flexible CHP systems could not only provide significant financial benefits to host facilities, but also to the grid system operator and all ratepayers. According to a 2018 manufacturing sector analysis conducted for the U.S. Department of Energy, widespread deployment of flexible CHP systems that are able to provide grid services could result in annual financial benefits of approximately $1.4 billion in the state of California alone. These savings consist of reduced energy bills for industrial facilities, reduced grid operating costs, and increased generation capacity of the new electric generators (alleviating the need to construct new centralized power plants).

Applications in Our Nation's Industry

Flexible CHP systems that can provide grid services are expected to be financially attractive investments in markets with high penetration of intermittent renewable resources, such as California, Texas, and several Midwestern states. This CHP system is expected to be suitable for both new and retrofit CHP applications in the power range of 1 to 20 MW, which is appropriate for many small and mid-size manufacturing facilities with both electrical and thermal loads. CHP technology is broadly applicable across a variety of industrial sectors, including the chemicals, food and beverage, plastics, and fabricated metals industries.

Project Description

The project goal is to develop and test a modular control system architecture to enable flexible CHP systems with advanced grid support functionality. The distributed control system architecture will enable facilities to more effectively utilize innovative power electronics equipment and controls to seamlessly interconnect CHP systems with the power grid. Additionally, the modular nature of the power converter will support voltage and power escalation without major system changes or deployment time reduction, and facilitate lower cost generation into the grid.

The high-efficiency SiC-based control system will be designed to integrate with gas turbine generation systems ranging from 1 to 20 MW of power production capacity. The system will comply with the Institute of Electrical and Electronics Engineers (IEEE) P1547 standard for interconnecting distributed resources with electric power systems, as well as the IEEE P2030.7 standard for the specification of microgrid controllers. At the end of the project, the system is also expected to be ready for UL certification.

Barriers

- Ensuring system stability in response to dynamic conditions in voltage, frequency ride-through, load rejection, and faulted conditions
- Demonstrating island mode transitions and resynchronization for reconnection with the grid
- Meeting system performance requirements to support advanced grid functions while keeping system costs in check

Pathways

This project consists of three phases. In the first phase, team members will initiate the design, implementation, and validation of the advanced grid controls system and the advanced generator controls. In the second phase, team members will complete the design, implementation, and validation of the advanced grid controls and advanced generator controls. The high-speed machine and gas turbine dynamics will be coupled with the advanced grid control and microgrid requirements.

In the final phase, team members will complete power hardware-in-the-loop (PHIL) testing of the fully coupled system and provide the path forward for certification testing of the technology.

Milestones

This three-year project began in late 2018:

- CHP generation converter algorithms completed and source code version for grid-tied CHP generation converter ready for validation (2019)
- Machine side control modifications complete and the source code ready to be implemented on the controller hardware-in-the-loop (CHIL) system (2019)
- Active power and reactive power set point control demonstration in the CHIL setup (2020)
- Power set points and ramp rate controls of the fully coupled system demonstrated in the CHIL setup (2020)
- Supervisory control and data acquisition (SCADA) interface controller demonstration to handle planned and unplanned transitions of the system into microgrid mode and successful reconnection into grid-connected mode (2020)
- Prototype set points and ramp rate controls of the fully coupled system prototype system (2021)
- Prototype voltage and frequency ride-through and load rejection scenarios demonstrated; prototype island transitions and reconnection with the grid demonstrated (2021)

Technology Transition

This project aims to develop a CHP product with reduced grid interconnection costs, greater system efficiencies, and increased operational flexibility. Upon successful development, this gas turbine-based technology would be an advancement over existing technology by implementing advanced grid support functions—including grid interactive controls and managing the gas turbine dynamics in ride-through scenarios through advanced control of the electric generator. Successful development may help increase the installed operating base of power electronic coupled CHP systems in the 1–20 MW range. Upon project completion, team members will look to engage potential customers to install the developed CHP system and validate performance in commercial applications.

Project Partners

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