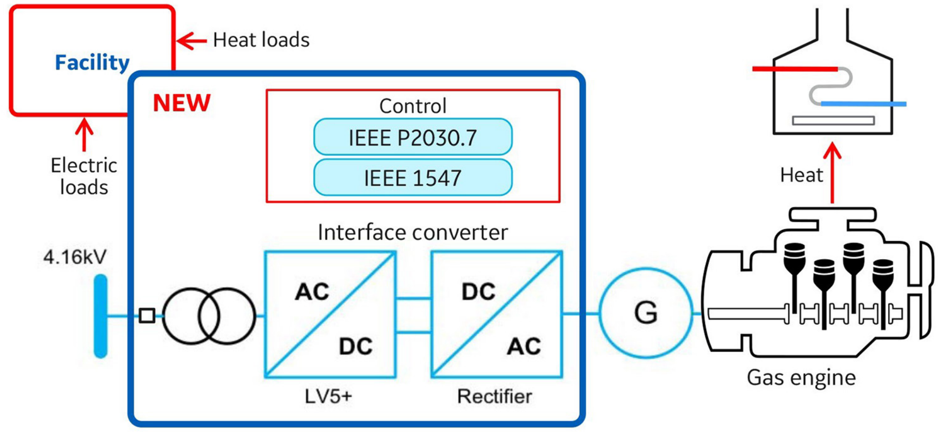
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Converter-Interfaced CHP Plant for Improved Grid Integration, Flexibility, and Resiliency



A schematic detailing the key technologies being developed: A converter-interface consisting of a rectifier and grid-ready inverter with an integrated controller.
Graphic image courtesy of GE Research.

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 megawatt (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 development of advanced power electronics and controls for flexible CHP systems is needed to meet grid interface standards and for the systems to have the ability to respond to rapidly changing grid conditions, while also achieving high resiliency and low cost.

This project seeks to address the challenge by developing a grid-interface converter and control system to interconnect small and medium-size CHP engines to the utility distribution grid. The system will comply with all grid interconnection standard requirements and be able to provide advanced grid support services while enhancing engine capability and efficiency

Benefits for Our Industry and Our Nation

The technology being developed is expected to increase the economic benefits of CHP systems for small and mid-sized manufacturing plants by enabling the systems to provide valuable advanced grid services, such as additional generating capacity during times of peak demand, frequency regulation, and voltage support. One of the important aspects of the proposed converter-interface solution is that it decouples the engine from the grid. This decoupling enables the size of the engine and its power output to be optimized because the engine can be run in an asynchronous mode and at a power factor close to unity regardless of grid conditions. It also helps improve engine efficiency and makes staging of multiple engines simpler.

In addition, having such flexible CHP systems could provide significant financial benefits not only 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.

CHP applications in the 1-20 MW size range are appropriate for many small and mid-size manufacturing and commercial facilities with both electrical and thermal loads. CHP technology is broadly applicable across a variety of industrial sectors, including chemicals, food and beverage, plastics, and fabricated metals industries, and different public and commercial sector buildings, such as hospitals, colleges, military bases, and municipal service facilities.

Project Description

The project goal is to develop a grid-interface converter and a control system to interconnect small and medium-size CHP engines to the utility distribution grid. The technology will be based on an AC-to-AC converter that will serve as an interface between the engine generator and the grid. The AC/AC "box" will consist of a rectifier connected to the engine output and an inverter connected on the grid side. The controller will meet all interconnection requirements, including Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 and P2030.7, as well as the specifications of the grid operator.

The converter will enable coordination among the inverter, engine, generator, and grid to optimally dispatch reactive and active power both in grid-tie and islanding modes. It will simplify the provision of grid support services with minimal impact on site operations and automatically connect and disconnect the CHP system from the grid. Such advanced control technologies are not currently available in the market. Another significant benefit of the technology is the ability of the converter to decouple the CHP system from the grid. This not only allows the engine to be operated at a frequency different from the grid but also the power factor at its terminals to be close to unity, removing the need to size the generator for reactive power provision, as is being done today.

Barriers

- Complexity of integrating controls of the reciprocating engine, inverter, and plant controller
- Comprehensive modeling of reciprocating engines, grid scenarios, and facility loads to evaluate system performance compared to conventional directly-coupled systems
- Ability of the system to take into account and integrate numerous grid code requirements, energy market dynamics, and other economic factors

Pathways

This project consists of two phases. In the first phase, the project team will confirm both the technical and economic benefits of a converter-interfaced CHP system compared to a directly-coupled system. To aid in this analysis, several use case scenarios and associated load profiles will be analyzed. To test the performance of the converter-interface system, a hardware-in-the-loop (HIL) simulation platform will be built around the actual inverter controller and a microgrid controller. HIL simulations will be conducted to validate the control algorithms and ensure compliance with IEEE 1547 and utility interconnection standards. In order for the project to move on to the second phase, the projected return on investment needs to be better than in directly-coupled systems and greater than 15% for at least one of the use case scenarios.

In the second phase, the performance of the converter-interfaced CHP system will be validated. A power hardware in the loop (PHIL) testbed will be built. A grid-ready inverter will be procured and installed, and inverter controls will be integrated with the microgrid controller. PHIL tests and simulations of the CHP system will be used to confirm compliance with IEEE 1547 and P2030.7 standards, including the CHP system's ability to successfully disconnect from the grid and reconnect, as well as its ability to successfully island and resynchronize.

Milestones

This two-year project began in late 2018:

- Evaluation of the technical merit and return on investment for converter-interfaced CHP systems as compared to directly-coupled CHP systems (2019)
- Development of electrical and heat load profiles for the demonstration site (2019)
- Validation of control algorithms through HIL simulations (2019)
- Controls integration and full operation of the inverter and microgrid controller (2020)
- Validation of the ability of the CHP system to successfully disconnect from the grid and reconnect (2020)

Technology Transition

The technology being developed simplifies the grid interconnection process and enables the performance optimization of CHP systems and capture of additional revenue streams from advanced grid support services, increasing the return on investment and profitability of CHP systems. Improved project economics and the plug-and-play approach offered by the converter-interface solution are expected to lead to increased market penetration of CHP systems in the 1-20 MW capacity range. GE Renewable has a strong presence and existing customer base in the power generation equipment market. Once the technology has been successfully developed and validated, the interface converter fits well into GE Renewable's product line-up and can be effectively marketed to both existing and new customers.

Project Partners

GE Research
Niskayuna, NY
Principal Investigator: Ibrahima Ndiaye
Email: *ndiaye@ge.com*

GE Renewable
Schenectady, NY

National Grid
Syracuse, NY

For additional information, please contact

Bob Gemmer
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5885
Email: *Bob.Gemmer@ee.doe.gov*

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/amo

DOE/EE-1913 · June 2019