U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

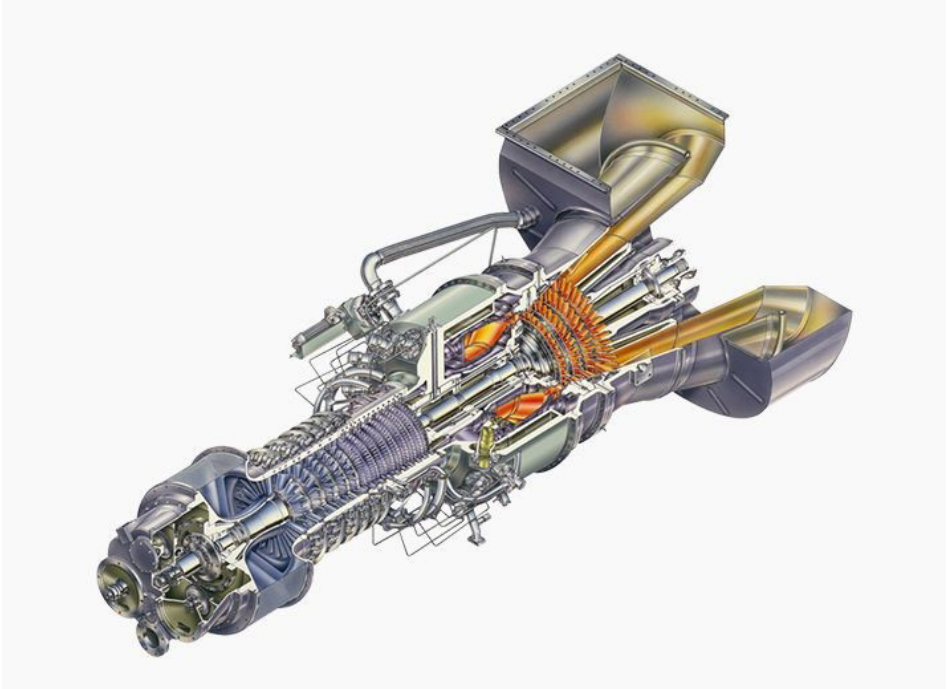
Gas Turbine Combustion System for Efficient, High Turndown Operation

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 presence of needed 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 benefits, the needs of the modern electric grid are other potential 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 resources 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.

In order for CHP systems to be seamlessly integrated with the grid and provide more advanced grid services, further technical development is needed. For such CHP systems to be cost-effective and able to respond to changing grid conditions, they must be able to maintain high system efficiency at partial load conditions and have the ability to ramp up or down quickly.

This project seeks to develop new combustion system solutions and technologies that will enable a gas turbine to maintain high efficiency and low emissions during high turndown operation. New combustion system innovations and modifications to the existing combustion system in a 17.5 MW existing gas turbine will be explored. The technologies developed will be applicable to a whole lineup of turbines from 1 MW to 20 MW in electric generating capacity.



The project will develop a new combustion system for a 17.5 MW gas turbine, Solar Titan 130, with the goal of enabling the turbine to sustain combustion and avoid lean blowout during high turndown operation. *Photo credit Solar Turbines Incorporated.*

Benefits for Our Industry and Our Nation

Because of the projected high system efficiency at part load conditions and the ability of the gas turbine to ramp up or down quickly, the new gas turbine technology would contribute to the development of flexible CHP systems that could be used to provide needed grid services, such as additional generating capacity during times of peak demand and voltage regulation. Having such highly efficient flexible CHP systems could not only provide significant financial benefits to the host facility, 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 lower industrial site energy costs, reduced grid operating costs, and capacity value of the new electric generators.

Applications in Our Nation's Industry

A CHP system consisting of a gas turbine that can maintain high efficiency and low emissions at part load conditions will be suitable for many small and mid-size manufacturing facilities with both electrical and thermal loads. The high efficiency of the gas turbine and its ability to ramp up quickly to provide needed grid services will improve the business case for the installation of CHP systems in the 1-20 MW size range.

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.

Project Description

Many gas turbines use dry low emission (DLE) combustion systems, which rely on lean premixed combustion to reduce the flame temperature and emissions of nitrogen oxide (NO_x) and carbon monoxide (CO). While operation of many gas turbines at less than 50% of rated capacity is possible, the methods used to reduce the amount of air entering the combustor result in significant efficiency penalties for the turbine. The project team will explore different options to develop a combustion system that will allow for efficient part load operation of the turbine while maintaining low NO_x and CO emissions. Increasing the efficiency of the turbine at part load conditions and expanding the lean operating envelope of the turbine to 30%-40% of rated capacity will significantly enhance the ability of a gas turbine driven CHP system to provide advanced grid services.

Barriers

- Maintaining high efficiency while producing low NO_x emissions at part load conditions
- Integrating new controls and other system components with the existing gas turbine configuration
- Need for autonomous operation and minimal maintenance due to lack of dedicated personnel at targeted host facilities

Pathways

The objective is to develop a low-emission combustion system that is capable of sustaining combustion and avoiding lean blowout during part load operation. In order to develop the new combustion system, the project team will explore modifications to an existing DLE combustion system in a 17.5 MW gas turbine as well as new low-NO_x combustion system concepts and components.

The project team will research potential methods for modifying the air and fuel flow into the combustor to improve the part load performance of the turbine. The most promising approaches will be identified and selected for performance evaluation in a test rig. Based on the initial test results, a design for the new combustion system will be finalized. The new combustor will be manufactured and its performance validated in rig tests.

To ensure that the developed new gas turbine combustion system and resulting flexible CHP system meets customer needs and can maximize the financial benefits from participation in electricity markets, the project team will conduct an assessment of interconnection, operating, metering, and direct telemetry requirements for small CHP systems in the California Independent System Operator (CAISO) territory.

Milestones

This three-year project began in late 2018.

- Identification and down selection of most promising method(s) to modify the existing combustor to improve part load performance (2019)
- Study on interconnection and direct telemetry requirements for connecting a smaller scale gas turbine-based CHP system to the grid (2019)
- Detailed design of a new modified DLE combustion system (2020)
- Fabrication and rig testing of the new DLE combustion system (2021)

Technology Transition

The rapid growth of intermittent resources on the grid, such as solar and wind, is creating increased demand for distributed dispatchable generating units. Small and mid-size CHP units located at end user facilities are well suited to provide local support to the grid because they can ramp up from part load to full load much faster than larger generating units. Solar Turbines, an established manufacturer of small and medium-size gas turbines, is in a good position to take new technologies developed in this project to the market. Among the main markets for the company's turbines and CHP units are universities, process industries, and other industrial facilities with both electrical and thermal loads. If the new technologies are successfully demonstrated, Solar Turbines will incorporate them into its 1-20 MW gas turbine lineup and market to potential customers through its existing sales network. The new combustion systems can also be offered to existing customers during a major maintenance overhaul of a turbine. The new technologies are not expected to result in a significant price increase for the turbines, which will aid market penetration efforts.

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DOE/EE-1915 · April 2019