High Efficiency Microturbine with Integral Heat Recovery

Improving the Operating Efficiency of Microturbine-Based Distributed Generation at an Affordable Price

This project developed a clean, cost-effective 370 kilowatt (kW) microturbine with 42% net electrical efficiency and 85% total combined heat and power (CHP) efficiency.

Introduction

The U.S. economic market potential for distributed generation is significant. This market, however, remains mostly untapped in the commercial and small industrial buildings that are well suited for microturbines.

Gas turbines have many advantages, including high power density, light weight, clean emissions, fuel flexibility, low vibration, low maintenance, high reliability, and excellent durability. These power generation systems are frequently used for aviation, utility power, and remote oil and gas applications.

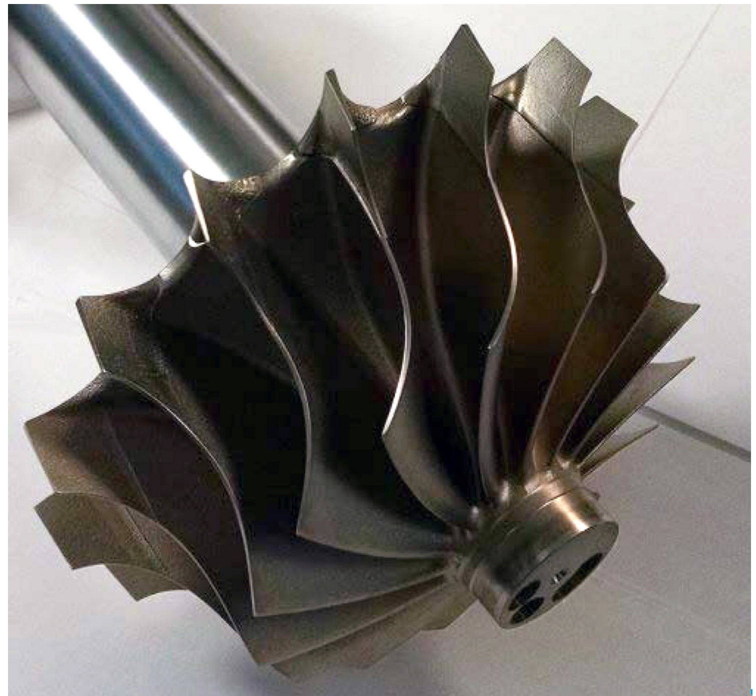
This project developed a 370 kW gas-fueled microturbine that would provide entry into additional markets because of its increased energy efficiency and reduced capital cost, which is estimated to be approximately $600 per kW. The microturbine technology maximizes usable exhaust energy and achieves ultra-low emissions levels.

The initial target for the C370 microturbine is the distributed generation market using existing fuel infrastructure, including fossil fuels, such as natural gas and diesel, as well as renewable fuels, such as landfill gas, digester gas, and syngas.

Benefits for Our Industry and Our Nation

The C370 CHP system will reduce U.S. industrial energy intensity, natural gas requirements, carbon intensity, and criteria pollutant emissions; provide more secure power; create jobs; maximize competitiveness of industry; and strengthen the economy. Potential benefits of a C370 CHP system include:

- Energy savings of 44% compared to a traditional system of separate electricity and thermal energy generation
- 59% reduction in carbon dioxide (CO_2) emissions compared to traditional system
- 95% reduction in nitrogen oxide (NO_x) emissions compared to traditional system
- Payback period of approximately 2.6 years, at an average electric price of $0.10 per kilowatt hour and average natural gas cost of $8.00 per MMBTU



A prototype of a bi-metallic turbine wheel for the C370. The design is based on the C65 turbine wheel, but the C370 requires a stronger material due to higher temperatures and speed.
Photo courtesy of Capstone Turbine Corporation

- Use of alternative fuels, including renewables and syngas, to reduce natural gas consumption

Applications in Our Nation's Industry

This project targets industrial, commercial, and government facilities that currently use the Capstone C200 (200 kW) microturbine or have the potential to employ the new C370. The C370 is not limited to small scale distributed generation using traditional fuels. Multiple C370 microturbines can be packaged into multi-megawatt systems for larger project sizes. Both dual fuel capability and uninterruptible power supply (UPS) functionality can be added in the future to increase reliability and energy security.

Project Description

The objective of this project was to demonstrate a microturbine-based distributed generation system with increased efficiency, reduced emissions, and improved customer value. The highest risk technical challenges were addressed early in the project and many components from current Capstone products were used to accelerate development.

The project used a modified Capstone C200 compressor and turbine assembly to act as the low-pressure section of a two-shaft turbine system. This resulted in an electrical output of 250 kW. A new high-temperature, high-pressure compressor and turbine acted as the second assembly. After an intercooler and the high-pressure assembly were added, the electrical output increased to 370 kW.

Barriers

- Developing a different design concept not currently used by microturbine manufacturers
- Developing new materials, such as ceramics or metal alloys, suitable for higher temperatures
- Designing a more compact and highly effective recuperator to operate at higher pressures
- Optimizing a new combustion chamber to operate at higher temperatures and pressures with reduced pollutants
- Testing the limits of air bearings for microturbine's increased output
- Developing control algorithms for multi-shaft microturbines
- Integrating a high-efficiency exhaust heat recovery system

Pathways

Capstone Turbine Corporation led this project. Oak Ridge National Laboratory (ORNL) and the NASA Glenn Research Center supported Capstone on specific project objectives. ORNL assisted with the high-pressure recuperator and high-temperature radial turbine materials. NASA Glenn evaluated a larger air bearing design for the high-speed generator.

The first phase of the project was to design and demonstrate the elements of the C370 CHP system that represented the greatest challenges of technical development. Capstone designed and integrated a low-pressure compressor and turbine system using a modified version of the C200; high-pressure, high-temperature compressor and turbine system; combustion system; intercooler; and high-pressure recuperator to create a two-shaft C370 engine.

Capstone then integrated heat recovery technology to complete the C370 CHP system. Integrated prototype system performance was estimated by utilizing a design cycle model.

Milestones

- Validation of technology and design
- Development of low pressure system
- Integration of low- and high-pressure systems
- Completion of C370 engine design
- Integration of heat recovery system
- Prototype testing and system performance modeling

Commercialization

The C200 was developed in part with support from the U.S. Department of Energy's Advanced Microturbine Systems program in the early 2000s. The 200 kW microturbine has a net electrical efficiency of 33%; this project proved that achieving 42% net electrical efficiency and 85% total system efficiency in a CHP application for the C370 is feasible. Such high efficiency combined with emissions levels that are below California Air Resources Board (CARB) requirements and competitive capital cost of $600 per kW is expected to make the C370 an attractive product in the marketplace.

Before entering the market, however, some remaining technical challenges—including durability of the bi-metallic turbine wheel and control system architecture for the high-speed system—need to be overcome. Once the product is ready for the market, Capstone will use its current distributor and original equipment manufacturer (OEM) business model to directly market the C370 microturbine CHP system.

Project Partners

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