Microturbine-boiler Integrations are Efficient and Practical Combined Heat and Power Solutions

Jay Johnson
Ingersoll Rand Energy Systems

ABSTRACT

An adequate thermal load is critical to a successful combined heat and power project. However, the integration of the waste heat stream from an on-site generator with a facility's existing steam or hot water system is often one of the more difficult and costly aspects of a project.

This brief article is intended to introduce the reader to the basic concept of integrating microturbines (small gas turbine generators in the 30 to 250 kW range) directly with existing building boilers, to achieve simple and highly efficient on-site generation systems.

The author discusses the direct use of microturbine exhaust in conventional industrial and commercial boilers. This type of thermal integration greatly simplifies the installation of an on-site generator with existing building systems, and provides the maximum possible utilization of the heat, in cases where a boiler is the primary source of thermal energy in the building.

BENEFITS OF USING MICROTURBINE EXHAUST AS BOILER COMBUSTION AIR

All gas turbine engines operate on very lean fuel-to-air ratios. Recuperated microturbines pass about 10 times as much combustion air as a traditional piston style engine of similar power output. This leaves the exhaust hot (typically 450ºF to 700ºF) and rich in oxygen (16% to 18% O_2). These conditions make the microturbine exhaust an excellent source of combustion air. The benefits of using microturbine exhaust as combustion air in a boiler are two-fold.

First, for every 35ºF to 40ºF degrees of combustion air temperature increase above ambient, there is a corresponding 1% increase in boiler efficiency. In other words, a typical boiler, which is 80% efficient when using 70ºF combustion air, can be boosted to between 90 and 92% efficiency when operating on 500ºF combustion air. Some high efficiency boilers can even reach greater than 95% efficiency when using 500ºF combustion air.

Second, using combustion air with slightly depleted oxygen content is an excellent approach to reducing the amount of NO_x (oxides of nitrogen) produced in a boiler. This practice typically takes the form of exhaust gas recirculation (EGR). In an EGR system, a portion of the boiler's exhaust gases are mixed back in with the combustion air to reduce O_2 levels, slowing the combustion process, and dramatically reducing NO_x production. With a microturbine integration, the same emissions benefits can be achieved, in addition to the efficiency enhancements stated above.

OPERATION AND ECONOMICS

The microturbine(s) should be installed within a reasonable distance (less than 50 ft) from the designated boiler. The boiler must be retrofitted with a special burner designed to accept the microturbine exhaust. Ductwork is provided to enable the burner to pull as much turbine exhaust as it requires for all potential operating conditions, and always allow the excess turbine exhaust to discharge out a stack to the atmosphere. It is also desirable to provide a means of introducing fresh air so the burner can operate when the microturbine(s) is shut down for routine maintenance.

During operation, the boiler's burner pulls from the turbine exhaust first, then from fresh air as required to support the heat load. By doing this, the system uses the maximum percentage of available thermal energy from the microturbine. Naturally, sites with boilers that can consume all or most of the exhaust produced by the microturbine have the best efficiency and strongest economics.

HISTORY OF BOILER INTEGRATION

This basic concept has been used for decades in multi-megawatt scale industrial projects. Commonly known as the topping cycle, it takes advantage of the fact that gas turbine exhaust is often hot enough to produce steam without any post firing at all. By adding additional heat to the exhaust, larger amounts of steam can be produced at very high efficiencies.

Traditionally, large turbines have been used for topping cycles, because they provided the best economies and highest efficiency. However as microturbine technology continues to improve, and society starts to demand higher building efficiencies, and place added value on the benefits of power security and ultra-low emissions, it is a natural progression to see the topping cycle be introduced for systems under 1 MW of electrical capacity. This brings the application into the range of medium sized industrial, and larger commercial and institutional facilities, some of which rely heavily on steam or hot water.

Microturbine topping cycle installations have been successful, but few in number. Gasunie Engineering & Technology (founded by N.V. Nederlandse Gasunie, one of the largest gas companies in Europe), has done significant testing and has started to demonstrate their "Burner-GenPack" in Europe.*

In the United States, the California Energy Commission has been funding some advanced integration work to build a microturbine directly into a burner; however this work is still in the development stages.

INGERSOLL RAND DEMONSTRATIONS

Ingersoll Rand, one of the world's leading microturbine manufacturers is currently working with New York State Energy Research and Development Authority (NYSERDA) to demonstrate this concept in a commercial building in New York City. The project is scheduled to go on line in late 2006.

This project will demonstrate:

- (2) 70-kW microturbines integrated with a single boiler
- A simplified installation with minimal impact on a historically significant building
- A dramatically reduced environmental footprint by significantly reduced boiler emissions and simultaneous generation of clean electricity for on-site use.

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*http://www.gasunierearch.nl/eng/news/archive/20021201.htm.

Upon successful launch of this demonstration, Ingersoll Rand has set aside funds to build, own and operate 20 larger demonstration projects in key areas of North America. The sites will be used to showcase the technology in each local market where current economic drivers make it a good investment. Ingersoll Rand will provide the companies who qualify with both the equipment and the complete installation.

The host companies will buy electricity and discounted thermal energy at a fixed price over the term of the contract (typically 5 to 10 years). The host companies will receive enhanced energy security as well as a reduced environmental footprint in exchange for agreeing to host the project, and will be able to see immediate bottom line energy savings as well.

ECONOMICS

Like most energy-saving measures, the microturbine-boiler integration is best suited for sites that meet certain key size and cost parameters. Most basic among these are:

Cost of electricity—the site should have a blended rate above $0.095/kW-hour, lower values can work if local governments provide incentives for self-generation or energy efficiency.

Thermal load—The boiler, which is to be integrated with the microturbine, should be operating year-round with a base-load greater than 8 million Btu per hour for each 100 kW of turbine capacity.

Electrical load—the site should have a year-round base-load electrical demand greater than the nominal rating of the proposed microturbine installation.

ABOUT THE AUTHOR

Jay Johnson is the solutions manager for Ingersoll Rand's Energy Systems business.

Jay has been part of the Ingersoll Rand microturbine group since 1996 when he joined the development team as its product manager. He can be reached at *Jay_Johnson@irco.com*.