Innovative On-site Integrated Energy System Tested

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Abstract

A prototype power plant could revolutionize on-site generation for businesses. The Department of Energy and Oak Ridge National Laboratory teamed with Austin Energy, a municipal utility, to develop this plant, called an integrated energy system. Burns & McDonnell developed, installed and is testing one of the largest systems in the nation to use a new technology approach: use the waste heat exhaust from a natural gas–fueled generator as the only fuel source for a chiller that provides air conditioning. Recycling waste heat to power another generator or to help run a chiller is not new. What is new is for a chiller of this size to be fueled by waste heat alone—without any supplemental fuel. The project's chiller, called an absorption chiller, is capable of delivering 2,500 tons of chilled water. By design, the full waste heat output of the natural gas-powered 4.5-MW Solar turbine closely matches the chiller capacity. Operation, which began in June 2004, should verify fuel efficiency of 70% to 80% against 55% efficiency for the best central power plant technology available today. Testing and verification of the skid-mounted design should lead to adoption of this system in commercial and institutional settings.

Recycling Waste Heat—a Key to Improving the Efficiency of Energy Supply

In an era of concerns over the ability to provide secure energy to developed countries and to expand energy supply to developing nations, implementation of technology that dramatically improves energy supply efficiency takes on a new urgency. One innovation cuts fuel use by more than half: on-site combined cooling heating and power technology. Heat produced during combustion of fuel used to generate electricity in centrally-located power plants is not recycled, resulting in 44-68% energy loss. High-voltage power transmission loses another 5-8% of the energy while transmission lines are difficult to site and maintain in both developed and developing countries. But when electricity is produced on-site, transmission lines are not needed and 'waste' heat can be captured for heating or cooling buildings. This paper describes a project which validated combined cooling heating and power technology by engineering, designing, installing and testing an Integrated Energy Systems (IES).

This first-of-a-kind system is creating interest in IES developed by the Department of Energy (DOE), Distributed Energy Program, through Oak Ridge National Laboratory (ORNL), in partnership with Burns & McDonnell and Austin Energy, a municipally owned utility (see Figure 1). In fact, the City of Austin's leadership and efforts to become the Clean Energy Capital of the World by implementing environmentally-friendly

Figure 1. Innovative Integrated Energy System creates interest in the engineering community and with the public.

projects factored into the selection of Austin as the site for this energy system. Burns & McDonnell engineered, designed and implemented this advanced IES project by teaming with Broad USA, Solar Turbines and Turbine Air Systems. The system provides power and cooling to a 1,200,000-ft^2 office, retail, industrial and residential space: The Domain. The Domain, in Northwest Austin, may add similar integrated energy systems in the future as the site fully develops.

Integrated Energy System—an Effective Equipment Configuration

Burns & McDonnell employed a modular system that integrates a 4.5-MW Solar turbine generator with an advanced waste heat-fired 2,500 ton Broad absorption chiller (see Figure 2). Electricity generated by the natural gas turbine is directed to Austin Energy's utility grid through an existing on-site substation for use at the Domain site or by other city facilities, depending on changing electric loads. With an aggregate electrical load of over 15-MW at the project site, the turbine is routinely base-loaded. The electrical output can be dispatched to provide grid support at the request of the Electric Reliability Council of Texas (ERCOT). While ERCOT does not exercise direct control over the operation or dispatch of the generator, Austin Energy can make the unit available for grid support during peak demand periods and to aid in transmission system congestion relief.

Inlet air to the natural gas turbine is cooled to improve electric efficiency using 200-300 tons of the system's chilling capacity. Heat from the ~900°F turbine exhaust is exchanged to evaporate water from a natural absorbent, lithium bromide. As the vapor condenses, chilled water is produced. This advanced double-effect chiller uses two stages of heat exchange to improve efficiency (see Figure 3).

System Replicability Promotes Technology Adoption

Burns & McDonnell Design Improves Replicability

This first-generation IES improved and standardized system design and constructability by developing skid-mounted modules (see Figure 4). Pre-fabricated skids include: natural gas compressor, turbine, turbine inlet air cooling, chiller, and chilled water pump. The modular design is adaptable to various capacity, space, and grid interconnection requirements. By thoughtfully considering equipment, electrical and piping layouts, the system was not only easier to construct, it will be easier to replicate.

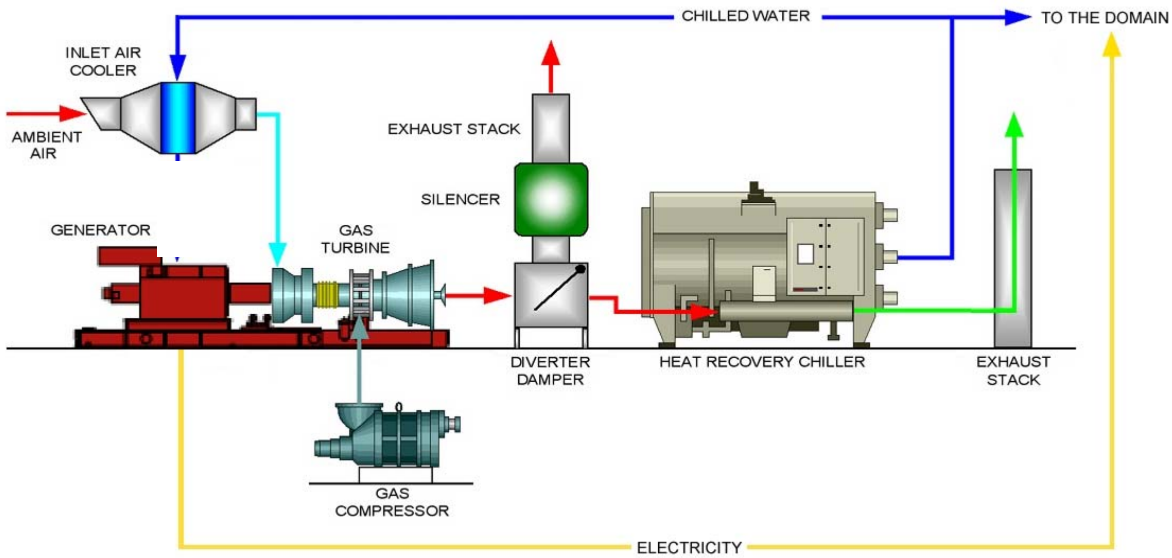

Figure 2. Integrated Energy System includes natural gas turbine and heat recovery chiller.

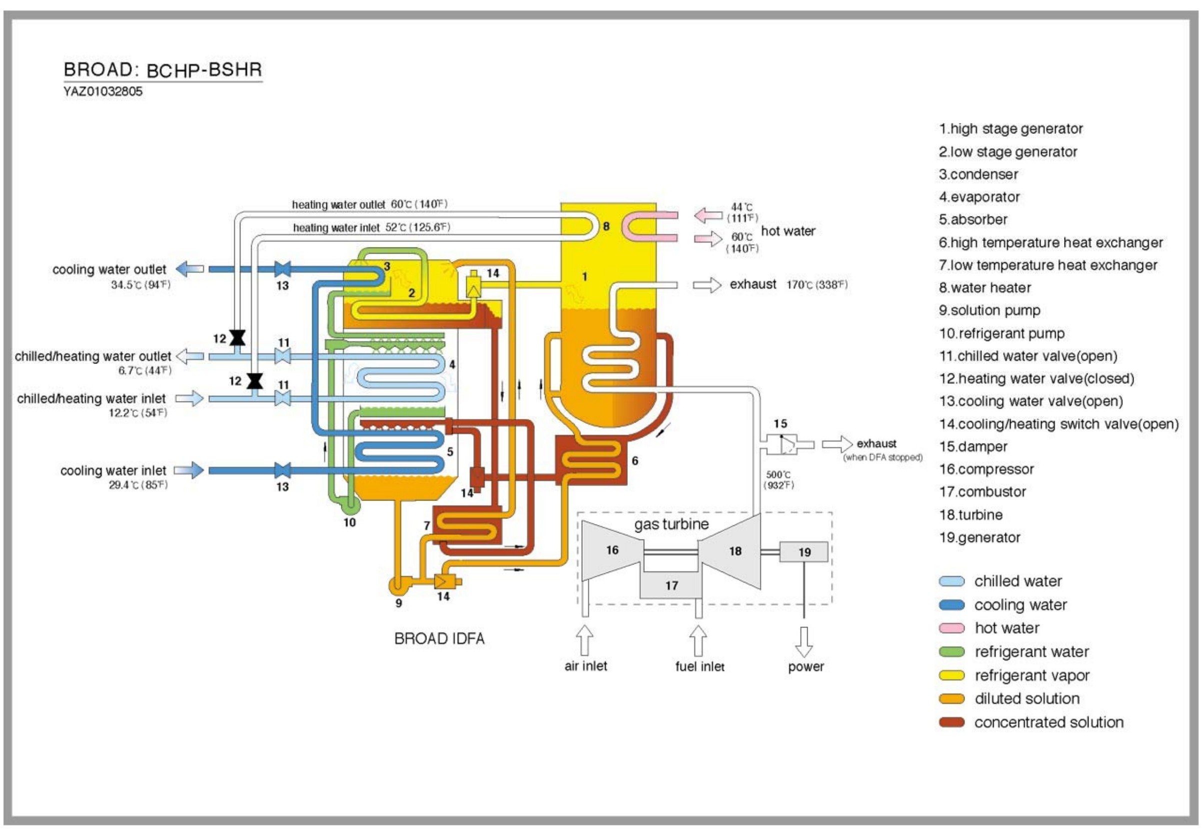

Figure 3. Double-effect absorption chiller uses heat from turbine exhaust to produce 2,500 tons of chilled water.

Figure 4. Skid-mounted equipment eases construction and replicability.

These five skids can be arranged for future installations to accommodate building structures at a specific site while maintaining features, which optimize system performance. The skid-mounted system could be dismantled and transported to another location mitigating difficult to quantify risks, such as changes in facility ownership or changes in site energy needs. These design features reduce uncertainty associated with making a capital investment in an innovative IES.

Field Data Provides Basis for System Replication

Data are being collected and analyzed to see how well the system performs in supplying energy and in reducing costs over a wide range of operating conditions. A thorough economic analysis was used to demonstrate that this on-site technology is commercially competitive even in a market where grid power is relatively inexpensive. Burns & McDonnell developed an economic analysis modeling tool and used the tool to analyze the commercial viability of this technology. The model can be used to assess system economics in a variety of applications across market sectors and in various locations. Based on a life-cycle-cost analysis method, this model calculates payback term, expense and revenue streams over the life of the project, as well as the net present value and investment rate of return under a variety of economic and technical conditions.

One principal finding of this economic modeling: it is critical to base-load the thermal component of an IES in order to maximize the revenue stream from sale of the thermal commodity (e.g., chilled water). In many markets, such as Texas, where grid-power cost is low relative to the cost of on-site generation, IES owners will only realize a return on their investment through full production and sale of the thermal commodity. An exception to this rule may be found in the case where a premium usage and/or demand rate can be charged for on-site generation. In other markets where grid power and traditional cooling methods are more expensive, the value of this type of on-site energy system is even more apparent.

In addition to the economic modeling, field data are being used to further develop an ORNL IES Design Model. This predictive tool provides a framework for analyzing system performance. Fundamental principals are used to model the performance of major system components with various capacities. Then components can be combined in varying configurations to predict system performance. This object-oriented model has been developed using a range of manufacturers' data and test results from ORNL's IES Integration Laboratory. This generic model will be further calibrated using the Austin Energy-Burns & McDonnell system data acquired during field tests at the Domain.

Output Based Emission Standards Demonstrated

Currently California and Texas are the only two U.S. states that have NO_x emission standards for on-site, distributed generation units. The Texas Commission on Environmental Quality developed a standard permit with output based standards to expedite the permit approval process for on-site generation. Output based standards allow the system owner to take credit for use of the thermal energy, because this off-sets use of centrally-generated electricity, using the following equation:

$$\text{EMISSION RATE} = \frac{\text{EMISSIONS}}{\text{THERMAL ENERGY + ELECTRIC ENERGY}}$$

The current east Texas standard for distributed generation units operating more than 300-hr/yr is 0.47-lb NO_x/MW-hr. This IES turbine-exhaust emission rate averages 0.42-lb NO_x/MW-hr. The output based standard calculation results in a permitted emission rate of 0.24 lb NO_x/MW-hr. The emission credit for this innovative IES is an important method to realize the value of highly-efficient use of clean natural gas fuel.

Conclusion

A public-private partnership developed, installed and is operating an innovative integrated energy system in Austin, Texas. DOE-DE Program, ORNL, Austin Energy and Burns & McDonnell are testing and collecting data on the benefits of on-site generation of electricity and chilled water. The project is rigorously analyzing performance, cost and emission data to verify the predicted benefits.

In addition to performance benefits, the pre-packaged design should promote replicability of the system in locations throughout the U.S. By improving the economic value of cooling produced solely from 'free' turbine exhaust using an absorption chiller, the project may encourage sites in warmer climates to benefit from secure energy supplied by on-site IES.