Microturbine Sessions 2003: A Review

by Debbie Haught, Microturbine Program Manager, Office of Distributed Energy, U.S. Department of Energy, Washington, D.C., USA

Abstract

Microturbines were once again a popular topic at ASME TURBO EXPO 2003, held last June in Atlanta, Georgia. Microturbines, small combustion turbines about the size of a refrigerator with outputs from 25 to 500 kW, are commercially available from five suppliers with other developers potentially entering the market. Microturbines and other distributed energy devices such as fuel cells and reciprocating engines supply local energy systems that generate electric, thermal or mechanical energy on or near customer sites. With microturbines, customers are reducing energy costs, avoiding power outages like the Northeast Blackout of 2003, reducing environmental impacts and meeting premium power needs. These customers include supermarkets, hotels, stores, industrial facilities, waste water treatment plants, schools and a whole host of others.

The three panel sessions hosted by the Microturbine & Small Turbomachinery Committee explored the status and advancements in microturbine technology and reviewed operating experiences in various applications. Microturbine developers discussed design and performance improvements in turbomachinery, combustion systems, and recuperators for current products. Development efforts for next generation high efficiency engines and integrated combined heat and power (CHP) packages were also presented. Representatives of users discussed the installation and operational experiences of microturbines in various applications in the United States and Canada. At the end of the meeting, the sentiment from the speakers and participants was that microturbines are a successful new technology on the verge of making significant penetration into the marketplace. Improvements are continuing to be made in the technology at the same time as more and more applications are being identified for microturbines and integrated microturbine based CHP packages. Public awareness of the technology continues to grow and this is fostering increased acceptance of microturbines and distributed generation. More detailed information about the 2003 sessions can be found on the web at: http://www.eere.energy.gov/der/turbo_expo_conf_03.html

Microturbine Users Panel

This session heard experiences from five speakers who discussed the various applications of microturbines. David Van Holde of Platts Research and Consulting kicked off the session with a summary of a multi-client study of early adopters of microturbines which included 52 in-depth interviews with microturbine users in Europe and North America. Key findings of the study concluded that microturbines are a successful new technology—though still a niche business. Early units had some reliability problems; but predicted microturbine life now seems likely based on later performance. He also pointed out that microturbines have a number of unique attributes compared to reciprocating engines. Highlighted successful applications of microturbine included: 1) Direct use of exhaust for green houses, combustion preheating, and drying for sludge, bricks, textile and polymer drying 2) Combined cooling, heating and power using double effect absorption chilling which takes advantage of co-incidence of electric and cooling loads in hot climates, 3) Biogas – using low methane fuel from landfills, anaerobic digesters and 4) Resource recovery at remote oil and gas sites. He concluded by indicating that microturbines have a future but are challenged to go beyond early adopters.

Vince McDonell from University of California Irvine (UCI) Advanced Power and Energy Program summarized microturbine installation and operational experience in the South Coast Air Quality Management District (SCAQMD) of California. The SCAQMD initiated a program in 2001 offering interested parties microturbine generators along with limited financial assistance for installation costs. As part of the project, UCI is monitoring and reporting the operational characteristics of the installed microturbines and in some limited cases, monitoring and reporting real time performance (e.g., efficiency, heat rate and emissions). Approximately 50 sites were initially chosen to go forward, with about 30% eventually backing out primarily due to cost reasons. As of the Atlanta meeting, approximately 20 sites were operational (at some level) with 11 sites operating reliably and consistently. The major issues encountered by the customers included – utility permitting, local building codes, air quality authority, installation issues such as cost and quality/schedule of installation, and challenges of getting management approval in light of uncertainty in future electric rates. Installations highlighted included combined heat and power (CHP) systems at a pharmaceutical R&D location, water reclamation plant operating on digester gas and a planned installation at a child care center. Additional information on the SCAQMD Microturbine Generator Program and monitoring data from the operational sites can be found at www.apep.uci.edu/aqmd.

Rob Brandon from the CANMET Energy Technology Center (CETC) in Ottawa Canada gave an overview of microturbine CHP experience in Canada. The vision of CETC's program is to assist in the development of a packaged microturbine CHP unit that can be installed by a Heating, Ventilating and Air Conditioning (HVAC) contractor with little or no consulting engineering requirement or putting it another way—A commercial boiler package that produces electricity. Mariah Energy, located in Calgary, Alberta has numerous microturbine CHP installations in Canada including ones at educational institutions, apartment complex, and at a greenhouse. Additionally, there are 25 microturbines in Western Canada oil field operating on flare gas, 20 of the units are operating on a 24/7 basis. CETC is also involved in research and development of thermally activated cooling technologies to use the waste heat from microturbines. They are working with commercial suppliers and also investigating technologies such as jet ejector, ammonia adsorption chillers, and intake air superchargers using evaporative cooling.

Bob James from National Energy Technology Laboratory discussed a project with the US Department of Agriculture (USDA) Agricultural Research Service (ARS) to design and operate a microturbine system that runs on methane biogas produced from animal manure. The animal waste is processed in an anaerobic digester to produce a biogas that contains methane which is captured and used in the microturbine generator. Many lessons learned from the project provided insights into the equipment selection, interconnection, gas handling and pre-treatment and operation.

Larry Golan from the South Carolina Institute for Energy Studies at Clemson University concluded the session with perspectives on using microturbines in a university setting to both reduce campus energy costs and provide educational and research opportunities. The campus can become a real-time laboratory of an actual distribution system.

Microturbine Equipment Panel

This session featured 6 speakers from microturbine researchers and developers who discussed design and performance improvements in turbomachinery, combustion systems, and recuperators for current microturbine products. Development efforts for next generation high efficiency engines and integrated combined heat and power (CHP) packages were also presented.

Dave Dewis from Elliott Energy Systems Inc. (EES) discussed product improvements which increased their microturbine electrical efficiency to 30% in conjunction with a 25% power output increase to 100 kW(net of gas boost compressor). In the combustion system, manufacturing process development has yielded significant improvements in flow consistency, while CFD and testing efforts have reduced emissions. Work on both outsourced recuperators and EES's annular recuperator have contributed to the efficiency gains and reduced cost. EES's new product is an integrated CHP package consisting of a 100kW microturbine in a low noise enclosure with an integrated heat recovery unit (HRU) and gas boost compressor. New initiatives also discussed were system integration with a direct fired absorption chiller and verification/validation testing using low BTU landfill gas.

Koichi Shinmura of Honda R&D Co gave a presentation on microturbine research at Honda. A microturbine system was designed to according to performance specifications of 42.2 kW with 26.7% efficiency (LHV) including parasitics and <2.5 ppm emissions. The presentation gave details of the design and performance of the major components including annular recuperator, two stage combustor (diffusion and premix) and air foil bearings.

Karl Sheldon from GE Global Research discussed research efforts to develop an Advanced Integrated Microturbine System (AIMS) under the Department of Energy Advanced Microturbine Program The objective of the AIMS program is to develop the next generation microturbine system that will advance the current generation system into a more efficient, cost effective, and environmentally friendly system. The resulting system will be designed such that it addresses both the current and emerging distributed generation markets. The 175 kW engine (with growth to 250+kW) is being designed to meet DOE program performance goals– 40% efficiency and single digit emissions. The conceptual design results and status of the major sub systems: turbomachinery, combustion, recuperators and control systems was presented. Lessons learned with experiences in core engine hardware procurement and prototype parts were shared. Testing of the microturbine system is expected to begin in early 2004.

Matt Stewart of Capstone Turbine gave an overview of the current applications of Capstone's 30 kW (C30) and 60 kW (C60) microturbine products. The design considerations, features, and benefits of the new integrated C60 CHP system with top mount heat recovery module were discussed. Capstone is also participating in the DOE Advanced Microturbine Program and gave an update on the status of the 200 kW (C200) unit. The C200 leverages experience from past microturbine development has a single shaft with annular recuperator and low emission combustion system, high speed air-cooled generator, single stage centrifugal compressor, single stage radial inflow turbine, air bearings, and IGBT-based power electronics. The first recuperated engine was tested at the end of 2002 with performance of the system on target including efficiency and emissions. The system expected performance is 34 -35 % net efficiency while meeting CA 2003 emission requirements. Commercial release is expected in 2004. The strategic business alliance between Capstone and United Technologies Corp (UTC) was also discussed. UTC Power will distribute Capstone products—leveraging UTC's experience in CHP and cooling. They will focus on integrated customer solutions including power and heat and chiller/heater (+ power) packages.

Jim Kesseli from Ingersoll-Rand Energy Systems discussed potential advancements in the IR 70 kW PowerWorks microturbine using a ceramic rotor. A moderate increase in rotor inlet temperature to 1000°C can take advantage of existing ceramic materials and manufacturing technology, yet still use metallic alloys for turbine housing and down stream component, including the recuperator. Design and analysis of the silicon nitride rotor for the microturbine was presented.

Dave Ainsworth of Bowman Power Systems Ltd finished the session with a status on evaluation and validation efforts on 8 different recuperator units and package integration with Bowman's microturbine engine. This included recuperator constructions such as: primary surface- annular, primary surface – box, plate and fin, and hybrid primary surface/plate and fin. The recuperators were evaluated for life, leak rate at expected pressure, effectiveness and pressure drop, and integration complexity. After completion of the testing program, a final decision on recuperators will be made weighing in commercial aspects such as supplier maturity, capital investment required and warranty costs.

Microturbine System Design Panel

The Microturbine System Design Panel was a new Session at IGTI, added this year based on feedback from previous conferences. The session was very well attended with a reasonable mix from industry, academia, original equipment manufacturers (OEM) and Users. The panelists covered a broad range of topics including advanced thermodynamic modeling, gas bearing development, recuperator testing R&D efforts and new product description.

Karl Sheldon from General Electric Global Research discussed exergy based microturbine cycle analysis. This included a comparison of design analysis between using first and second laws of thermodynamics. He concluded that second law analysis can provide greater insight into system losses than a first law analysis alone and can be a powerful tool to optimize thermal efficiency.

James Walton from Mohawk Innovative Technology Inc gave a summary of design and integration of oil-free bearings into mesoscopic to mini-turbine engines and generators. He described the design approach to foiling bearing technology for gas turbines ranging from speeds above 700,000 to 27,000 rpm and demonstrated good correlation between prediction and test results achieved.

Jim Kesseli from Ingersoll-Rand Energy Systems concluded the session with an overview of IR's new 250 kW microturbine. The microturbine design is "scaled down" from an existing IR 1.7MW single shaft engine (KG-2) and includes a radial turbine and compressor, cool-end bearings and drive, and combustor integral with recuperator. This design takes advantage of the proven history of the KG-2 over 30 years of 1000 units where one unit has 120,000 hours with a major overhaul. The expected performance of the unit is 32% target efficiency with single digit emissions at full load.