VOLVO AERO

Microturbines

2005-04-21
Rolf Gabrielsson, Volvo Aero Corporation
Section 2
# Operators on the microturbine market

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Capstone C60 Microturbine System

Microturbine Generator

Capstone C60 Microturbine System

Ref.: Capstone Product Datasheet
Capstone Turbine – Advanced Microturbine Program

DOE Funding: $10.0 M over 5 years

Partners: Kyocera, Honeywell Ceramic Components, ECI, Solar Turbines, ORNL, UCI, UCLA

Design concept for 100 – 200 kW microturbine with

- Single shaft powerhead / generator
- Air bearings
- Recuperated cycle
- Lean premix combustion
- High efficiency components, including ceramics

Turbec Microturbine

T100 installed in a boiler room
Turbec Microturbine

Ref.: Turbec datasheet, www.turbec.com
Turbec T100 CHP biogas package

Following on from their early success with T100 biogas installations, NewEnCo, the UK Turbec distributor, exhibited at the Chartered Institute of Waste Management annual conference and exhibition at Torbay in the second week in June 2003. The T100 attracted significant interest in this sector, primarily for landfill gas applications. The unit sets new standards for emissions from landfill gas generation and is promoted by NewEnCo as ‘best available technology’.
Bowman Microturbines

Features

The BPS systems offer the following standard and optional features:

- Recuperated or simple cycle Microturbo Generator
- Pre-engineered compact Package
- Gas fuel capability
- Alternative fuels: Diesel and Jet Fuel (Optional)
- Low emissions
- High operational flexibility allowing both 'Heat or Power demand following'
- Low acoustic noise level
- Low temperature hot water output (90 degrees C.)
- Capability to produce high pressure hot water
- Capability for steam production
- Power output with utility network interface for grid connection (Optional)
- Power output for standalone operation (Optional)
- Peak shaving and load following (Options)
- Remote control and monitoring (Options)
- Data logging (Options)

See Bowman Brochure PDF
See Bowman spec sheet PDF

Microturbine Engines

These very small high speed gas turbine engines are simple radial designs, closer in temperature extremes which together with their simplicity is conducive to low cost when produced in volume.

In comparison with reciprocating engines, they offer more mature engine technology, lower emissions and maintenance costs, making them the ideal engine choice for cogeneration and CHP systems.

Turbo Alternators

A conventional small gas turbine generator set consists of a high speed turbine (e.g. 30,000 rpm) driving an alternator, typically under a generator. However, the maximum speed achievable by conventional designs is limited. The electrical output achievable is not high enough to use the gas turbine drive for conventional applications. Consequently, if the electrical power required is to be supplied as a single stage, a two-stage configuration is needed. The electric power range for the turbo alternator technology is up to 1 MW. However, for certain applications it is assumed to be used below 100 kW and possibly up to 1 MW.

BPS first systems cover the range up to 1 MW, with a request for up to 10 MW.

See Turbo Alternator spec sheet PDF

Recuperators

This type of recuperator design is efficient and has a compact design. It increases the efficiency of the gas turbines in the hybrid system compared with conventional gas turbine designs. The recuperator is the heart of the recuperated gas turbine and thereby reduces the amount of fuel used in each operating scenario.

Power Conditioners

This unit is the key component in the hybrid system. It is designed by ABB and provides the interface to allow the BPS to operate in parallel with the utility supply (grid connected). It is a dual-oscillation, full-bridge, SCR type of synchronous alternator. The power conditioner is designed to integrate the gas turbine into the electrical power grid and to control the power flow from the generator to the grid. The output is a clean, constant frequency, constant voltage, and constant power supply that matches the grid requirements.

See Power Conditioner spec sheet PDF
ELLIOTT Microturbine

100 kW CHP Microturbine

Main Features:
- Rated Power Output: 100 kW (390 HP)
- Thermal: 105°C (221°F)
- Noise: 60 dB @ 10 m
- Electrical Data: 400 VAC 3-Phase, 50/60 Hz, 54-60VDC
- Standard Equipment:
  - Microturbine
  - 4-Fract Permanent Magnet Generator
  - Automatic Voltage Regulation
  - 24-48VDC Electrical System
  - Battery Charger
  - Single Stage Dry Type Air Filter
  - Corrosion Resistant Hardware
  - Digital LCD Display
  - System Protection including Under and Over Voltage
  - Under and Over Frequency
  - Over Current
  - Optional Outdoor Kit (NEMA 3R, IP 14)
  - Optional Stack Start
  - Integral Gas Compressor
  - UL Compliant
  - CE Compliant

Compressor
The compressor is a rugged stainless steel radial flow design. The approximate pressure ratio is 4 to 1.

Combustor
The combustor is computer designed and tested on a flow bench to provide low emissions of NOx and CO in the exhaust across a wide operating range and superior overall turndown ratio.

Turbine
The super alloy turbine drives the compressor and alternator. The combusted gas expands through the turbine.

High Speed Alternator
The electric power is generated through a permanent magnet alternator rotating within an oil cooled stator assembly. The stator assembly is energized as a motor during initial start-up reducing the need for auxiliary starting hardware.

Heat Exchanger
The heat exchanger is an air to liquid heat exchanger and counter current flow design, fed by the exhaust gas. The tube and fin materials have been selected to provide long life, maximum thermal efficiency and allow for portable liquid applications. The outlet liquid temperature is dependent upon inlet liquid temperature and liquid flow.

Control System
The control system provides automatic control of the rectifier, inverter and grid protection features.

Rectifier
The rectifier converts the high frequency alternator output to VDC for input to the inverter.

Inverter
The inverter converts the VDC to the required 50 or 60 cycle, 400 or 480A AC voltage.

Ref.: ELLIOTT datasheet
## ELLIOTT Microturbine

### Turbo Alternator™ Specifications

<table>
<thead>
<tr>
<th><strong>Performance:</strong></th>
<th><strong>Emissions, Natural Gas (Typical):</strong></th>
<th><strong>Exhaust Gas:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>CO: &lt; 41 PPM @ 15% O₂</td>
<td>Temperature: 170ºF / 76.69ºC</td>
</tr>
<tr>
<td>Output</td>
<td>&lt; 24 PPM Volume</td>
<td>With Full Bypass: 535ºF / 279ºC</td>
</tr>
<tr>
<td>Turndown</td>
<td>54 lbm/1000 ft³ @ 15% O₂</td>
<td>100%</td>
</tr>
<tr>
<td>Efficiency*</td>
<td>1.58 lbs/ MWh</td>
<td>Batteries: 12VDC min.</td>
</tr>
<tr>
<td></td>
<td>0.50 grams/hr</td>
<td>Battery Quantity: 2 (Wired in Series)</td>
</tr>
<tr>
<td></td>
<td>0.1250 lbs/MBTU</td>
<td>YUASA NP 30-12, (36Ah / 12V nominal voltage each.)</td>
</tr>
<tr>
<td></td>
<td>14 PPM Volume</td>
<td>Total Weight with Enclosure:</td>
</tr>
<tr>
<td></td>
<td>51.9 mg/m³</td>
<td>Indoor: 4,400 lbs / 1,995 kgs</td>
</tr>
<tr>
<td></td>
<td>50 mg/m³/hr</td>
<td>Outdoor: 4,500 lbs / 2,041 kgs</td>
</tr>
<tr>
<td></td>
<td>1.49 lbs/ MWh</td>
<td>0.48 grams/hr</td>
</tr>
<tr>
<td></td>
<td>0.1250 lbs/MBTU</td>
<td>Without Gas Compressor</td>
</tr>
</tbody>
</table>

* Without Gas Compressor

### Engine Specifications

- **Manufacturer:** Elliott Energy Systems
- **Model:** TA-100 CHP
- **Type:** Recuperated Gas Turbine
- **Pressure Ratio:** 4:1
- **Fuel Type:** Natural Gas

### Cooling System

- **Engine:** Oil Cooled
- **Alternator:** Oil Cooled
- **Inverter:** Air Cooled
- **Enclosure Cooling:** 3,700 CFM

### Exhaust System

- **Outlet Size:** 10”
- **Rated Back Pressure:** 0” wc
- **Max. Back Pressure:** 5” wc
- **Fuel Supply Pressure Required:** 0.5 - 5 PSIg
- **Lubrication System:** Mobil SHC 824
- **Oil Capacity with Filters:** 5 US gal. (19 L)
- **Oil Filter:** Spin On Type, 3 Micron

### Emissions

- **NOx:**
- **CO:**
- **CO₂:**
- **O₂:**
- **H₂O:**
- **N₂:**
- **O₃:**
- **PM:**
- **SO₂:**
- **VOC:**

For more information please contact:
Elliott Energy Systems, Inc.
2901 S.E. Monroe St.
Stuart, FL 34997
Tel: 772-219-8449
Fax: 772-219-8448
Website: www.elliottenergysystems.com
The specifications in this catalogue are subject to change without prior notice.

Ref.: ELLIOTT datasheet
Ingersoll-Rand Microturbine
PowerWorks 70 kW and 250 kW

- 70 and 250kWe
- Electrical efficiency 29-30% LHV at ISO
- Low emissions with natural gas
- NOx< 9 ppm, CO< 9 ppm @15% O2

Ref.: Ingersoll-Rand, IGTI Microturbine session, June 16, 2003, Atlanta, USA
Ingersoll-Rand’s Advanced Microturbine Program

- DOE Funding: $1.4 M over 4 years
- Partners: Kyocera, Honeywell Ceramic Components, ORNL, NASA
- Approach: Apply today’s Si₃N₄ turbine technology to PowerWorks™ platform:
  - Power Gen (100 – 250 kW with an electrical efficiency of 40% LHV)
  - High efficiency direct-drive air compressor
  - Advanced high efficiency chiller and refrigeration packages

Applying today’s Si$_3$N$_4$ technology to microturbines will achieve near-term product success:

- PowerWorks™ air compressors use turbine rotors comparable in size (<3 in dia.) and geometry to Si3N4 turbochargers that have been produced in high-volume.

- These small turbocharger rotors are low in cost, and operate at temperatures above that of uncooled metallic candidates.

GE Microturbine system

Conceptual Design

**TASK FOCUS:**
- Determine system thermal design to achieve the 40% efficiency target
- Reduce the operating temperature of the cycle to “metallic” levels
  - this process allows for proof of component technologies prior to the introduction of advanced materials

<table>
<thead>
<tr>
<th></th>
<th>Target Value</th>
<th>Design Value</th>
<th>% Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle Output</td>
<td>175 kW</td>
<td>179.6 kW</td>
<td>2.6 %</td>
</tr>
<tr>
<td>Cycle Efficiency</td>
<td>35 %</td>
<td>35.7 %</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Cycle Output</td>
<td>250 kW</td>
<td>257.3 kW</td>
<td>2.9 %</td>
</tr>
<tr>
<td>Cycle Efficiency</td>
<td>40 %</td>
<td>40.7 %</td>
<td>1.8 %</td>
</tr>
</tbody>
</table>

Ref.: Karl Sheldon presentation at the IGTI Turbo Expo June 18 2003, Atlanta USA
GE Microturbine system

Ref.: Karl Sheldon presentation at the IGTI Turbo Expo June 18 2003, Atlanta USA
GE – Advanced Microturbine Program

- DOE Funding: $4.7 M over 4 years
- Partners: GE (Corporate Research, Power Systems, Industrial Systems), Semikron, Kyocera

Design concept for 175-350 kW microturbine:
- Advanced recuperator design
- Low emission combustion system
- Advanced sealing and material usage
- State-of-the art power electronics and controls
- Compressor and turbine advanced turbomachinery design methodology

UTC - Advanced Microturbine Program

- DOE Funding: $8.6 M over 5 years
- Partners: UTRC, DTE Energy, P&W Canada, TurboGenset, Hamilton Sundstrand, SatCon, Kyocera, ORNL, Solar Turbines
- Approach: Demonstrate new product capability of enhanced ENT-4000 microturbine system
  - 400-kW class recuperated microturbine based on PWC ST5 engine, 30% electrical efficiency
  - Launched in July 2000 through partnership of DTE Energy Technologies, P&W Canada, and TurboGenset
  - Initial product delivery in March 2002

UTC Advanced Microturbine System: Approach

- Approach:
  - Identify & develop technologies to achieve DOE goals for electrical efficiency, NOx, cost, and life
  - Demonstrate performance on test-stand, and durability in microgrid

- 3-Part Strategy for >40% Electrical Efficiency
  - Increase RIT using uncooled, ceramic hot section components
  - Increase power generation/conversion efficiency
  - Convert exhaust energy with Organic Rankine Cycle (ORC)

- Preserve low NOx with affordable, small-scale fuel-air mixers

Alternative fuels for microturbines

- Natural gas - Standard fuel, but increasing price in the US
- Propane
- Medium Calorific Value gas (MCV)
  Example: Landfill gas and Sewage gas
- Diesel, kerosine
- Methanol, Ethanol
Microturbine systems / users

- Distributed power generation
  Example:  - Industrial applications to boost electric power reliability
  - Remote locations

- Standby power
  Example:  - Restaurants, Hospitals

- Combined Heat and Power generation (CHP)
  Example:  - Commercial buildings (el and heat)
  - Hospitals (el and steam)
  - Residential buildings (el and heat)

- Mechanical drive for air conditioning systems

- Power generation from alternative fuels
  Example:  - Landfill gas and Sewage gas

- Hybrid systems. Fuel cell - microturbine
Ref.: Capstone Product Datasheet
Landfill Gas Microturbine
Calgary Alberta

- 30 kW Capstone and gas compressor and gas cooling system
- 1000 hrs of operation in 2002. Currently being rebuilt with heat recovery and DY thermally driven chilling system
- Project objective is to determine if chilling the LFG to condense water and contaminants will reduce overall cost of gas treatment system
Microturbines in Greenhouses

- Morningside Rose Gardens, Alberta
- 4X70 kW Ingersoll Rand
- In operation over 02/03 Winter
- Turbines undergoing refurbishment by IR
- Future work will be to improve the heat recover efficiency and use exhaust gas directly in the greenhouses

Ref.: Rob Brandon, CANMET Energy Technology Centre, presentation at the IGTI Turbo Expo June 18 2003, Atlanta USA
Microturbines today

- Around 3 000 units shipped (as of Nov 2002):
  - Capstone: >80% of market share. 30 and 60 kW (develops 200 kW). 2 400 units shipped
  - Bowman: 80 kW. 125 units shipped
  - Ingersoll-Rand: 70 kW (develop 250 kW). 80 units shipped
  - Turbec: 100 kW. 150 units shipped
  - Elliott: 80 kW. 125 units shipped

- Cost about 1000 $/kW

- Electric efficiency 27 – 31%

- NOx < 25 ppm (some < 9 ppm)
Microturbine market 2003

• 2003-2004 sales next to zero

However:

• Experiences of power interruptions (black-outs) led to new market for "high grade" power capable of supporting the "digital world" → Willing to pay a premium for reliable, uninterrupted power.

• Green energy production → certificates
World Gas Turbine Industry
Unit Production By Application
2002 - 2011

Note: Vehicular Applications - less than 1%

Alternative energy machines will erode Mini/Micro market after 2010

Microturbines, section 2

- Production to grow steadily thru 2009
- Fuel cells to gain market share after 2009
- Capstone and I-R are early “majors”

Microturbines - Design Trends

• Single shaft engines, 100 – 400 kW

• Air bearings

• Lean premix, low emission combustors

• High efficiency components
  → higher turbine outlet temperature (650 → 732°C - Solar Turbines)
  or higher Turbine Inlet Temperature (UTC). Both these temperature raises imply advanced materials such as ceramics
US Department of Energy, DoE
Advanced Microturbine program

6-year program 2000 – 2006 of $60 Million

Focus for the next generation:

• Fuel-to-electricity conversion efficiency of at least 40%
• NOx-levels below 7 ppm (for natural gas)
• System cost < 500 $US/kW
• Cost of electricity that are competitive with the alternatives for market applications
• 11 000 hours of reliable operations between major overhauls and service life of at least 45 000 hours
• Options for using multiple fuels, including diesel, ethanol, landfill gas and bio-fuels

The five participating manufacturers that have been chosen for this program are Capstone, General Electric (GE), Ingersoll-Rand, Solar Turbines and United Technology (UTC)