Project Title: Micro Turbine Generator Program

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Abstract

A number of micro turbines generators have recently been announced as currently commercially available for sale to customers, such as end users, utilities, and energy service providers.

Manufacturers and others are reporting certain performance capabilities of the turbines; however, no consistent third-party independent testing as been done to confirm or discredit such performance claims. The purpose of this project is to provide such an independent, third party testing assessment.

This project purchased, installed, operated and tested micro turbines to assess their performance. Data was collected electronically and manually. This project generally reports the performance testing program.

The paper will reveal the relative maturity of the technology overall and look forward to the needs of the "next generation" of microturbines.

1 Overview

There are several manufacturers of Micro turbine generators (MTGs) announcing their products as currently commercially available. Their potential customers are end-users, utilities, and energy service providers.

The chart shows some of the MTG Manufacturers and current MTG operating features.

To be competitive with existing technology, most MTG manufacturers rely on enhanced reliability and lower maintenance costs. MTG manufacturers expect to achieve greater reliability and lower costs by using fewer moving parts and lower manufacturing costs. Manufacturers thus expect economy of manufacturing of microturbines to replace economics of scale for central plants.

For MTGs to be competitive in the marketplace, minimum customers' expectations are:

- 40,000 hour "wheel life"
- Heat rate of 12,000 to 16,000 BTU/kWh
- Good part load performance
- Emissions < 9ppm
- Noise < 70 dB
- Cheap and easy installation and maintenance

There is a tremendous potential market for MTGs if the MTG manufacturers can make their products competitive with the other forms of energy available at the meter. Using turbo-charger technology, the cost of producing an MTG can become lower and lower -- depending on the manufacturer's expertise in economy of manufacturing. This is especially true if the manufacturer can use a casting process versus a machined process. The MTG manufacturers realize that with an adequate volume of sales, relying on low cost economics of manufacturing, MTGs have a stronger potential to compete well at the meter with large central power plants. Additionally, on site power maybe able to pick off other markets within niches to provide for future product development.

MTGs are intended to provide the energy industry with dispersed power generation assets that may be located close to the loads they serve. For utilities, interest in MTGs is based on deferred central power plant construction, deferred distribution line upgrades, and improved reliability. End use customers may view MTGs as an alternative to other small generators, an environmentally acceptable power generation device, and a reliability improvement mechanism.

There is speculation that MTGs may be an integral part of the future utility infrastructure. In such as speculation, numerous, small generators are scattered throughout a utility's traditional distribution network working in parallel with central power plants. Some believe this will emulate what personal computers and local area networks did by working in parallel to mainframes.

MTG manufacturers and others are reporting certain performance capabilities of the turbines; however, no consistent, independent, third party independent testing has been done to confirm or discredit such performance claims.

However, MTGs will only be considered if they perform acceptably and meet customers' requirements for power quality, reliability, availability, environmental considerations, cost effectiveness, usability and system efficiency.

As a part of the overall testing program, MTGs are purchased, installed, operated and tested to assess their performance. Data was collected electronically and manually.

Ultimately results, as applicable for each unit, include the following performance measures:

- Starts/stops
- Overall unit efficiency
- Net power output
- Operability
- Emissions level monitoring
- Power quality monitoring
- Endurance testing

2 Technical Background

MTGs are small, high-speed power plants that usually include the turbine, compressor, generator, and power electronics to deliver the power to the grid. These small power plants typically operate on natural gas. Future units may have the potential to use lower energy fuels such as gas produced from landfill or digester gas.

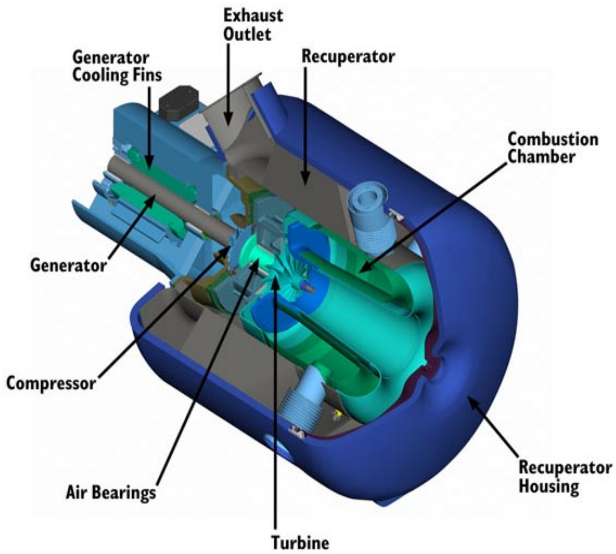

Figure 1. MTG Components

MTGs have a high-speed gas turbine engine driving an integral electrical generator that produces 20-100 kW power while operating at a high speed, generally in the range of 50,000-120,000 rpm. Electric power is produced in the 10,000s of Hz, converted to high voltage DC, and then inverted back to 60 Hz, 480 VAC by an inverter.

Most of MTG engine designs typically have one or several power producing sections, which include the turbine, compressor, and generator on a single shaft.

During engine operation, engine air is drawn into the unit and passes through the recuperator where temperature is increased by hot exhaust gas. The air flows into the combustor where it is mixed with fuel, ignited and burned. The ignitor is used only during startup, and then the flame is self-sustaining.

The combusted gas passes through the turbine nozzle and turbine wheel, converting thermal energy of the hot expanding gases to rotating mechanical energy of the turbine. The turbine drives the compressor and generator. The gas exhausting from the turbine is directed back through the recuperator, and then out the stack.

3 MTG Testing Program

This MTG test program is expected to provide valuable insight, both qualitative and quantitative, into the installation, performance and maintenance requirements of units presently available to the market. Test results are based on actual operating conditions at the test site in Irvine, California. In addition to the results and experiences derived from installing and operating these units, performance data are collected to trend and profile operating characteristics via a Data Acquisition System and manually.

3.1 Data Acquisition System (DAS)

The Data Acquisition System (DAS) installed at the MTG test site provides interval sampling of MTGs in operation. Raw data is collected in 5-minute intervals from various measurement sensors that feed a datalogger with either pulse or analog signals. The raw data is collected nightly, and processed once a month.

Each MTG is retrofitted with sensors at various locations. Additionally, environmental parameters are collected for the entire site. Data parameters collected are described in Table 1.

Table 1. MTG DAS Monitoring Parameters

Parameter	Instrument
Electrical Energy Produced	3-phase electrical meter with pulse output module
Fuel Consumed (Gas Flow)	Gas flow meter
Fuel Temperature	RTD
Gas Pressure	Pressure transducer
Water Flow*	Water flow meter
Boiler Air Temperature – Inlet and Outlet*	Thermocouple
Water Temperature – Inlet and Outlet*	Resistance Thermal Detector (RTD)

Parameter	Instrument
Power Quality Snapshots	BMI 7100 and BMI 8010 power quality meters
Ambient Temperature	Temperature Probe
Relative Humidity	Solid State IC
Barometric Pressure	Barometric pressure transducer

* Only MTGs with boilers are instrumented with these sensors

3.2 Test Procedures

To fully evaluate the MTGs, a series of tests were developed. Testing of MTGs is categorized into three phases:

- Installation and Startup
- Operation and Maintenance
- Performance

3.3 Installation and Startup

Each MTG delivered to the test site is inspected and noted to include operating instructions, repair parts or a recommended spare parts list, consumable supplies, trouble-shooting and maintenance procedures/guides, and a drawings and diagrams to sufficient to support maintenance

Once installed, the MTGs start and stop capabilities are tested. Units are expected to withstand the wear of daily starts and stops. Operators at the test site manually shut down the units several times per month. At other times, the units shut down (e.g. loss of grid) and/or were manually restarted.

Figure 2. Bowman MTGs

Bowman 60 kW rated MTG (left) and a Bowman 35 kW rated MTG (right) are shown installed at test location.

4 Machine Performance Test Criteria

4.1 Endurance

For the test program, MTGs will be operated for as long as practicable at nominal load. Daily operating parameters: fuel flow, ambient air pressure, temperature and humidity, energy (kWh), operating temperatures and pressures will be recorded. Critical MTG parameters will be recorded with the intent of correlating degradation with factors other than wear and tear.

4.2 Transient Response

MTGs should be able to respond adequately to load changes. Units that are not capable of isolated bus operation will operate in parallel with the system grid. Changes in system load will be picked up by the grid and not by MTG units. Load changes on these MTG units will be accomplished by manually setting load using the control system.

4.3 Harmonic Distortion

The power output will be measured with a BMI or equivalent recorder, which will measure total harmonic distortion (THD). The BMI will also be used to determine the power factor of the fully loaded unit during the endurance test. The measured power factor will be used to verify that the package achieves rated output when connected to the utility grid.

4.4 Noise Measurement

Ambient noise levels will be measured using a handheld noise meter. Each unit will be operated independently to acquire the noise measurements during operations.

4.5 Emissions Measurement

For each MTG type tested, one certified test will be conducted to determine compliance with South Coast Air Quality Management District Rule 2005 for NOx emissions. Additionally, periodic measurements with available handheld equipment would be made to determine trends and any condition of degradation that may occur with operating hours.

4.6 Peak Load Gross and Net

Peak load gross and net measurements will be taken with a BMI meter or equivalent recorder that measures power. For units without compressors, or compressors that are externally powered, the net output must be determined by subtracting the external power requirements to sustain MTG operation. Results of this test will yield performance characteristics such as efficiency, heat rate, fuel consumption and operating hours. Comparisons will be made to manufacturer specifications.

Figure 3. Capstone 28 kW MTG

5 Summary

In summary, if current technology proves itself; the next hurdles are those of specific application such as power quality, standby power, and peak shaving. Advancing technology that proves itself in specific applications will grow in value by offering customers new options.