THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**Natural-Gas-Fired Microturbine**
APPLICATION:	**Distributed Electrical Power Generation**
TECHNOLOGY NAME:	**Parallon® 75 kW Turbogenerator**
COMPANY:	**Honeywell Power Systems, Inc.**
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the purchase, design, distribution, financing, permitting, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups that consist of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated, and that the results are defensible.

The Greenhouse Gas Technology Center (GHG Center), one of six verification organizations under the ETV program, is operated by Southern Research Institute, in cooperation with EPA's National Risk Management Research Laboratory. The GHG Center has recently evaluated the performance of Honeywell Power System, Inc.'s microturbine, the Parallon® 75 kW Turbogenerator (Turbogenerator). This verification statement provides a summary of the test results for the Turbogenerator in a grid-connected application.

TECHNOLOGY DESCRIPTION

During the last decade, technical and manufacturing developments in gas turbine technology have occurred which have enabled the introduction of microturbines, with generation capacity ranging from 30 to 200 kW. The Turbogenerator represents a new generation of compact natural-gas-fired microturbines with the capability to produce approximately 75 kW of 3-phase electricity at 275 volts alternating current (VAC). This distributed energy technology generates electricity at a site closer to customers than a central power station, and can be connected directly to the customer or to existing transmission and distribution lines. The power electronics within the standard Turbogenerator allow the system to operate in parallel with the utility grid to provide stand-by generation, peak shaving, baseload generation, or cogeneration (combined heat and power generation). A stand-alone or isolated configuration requires an optional "black start" battery to provide starting current to the power system.

The Turbogenerator operates on natural gas at a fuel pressure ranging from 75 to 125 psig. An optional booster compressor is offered which allows low-pressure natural gas to be pressurized to these operating conditions. The Turbogenerator consists of two main sections: an engine and an electrical section. In the engine section, filtered air enters the compressor where it is pressurized. The pressurized air then enters the recuperator, which is a heat exchanger that adds heat to the compressed air using exhaust heat. It then enters the combustor where it is mixed with fuel and heated further by combustion. The resulting hot gas is allowed to expand through the turbine section to perform work, rotating the turbine shaft which turns a generator to produce electricity. The compressor is mounted on the same shaft as the electrical generator, and consists of only one rotating part. Because of the inverter-based electronics that enable the generator to operate at high speeds and frequencies, the need for a gearbox and associated moving parts is eliminated. The high-speed rotating shaft is supported by airfoil bearings, and does not require lubrication. The exhaust gas exits the turbine and enters the recuperator, which transfers waste heat from the combustor into the combustion air stream, improving the overall efficiency of the system. The exhaust gas then exits the recuperator through a muffler with sufficient heat energy for cogeneration applications or, alternatively, for release to the atmosphere.

The permanent-magnet generator produces high frequency alternating current, which is rectified, inverted, and filtered by the line power unit into conditioned 275 volts (VAC). This can be converted to the voltage level required by the facility using either an optional internal transformer (120/208 VAC) or external transformers for distribution. The unit can supply an electrical frequency of 50 or 60 Hertz (Hz). The Turbogenerator is supplied with a control system, which allows for automatic and unattended operation. All operations, including startup, synchronization with the grid, dispatch, and shutdown, can be performed manually or remotely using an optional Supervisory Control and Data Acquisition (SCADA) system.

VERIFICATION DESCRIPTION

Verification of the Turbogenerator was conducted at a commercial office building at the University of Maryland - College Park campus. The University's Center for Environmental Energy Engineering (CEEE) has established a test facility at the office building to evaluate distributed energy conversion systems and heating, ventilation, and air-conditioning (HVAC) systems. The Turbogenerator was connected to the electric grid and provided about 30 percent of the electricity demand at the 55,000 ft^2 office building. It was equipped with an optional booster compressor and a 480-volt transformer. The unit was programmed to operate during regular business hours (9:00 am to 5:00 pm weekdays), at full load (75 kW nominal).

The verification test consisted of a series of short periods of “load testing,” in which the GHG Center intentionally modulated the unit to produce electricity at 100, 90, 75, and 50 percent of rated power (75 kW nominal). The 2 days of load testing was followed by 24 days of extended monitoring to verify electric power output, power quality, and operational performance. Details on verification test design, measurement test procedures, and quality assurance/quality control (QA/QC) procedures can be found in the Test Plan titled:

Test and Quality Assurance Plan – Honeywell Power Systems, Inc., Parallon® 75 kW Turbogenerator. Copies may be downloaded from the Center Web site (www.sri-rtp.com) or through ETV program Web site (www.epa.gov/etv).

The specific verification factors are:

Electric Power Production Performance
Emissions Performance (NO_x, CO, THCs, CO_2, and CH_4)
Power Quality Performance
Operational Performance

Evaluation of power production performance includes verification of power output, heat input, and electrical efficiency at the four loads cited earlier. Electrical efficiency was determined according to the ASME Performance Test Code on Gas Turbines (PTC22), and consisted of direct measurements of fuel flow rate, fuel heating value, and power output. Ambient temperature, barometric pressure, and relative humidity measurements were also collected to characterize the condition of the intake air.

Emissions performance was evaluated simultaneously with electrical efficiency determination. Pollutant concentration and emission rate measurements for nitrogen oxides (NO_x), carbon monoxide (CO), total hydrocarbons (THCs), carbon dioxide (CO_2), and methane (CH_4) were conducted in the turbine exhaust stack. All test procedures used in the verification were U.S. EPA Reference Methods. Pollutant concentrations in the exhaust gas are reported in units of parts per million volume, dry (ppmvd) corrected to 15 percent oxygen (O_2), and mass per hour (lb/hr). The mass emission rates are also normalized to turbine power output and reported as pounds per kilowatt hour (lb/kWh). Using these results, NO_x and CO_2 emission reductions are estimated for displacing electricity from central power stations.

Electrical power quality performance was verified during the 24-day extended test. Electrical frequency and voltage output were measured for the Turbogenerator and the utility grid to characterize synchronization with the grid. Other performance parameters, such as current and voltage total harmonic distortion (THD) and power factor, were also monitored to characterize the quality of electricity supplied to the end user. The guidelines listed in the Institute of Electrical and Electronics Engineers' Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems were used to define the power quality verification approach.

Turbogenerator operational performance consisted of verifying cold-start time, number of successful and unsuccessful cold starts, and operational availability for the 24-day extended test. Cold-start time represents the time required to obtain full power after a start command is sent to the unit, and the unit has been down for a minimum of 8 hours. Operational availability represents the percentage of time the unit is available to serve the load when called upon, and accounts for unscheduled downtimes due to failures of the unit and scheduled downtimes for routine maintenance.

Testing started on December 14, 2000, and continued through April 10, 2001. Emissions and electrical efficiency testing at the four loads first occurred on December 19, 2000 but, after measuring unexpectedly high emissions of NO_x and CO (>100 and >30 ppmvd, respectively), Honeywell reported a malfunction in the Turbogenerator software system. Upon further investigation, Honeywell identified an error in the software module that controls burner fuel distribution. As a result of these findings, Honeywell developed a new version of the software (Version 2.4F) which corrected the error, and requested a re-test with the GHG Center. On April 5, 2001, Honeywell upgraded the software system at the test site, and emissions and electrical efficiency tests were repeated on April 10. This verification statement presents a summary of the April 2001 test results. Details of the verification test results can be found in the report titled *Environmental Technology Verification Report, Honeywell Power Systems, Inc., Parallon® 75 kW Turbogenerator*, and can be downloaded from the EPA and GHG Center Web sites identified earlier.

VERIFICATION OF PERFORMANCE

Power Output Performance

- All load tests occurred near standard conditions (ambient temperatures: 62 to 66 °F; barometric pressure: 14.64 to 14.65 psia; relative humidity: 55 to 63 percent).

ELECTRICAL POWER OUTPUT AND EFFICIENCY			
Test Condition		Power Delivered[a] (kW)	Electrical Efficiency[a] (%)
% of Rated Power	Power Command (kW)		
100	75	71.26	23.45
90	68	64.71	23.22
75	56	53.36	22.71
50	38	35.90	19.82

[a] Includes energy consumed by booster compressor and 480 volt transformer

- At full load, 71.26 ± 0.04 kW of power was delivered to the building. Heat input at full load was about 1,037 MBtu/hr, which is equivalent to 18.19 scfm (49.12 lb/hr) natural gas. Heat rate at full load was 14,552 Btu/kWh.

- At full load, electrical efficiency was 23.45 ± 0.08 percent. The efficiency may increase to 24.85 percent if the optional booster compressor is not needed, such as at facilities where on-site high-pressure natural gas is available.

Emissions Performance

CRITERIA POLLUTANT AND GHG EMISSIONS								
Test Condition		(ppmvd @ 15% O_2)			(lb/kWh)			
% of Rated Power	Power Command (kW)	NO_X	CO	THC	NO_X	CO	THC	CO_2
100	75	18.6	1.7	< 5.00	9.74E-04	5.18E-05	< 9.86E-05	1.70
90	68	19.7	7.0	< 5.00	1.05E-03	2.29E-04	< 1.03E-04	1.72
75	56	27.9	57.2	< 5.00	1.51E-03	1.89E-03	< 1.14E-04	1.77
50	38	42.2	780.7	49.30 [a]	2.62E-03	2.95E-02	1.06E-03[a]	2.10

[a] 80% of these emissions were methane

- At full load, average NO_x concentration was 18.6 ppmvd (corrected to 15 percent O_2), which equates to a mass emission rate of 0.069 lb/hr. Maximum NO_x concentration and emission rates occurred at the 50 percent operating load (42.2 ppmvd and 0.094 lb/hr, respectively).

- CO emissions at full load were extremely low and within the sensitivity of the sampling system (1.7 ppmvd or 0.0037 lb/hr). Concentrations increased dramatically at the 50 percent load condition (780.7 ppmvd or 1.06 lb/hr).

- Emissions of THCs were lower than the sensitivity of the sampling system at the three highest loads tested (< 2 ppmvd). At the lowest test condition, 49.30 ppmvd THCs was measured, of which 80 percent was methane.

- At full load, NO_x emissions per unit of electrical power output were 0.000974 lb/kWh, which are well below the levels reported for the local utility (0.0057 lb/kWh). The NO_x emission rate is also below the current average rate for coal and natural-gas-fired power plants in the U.S. Based on a 4.7 percent transmission and distribution line losses in electricity between plant fence line and the end user, NO_x emission reductions are estimated to be 86 percent at the test site.

- At full load, CO_2 emissions per unit of electrical power output were 1.71 lb/kWh. The emission rate for the local utility's dual-fired (coal and oil) power plants is 2.23 lb/kWh. CO_2 emission reductions at the test site are estimated to be 27 percent for generating electricity on-site, as opposed to generation at a central power plant and distribution through a grid.

Power Quality Performance

- Throughout the 24-day test period, the Turbogenerator maintained continuous synchronization with the utility grid. Average electrical frequency was 60.000 hertz, and average voltage output was 487.27 volts.

- The Turbogenerator power factor, pre-set to 100 percent, was 99.98 ± 0.20 percent.

- Current and voltage THDs were consistently below the ± 5 percent threshold specified in IEEE 519. The average current THD for the Turbogenerator was measured to be 3.56 percent, and the average voltage THD was 0.94 percent.

Operational Performance

- Cold-start times ranged from 4.83 to 6.28 minutes, with an average of 5.34 minutes.

- No unsuccessful starts were measured during the verification period.

- Operational availability was determined to be 95.7 percent (i.e., 8 hours of down time during a 187 hr monitoring period).

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