M&V Plan for DG/CHP System

Roosevelt Terrace Cooperative

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New York State Energy Research and Development Authority

17 Columbia Circle

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Introduction

All Systems Cogeneration, Inc. (ASC) has installed a combined heat and power (CHP) system at Roosevelt Terrace Cooperative in Jackson Heights, NY, a multi-family, multi-building cooperative. The CHP system is based around one (1) INV-100 100 kW InVerde 100 cogen unit provided by Tecogen. The InVerde unit includes a natural gas-fired reciprocating V8 engine, water cooled permanent magnet generator, jacket water and exhaust heat recovery systems, and self-contained inverter in a sound attenuating enclosure. The unit can provide 100 kW of continuous power, 125 kW of peak power, and 700 MBtu/h of thermal output as hot water.

The CHP system contains a low temperature loop for useful heat recovery and an inverter cooling loop. The low temperature loop includes a heat exchanger (HX) for domestic hot water (DHW) loads, a HX for condensate heating and a dump radiator to remove excess heat. The inverter cooling loop flows directly to a cooling radiator.

Monitoring System

A monitoring system was installed to measure the performance of the CHP system. The monitoring system is based around an Obvius AcquiSuite data acquisition server (DAS). ASC provided and installed the flow meter and gas meter. CDH Energy (CDH) provided the DAS, cellular modem for communications, current sensors for measuring parasitic power, and temperature sensors. CDH installed and commissioned the monitoring system. The critical monitored points to quantify the CHP system performance are listed in Table 1.

The total useful thermal output of the system (**QU**) is calculated using the measured temperatures across both the DHW HX and condensate HX and the flow measured by the flow meter (**FL**, **TLS**, **TLR2**). Heat rejected by a dump radiator is also calculated using the flow and temperatures measured across the dump radiator (**FL**, **TLR2**, **TLR3**).

The generator gross power output (**WG_{GROSS}**) is read directly from the cogen unit. The parasitic power (**WP**) is calculated using the measured current (**IPARA**) of all the loads in the parasitic electrical panel. The parasitic loads include cogen loop pumps and fans. The total parasitic load is subtracted from the gross power (**WG_{GROSS}**) output to calculate the unit's net power (**WG**). Natural gas to the cogen unit (**FG**) is measured using a Romet RM2000 gas sub meter with a pulse output.

Table 1. Monitored Data Points

Logger Channel	Data Point	Description	Eng Units	Instrument / Transducer	Output
MB-002	WG_GROSS	Gross Power Output	kW	Inverde Modbus Output	Modbus RS-485
	WG_ACC	Energy – Gross generator output	kWh		
	WG_INT	Energy – Gross generator output per interval	kWh		
-	WP	Power – Parasitic loads	kW	-	Calculated
-	WG	Net power output	kW	-	Calculated
Exp IN-1	FG	Cogen gas consumption	Cf	Gas sub meter w/ pulse	Pulse
Exp IN-2	FL	Flow – Heat recovery loop	Gpm	Onicon F-1111	4-20 mA
Exp IN-3	TLS	Temperature - Supply	ºF	Veris 10k Type II Thermistor	Resistance
Exp IN-4	TLR1	Temperature - After DHW HX	ºF	Veris 10k Type II Thermistor	Resistance
Exp IN-5	TLR2	Temperature – After condensate HX	ºF	Veris 10k Type II Thermistor	Resistance
Exp IN-6	TLR3	Temperature – After dump fans	ºF	Veris 10k Type II Thermistor	Resistance
Exp IN-7	IPARA	Current – 208V parasitic panel	A	Veris H921	4 - 20 mA
-	QDHW	DHW Heat Recovery	MBtu/h	-	Calculated
-	QCOND	Condensate Heat Recovery	MBtu/h	-	Calculated
-	QU	Total Useful Heat Recovery	MBtu/h	-	Calculated
-	QR	Rejected Heat Recovery	MBtu/h	-	Calculated

Sensor Details

- Temperature
  - Veris Industries – 4" Remote Probe 10K Type 2 Thermistor
- Water Flow
  - Onicon – F-1111 Insertion Style Impeller Flow Meter
- Gas Flow
  - Romet Gas Sub Meter with 10cf/pulse, Pulse Output

Data Logging System

CDH provided, installed, and wired the DAS, cellular modem, current and temperature sensors. ASC provided and installed an Onicon flow meter for the low temperature loop and the gas sub meter. The DAS connects to the internet via the cellular modem that has a static IP address. The DAS uploads data to CDH, who serves it up to the NYSERDA Data Integrator web site.

Data Analysis

Heat Recovery Rates

The heat recovery rates are calculated using the 1-minute data collected.

Total Useful Heat Recovery

$$QU = k \cdot \frac{1}{N} \cdot \sum FL \cdot (TLS - TLR2)$$

Rejected Heat Recovery

$$QR = k \cdot \frac{1}{N} \cdot \sum FL \cdot (TLR2 - TLR3)$$

“N” is the number of scan intervals included in each recording interval (e.g., with 1-minute data, N=60).

The k-factor is the product of the density and specific heat of the heat transfer fluid. The heat transfer fluid for the high temperature loop is expected to be a water glycol mixture, which has a k-factor of $480\ \mathrm{Btu/h \cdot gpm \cdot {}^{\circ}F}$ at an operating temperature of 180°F.

Calculated Quantities

The net power output from the CHP system (**WG**), is defined as the gross output of the generator (**WG_{gross}**) minus the measured parasitic loads (**WP**).

The net total efficiency of the CHP system, based on the higher heating value of the fuel, is defined as:

$$TE_{net} = \frac{QU + 3{,}413 \cdot WG}{HHV_{gas} \cdot FG}$$

Where:

QU	-	Useful heat recovery (Btu)
WG	-	Net generator output (kWh)
FG	-	Generator gas consumption (Std CF)
HHV_{gas}	-	Higher heating value for natural gas (~1,032 Btu/CF)

Site Photos

100 kW Cogen Unit

Cogen Unit Name Plate

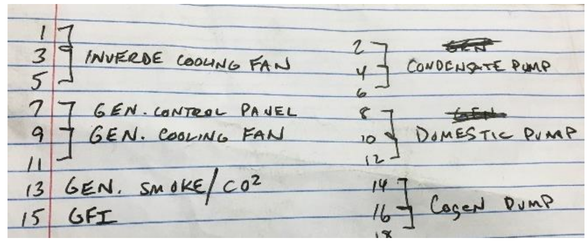
CDH Monitoring Enclosure w/ Obvius Data Logger

HW Loop Onicon Flow Meter (In Garage)

DHW HX (HX1) Left and Condensate HX (HX2) Right with TLS, TLR1 and TLR2 shown.

Heat Recovery Supply and Return and Gas Supply on Cogen Unit with TLR3 shown (before gas sub meter installed).

Romet 2000 gas sub meter w/ 10cf/pulse pulser



Parasitic Panel Door Card

Veris H921 Analog CT measuring current on 1 of 3 phases for whole parasitic panel.

208V Parasitic Panel in Cogen Room

Addendum - Roosevelt Terrace

Location

Roosevelt Terrace Apartments
35-50 85th Street
Jackson Heights, New York 11372

Site Contact

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- CDH was on site 12/29/2016 to install a data logger, terminate meter wiring, and setup communications.
- ASC was on site 1/18/2017 to shorten the flow meter stack height.
- ASC was on site 1/31/2017 to install gas sub-meter.
- CDH was on site 2/22/2017 to wire gas sub-meter and verify flow meter.

Summary

CDH provided the data logger, enclosure, communications, current sensors, and temperature sensors. All Systems Cogeneration installed the CDH enclosure and thermowells. CDH performed all the necessary wire pulls and provided 120V power to the enclosure and terminated wiring to the data logger and to the sensors.

On 1/18/2017, All Systems Cogeneration was on site to shorten the flow meter stack height. While performing this work, a wire broke off one of the flow meter circuit boards and had to be re-soldered to the board. Once the repair to the wire was made, the flow meter began to work properly. We compared the Onicon flow meter to ASC's inline flow meter, and we were seeing less than 1 gpm difference between the two meters.

On 1/31/2017, All Systems Cogeneration was on site to install a Romet 2000 gas sub meter. It was installed on the side of the cogen cabinet upstream of the cogen gas valve. See photos above in the M&V Plan for a photo of the gas sub-meter.

On 2/22/2017, CDH was on site to wire the gas sub meter to the data logger and to verify the flow in the heat recovery loop. See verification section for results.

Monitored Data Points

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Verification

Flow

The Onicon flow meter was verified using a Fuji Electric, transit-time, ultrasonic flow meter.

FL	Onicon	Ultrasonic
	38.2	41.4
	38.1	41.3
	38.3	41.7
	38.3	41.8
	38.3	41.7
	38.2	41.6
	38.2	41.9
	38.1	41.7
	38.2	41.7
	38.2	41.8
Avg.	38.2	41.7

Temperature

The temperatures were verified using a Fluke temperature probe.

TLS	Fluke	Veris
	182	186
	183	184

TLR1	Fluke	Veris
	168	171
	167	170

Parasitic Current

The parasitic current was verified using a Fluke power meter.

IPARA	Fluke	Veris
	14.2	15.1
	17.1	18.1
	17.2	18.3
	17.2	18.3
	14.2	15.1

The parasitic loads include the Inverde cooling fan, condensate pump, generator control panel, generator cooling fan, DHW pump, and the cogen loop pump. These loads are all 3 phase loads with the current for a single phase from each being measured.