Rentricity – Aquarion Water Energy Recovery Pilot Study

July 2007

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RENTRICITY INC. RENEWABLE ENERGY RECOVERY AQUARION WATER PILOT PROGRAM 2004-2006

Rentricity, in partnership with Aquarion Water Company, conducted a joint pilot demonstration program from 2004 to 2006 to determine the energy recovery potential of various sites in the Southwestern Connecticut region. Rentricity identified over six addressable sites totaling approximately 500kW of clean energy recovery potential and commenced top-level design and a cost-benefit analysis for a pilot demonstration site.

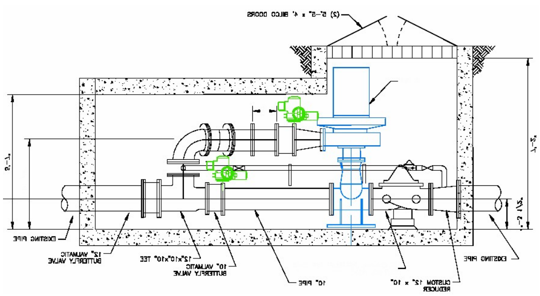
Simultaneously, Rentricity petitioned for Class 1 renewable status. On February 19, 2004, the State of Connecticut, Department of Public Utility Control ("DPUC") granted Rentricity Class I renewable status, which enables the Company to sell the electricity it generates within the entire ISO New England service territory for a premium above market rates. Historically, the premium has averaged between three and four cents per kWH above the underlying wholesale market price.

Site Description & Development

Rentricity in coordination with Aquarion Water Company installed a micro-turbine generator and associated appurtenances at a vault located on Newfield Avenue in Stamford. CT. A tee fitting was installed on the upstream side of the existing pressure reducing valve (PRV) and a new 10 inch class 53 cement lined ductile iron pipe was fitted to it. A 40 kW Flow-to-Wire turbine generator measuring 24-inch in diameter and 45-inch high was installed on a new 10-inch pipeline. The unit is made mostly of cast iron and stainless steel materials. A butterfly valve was installed on both new and existing pipes downstream of the tee connection to isolate the water flow during emergency situation. When the generator is activated, the butterfly valve on the existing pipe is closed to allow the water to pass through a new 10-inch pipe that would spin the impeller of the micro-turbine and energize the generator to produce electricity. The discharge from the micro-turbine generator is diverted back to the existing pipe just upstream of the PRV. The water passes through the PRV and flows through the distribution line that serves the customers in downstream area.

Monitoring devices were installed on the pipe just downstream of the micro-turbine generator unit to continuously monitor the water pressure and flow. Likewise, the unit is equipped with a protective device that can be used to automatically isolate and shutdown the unit during emergency cases

The Original Newfield Regulator and In-Vault Turbine Configuration Design



The demonstration pilot project included the following activities:

1. Identify Installations: A total of six sites were identified within the Aquarion water distribution system that demonstrated the flow and pressure characteristics to generate power. The site shown above was selected because of its small size.

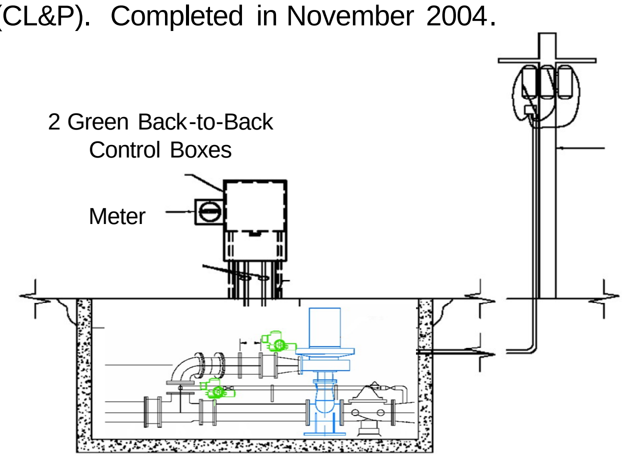
2. Class 1 Renewable Application: The Connecticut DPUC approved Rentricity as a Class 1 renewable technology in February 2004. The Company became a member of ISO New England and intended to participate in the market as a Settlement Only Generator under NEPOOL rules. Renewable Energy Certificates ("RECs") would be sold through the NEPOOL Generator Information System.

3. Engineer System Components: Rentricity developed schematic drawings and pressure and flow data to the Flow-to-Wire^{sm} system supplier in January 2004. An engineering team comprised of individuals who work for Aquarion, Golder Associates, and Rentricity determined the exact Flow-to-Wire^{sm} component requirements and selected a 40kW turbine configuration for the pilot. The team devised an installation strategy to position the smart micro-turbine in its final location. Completed in October 2004.

Vault Characteristics

- Upstream Pressure: 72 PSI or 166 feet of head
- Downstream Pressure: 25 PSI or 58 feet of head
- Pressure Reduction: 47 PSI or 108 feet of head
- Flow: Variable; up to 2.5 MGD in Summer
- Electricity available in Vault

4. Finalize Electrical Design and Apply for Interconnection Approvals: An engineering team from Rentricity, Power Concepts, and Golder Associates developed a comprehensive set of electrical and control system requirements. A design for the systems was finalized and equipment vendors selected. An interconnection package was prepared, submitted and approved by Connecticut Light & Power (CL&P). Completed in November 2004.



5. Select Contractors: Rentricity assign mechanical and electrical contractors, approved by Aquarion, to perform the installation. The Company also contracted with Northeast Utilities to install 3-Single Phase Transformers on the nearby utility pole. Completed November 2004

6. Procure and Assemble System: Rentricity initiated procurement of long lead time electrical, instrumentation, and mechanical components. Once Rentricity received interconnection approval from the electric utility, the Company instructed the suppliers to complete the Flow-to-Wire^{sm} system. Procurement and assembly time was ten weeks and was contingent on specifications from the generator provider and deviations needed for the flywheel specification. Completed: February 2005

7. Configure RenFlo^{sm} Services: The Company programmed and installed identification information into its RenFlo^{sm} system and prepared it to receive data transmissions from the pilot facility. Completed: June 2005

8. Permitting: Since the Rentricity Control Panel was targeted to be installed in the City of Stamford "right of way" Rentricity was required to work with the City of Stamford Engineering Office. After an unexpected 5 month delay, Rentricity choose to install the panel above ground on private property instead of bunkering the cabinet below ground in the City "right of way". Completed: July 2005

9. Complete Installation: The supplier shipped Rentricity's Flow-to-Wire^{sm} system to the Stamford site, where construction contractors, partner construction staff, and electricians installation commenced. The activity required a small crane to maneuver the Flow-to-Wire^{sm} system, which can weigh over 2,500 lbs, into position. Beside installation of the smart micro-turbine, construction activities included installation of conduit, 3 single phase step-up transformers, control panel, and interconnects to the utility pole or end-customer. Northeast Utilities representatives oversaw all installation activities to ensure they conform to applicable State and local codes. Completed: December 2005.

Aquarion Site Preparation - New PRV Installed

Stamford Pilot Program Site: 5' by 15' Vault with 8-inch Main and Claval PRV Located Next to Road with Electricity Available on nearby Utility Pole

Aquarion Mechanical Installation

Stamford Pilot Program Site: Tee Flange installed Upstream of PRV Installed Flow-to-Wire Turbine, By-pass piping & electronic valves

Completed Installation – October 2006

Stamford Pilot Program Site: Completed installation with 3 Single Phase Transformers, Underground Turbine, and Above Ground Control Panels

10. Preoperational and Startup Testing of the Flow-to-Wire[SM] system: A test plan was prepared and implemented, which confirmed the initial configuration and operability of the system's components. In addition, a series of integration tests was conducted to verify system level performance during normal operation and upset conditions. The data was evaluated and Rentricity, Aquarion, and its partners verified acceptability of the test results. Completion: April – March 2007.

Aquarion- Newfield Ave PRV Vault - Energy Recovery
Top Line Data Summary

Project Stage	Period/Dates	Flow (mgd)	Pressure Drop in Vault Across PRV w/o T/G Operating	Available Press (PSI) Across T/G Calculated or Measured	Generation Rate (kw) Calculated(C) or Measured(M)
Feasibility/ Pre-Design/Development	Jan-July, 2004	2.4	47 (assumed)	47 (Calc)	35 (Calc)
Preliminary Design	Aug-Dec, 2004	2.2	42	42 (Calc)	25 (Calc)
Pre-Operational Testing	Dec, 2005-Sept,2006	1.2	40	30 (Meas)	5 (Meas)
Power Ascension Testing	Dec, 2006 - Mar, 2007	1.2-1.75	40	~35 Meas	5 - 15 (Meas)

Operational Testing and Assessment

Operational Parameters

The above table provides a top line summary of the key energy recovery data during the various stages of the project. At the feasibility/pre-development stage, anticipated flow and pressure information was provided by Aquarion Water Company (Aquarion). A preliminary calculation determined the amount of recoverable generation was approximately 35 kW. This assumed that the entire pressure drop would be available across the turbine-generator and minimum pipeline pressure loss as a result of the installation. Also, assumed was a system that would be at least 70% efficient in the expected range of operation of the vault.

At the preliminary design stage, a detailed site survey was conducted. Specific measurements and readings were taken of the flow and pressure conditions in the vault. In addition, with the Aquarion's assistance, records were retrieved of near term operations, covering both diurnal and seasonal variations. It was verified that the pressure reducing valve (PRV) vault usually operated at the nominal full flow/pressure conditions (2.2 MGD and pressure drop of ~ 40 lbs) essentially 24X7 during the April through September period. The flow trended linearly downward to about 50% of nominal full flow by December. The January to early March period, no more than 100/200k gallons per day passed through the vault.

It was learned during the preliminary design stage that the Aquarion had installed special set-point settings in the control scheme which would restrict movement of the PRV stem. With the nominal full flow conditions, the PRV was effectively set to ~35% of full open condition which reduced the pressure in the water by ~40 lbs. The control scheme restricted stem travel to this position if the inlet pressure dropped at any time to 65 lbs or less. Aquarion maintained this control restriction to preserve the reliability in the system in the face of upsets such as pipe breaks, fire demands, etc.

Rentricity and Aquarion decided that any adjustment, either temporary or permanent would be implemented after the completion of the installation and testing. It was also recognized that the winter period conditions would not be conducive to energy recovery given inherent limitations of the turbine generator equipment. Therefore, it was decided to size the energy recovery system to accommodate the nominal full flow and pressure conditions (summertime).

Testing

A series of pre-operational tests was conducted in the December 2005 to September 2006 period. These tests included individual mechanical and electrical component checks. These tests were followed by a series of tests to manually transition the PRV vault from classic pressure reduction (flow bypassing the turbine) to flow diverted manually in very controlled steps to the suction of the turbine. These initial flow tests determined:

a. the relationship between turbine speed and bypass valve closure position
b. Hydraulic sensitivities in the vault and upstream to the Water Station (almost 1 mile upstream).
c. The extent to which flow and pressure would be impacted with the combined resistance of the PRV and turbine generator in series.
d. Adjustments levels to several set-points in the Beckwith relay controls.

The following key results of the pre-operational tests were noted:

a. The turbine began rotating when the bypass control valve was more than 25% of full closed position.
b. The flow followed a linear trend line declining from ~2.2 MGD to ~ 1.2 MGD as the bypass control valve traversed from 25% of full closed position to FULL closed position. During this period the turbine generator was able to reach the permissive set-point for the contactor to close and allow power to flow into the grid. The PRV position remained in its fixed position ~33% OPEN.
c. The Beckwith relay providing electrical protection for the grid and the system equipment tripped out several times on over current function following contactor closure.
d. Once the Beckwith relay set-point adjustments were made (with the Electric Utility's approval), several uninterrupted periods (hours) of low power operation were observed.

Rentricity and its partners reviewed the results of the pre-operational testing. Adjustments were made in the Beckwith relay to account for actual in-rush current/time sequences and phasing of the Power Correction Capacitor Bank was implemented. These efforts were accomplished during November 2006. In parallel, attention was focused on the hydraulic test results. Review of the hydraulic data concluded:

a. The in-line PRV was "consuming" 6-8 PSI; thereby reducing the available head to be consumed across the turbine generator.
b. The tight elbows at both the suction and discharge tees in the vault were contributing to line losses of possibly 2-4 PSI relative to the condition with the flow bypassing the turbine.
c. The turbine generator was operating at the entry points on the flow/head curve once the contactor closed. These points corresponded to flow of ~1.2 MGD and a pressure across the turbine of ~ 33 PSI (0-2.5 kW).
d. The controls - permissives on the PRV needed adjustment. Specifically, effective resistance in the PRV needed to be reduced to maintain constant backpressure exiting the vault when the turbine was operating.

This review resulted in plans to conduct a series of tests in the January – March 2007 time period (weather permitting). The objectives of the tests were to determine:

a. The true impact the PRV was having on the performance of the turbine generator with it fixed to a maximum of 33% of full open position.
b. A more accurate assessment of the incremental line losses experienced with the tight radius elbows, nozzles, etc.
c. Confirmation that the adjustments to the Beckwith relay, controls, and wireless package were acceptable.
d. Confirmation that the electricity monitoring with CL&P and ISO New England were acceptable.

The final series of confirmatory tests was conducted in February/March 2007. The plan was to set a controlled environment for the turbine generator to operate with the effective resistance of the PRV reduced to zero. A manual gate valve downstream of the vault was set up to provide effective, manual backpressure control for the downstream portion of the Water utility's system. The position of the valve stem was calibrated to the known, pre-existent flow/pressure conditions exiting the vault.

With the gate valve mimicking the resistance of the PRV, flow was carefully diverted from the bypass the suction of the turbine generator. As expected, the flow dropped off linearly as the turbine generator reached 1200 rpm allowing the contactor to close. The flow at this point was approximately 1.2 MGD with approximately 33 PSI drop across the vault. A series of controlled adjustments were made to the Gate valve to reduce its resistance allowing the delta P across the vault to gradually increase from ~33 to 38 PSI. From the period just prior to after the last adjustments on the gate valve, the power (kW) varied from a base of 1-2 kW to a maximum of 10-12 kW.

Testing Assessment
Rentricity & Aquarion concluded from the data that:

a. The turbine generator performance was consistent with the calibrated flow/head curve.
b. Line losses of 3-5 lbs were experienced due to the sharp radius elbows, pipe sizes, etc.
c. Control adjustments could be made to the PRV to effectively eliminate the added loop resistance during turbine operation.
d. Further analysis would need to be done to understand to operational performance curves and controls for equipment at the Aqaurion's Pump Station.

Rentricity and Aquarion agreed that this project achieved its primary objectives:

a. Demonstrate ability to integrate a series of technologies and effectively recover energy for local supply.
b. To work the permitting process at the State and Federal levels.
c. Define limits and conditions, physically and regulatory based, which if modified can make this approach economically viable for a large variety of sites.

Major Technical Challenges

Mechanical
Four major top line criteria the installed system had to meet were:

a. No impact on the water company's primary mission; that is providing safe, reliable drinking water to its residential and commercial customers. The system design had to include features that would provide transparency to its customers and operations.
b. Operation of the system or recovery during/following any upset conditions should not increase the loadings and piping and equipment upstream or downstream of the vault.
c. Any modifications had to be installed within the existing space limitations of the vault.

d. Operations of all equipment in the vault including the energy recovery system would at all times be controlled by the Water Company unless Rentricity required the unit be taken offline.

Rentricity met these challenges by designing in features that included:

a. An integral flywheel to all but eliminate pressure pulses during upset conditions/major changes in flow due to system demands or electrical grid upsets.
b. Two additional control valves; one in each of the suction and bypass legs to divert/direct flow either manually or remotely to or around the Turbine Generator.
c. A UPS to provide sufficient power to operate the valves, controls, etc. in case of a local grid upset or power loss.
d. PLC based controls to assess real time the conditions suitable for continued operation.

Electrical

The top line criteria the system had to meet were:

a. Interconnection to the grid was governed by criteria from the electric utility – CL&P.
b. Power quality had to be continuously monitored with interrupt set-points associated with frequency, voltage, Harmonics, flicker, etc. set by CL&P independently verified by a test lab acceptable to CL&P.
c. The grounding scheme associated with the interconnect to the grid and the company supplied system had to be compatible with codes and standards set by CL&P, National Electric Code, and local standards.
d. Any controls and monitoring equipment had to provide sufficient protection to preclude permanent damage to either Rentricity or Water Company supplied equipment.

Rentricity met these challenges by including in the design the following features:

a. A special automated relay device to monitor power conditions/quality real time that met utility standards.
b. Wireless interface to verify system status and performance real time on an independent and remote basis.
c. Local disconnect breakers and switches to provide equipment and worker protection before and during maintenance/repair sequences.

<u>Water Quality</u>

The pilot site PRV and new energy recovery equipment was installed in a section of the distribution system that serves an estimated population of 19,200 persons. Given this, the Department of Public Health (DPH) required a review to determine impact on water quality specifically resulting from thermal effect.

In response, when the project installation was completed, the pipes and associated appurtenances were disinfected in accordance with AWWA standards. Water samples were collected from representative locations and tested for coliform bacteria and physical parameters (pH, color, odor. turbidity). Also, chlorine residual concentration was measured at the same point in the distribution system and at the same time that total coliform samples are collected. The test results were in accordance with DPH requirements prior to placing the pipeline into active.

In addition, sample taps were installed upstream and downstream of micro turbine generator unit for water samples collection and a blow-off valve was installed on the existing pipe downstream of the butterfly valve to flush stagnant water.

Further, all materials used in this installation such as pipes, valves, flushing hydrants, pipe coating materials that are in contact with water are NSF certified for potable drinking water applications.

Components Materials

• Valves	-Ductile Iron -Ductile iron -SS 304 -SS 316 & BUNA – N -ANSI/NSF 61
• Piping	-Ductile Iron – Cement Lined (AWWA – C151) - Minimum Thickness Class 53
• Flange Tees	-Ductile Iron – Cement Lined -Minimum Thickness Class 53 -Flange – AWWA C110, Class 150
• Bolting Materials	-High Strength Corrosion Resistant SSs

Turbine Material

Components	Materials
- Volute Casing - Discharge Cover - Seal Gland	-Cast Iron ASTM A48 Class 30
- Shaft	-Alloy 1040 Cold Rolled Steel or Stressproof
- Runner Washer, Key & Screw	-SS 304
- Seal Cartridge Assembly Spring Disc, Retainer, Etc.	-John Crane Mechanical Seal SS 304, SS 316
- Seal Faces	-Fixed – Cast Iron -Rotating – Carbon -Wedge - Teflon

Overall Challenges & Learning

Renewable energy projects, like energy recovery in water systems, require special priority and handling at the water company. Projects of this type need to be included within the context of overall capital improvement and energy efficiency programs. With existing infrastructure, the opportunity exists to plan upgrades to regulator vaults to include energy recovery devices. For new infrastructure, water companies' can design energy recovery as part of the vault excavation and integration into the distribution system. The Rentricity pilot program faced many challenges during the development period. They following are learning points that should be integrated into any energy recovery program for a municipal or private water system:

- Local government relations should start early in the project cycle if the project will be placed within a vault in the "Right of Way."
- Local government & utility advocates need to be appointed to help projects through respective city and utility approval processes.
- Prior to project kick-off, a detailed project plan should be prepared that lists the time and budget required of all parties. This budget should be consistent with the allowances and requirements of the existing rate case/conditions that in effect over the period of the project.

- Gathering data and a solid understanding of site hydraulic characteristics is critical to the design.
- Prior to construction, a formal and fully funded design should be prepared, and proper reviews by all parties should be incorporated into the design process.
- System or region wide implementations will capture synergies and economics of scale reducing overall costs of the various site projects.

Conclusion & Recommendations

Water companies in the United States are experiencing rising electric costs, now surpassing staffing costs to maintain drinking water distribution to customers. Energy efficiency programs need to be extended to include energy recovery opportunities that can offset electricity use and create a revenue stream for the water company. The following recommendations are suggested for any water company manager planning an energy recovery program:

- Prepare a detailed project cost and schedule plan
- Assure water utility has sufficient historical hydraulic data/projections and accurate piping/mechanical design information
    a. accurately calculate the generation potential
    b. Size and source the optimal turbine generator design, piping and valve configuration.
- Assure that the water utility's budget and resource plan supports the overall project plan.
- Understand requirements of permits and attain start permit process before procurement and installation
- Place priority on working with the utility's preferred, local mechanical, and electrical contractors
- Assure that both home office and field operations personnel review the intended interconnect and local isolation hardware for system prior to procurement of equipment.