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In-Pipe Hydropower Achieves Net-Zero Energy

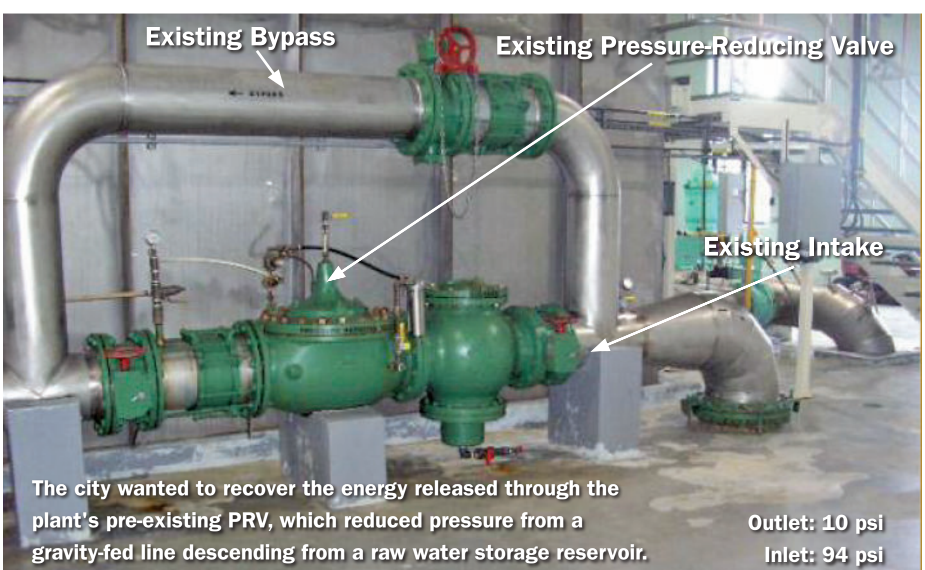
Harvesting energy generated in a New England water utility's pipes via pressure-reducing valves doesn't affect required operations, but the process changes the monetary and renewable energy equation.

BY FRANK ZAMMATARO, AL SPINELL, BEN CROWDER, AND DONNA HANSCOM

WORKING WITH an engineering consultant, operators at the Keene (N.H.) water treatment plant customized and integrated energy recovery solutions with the utility's supervisory control and data acquisition system (SCADA), providing transparent control and real-time power, flow, and pressure data. By implementing an energy harvesting technology, the Keene facility became the first energy-neutral water treatment plant in North America.

REALIZING NET-ZERO ENERGY

Located in Cheshire County, N.H., Keene has about 23,000 residents and a water treatment plant that treats up to 4,200 gpm of water. To help the city reduce its carbon footprint and create a more sustainable plant, officials commissioned the consultant to design an in-pipe hydropower system that would fully power the facility. With city support, the consultant installed a 62-kW dual-turbine in-pipe hydropower system at the plant, saving the city significant amounts of energy and money.



The city wanted to recover the energy released through the plant's pre-existing PRV, which reduced pressure from a gravity-fed line descending from a raw water storage reservoir.

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Pre-existing Conditions. Keene's water treatment plant treats water that comes from a gravity-fed piping system. Raw water passes through a strainer and a pressure-reducing valve (PRV) to three filter trains, each controlled by a flow control valve (FCV). Filter train operations can be set individually, based on water needs. The facility experiences significant diurnal flow swings, based on customer demand, varying between 700 gpm and 1,400 gpm, and sometimes reaching up to 4,200 gpm. The plant and the distribution system are monitored and controlled by a SCADA system from a central control room with remote dial-up access.

The existing PRV reduced pressure coming from the gravity-fed line descending from the plant's raw water storage reservoir. The energy released through the PRV was systematically dissipated as waste heat energy. The city wanted to recover this source of clean, reliable energy yet maintain the plant's flow regimes, daily maintenance requirements, and other normal operations. Furthermore, the city wanted the ability to use the generated power to offset demand inside the water treatment facility and to export the excess to the local grid.

Energy Recovery by the Numbers. The consultant installed an in-pipe hydro-

Keene's in-pipe hydropower system consists of two turbine generators with different capacities to maintain continuous operation during all flow and pressure differential ranges.

power system in parallel to the existing PRV inside the plant. Because of significant diurnal flow ranges, the in-pipe hydropower system consists of two turbine generators with different capacities to maintain continuous operation during all flow and pressure differential ranges. The in-pipe hydropower system also consists of associated electrical controls and water process controls.

The system maximizes flexibility in operations while maintaining complete transparency to the city's primary mission—providing safe, reliable drinking water. The system's operating ranges include the following:

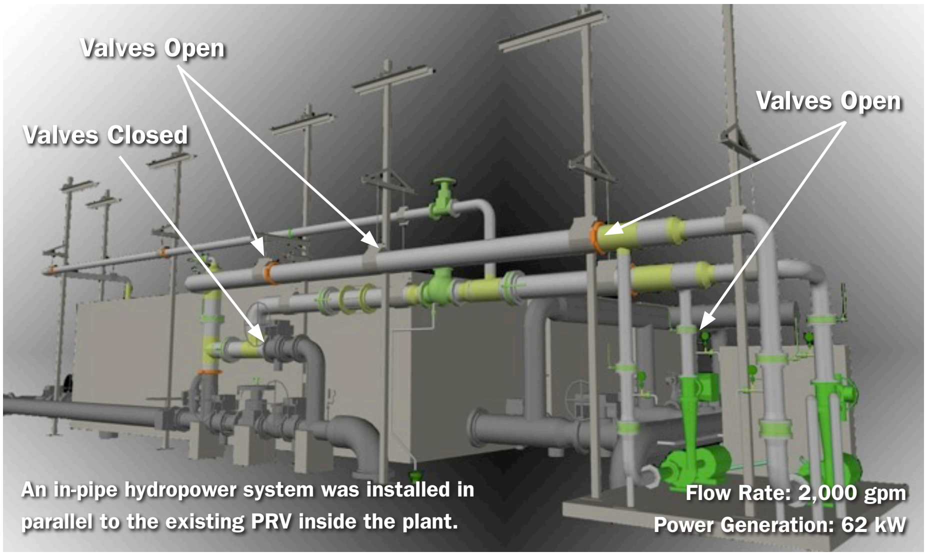
- Turbine generator 1 at 190–196 ft differential head around 700 gpm, generating 17–18 kW power
- Turbine generator 2 at 190–196 ft differential head around 1,400 gpm, generating 36–38 kW power
- Turbine generators 1 and 2 operating in parallel at 176–189 ft differential head around 2,100 gpm, generating 50–55 kW power
- One or both turbines operating in combination with the PRV
- Nonoperational with pressure reduction through the PRV.

The system is fully automated through SCADA, switching between scenarios seamlessly as flow rates change. All electrical, hydraulic, and turbine generator data are monitored through the SCADA system to provide the plant's operations staff with all the needed information to monitor the in-pipe hydropower system in real time.

Startup of either one or both turbine generators can be initiated via the SCADA system or a local control panel. Shutdown can be initiated through the SCADA system, a local control panel, or automatically via protective devices during various upset conditions, such as a loss of utility power or voltage surges. Moreover, the system can be set up to automatically switch to any of the previously mentioned turbine generator and PRV combinations according to flow rate. A surge release valve operates in accordance with local conditions to prevent overpressure or water hammer effects in the event of a rapid unplanned turbine shutdown. Surge release discharges into a waste drop box that in turn drains into recycled water storage tanks. Also, a switchgear cabinet was installed inside the electrical room that connects the plant's electrical distribution system in accordance with the local cogeneration interconnection and net metering requirements.

Recovery Results. With the new system, the city recovers energy that was previously lost through a PRV as waste heat. Approximately 269,000 kW•h of clean energy were generated in the first year of operation. Note the $7,800 of electricity consumed is associated with backwash operations when the turbine isn't operating.

Reliability and Financial Gains. The plant's energy recovery systems are designed to last 40 years with little operation and maintenance costs. The rate of return is attractive, with a short technology payback period and



An in-pipe hydropower system was installed in parallel to the existing PRV inside the plant.

high-capacity factor of approximately 80 percent. Federal, state, and local incentives, including grants and other subsidies, have dramatically increased the rate of return. The city was awarded a grant for more than $250,000, resulting from the American Recovery & Reinvestment Act of 2009, for an accelerated payback on the project.

The Keene in-pipe hydropower project's cost of energy is approximately $0.063/kW•h, and the system can provide the city with continuous revenue from selling electricity back to the grid. It was estimated that the city's savings would total nearly $1 million over a 30-year period.

LESSONS LEARNED

Although the plant operated at net-zero for approximately 2 years, operational requirements changed the turbines' duty cycle and contribution to the plant's energy recovery system as follows:

- Required changes in flush frequency to remove chemical, organics, and inorganics on the clarifier media went from 1,100 min between flushes down to 300 min, resulting in a plant electricity increase and reduced turbine operations. This change resulted in a 15 percent reduction in the turbines' overall contribution to the plant's energy needs.
- Expect approximately 8 hours a month in maintenance. In addition, an electrical "trip" in the smaller unit has caused outages and lower output. The city is working with the turbine manufacturer to identify the fault.
- Further review of future plant operations may be required to reoptimize to net-zero energy.
- Although energy recovery projects are forward thinking, planning is critical to integrate them into operational and regulatory processes. Turbines allow for smart energy management and provide an additional level of flexibility for future upgrades. Making water infrastructure "net-zero ready" will be a best practice for water utilities promoting sustainability and resilience.

UNLEASH SUSTAINABLE HYDROPOWER

More than 4 percent of domestic electricity consumption is associated with water and wastewater processing—sometimes referred to as the "water–energy nexus." The Keene project represents a new best practice for drinking water, wastewater, irrigation, and industrial water operators whereby electricity demand can be offset by clean, renewable energy.

First-Year Electricity Profile

Approximately 269,000 kW•h of clean energy were generated in the first year.

	Before Installation	After Installation
Electricity Consumed	(174,000)	(7,800)
Electricity Generated	0	194,000
Net Electricity Consumed	(174,000)	–
Total Electricity Generated (First Year)	0	269,000

Project Economics

With the new system, the city recovers energy that was previously lost through a PRV as waste heat.

Reduced Electric Purchases	$26,592
Simple Payback (Years)	10.7
Levelized Cost of Electricity ($/kW•hr)	$0.063
Projected Savings Over 30-Year Life	**$797,760**

Water facilities can collectively harness their water distribution and transmission systems' flows and thereby generate billions of megawatt hours of electricity to help run power-dependent systems on-site or feed the electricity back into the power grid to offset energy costs. As the United States upgrades its aging water infrastructure, in-pipe hydropower offers new solutions to help make water infrastructure smarter and more sustainable and resilient.