IN-PIPE HYDROPOWER

GC PROJECT

INTRODUCTION

Research paper on in-pipe hydropower

This research paper is about turning the excess pressure in piping systems into mechanical and then into electrical energy at high efficiency and is about effectively harnessing electricity from the water flowing through pipe lines.

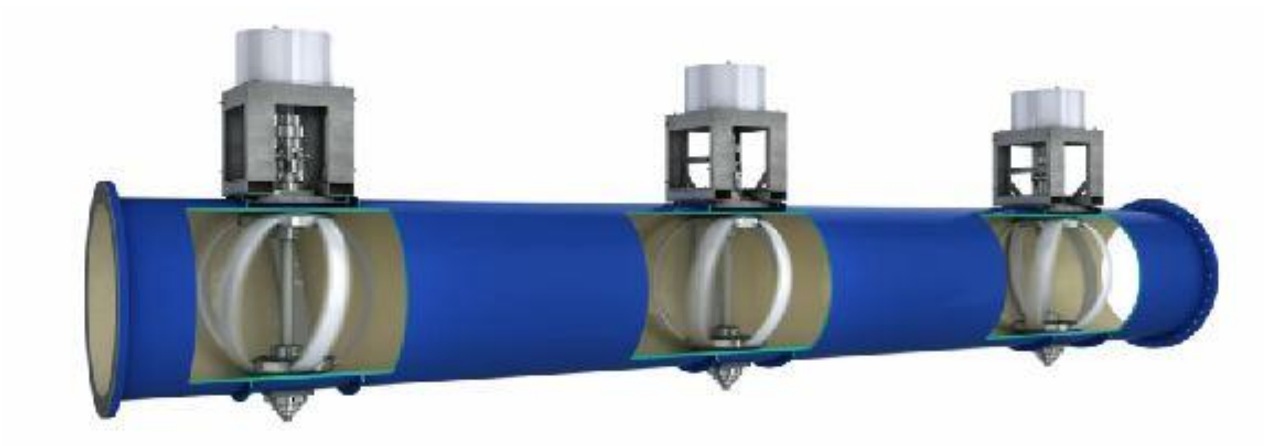
Traditionally hydroelectricity is generated from Dam, which is built on a large reservoir.

This mechanism usually works by using the power from the water to turn a turbine. The turbine in turn causes a shaft to rotate and turn a rotor inside a generator, creating electricity. Then the power cables attached to the generator, supply the electricity to the consumers.

Hydroelectric power generation is by one of the most efficient and viable method of large scale electric power generation.

The most standard and reliable way of transporting water from the source to the consumers is through pipe lines.

Hydroelectric Energy does not have any kinds of waste products or emissions or radiations that are harmful to the environment, which makes it a clean and a green source of energy.



The implementation of this technique will lead to conservation of energy, and generation of surplus energy.

Review of literature

❖ What is Hydro Power?

Hydro Electrcity referrers to the conversion of energy from flowing water into electricity. The generation of electricity ids done with the help of turbines and generators.

This mechanism usually works by using the power from the water to turn a turbine.

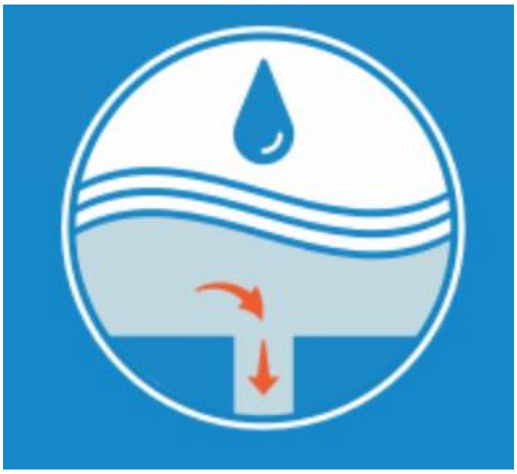
The turbine is connected to electro magnetic generator , wh9ch produces electricity when the turbine rotates. Hydropower is an abundant low cost, largest and a renewable source of energy production. It accounts for 6.7% of world wide production of energy.

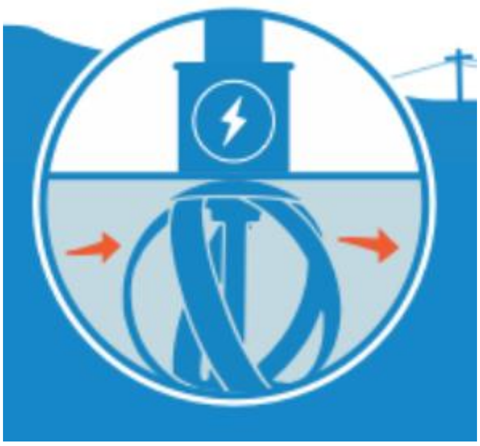
❖ What is in-pipe hydropower?

Water from rainfall fills remote reservoirs, feeding pipelines that move water to the point-of-use. As the water flows downhill, gravity creates pressure in the pipeline that is normally relieved by pressure-reducing valves.

The In-Pipe Power System generates environmentally-friendly hydropower with no impact on water delivery. Unique, spherical turbines are installed inside large-diameter gravity-fed water transmission pipelines. The turbines spin as water passes through them, converting excess head pressure into electricity. Multiple turbines can be mounted in series, one after the other, to maximize energy output.

The LPS can be placed in-line in the pipes of a water transmission network, and can generate electricity from excess pressure in the pipeline, reducing the work done by pressure-reducing valves.





Methodology

The conventional method for harnessing electricity/energy from water from penstock(a huge steel pipe which carries water) is taken into the water turbine. The turbine is mechanically coupled to an electric generator. Kinetic energy of the water drives the turbine and consequently the generator gets driven.A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

- ❖ Why is in-pipe hydropower better than conventional hydropower?

Unlike conventional hydropower , the In-pipe hydropower system, does not inhibit water delivery and operates in a wide range of pipe diameters and pressure/flows.

Conventional hydropower technologies have been adapted for in-pipe applications, but are not suitable for use in water transmission pipelines because they deplete 95% of the pressure and usually require bypass loops.

In-pipe pressure reduction valve (PRV) replacement technologies extract significant pressure and are not suitable for use in large-diameter water transmission pipes where pressure and flow velocity must be maintained.

The hydropower generation does not harm the environment we live in.

This technique can used anywhere anytime rrescptive of the location.This technique generates power 24/7, all round the time.

For construction of dams, reservoirs, and hydropower plants, forests are being cut for generation of electricity.This has lead to deforestation on a large scale. Deforestation affects wild animals, plants and humans in at least four distinct ways:

- Soil erosion leads to clogged waterways and other problems;
- Water cycle disruption, which can lead to desertification and habitat loss;
- Greenhouse gas emissions, which contribute to global climate change.

Viability

This system comparatively has lower cost than other non-conventional sources of energy like solar and wind energies. Unlike solar and wind energies where both sources are constantly required, the in-pipe hydropower system will have a 24/7 utilization. Regions such as Norway, Finland and Alaska where the availability and intensity of sun rays is not sufficient for the photovoltaic cells to function optimally. Also, the maintenance of photovoltaic panels is a major issue.

The In-Pipe Power System is designed for use by water utilities that have:

- Gravity-fed water delivery pipelines.
- Large pipes with flow and pressure matched to turbine size.
- Excess pressure available to be removed.
- Planned pipeline repair or installation, or above-ground location.
- Grid connection for sale of electricity through power purchase agreements.
- Off-grid connection for behind-the-meter use, distributed energy, battery charging.

Advantages of LucidPipe:

- Hydropower that doesn’t harm ecosystems
- Can generate consistent, predictable energy 24/7
- No impact on water delivery
- Turns excess pressure into a revenue stream through power purchase agreements
- Provides grid-connected or off-grid power
- Use for distributed electricity, peak-energy and battery charging

RETURNS ON INVESTMENTS:

Electricity generated by the LucidPipe Power System can be used behind the meter or sold to energy utilities through power purchase agreements (PPA). The target Levelized Cost of Electricity (LCOE) is between $0.05 and $0.12 per kilowatt hour, depending on local energy rates and other project financing factors. Target project payback is 10 years.

FINDINGS

Case study 1:

PORTLAND WATER BUREAU • Portland, Oregon

Water Bureau (PWB) in Portland, Oregon has turned a major city water pipeline into a generator of renewable energy from in-pipe hydropower. The 200kW LucidPipe™ Power System from Lucid Energy harvests excess pressure from the gravity flow of water inside the PWB pipeline. Four 42” spherical turbines spin as fast-moving water flows through them, generating an average of 900 megawatt hours of electricity per year – enough to power approximately 100 homes and help the city meet its Climate Action Plan goals with clean hydropower that doesn’t harm ecosystems.

The Portland LucidPipe Power System serves as a pilot for the multi-turbine system installation and for it’s funding model. Similar to how many solar and wind projects are financed, the LucidPipe installation was funded entirely through private investment. PWB shares in the revenues produced by the sale of electricity to Portland General Electric through a 20-year Power Purchase Agreement (PPA). After 20 years, PWB will have the right to own the system and all the energy it produces. Since pipelines have useful lives in excess of 50 years, this is an excel-lent opportunity for the investor and for the City. The Portland LucidPipe project has the distinction of being the first in the U.S. to secure a 20-year PPA for renew-able energy produced by in-pipe hydropower in a municipal water pipeline.

The patented LucidPipe turbines are specially designed to turn excess pressure in gravity-fed water pipelines into electricity – with no impact on water delivery. The Portland turbines are installed inside a section of large-diameter, gravity-fed water pipeline just upstream of a pressure reducing valve (PRV) below the city's new Powell Butte reservoir. The 4-turbine system extracts approximately 20psi of pressure from the pipeline and converts it into electricity. In addition to recapturing energy that would otherwise have been lost through the PRV, this placement of the LucidPipe system reduces the workload of the PRV and helps extend its life.

PROJECT FACTS:

Location: Portland Water Bureau pipeline, Portland, OR USA.

System: A four-turbine, 42” 200kWsystem inside a 48-inch diameter water-pipeline.

Placement: Upstream from P.R.V. turbines placed 4-diameters apart.

Reliability: >95% availability in first 8months of operation.

Output: 900 MWh per year. Electricity is fed to the grid.

SYSTEM BENEFITS:

Clean energy: turns water infrastructure into a source of renewable energy (LCOE: 5-12 cents perkWh).

Sustainable: operates seamlessly with no impact on water delivery.

Consistent: not weather-dependent ,power production is under water agency control

Environmentally-friendly: provides hydropower that doesn’t harm ecosystems.

Reduces valve wear: through a slight reduction in pressure in the pipeline.

LUCIDPIPE SYSTEM INFORMATION:

- Tested and certified to ANSI/NSF Standard 61 for use in potable drinking water systems.
- LPS pipe sections comply with AWWA C200.
- Gross system weight ~6,500 lbs.
- Rated output - 50 kW per 42” turbine.
- Turbine materials: Composite and stainless steel.
- Inverters tested to UL 1741.
- 150 PSI max working pressure.

Case Study 2:

RIVERSIDE PUBLIC UTILITIES • Riverside, California

since March 2010, the Gage Canal pipeline in Riverside, California has been the test bed for long-term research and development of the LucidPipeTM Power System. Working closely with the team at Riverside Public Utilities (RPU), Lucid Energy piloted three versions of the unique in-pipe hydropower system that uses a patented, spherical turbine to recapture the energy of fast-flowing water inside large-diameter, gravity-fed water pipelines. Through real-world testing of LucidPipe, Lucid Energy was able to refine theturbine design and optimize the system for durability, reliability and energy output, while ensuring that LucidPipe operates seamlessly within a working water system environment, with no disruption to flow. Lucid Energy completed the first commercial installation of a 42”, single-turbine system at RPU in January2012 and is using the site to conduct ongoing in-system testing of turbine design refinements.

Riverside Public Utilities (RPU), a leading Southern California leading water utility, collaborated with Lucid Energy to become the first pilot and deployment site for the LucidPipe Power System. The system has enabled RPU to turn a gravity-fed water pipeline with excess head pressure into a generator of renewable, carbon-free electricity. RPU uses the electricity to power their water operations during the day and city streetlights at night

The system earned RPU an “Outstanding Energy Management Award” from the California-Nevada section of the American Water Works Association (AWWA) and has garnered the attention of media and global leaders in both the energy and water fields who visit RPU to see and evaluate the system in action. The LucidPipe test site in Riverside, CA continues to serve a role in the development and testing of new turbine refinements, as Lucid Energy continues its R&D to drive higher power output and lower costs, making the LPS accessible to a wider range of water utilities worldwide.

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PROJECT FACTS:

Location: Gage Canal pipeline in Riverside, California, USA.

System: A single, 42”, 20kWLucidPipe turbine inside a 60-inchdiameter water pipeline.

Placement: Upstream from a valve used for flow control.

Reliability: 97.8% availability during test period in 2013.

Output: Can produce 50-60 MWh per year. Electricity is fed directly to the utility.

SYSTEM BENEFITS:

Clean energy: turns water infrastructure into a source of renewable energy (LCOE: 5-12 cents per kWh).

Sustainable: operates seamlessly with no impact on water delivery.

Consistent: not weather-dependent, power production is under water agency control

Environmentally-friendly: Hydropower that doesn't harm ecosystems.

Reduces valve wear: through a slight reduction in pressure in the pipeline.

LUCIDPIPE SYSTEM INFORMATION:

- Tested and certified to ANSI/NSFS standard 61 for use in potable drinking water systems.
- LPS pipe sections comply with AWWA C200
- Gross system weight ~6,500 lbs.
- Rated output - 50 kW per 42" turbine.
- materials: Composite and stainless steel.
- Inverters tested to UL 1741.
- 120 PSI max working pressure.

Case study 3:

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

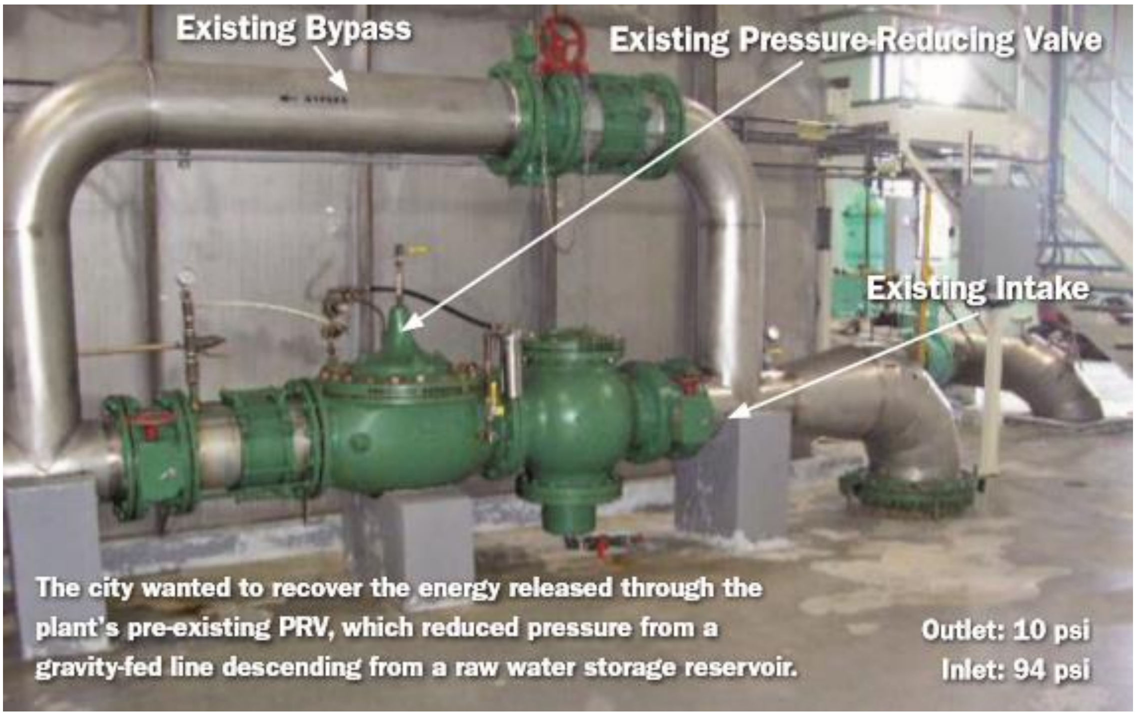
WORKING WITH an engineering consultant, operators at the Keene (N.H.) water treatment plant customized and integrated energy recovery solutions with the utility's supervisory control and data acquisition system (SCADA), providing transparent control and real-time power, flow, and pressure data. By implementing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

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-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. Start-up 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.

<u>Recovery Results</u>.

With the new system, the city recovers energy that was previously lost through a PRV as waste heat. Approximately 269,000 kWh 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 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:

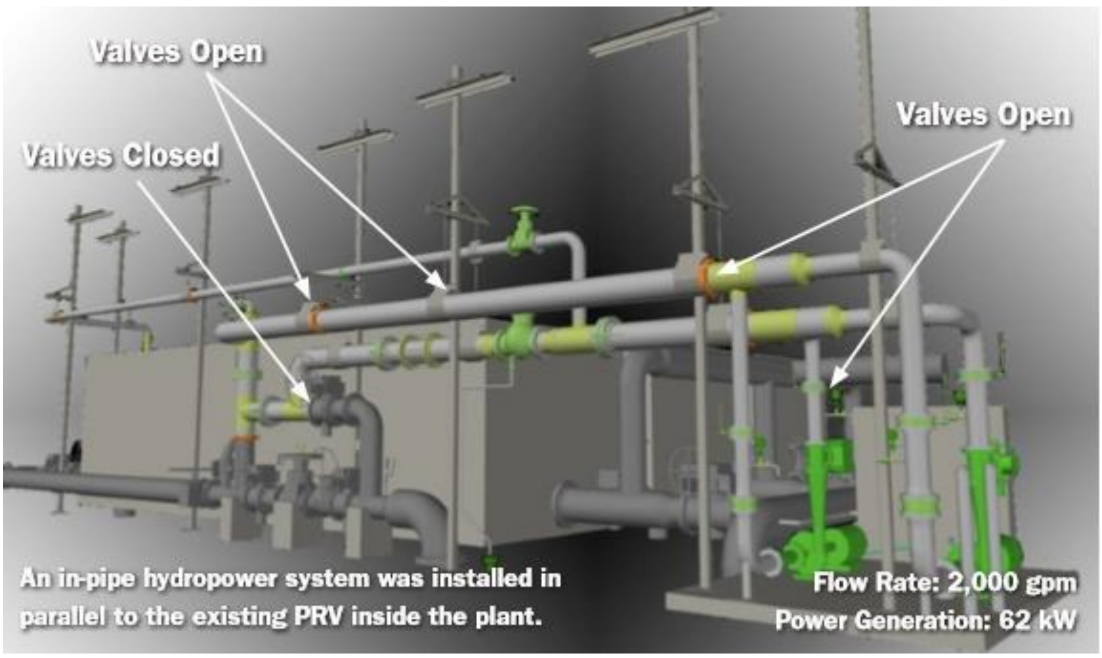
■ Required changes in flush frequency to remove chemical, organics, and inorganics on the clarifier media went from 1,100 min between flushes down to 300 min, resulting in a plant electricity increase and reduced turbine operations. This change resulted in a 15 percent reduction in the turbines'

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.



<u>**UNLEASH SUSTAINABLE HYDROPOWER**</u>

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.

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.

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**

Case study 4:

In-pipe power – developing hydropower from urban water-systems

In a bid to harness the power from gallons of high pressured water that flows through a city's water system every day, more and more local governments are exploring the possibility of in-pipe hydropower technology. Frank Zammataro, President of in-pipe hydropower company Rentricity, talks about the long-term potential of this burgeoning industry, its current challenges and cost-effectiveness. By Heidi Vella.

In every Western urban city, gallons of high pressure water relentlessly shoots and flows around a hidden labyrinth of water pipes, with the key purpose of providing clean water to thousands of homes and buildings. As the system goes through its daily labour, it produces an abundance of useable energy that, if not captured, is simply lost.

There is a small but burgeoning movement to harness this power and feed it into the national grid, creating clean, usable, renewable energy that would otherwise be wasted.

New York-based Rentricity is a leading company that has created technology to capture this power, which is known as 'flow to wire'. This includes a reverse pump, a generator and controllers that can be installed at a water treatment plant or underground water system vaults that provide water to neighbourhoods.

The technology harnesses this highly pressured water, which typically goes through underground water utility substations, where its flow and pressure is reduced, in preparation to enter the smaller pipes of homes and businesses. The energy is then sold directly to the grid.

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Case Study 5:

RENTRICITY CASE STUDY

City of Barre, Vermont

INTRODUCTION

Rentricity is an alternative energy company that converts excess pressure in piping systems to clean, renewable power. Rentricity's experience includes design and implementation of turnkey hydrokinetic systems, custom designed for a site's operational conditions and constraints, inclusive of all requisite monitoring, controls and protective relays. Systems can be stand alone or integrated into the client's existing SCADA system and can be fitted with sensors for smart water system monitoring. Energy can be recovered throughout a water distribution system, typically at mandated releases, pressure reduction valves (PRV) and transfer stations. Rentricity also works with clients to comply with all electrical utility intertie and safety requirements, as well as government permitting and licensing procedures.

The Barre project was advanced after Rentricity completed a 2006feasibility study. The Nelson Street regulator vault project was determined to be the most viable among several potential small hydroelectric projects within the water system serving the City. The project was the first application in the country to meet the qualifying criteria from the Federal Energy Regulatory (FERC) for a conduit exemption under the "Hydropower Regulatory Efficiency Act of 2013". The project was given FERC approval to proceed in less than two months, as compared to the former one plus years to complete the rigorous license permitting process of the Federal Power Act.

THE CHALLENGES

• Generate enough kWh per day/per month to be able to show a reasonable payback. The project required a subsidy ($100k) from the Vermont Clean Energy Fund as well as additional funding to replace the entire infrastructure with a new, larger vault and piping.

• The diurnal nature of the flow which included large variation in demand from daytime to nighttime. For example: the daytime demand is 3 to 4 times the overnight demand. Even though the pressures remain essentially constant, the selection of the turbine had to be optimized to operate (generate power) as much of the day as possible.

• Barre required the maintenance of a tight pressure band downstream of the Pump as Turbine (PAT) at all times including grid transients and transfers back and forth between the PRV and the PAT as flow decreased overnight or increased in the morning.

RENTRICITY’S SOLUTION:

Rentricity installed its Flow-to-Wire PAT in parallel with the larger PRV and bypass PRV. The electrical/control system interfaces with Barre's SCADA so the City has complete control of the operation of the system at all times both in remote/automatic and local mode. Power is generated and net metered to the local Green Mountain Power (GMP) grid. Barre receives a rate for the power as a virtual net meter arrangement; therefore they receive an offset at the same rate that GMP charges. System mechanical integrity is assured by passive overpressure protection relief system. Pressure management is assured by providing a close-coupled system between the PAT, inlet control valve and the control system to sequence and optimize the timing of the changes in operating the system.

RENTRICITY’S RESULTS:

The system operates as designed and delivers approximately 11-12 kWs of clean power. The Flow-to Wire System operates for 14-18 hours per day and passes typically ~400 GPM with a pressure breakdown of ~110 psi. The full cost for design, procure, and construct of the energy recovery system was $175,000. As noted above, approximately $100k was via a grant from the Vermont Clean Energy Fund, with the balance provided by the City and secured by a low interest loan from the State. The system is expected to generate ~90,000 kWh per year achieving ~ $12k offset against Barre's electricity bill.

THE FINANCIAL CASE

Rentricity's energy recovery systems are durable and reliable, designed with a 40-year lifespan with little need for maintenance. The rate of return is very attractive, with a much shorter base case payback period than other renewable energy systems and project costs around $0.04/kWh. Federal, State and local incentives including, grants and other subsidies, increase the rate of return and decrease $/kWh dramatically. The city of Barre, VT, was awarded $125,000 in grants, including $100,000 from the Clean Energy Development Fund, and $25,000 from the ANR Green Reserve Fund.

Case Study 6:

RENTRICITY CASE STUDY

Halifax, Nova Scotia

INTRODUCTION:

Rentricity is the leading developer of in-pipe hydropower solutions that provide clean electricity from existing gravity-fed water pipeline infrastructure. Rentricity's Flow-to Wire™ equipment as well as design and installation of custom turnkey systems, inclusive of all requisite monitoring, controls and protective relays. Systems are stand alone or integrated into a client’s existing SCADA system, and can be fitted with sensors or treatment technology. Energy can be recovered throughout a water distribution system, typically at mandated releases, pressure reduction valves (PRV), inlets to water treatment plant and industrial facilities and water transfer stations. Rentricity works with clients to comply with all electrical utility intertie and safety requirements, as well as government permitting and licensing procedures.

The Halifax Water project is the Commission's first in-pipe hydroelectric project and the first such project in Canada. Planning and initial site assessments for the project began in 2011. In December 2012, Rentricity and Halifax Water commenced design of a pressure-release facility near Bedford, Nova Scotia, which was the most viable site that met no serious challenges.

THE CHALLENGES:

The underground vault space limitations required the Rentricity team to design its first commercial vertical pump as turbine (PAT) installation, requiring a unique support structure for optimal piping and equipment layout.

Further, an NSF-61 (safe water certification) for the PAT was required mid-project which required Rentricity to fast track component review by A US-based standards organization.

The operation of the vault also required new design improvements as part of shutdown and water surge relief sequences for mechanical protection of the system. All challenges were handled in order to minimize cost and time delays to the project.

RENTRICITY’S SOLUTION:

The system’s mechanical integrity was assured by a passive overpressure protection relief system. Pressure management was assured by providing a close-coupled system between the PAT inlet control valve and the control system. The electrical/control system interfaces with existing SCADA controls so that the utility has complete control of the operation of the system at all times, both in remote/automatic and local mode. The site is integrated with Nova Scotia Power grid to provide clean energy to nearby residents through the Province’s Community Feed-In Tariff (COMFIT) Program. Major long-term benefits for Halifax Water and their customers include a reduction of electricity costs and the creation of sustainable and resilient infrastructure. Halifax Water is considering several other sites for similar pumps as turbines.

RENTRICITY’S RESULTS

The Halifax Water energy recovery system operates as designed and delivers approximately 31 kilowatts of clean electricity to Nova Scotia Power's grid. The system operates for 19 hours per day and passes 1,650 gallons per minute, use a differential head of 56 pounds per square inch, which would otherwise be dissipated with a pressure reduction valve. The system is expected to generate approximately 225,000-kilowatt hours per year. Rentricity expects the Halifax energy recovery systems to operate for 40-years with minimal maintenance.

FINANCIAL REVIEW

Halifax Water spent approximately $500,000, 25% below budget Halifax Regional Water Commission, the Water Research Foundation and the Department of the Environment teamed up to fun the system, which will produce 225,000 kilowatt hours of energy per year from its Bedford location. Halifax Water expects to generate approximately $30,000 of revenue per year from the sale of the power.

Case Study 7:

RENTRICITY CASE STUDY

Municipal Authority of Westmorland County, Pennsylvania.

INTRODUCTION:

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THE CHALLENGE

The Pennsylvania Department of Environmental Protection mandates a continuous discharge from the Municipal Authority of Westmoreland County (MAWC) Beaver Dam into the Beaver Run Creek at a minimum flow rate of 6.5 million gallons a day (MGD).

By releasing water through a gravity main from the reservoir, energy is lost that can otherwise be used to generate electricity. With rising electric costs and rate caps coming off, rates are increasing over the next 3 years. The MAWC was faced with the question of how to comply with its discharge requirement, noninvasively recover energy for self-generation.

RENTRICITY’S SOLUTION

The existing mandated discharge system consisted of two parallel pipes, one 8-inch diameter and one 12-inch diameter, both leading from the industrial raw water main to the Beaver Run Creek. A below ground vault allowed access to the two pipes, each one with an insertion flow meter interfaced with the SCADA system.

The mandated discharge system was adjacent to, but functionally separate from, the Beaver Run Raw Water Pump Station that provided raw water to the treatment plant on the adjacent hill.

Rentricity designed a system utilizing existing technologies and retrofitted them to recover the energy. A new below ground vault was constructed for housing a horizontally mounted 30kW turbine generator and associated hardware and appurtenances. A pressure tap was installed on the pipe with a local readout and remote pressure signal. The new turbine generator assembly was also inclusive of a hydraulically actuated inlet valve.

In addition to the energy recovery system, a 12-inch bypass line was also installed in the vault, replacing the 8-inch line which was only able to accommodate a maximum flow of 3.7 MGD. This new 12-inch pipe was installed parallel to the turbine generator assembly, to release the mandated 6.5 MGD flow in the event the turbine generator is offline. This replacement 12-inch line was fitted with a flow control valve to modulate the flow between 1.1 MGD, when the turbine generator is in operation, to at least 6.5 MGD when it is offline, with a total combined flow through the two lines of at least 6.5 MGD.

As a continuous flow mandated release site, in normal operation the turbine generator will run continuously. Static head, as measured at the inlet to the turbine, results in a sustainable flow through the turbine of about 5.4 MGD. Additional flow, as desired or mandated can be routed through the parallel 12-inch pipe for discharge into the creek.

A control panel in the adjacent pump house allows for local or remote startup. Local startup mode is operated by switch control while remote startup mode is operated by keyboard command from the MAWC SCADA system. In the event of shutdown due to fault, loss of grid power, or initiated for preventive maintenance, the turbine generator will shut down automatically, with the hydraulic actuator, automatically closing the turbine inlet valve, a process that takes 30 to 60 seconds. The valve on the bypass line will open to permit the 6.5 MGD mandated release. The turbine generator will remain offline until manually started again on the control panel.   Similarly, shutdown can be operator initiated by the same procedure.

The electricity generated from the new 30 kW turbine generator system is utilized “behind the meter” to partially power the adjacent pumps that transfer raw water from the Beaver Run Reservoir to the neighboring water treatment plant, decreasing demand from the electrical utility grid.

RENTRICITY’S RESULTS:

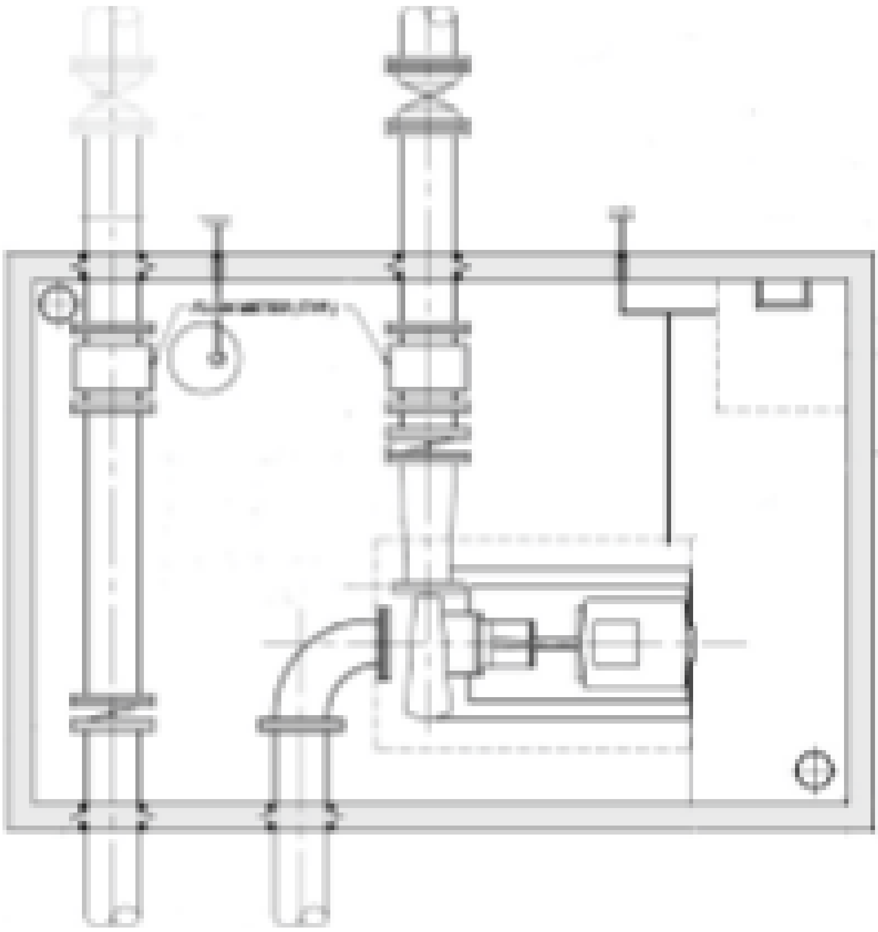
MAWC is now recovering energy that was previously lost, moving closer to a more sustainable and efficient water system.

Electricity costs account for one-third of MAWC!s production budget. It is estimated that Rentricity!s single system, producing over 250 MWh a year, will save MAWC $40,000 in electricity costs per year because costs are anticipated to increase.

Case	CoE $/kw-hr	Grants	RECS ($/kw-hr)	Payback Yrs	% IRR	Comments
1	$ 0.08	$ -	$ -	16	6%	Base Case
2	$ 0.08	$ -	$ 0.03	11	8%	Add RECs
3	$ 0.08	$ 200,000		6	18%	Grant
4	$ 0.08	$ 200,000	$ 0.03	4	25%	Grant + RECs
5	$ 0.12	$ -	$ -	10	10%	Anticipated COE Increase Base Case
6	$ 0.12	$ -	$ 0.03	8	12%	Anticipated COE Increase + RECs
7	$ 0.12	$ 200,000		4	28%	Anticipated COE Increase + Grant
8	$ 0.12	$ 200,000	$ 0.03	3	35%	Anticipated COE Increase + Grant + RECs

THE FINANCIAL CASE

Rentricity!s energy recovery systems are durable and reliable, designed with a 40-year lifespan and little need for maintenance. The rate of return is very attractive, with a much shorter base case payback period than other renewable energy systems and project costs around $0.04/kWh. Federal, state and local incentives including, grants and other subsidies, increase the rate of return and decrease $/kWh dramatically. The MAWC was awarded a state grant of over $200,000, for an accelerated payback. The following shows the different payback scenarios for the site, including anticipated rise in energy costs.



Case Study 8:

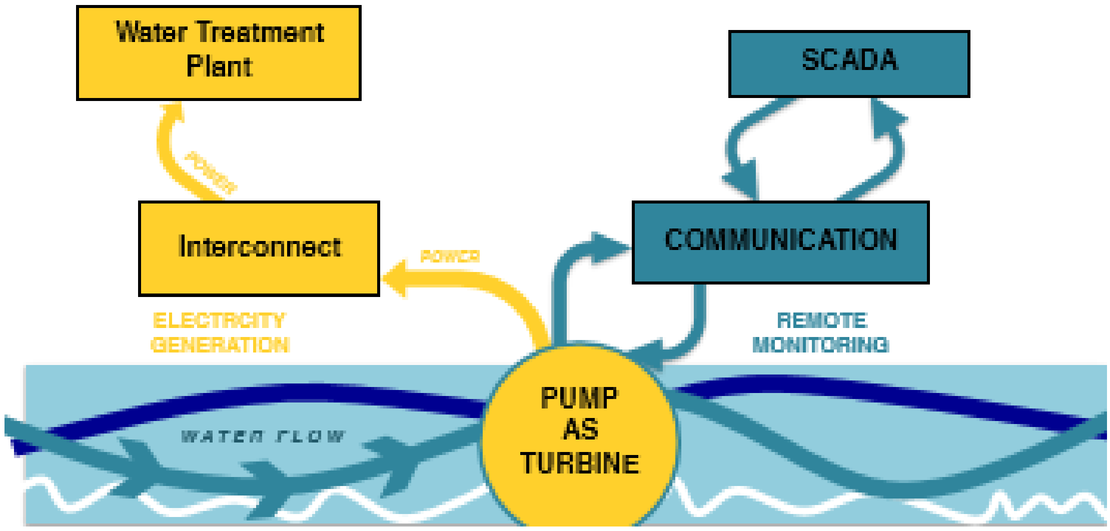
Rentricity Case Study.

Pennsylvania American Water Company.

Pennsylvania American Water Oneida V alley Water Treatment Plant Butler, Pennsylvania.

PROJECT SUMMARY:

Rentricity installed its Flow-WireSM in-conduit energy recover system at a raw water intake at Pennsylvania American Water's (PAW) Oneida Valley Water Treatment Pl ant. The system generates clean electricity, offsetting electricity used to pump and tr eat water at the plant. Rentricity's energy recovery system is integrated into PAW's i nfrastructure which transfers water from the Oneida and Thorn Run reservoirs to the water treatment plant.



THE CHALLENGE

PAW's gravity-fed system includes a pressure reduction valve (PRV) to reduce water pressure before the treatment plant. The water distribution process, including water t ransfer, treatment, and storage is extremely energy intensive, and converting the exce ss water pressure into electricity, instead of waste heat, can help offset the plant's el ectricity usage.

Rentricity's Solution:

Rentricity's flow-to-wire system was custom designed for the PAW sites specific hydraulic condition. It included a turbine generator with a piping by pass around the existing PRV, electric control, and water process control keep the energy recovery system trasparetn to

PAW’S normal operation.The project also rerouted in-flow pipes from the Thorn Run and Oneida reservoirs so that they now enter the plant through one common pipe.

RENTRICITY’S RESULT:

The PAW Flow--to--WireSM installation has a capacity of 30 kW, generating 131.4 megawatt hours annually, allowing the company to offset electricity purchased from the grid. The Flow--to--WireSM system has an estimated 40--year life span, providing decades of predictable revenue and clean energy generation for Pennsylvania American Water.

Project Facts:

Installation Size: 30 kW

Annual Energy: Generation: 131.4 MWh

Facility’s Energy: Offset: 5% of the plant’s annual electricity use

Annual Reductions: in Greenhouse Gas Emissions: 90.6 tons per year

Grants/Subsidies: $180,000 from Pennsylvania Energy Development Authority (PED)

Case Study 8:

Rentricity – Aquarion Water Energy Recovery Pilot Study.

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-Wiresm system supplier in January 2004. An engineering team comprised of individuals who work for Aquarion, Golder Associates, and Rentricity determined the exact Flow-to-Wiresm 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.

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

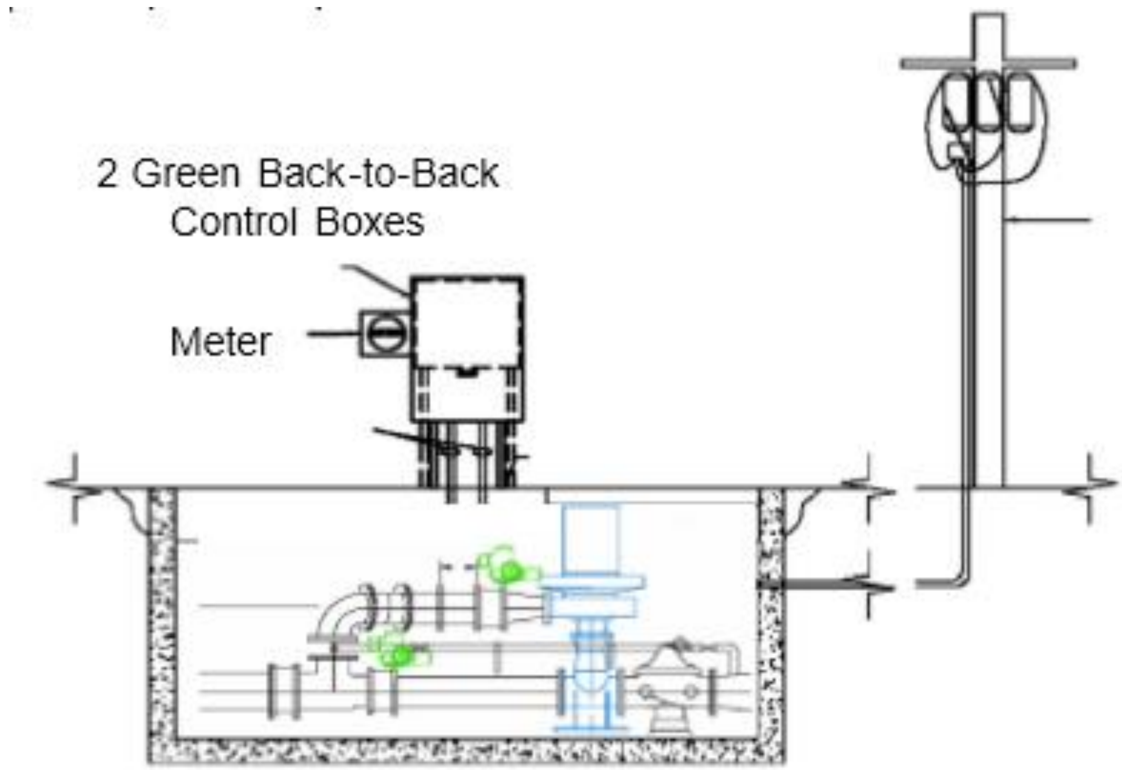
Vault Characteristics

- 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

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-Wiresm 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 RenFlosm Services: The Company programmed and installed identification information into its RenFlosm 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-Wiresm 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-Wiresm 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.

10. Preoperational and Startup Testing of the Flow-to-WireSM 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.

CONCLUSION

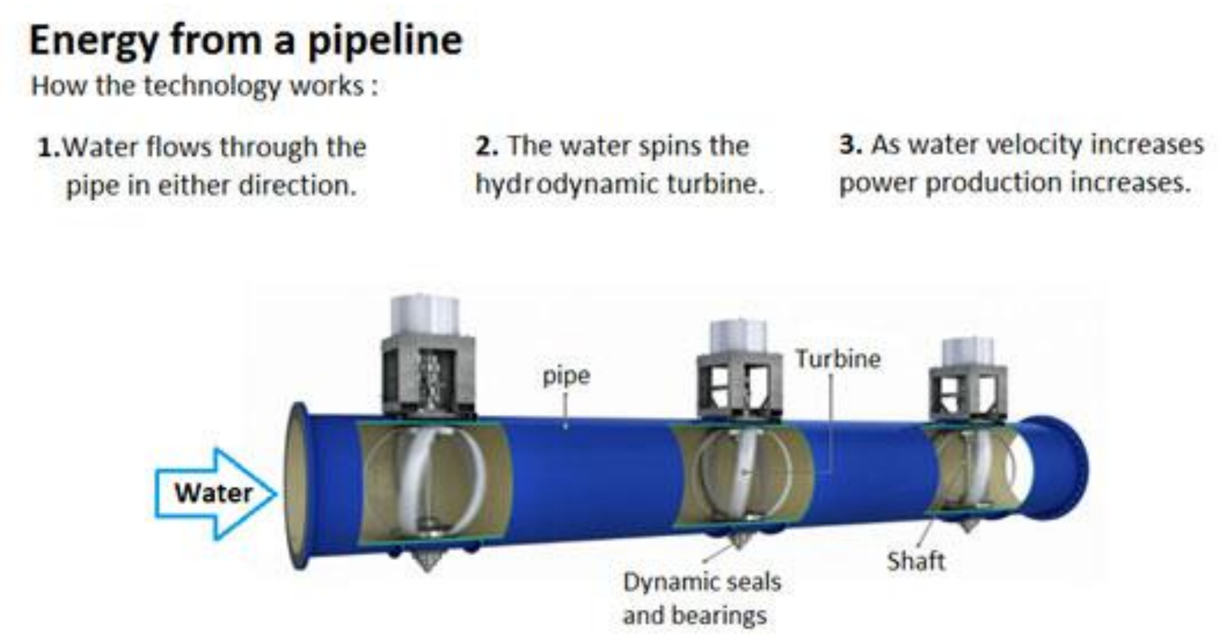


Fig. 3: Hydro-kinetic power generation using multiple turbines (Lucid Energy System)[9].

Water companies all over the World 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.

When water is flowing through pipelines, there is energy that can be harvested. If those pipelines are from large municipal pipelines or industrial manufacturers pumping millions of gallons of water a day, the amount of renewable energy is huge. This is known as “in-pipe hydropower” or “smart water infrastructure”.

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