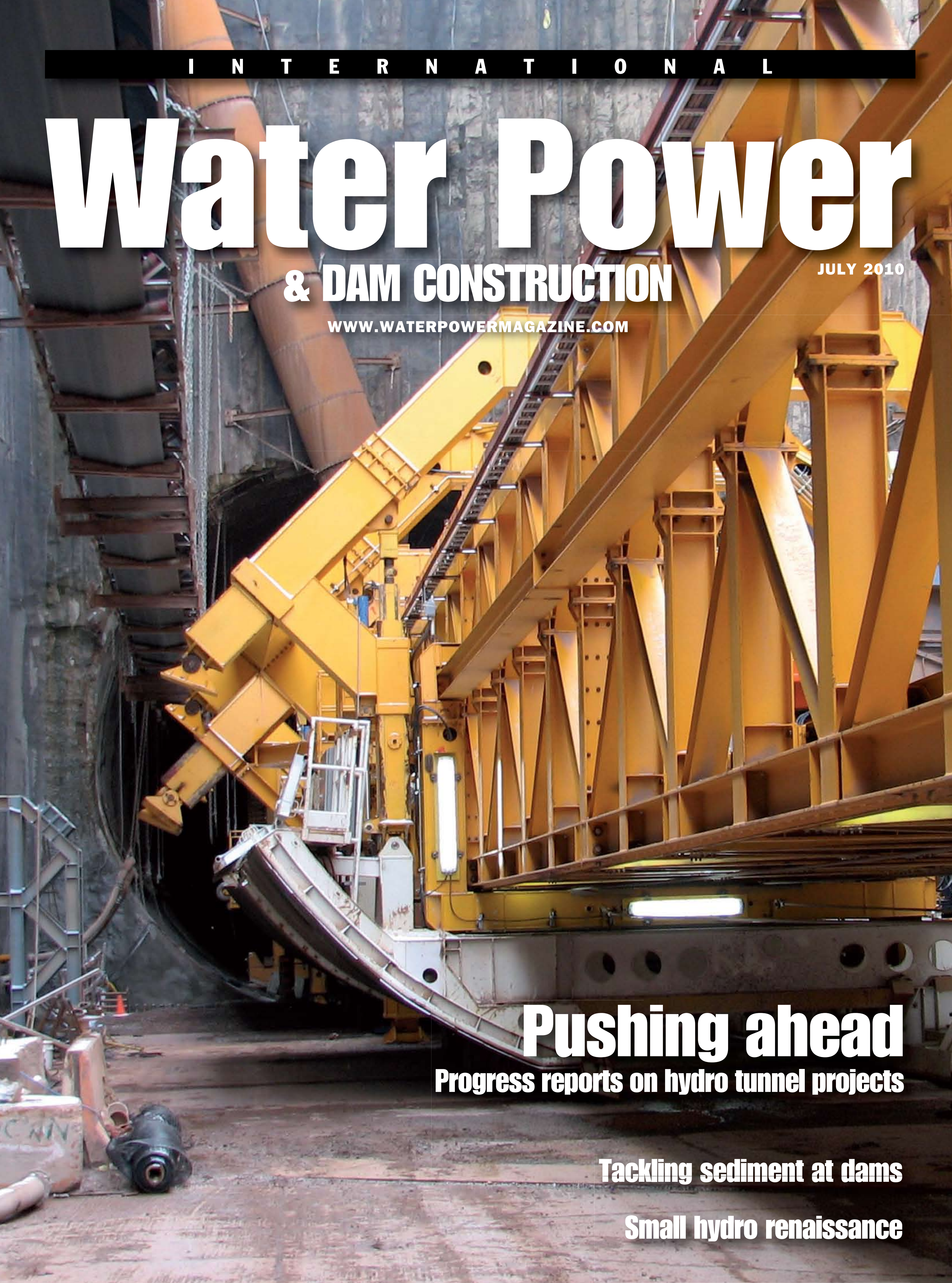
INTERNATIONAL

Water Power

& DAM CONSTRUCTION

JULY 2010

WWW.WATERPOWERMAGAZINE.COM



Pushing ahead

Progress reports on hydro tunnel projects

Tackling sediment at dams

Small hydro renaissance

Serving the hydro industry for over 60 years

Energy recovery from public water systems

Public water systems are often an ideal application for small hydro systems. The existing water supply provides a finished intake and penstock, and in many cases a pressure reducing valve can be bypassed with a hydro turbine that generates a positive return on investment for the community. Michael Maloney reports.

TAPPING into the wasted energy of public water systems doesn't typically generate large amounts of power: a few hundred kilowatts at best. On the other hand, the existing infrastructure already provides almost everything needed for a hydro system except the turbine/generator set. Public utilities routinely bleed off excess pressure that could be put to work simply by opening a coupling and bolting in a turbine. Even though power output may be nominal, this low cost solution can quickly pay for itself.

Unlike most hydro systems, however, energy recovery systems are often subject to unusual constraints. For example, community water usage directly affects flow, which can vary dramatically over the course of a day. In addition, it is often necessary to maintain water pressure at the turbine output to ensure adequate pressure for the community. These factors can complicate the selection of turbine equipment.

It is also important to remember system priorities. The highest priority is uninterrupted water supply to the community, with power generation coming in a distant second. These priorities can collide at times. For example, if an electrical problem abruptly trips the generator offline, water must continue to flow to the community even though the turbine/generator may be suddenly freewheeling under no load.

Beyond technical issues, regulatory hurdles can significantly delay an energy recovery project, if not kill it entirely. Conventional wisdom would suggest approval would come quickly, since the entire system is usually a simple revision of plumbing. But these low impact projects are subject to the same regulatory processes as larger scale hydro systems, in the US requiring FERC permitting and – surprisingly – the need to deal with environmental opposition.

SOAR Technologies specialises in solving these types of problems for communities. The company provides specialised turbine systems, as well as assistance with feasibility assessment, technical design, and the long journey toward regulatory approval. Over the past few years, SOAR has installed energy recovery systems in Hawaii, Vermont, Oregon, and other locations across the US.

Technical challenges

Two major issues are commonplace with water supply systems: variable flow and pressurised distribution to the community. These factors create a challenging dilemma for hydro systems designers, especially when encountered on the same project.

Variable flow, for example, would suggest the use of impulse turbines such as Pelton or turgo. With a broad efficiency curve, impulse turbines can often deliver good performance down to 10% of design flow. But a pressurised output complicates matters. Impulse turbines, by definition, run in open air and typically employ a tailrace that is not easily pressurised.

A 35kW Pelton-type SOAR GPRV installed for the County of Hawaii Department of Water Supply

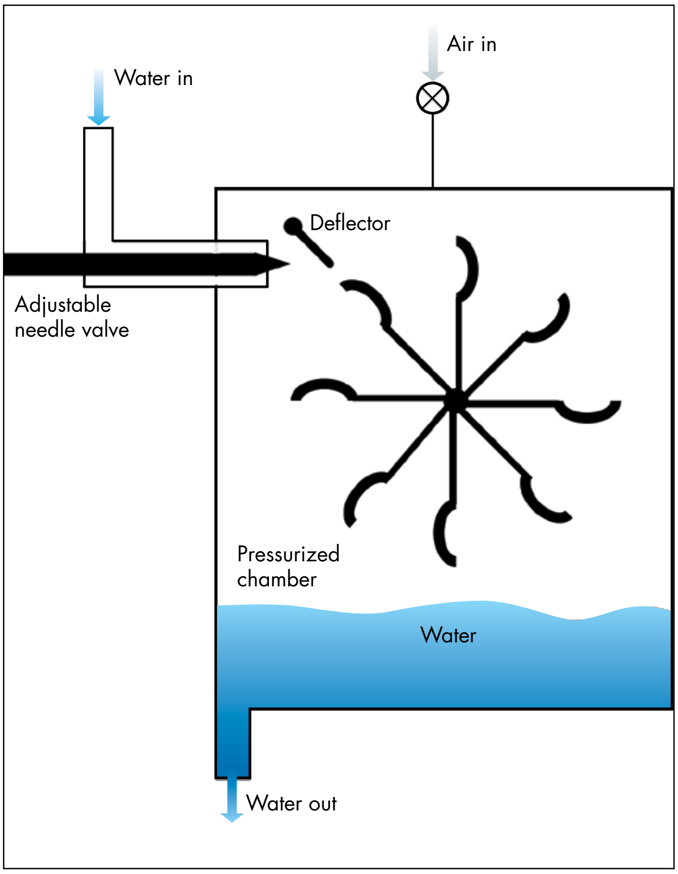
In contrast, reactive turbine types such as Francis and Kaplan operate well in a pressurized environment, since they are never exposed to the atmosphere. As long as there is a pressure difference between turbine input and output, reactive designs can produce power. Unfortunately, they are less forgiving of wide swings in flow. Below 50% of design flow, efficiency drops dramatically.

Then there is the issue of priority. By definition, community demand determines flow rate; the power generation system cannot alter flow in any way. Water must continue to flow unimpeded even when the generator is suddenly thrown offline. Impulse turbines have the advantage here; a deflector shield simply directs the stream of water away from the runner without affecting flow. Reactive turbines are more of a challenge since the flow of water always wants to spin the runner. In addition, the resistance of the runner itself has an effect on flow.

All of the energy recovery systems installed by SOAR are designed to run in parallel with the existing water system. This allows the turbine/generator to be taken offline for maintenance without impacting the community water supply. Most systems use hydraulic actuators, allowing switchover to be manual or automatic.

Developing the GPRV

In 2004, SOAR participated in a research project to develop a generating pressure reducing valve (GPRV). SOAR worked with the



A line drawing of a Pelton-type GRPV. The SOAR Pelton-type GPRV pressurises a sealed runner chamber with compressed air to maintain water pressure at the outlet

California Energy Commission and San Diego State University to develop a simple method for replacing existing PRVs with small hydro systems. Over the course of several months a number of working test models were constructed to produce a preliminary design for a pressurised impulse turbine system. SOAR later patented this design for commercial production.

The original GPRV was essentially a Pelton turbine enclosed in a sealed housing to maintain positive pressure at the tailrace. As with all Pelton designs, the turbine runs in air, but the air is compressed within a sealed chamber. SOAR teamed with Canyon Hydro to manufacture this new design, and installed the first GPRV unit in a water system on the island of Hawaii.

This early version of the GPRV employed a vertical (horizontal shaft) Pelton runner, coupled with a standard air compressor to pressurise the system. The expected power output was achieved but there were significant issues with air entrainment. Air in the water is not harmful; in fact, it tends to improve the water treatment process downstream. But since air must be compressed to run the system, and compressors require energy, any air loss down the pipeline is essentially a loss of efficiency. With the vertical runner design, the compressor was running almost constantly to replenish lost air.

To better manage air entrainment, SOAR engineers ran extensive computational fluid dynamics simulations, resulting in development of a new design that uses a horizontally-oriented (vertical shaft) Pelton runner for significantly improved operation. Using a horizontal runner, the water tends to spin its way out of the turbine, helping to separate the air before the water exits down the pipeline.

SOAR has also developed reactive versions of the GPRV using Francis and reverse-pump designs. These fully immersed turbines simplify pressurised operation but are constrained to a much narrower operating range for changes in flow. In addition, special provisions are necessary to accommodate continuous flow even when the turbine trips offline.

Flow through a Francis turbine changes drastically when generator load is removed. A reactive turbine in an over-speed condition tends to choke flow, an unacceptable scenario in a water supply system. To alleviate this problem, SOAR developed a multi-stage Francis design to maintain nearly constant flow in any situation.

The SOAR Francis GPRV uses a modified impeller design and uses two to five Francis runners in series. Head pressure determines the number of runners in the system. Because space is often at a premium in existing water systems, runners are oriented vertically to save room. Unlike conventional Francis turbines, the water inlet and outlet are aligned to facilitate easy installation into an existing pipeline.

Determining project feasibility

The growing global focus on green energy and sustainability has sparked a sharp spike in interest for energy recovery systems. Water supply systems are the most common application; however, there is also potential for wastewater system applications.

Wastewater systems are generally more difficult to cost justify. They tend to be low head, high flow environments, which require physically larger turbine systems to handle the additional flow. Because physical size bears a direct relationship to turbine cost, SOAR has yet to evaluate a wastewater application that forecasts a positive return on investment.

When invited to assess the feasibility of a potential project, SOAR focuses on four key parameters: head, flow, flow duration (variability), and regulatory process. Most of our systems have been installed for use with a net metering plan, where generator output offsets some of the power normally purchased to run the plant. In effect, net metering pays the power producer retail rates for electricity, substantially accelerating system payback.

Unfortunately, regulatory requirements are often a major obstacle. Whenever public water and public power come together, approvals from both FERC and the local power company are required. Currently the lead time for gaining FERC approval of conduit projects is about six months, and the FERC application itself usually takes at least two months to prepare. Before submitting the application, multiple agencies, environmental groups, tribal leaders and other stakeholders must reach agreement.

Unfortunately, the cost to obtain regulatory approval sometimes makes it impossible to justify an otherwise viable project. But good news may be forthcoming. FERC has indicated that it will streamline and simplify applications for energy recovery projects.

Most of the inquiries SOAR receives originate from local water system operators. These are the hands-on water experts who know their systems and can identify opportunities for energy recovery. Even so, nearly every project requires buy-in at the executive level, and the cost must always be justified. A good part of SOAR's effort goes into pulling many disparate groups together to ensure project success.

Looking ahead

Worldwide interest in energy recovery appears to be growing, and SOAR anticipates more projects will emerge as word spreads between water districts. Green energy, despite the economic slowdown, still promises strong growth – especially on the heels of the disaster in the Gulf of Mexico. As technologies such as the GPRV continue to improve, and assuming the regulatory process is further streamlined, future energy recovery projects should be easier to justify and faster to implement. IWP&DC

Michael Maloney is president of SOAR Technologies, a hydropower design and project consulting firm based in Washington State, US.
Email: mmaloney@soartechinc.com.
www.soartechinc.com