SOLAR-POWERED AUTOMATION ON IRRIGATION DELIVERY SYSTEMS

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ABSTRACT

For the last 20 years, the Bureau of Reclamation (Provo Area Office) has been working with irrigators throughout the Intermountain West to develop, install, and test solar-powered DIY (do-it-yourself) gate actuators and other water monitoring and control devices. To date, over 100 control devices have been installed in Utah, Wyoming, Idaho, Oregon, Colorado, and New Mexico. Demonstration units have also been sent to Kansas, Mexico, and China. Reclamation has also worked with several manufacturers and vendors in the development of 24-VDC commercial gate actuators. Additionally, manufacturers have started marketing a wide variety of complete automated solar-powered gate units.

VISION

In Utah and the surrounding areas, systems of weather, hydrologic, and other environmental sensors are being distributed basin-wide (Hansen et al, 2002). This trend will continue to expand as motes and nanotechnologies continue to evolve, and communication options become more sophisticated. Real-time data from ever-increasingly sophisticated environmental sensors combined with information from other sources (e.g. human, webcam, remote sensing) can then be linked by wireless and Internet communications to data collections and analyses centers outfitted with data-fusion, decision-support tools (including ever more realistic simulations).

From this developing "central nervous center," signals are sent back to water control structures. Future self-regulating river basins are created, which will be critical for 24/7 operations and for adapting to uncertain hydrologic variation created by global climate change. Tightly regulated rivers are susceptible to precise operations. For example, with automation it is possible to return diurnal fluctuation to stretches of a river. Real-time operating systems will also be the foundation for sustainable future development.

Comprehensive real-time monitoring and control facilities have been installed in several Intermountain river basins including the Sevier, San Rafael, Duchesne, Spanish Fork, and Bear (see Figure 1). A system on the upper Green River is currently in its nascent stage. The Sanpitch and Price Rivers currently have partial systems. All real-time information is currently being reported on the following river basin websites: www.sevierriver.org,

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www.ewcd.org, www.duchesneriver.org, www.spanishforkriver.org, and www.bearriverbasin.org.

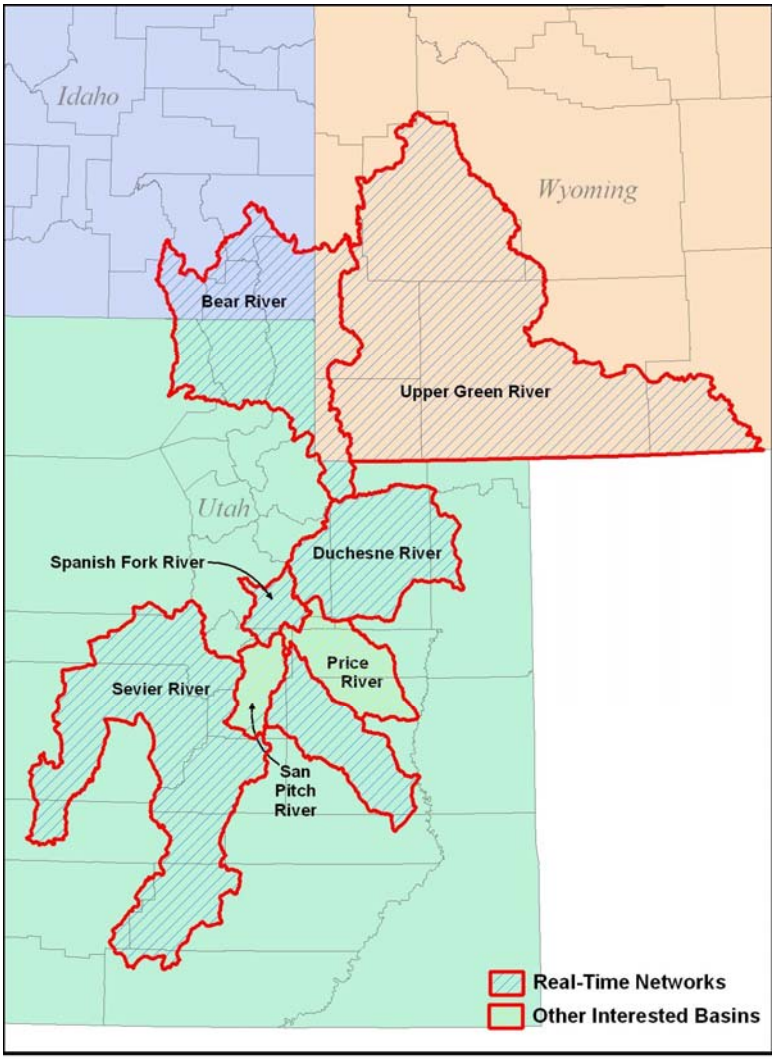


Figure 1. River Basin Real-Time Monitoring and Control Systems

BACKGROUND

Key ingredients in the river-basin mélange are control devices and structures, many of which are in very remote areas requiring alternative power sources (Pugh and Hansen, 1996). Over the last 20 years, Reclamation staff has experimented, tested, and installed a variety of solar-powered gate actuators. The examples below are not exhaustive, but do represent a cross-section of the technologies that are available and that the Provo Area Office has installed and evaluated.

Many modernization programs for the operation of canals and river basins involve the mechanization of water control gates. Gate actuators provide a method of raising and lowering canal gates using DC-powered electric motors instead of human power. A

common response to studies recommending automation has been that the cost of purchasing and the problems and complexity of maintaining commercially available actuators are high, thereby jeopardizing implementation plans. However, recent advances with solar-powered gate actuators have made automation feasible for the majority of applications (Hansen and Pugh, 1997).

Reclamation has tried several permutations of solar-powered gate actuators (Hansen et al, 2001) including: (1) mechanical DIY units on slide gates; (2) hydraulic DIY units on slide gates; (3) commercial units on slide gates; (4) mechanical DIY units on radial gates; (5) commercial units on radial gates; (6) commercial drawbridge gates; (7) commercial pillow gates; and (8) commercial scissor gates. Solar energy has also been used to power real-time environmental monitoring systems. Other types of alternative power have also been tried including a micro-hydro unit on Joe's Valley Dam, a Federal facility in central Utah. This unit provides all the electricity needs for lights, monitoring and control equipment, webcams, and security systems. The Joe's Valley micro-hydro unit replaced an existing diesel generator.

DO-IT-YOURSELF ACTUATORS

Mechanical

The most popular automation model for a frame-model slide gate (undershot) is the DIY mechanical actuator which consists of a $1/16^{th}$ horsepower gear motor, a bicycle-type lift apparatus (chain and sprocket), and a cover over the gate stem which contains a gate position sensor and limit switches. Utah State University staff demonstrated the feasibility of these in the 1980s and Reclamation staff made refinements in subsequent years.

A gate system is typically powered by 1 or 2 deep-cycle batteries which are charged by a 20-, 30-, or 40-watt solar panel. The latter also powers the remote terminal unit or RTU (which includes a communication system). The preexistent slide gate requires only minor modification for the installation of a large gear which is attached to the 12-VDC gear motor with an industrial chain. The gate actuator takes a day or two to install (see Photographs 1, 2 and 3). In the event of subsequent problems, troubleshooting and repairs are trivial and the parts are inexpensive. The total cost of parts for one gate is approximately $3,000.

Photograph 1. Huntington Canal Diversion Structure Prior to Gate Actuator Installation near Huntington, UT

Photograph 2. Gate Actuators Being Installed on Huntington Canal Diversion Structure

Photograph 3. Gate Actuator Installed on Scipio Canal near Scipio, UT

This DIY actuator can also be installed on a pedestal gate, but a frame needs to be constructed over the pedestal, and the larger sprocket is mounted to the top of the wheel (see Photograph 4). A similar system can also be used on radial gates. A permutation of the DIY gate was also developed to keep the gate stem open. This latter feature is valuable when using a webcam to monitor conditions at and around the structure (including gate position). Discussing this latter option, "ITRC (International Training and Research Center, 2000) feels the device (the one that leaves the gate stem open) is too complex for most (irrigation) districts to construct and any cost savings would be offset by the time required for construction."

Photograph 4. Gate Actuator Being Installed on a Pedestal Gate on Scipio Dam Outlet Works near Scipio, UT

Hydraulic

To automate a hydraulic gate, two things are needed: (1) gate position and (2) gate control. The preferable gate position reading is taken by direct connection to the physical gate or gate stem. This reduces the chances of false readings due to gear slippage, slop, or mechanical failure. The gate position can be taken using a retractable cable sensor connected to the gate itself or the hydraulic ram if the gate is not accessible.

Hydraulic gate control can be added to several types of existing systems. For a gate controlled by a hand-operated hydraulic pump, the automation system must be added leaving the existing system functional. To automate a hand-control gate, an electric hydraulic pump (preferably 12 or 24 VDC), and electronic solenoid valves must be added. The solenoid valves and the motor must be placed in parallel with the hand valves and hand pump.

Hydraulic gate control can also be installed on an existing motorized hydraulic system. An electric switch must be added so either an automated or a manual mode can be selected but not run simultaneously. If the valves are manual, solenoid valves must also be added. If the pump on/off switch can not be controlled automatically, a relay must be added.

For a new system with an existing gate, hydraulic rams, an electric hydraulic pump, solenoid valves, and pump control relays must be added. For a simpler version, using a pressure switch and an accumulator tank (a tank which acts as a pressure reservoir) to maintain hydraulic pressure can replace the pump control solenoid.

COMMERCIAL PRODUCTS

Commercial Gate Actuators

A variety of commercial gate actuators and systems that can be solar powered are also available. When Reclamation initially started 20 years ago, none of the major actuator manufacturers had 12- or 24-VDC models. On one test site, an inverter was installed to power a 110-VDC gate actuator system. This test, while successful, was not a very efficient or elegant solution. Eventually a local vendor was willing to install a 24-VDC motor on a commercially available actuator. This proved to be a very acceptable solution. Eventually other manufacturers developed similar products. These systems work fine, but are frequently over-engineered for many irrigation applications. For example, maintenance is considerably more complicated than with the DIY model. According to the previously mentioned ITRC report: “Commercial actuators generally have additional electronic features built into them for control or safety purposes, and all of the components are placed into a tight bundle. ITRC has found that irrigation district personnel (especially in small irrigation districts) are unable to troubleshoot or repair the commercial actuators. Therefore, if one small component has a problem, the complete unit will often be abandoned. Irrigation district personnel appear to be willing to forego

some of the extra capabilities in order to gain simplicity and ease of service and component replacement." Reclamation has had similar experiences.

Commercial Gates

There are several overshot gate models that include the gate and other parts of the structure in the total package. Three examples or these are the: (1) draw-bridge gate; (2) scissor gate; and (3) pneumatic crest gate. All can be powered by solar energy systems.

Drawbridge Gate: This overshot gate consists of a gate leaf, hinge, and hoist mechanism. This gate is likened to a drawbridge hinged across the bottom of a vertical-walled channel. When the gate is horizontal (fully open), water flows through the channel uninterrupted. As the cable hoist raises the downstream end of the gate, water flows over the lip while the channel sides restrict the water. The hoist can be operated by a 12- or 24-VDC motor.

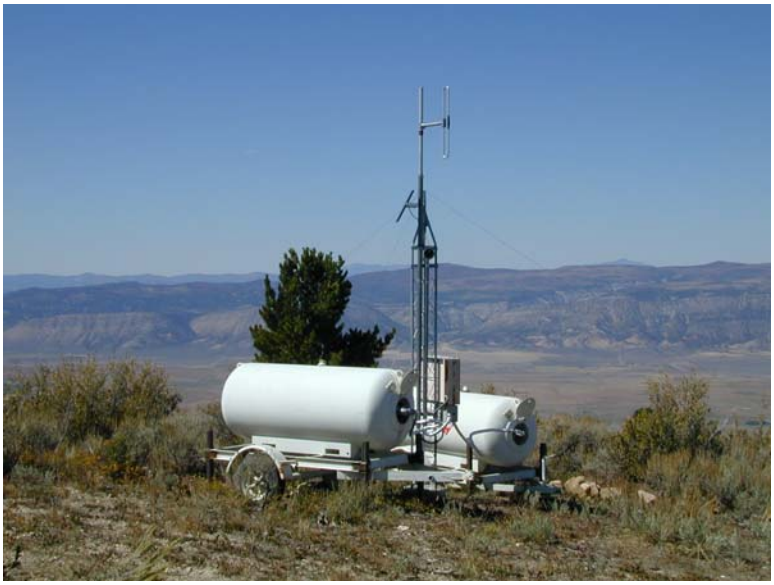
Scissor Gate: One version of the scissor gate, invented by Peter Langemann and manufactured by AquaSystems 2000 Inc. (a Canadian firm), is an arrangement of hinged leaves that function as an adjustable weir to provide either flow control or upstream level control. Each gate is fully self-contained and incorporates a 12-VDC motor and gear reducer, limit switches, and electrical control panel.

Pneumatic Crest (Pillow) Gate: Working with Obermeyer, Inc. (Ft. Collins, Colorado, USA), an overshot gate for use in check and similar structures has been tested. The Obermeyer gate is hinged across the bottom and is moved up and down by an air bladder. A small 12-VDC air compressor is used to inflate the bladder. During 1994, an Obermeyer gate was retrofitted into a check structure of a canal in north-central Utah.

OTHER SOLAR-POWERED ACTIVITIES

A variety of other water and water-related facilities have been solar powered, including: (1) real-time flow measurement and soil-moisture monitoring (see Photograph 5) units; (2) webcams for security and monitoring real-time water and weather conditions; (3) mountain-based cloud-seeding units (and potentially other geoengineering activities) (see Photograph 6); and (4) outdoor kiosks that dispense real-time and other information. It is anticipated that in the near future, solar-powered monitoring and control systems will be densely packed throughout river basins.

Photograph 5. Installing Soil-Moisture Monitoring Units near Delta, UT



Photograph 6. Solar Powered, High-Mountain Cloud-seeding Units in Sanpete County, UT

CONCLUSIONS

Solar power makes the installation of SCADA (real-time monitoring and control) systems on even small reservoirs and canals financially feasible. There are a variety of funding mechanisms that encourage water resource automation. For many irrigation systems, solar-powered automation systems are the "best bang they can get for their water – efficiency bucks."

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