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Cost-Effective Scada Development For Irrigation Districts: A Nebraska Case Study

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COST-EFFECTIVE SCADA DEVELOPMENT FOR IRRIGATION DISTRICTS: A NEBRASKA CASE STUDY

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ABSTRACT

Irrigation districts across the West face economic hardship brought about by increased maintenance costs, reduced water supplies, and a shortage of skilled labor. One opportunity for a district to offset these challenges is by implementing a Supervisory Control and Data Acquisition (SCADA) system. However, historically these systems have been out of the reach of smaller and less-affluent districts because of the large capital outlays required for adoption.

Reclamation's Nebraska-Kansas Area Office in cooperation with Reclamation's Hydraulic Investigations and Research Laboratory is working with the Bostwick Irrigation District in Nebraska to create a monitoring and control system suitable to the needs of a small irrigation district with limited resources. Specifically the project has focused on low acquisition and installation costs, district driven solutions to SCADA operational issues, and minimization of technical expertise for maintenance purposes.

This paper chronicles the efforts to develop a SCADA solution for the Bostwick Irrigation District in Nebraska that meets each of these needs through innovative product choices, materials fabrication, and low-cost solutions. Current project status and future project direction are discussed in context of the District's operating environment in light of the complex issues facing all the water users in the Republican River Basin upstream from Kansas.

BACKGROUND

The Bostwick Division was authorized in December of 1944. The Bostwick Division is comprised of two sub-units, Bostwick Irrigation District in Nebraska that currently serves approximately 20,500 acres in Nebraska, and the Kansas-Bostwick Irrigation District currently serving approximately 62,000 acres. Harlan County Lake, a multiple use water storage and flood control facility constructed by the US Army Corps of Engineers (USACE) on the Republican River near Republican City NE serves as storage for both the Nebraska and Kansas Bostwick Districts. Lovewell reservoir on White Rock Creed provides additional storage for the Kansas-Bostwick District.

Nebraska Bostwick Irrigation District is geographically in the middle of the area that was the focus of recent US Supreme Court litigation among Kansas, Nebraska and Colorado regarding use of Republican River Basin water resources. In 2004 with Harlan County Lake at

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approximately one-third normal storage capacity, no water was delivered to District shareholders for the first time since water delivery operations were initiated in the 1950's. 2005 was again a water short year and for the second consecutive year, no deliveries were made to Nebraska Bostwick irrigators. With return of precipitation in the basin to rates closer to the historical norm, Nebraska Bostwick water deliveries resumed in 2006 and have continued through 2009. Going into the 2010 season, Harlan county lake is at full storage, which bodes well for normal deliveries in 2010

With these recent uncertainties in its operations, Nebraska Bostwick has been aggressive in enhancing water conservation capabilities in their delivery network. The District has taken advantage of the comparatively high elevation of the Franklin Canal relative to the delivery areas served by laterals off the Canal and in Spring, 2010 is completing a multi-year project to replace multiple open laterals with buried pipe. In an effort initiated in 2009, Nebraska Bostwick began to integrate electronic control and radio communications equipment which will enable local automation and/or remote operation and monitoring of structures in the canal system. The control/communications project is the focus of this paper.

PROJECT SCOPE

All field locations included in initial phase of Nebraska Bostwick's control/communications project are located on the main stem of the District's Franklin Canal. The Franklin Canal runs along the north side of the Republican River beginning at the turnout gates just below Harlan County Dam. The canal continues for almost 47 canal miles eastward paralleling the Republican River along the north side of the valley. The upper end design capacity of the Franklin Canal is 230 ft^3/s.

Sites selected for equipment installation are ten check structure along the canal reach between Harlan County Dam and Red Cloud NE. The selected checks represent approximately every third check structure. Distance in canal miles between instrumented checks ranges from a low of 2.1 miles to a high of 5.6 miles. The average distance is approximately 3.6 miles.

Lands under Nebraska Bostwick are subject to frequent intense and often localized thunder storms. As a result, irrigators routinely need to drop scheduled deliveries on short notice. Additionally, storm water runoff can lead to significant unanticipated canal inflows. Throughout its operating history, Nebraska Bostwick has experienced significant spillage losses due to impacts of weather events.

Primary among upgraded capabilities being sought by the district were 1) improved delivery reliability, and 2) the capability to utilize in-canal storage to limit spillage losses. Additional benefits such as reduced vehicle mileage and staff travel time required to monitor the system were considered secondary to improving system performance and enhancing water conservation.

To meet District objectives, Reclamation engineers worked with District staff to develop a plan for equipping the ten designated check structures for local automated upstream level control with the capability to adjust target levels either onsite, or remotely. Additionally, Reclamation engineers attempted to develop a methodology for using the installed gates as a flow measurement device to determine flow passing the instrumented check structures.

EVALUATION OF EXISTING STRUCTURES

The ten selected checks represented two general design configurations. The upper seven checks were each three-bay structures. The two outer bays were stop-log controlled and the center bay was a vertical slide gate. None of the gates were motorized. District staff indicated that the vertical slide gates had remained in closed position at all times for as far back as presently employed personnel could remember. The District opted to rebuild existing gates prior to installing the control and communications equipment. Since district staff was tied up on the project of converting open laterals to buried pipe, the District contracted with a local welding shop to construct new gates for the seven upper three-bay structures. Figure 1 is a photo of the three-bay 5.4 check

Figure 1. Reclamation Engineer Clinton Powell (L) and Nebraska Bostwick Manager Mike Delka Inspect the 5.4 Check in February, 2009

. The three checks lower on the canal that the District selected for motorized gate operation initially had no gates installed. Each of these sites was a two-bay structure with stop-log control in each bay. The District staff fabricated new vertical slide gates to install in one of the stop-log bays at each of these checks. Figure 2 shows the 34.2 check site.

Figure 2. Nebraska Bostwick 34.2 Check in February 2009

RADO PATHWAY CHECK

In March of 2009, Reclamation engineers worked with Nebraska Bostwick personnel to test radio transmission signal strength. Radio/control units manufactured by Control Design Inc. (CDI) were selected for the tests based on the successful performance of their equipment on other projects. Compared to other available alternatives, CDI equipment was cost effective and demonstrated good signal strength. For the tests, an antenna was temporarily installed on the communications radio tower at the District's Red Cloud office. A battery-powered radio was connected to the antenna at the tower base. A second antenna was attached to a ten-foot mast and taken to each check structure, beginning with the site nearest Red Cloud and working outward. A second battery powered radio/control unit programmed with a calibration algorithm to determine receiver signal strength indicator (RSSI) levels was linked to the field antenna.

Communications with the Red Cloud office were tested at successively further west sites until a site was reached at which a reliable link could not be established. At that time, the field antenna was taken to the District's Franklin office and temporarily installed on the Franklin communications radio tower to attempt direct contact with Red Cloud. Attempts to make direct contact between the office sites were unsuccessful. To continue the tests, the antenna at Red Cloud was taken down and mounted to the ten-foot mast to use at remaining field sites in checking communications linkage with the Franklin Office. The later tests showed that communications from Franklin were possible with the westernmost check that could be contacted from Red Cloud, and with all of the rest of the field sites west from that point plus the gate house at Harlan County Dam.

Based on findings of the radio pathways testing a comparatively simple radio network was sufficient to establish communications among all sites and both offices without including any dedicated repeater sites. Each office base could be programmed to communicate directly with field sites within its range. The system was designed such that for out of range sites, each office would repeat first through the field site (the 28.6 check) that could directly communicate with both offices. A second repeat could be made through the base at the other office, then back to the selected field site. Built-in networking configuration tools in the CDI equipment enables each unit to perform as a base or as a field Remote Transmission Unit (RTU) and simultaneously function as a repeater. Figure 3 is a sketch of the project layout showing relative positions of Harlan County Lake, instrumented check sites, the Franklin and Red Cloud offices, along with the check site that also functions as a repeater.

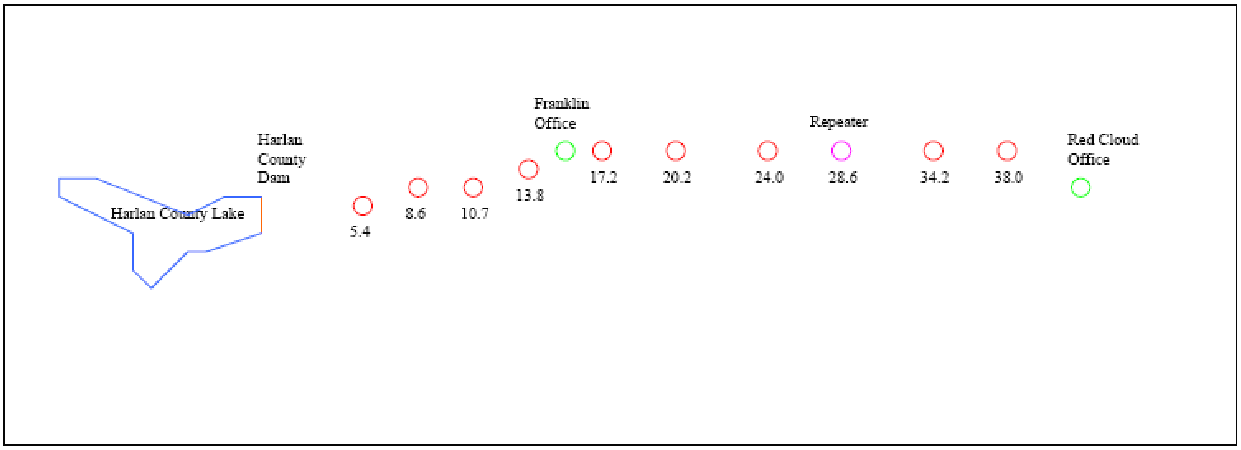

Figure 3. A Layout Sketch of Approximate Locations of the Radio/Communications Sites.

A sense of scale may be derived from Figure 3 from check identifier names. The identification number for the Franklin Canal checks represent the number of canal miles they are located from the gate house below the Harlan County Dam. It should be noted in the context of the discussions on radio transmission paths that the landscape throughout the project area can be characterized as rolling hills. Much of the radio pathway being utilized is not line of sight.

GATE MOTORIZATION

Nebraska Bostwick considered a range of gate motorization alternatives. Prior to embarking on this project, two members of the District staff participated in a Reclamation-sponsored Canal Modernization Workshop held in February of 2009 in Hot Springs SD. During the workshop, staff of the Belle Fourche (SD) Irrigation District reported on their canal modernization project that included using linear actuators on previously hand-operated gates. Belle Fourche has also installed commercially produce canal gate actuators produced by Limitorque. Information was also presented on a chain drive gate motorization that was developed by Reclamation over a decade ago that has been in service over an extended time period at sites in multiple states.

For reasons of simplified installation and for the attractive affordability offered, the District opted to motorize the vertical slide check gates using linear actuators. Availability of units with built-in travel limit switches as well as built in positions sensors were perceived as key benefits over the chain drive option. From an affordability standpoint, the linear actuators are almost an order of magnitude lower in cost than commercial actuators.

The new gates, which were either built by District staff or by a contractor, were configured during construction for linear actuator operation. In lieu of the threaded rods previously used to lift gates, a short section of smooth shaft was affixed to the gate on the lower end and has a clevis-type connector for linkage to the linear actuator on the upper end. The function of this rod is to keep all components of the linear actuator above the water surface at any gate position.

2009 INSTALLATIONS

New gates were installed at each of the selected check sites in early June prior to the initial water-up of the system. Tubing and protective conduit for bubbler level sensors were also installed at check structures prior to watering up the system. Each site was equipped for upstream and downstream level measurement if submergence conditions are present.

Installation of linear actuators, along with batteries, solar charging systems, and manual operation toggle switches began prior to water-up and continued through out much of the irrigation season. Limitations on the time commitments of Reclamation staff proved to be a bottleneck in completion of this task. Reclamation's staff was primarily responsible for calibration and testing of electrical and electronic components. At sites where gate motorization was not yet functional, canal stage adjustments were made by adjusting stop logs in bays adjacent to the gated bays, in the same manner the system has been operated in previous years. Figure 4 shows the final stages of hardware installation at the 20.2 check. Figure 5 is a photo of the same site from a different angle.

Figure 4. Reclamation Engineer Clinton Powell Making Wiring Connections on the Linear Actuator at the Nebraska Bostwick 20.2 Check

Figure 5. Completed Hardware Installation at the Nebraska Bostwick 20.2 Check

CONTROL SYSTEM COMPONENTS

As noted earlier, bubbler level sensors were selected to measure upstream canal pool level. Downstream levels are needed for gate flow measurement where submergence is present. The bubbler equipment employs a single bubbler setup plumbed through a bi-directional solenoid valve to enable the same sensor to measure water level at two locations. The installation was made easier because CDI had previously provided a board with all components needed for this multiple level bubbler sensor for use with a submerged flume measuring system Reclamation has been field testing in Arizona.

This multiple location bubbler level sensor was a cost competitive alternative for measuring two levels. The bubbler technology also eliminates water quality concerns associated with use of submersible pressure transducers, functions effectively without a stilling well, and does not require the temperature compensation that is often needed with ultrasonic level sensors.

Gate operation circuitry that Reclamation (and others) have utilized at multiple DC powered canal gate installations utilizes triple-pole, double-throw plug-in relays with relay contacts located in a sealed chamber filled with inert gas. Two relays are utilized for each gate. When a relay coil is energized, two of the normally open triple pole contacts close to complete both the ground and positive legs of the gate motor circuit. The coil energizing circuit utilizes normally closed contacts on the third pole of the companion relay. Thus when one relay coil is energized, all normally closed poles are opened. It is not possible to simultaneously energize both relay coils.

CDI has created a circuit board with sockets for the plug-in relays that utilize the same circuitry as hand-wired installations Reclamation has used successfully along with diodes to protect against reverse current flow resulting from collapsing fields as circuits are switched. An additional feature built into the CDI boards are terminal connections for installation of toggle switches to switch control from the on-site programmable logic controller (PLC) to hand operated toggle switches to raise and lower gates.

The CDI radio control units are assembled as a single unit consisting of a programmable logic controller, a modem and the radio. The current product line which was introduced in 2007 may be configured with or without an on-board 4 x 20 display and with or without an on-board 6 button keypad. At similar installations where CDI equipment has been utilized, an on-site user interface has proven to be a desirable configuration. Figure 6 shows installation of control equipment at a Nebraska Bostwick check site with remotely located display and 4 x 4 keypad.

Figure 6. Control Components (upper enclosure) and
User-Interface Components (lower enclosure)

A drawback to the on-board display and keypad is that if these user interface components are frequently accessed, there is high potential for the enclosure cover to be insufficiently closed and sealed leading to issues with moisture and/or insects disrupting function of electronic components. For the Nebraska Bostwick project, external display and keypad components are located in a separate electrical enclosure to reduce potential for exposure of sensitive electronic components to the elements. To further isolate sensitive components from potentially corrosive agents, the battery is housed in a separate enclosure on the opposite side of the pole from control equipment.

2010 PROJECT STATUS AND FUTURE PLANS

During the 2009 irrigation season, as linear actuators along with batteries and charging systems were installed, ditch riders adjusted the motorized check gates manually using toggle switches (seen in Figure 6 below the display and keypad face plate). The upstream level control programming will be installed in the CDI units and tested during the 2010 irrigation season.

After manually operating the motorized gates in 2009, the ditch rider staff is in favor of a program to upgrade all stop log bays with gate structures. The District recognizes the advantages of the configuration of the three-bay checks in the upper reaches of the Franklin Canal whereby the center vertical slide gate enables passage of bed sediments while flow passing over stop logs on the side bays can enable much of the floating debris to also pass the structure.

To maintain the ability to pass floating debris, overshot gates were identified as the preferred alternative for upgrading stop-log bays at checks where vertical slide gates already exist. Following a scoping-level investigation of prices for commercially available overshot gates, the District opted to participate in a Reclamation Science and Technology Program research project that is seeking to develop guidelines for overshot gates that irrigation districts can self-construct. The research project is focused on structures that can be fabricated as “drop-in” units for existing stop-log structures.

In this effort the District has constructed overshot gates to install in stop log bays at three of the checks where motorized slide gates were installed in 2009. Similar to the motorization alternative selected for vertical slide gates, the overshot gates will also be operated by DC powered linear actuators. Based on a projection of forces that will act on the gates, two actuators with gear heads linked by a drive shaft will be used to operate the gates.

As operation of the overshot gates is incorporated into the automated upstream level operation, the algorithm will call for coarse adjustments to be accomplished with overshot gate movements while small adjustments will be made with vertical slide gate movements. Once the automation system is functional, water level target adjustments may be entered on-site following on-screen prompts and keypad input, or remotely via radio. Manager Mike Delka sees the District expanding this modernization effort at an affordable rate until ultimately all main canal checks have similar automated or remote operating capability. Figure 7 is a photo of the District’s 28.6 check where motorized gates have been installed in previously stop-log controlled bays by the beginning of the 2010 irrigation season.

Figure 7. Vertical Slide and Overshot Gates at the 28.6 Check
Both Motorized using DC Linear Actuators

SUMMARY

For an initial experience with integration of electronic control and communications equipment into canal operations, the scope of Nebraska Bostwick's project represents a comparatively ambitious step. The seemingly boldness of the initial project scope is tempered considerably when considered in the context of current operating realities including the complete shut-down of deliveries in 2004 and 2005. Improving the District's water management capabilities to enable more efficient delivery operations is a key focus for District staff and producers alike.

The situation Nebraska Bostwick finds itself in is similar to the plight of many irrigation systems throughout the western United States. Many water users are being faced with the alternative of seeking affordable means of stretching limited water supplies, or risk being unable to afford to remain viable. The approach Nebraska Bostwick has selected is to rely on in-house talents and develop new in-house capabilities to the extent possible to make adoption of new technologies in system operations an affordable process that can help sustain the District with limited reliance on external expertise.