

SCADA EXPERIENCE IN MEXICO

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ABSTRACT

Since 1989, with the transfer of operation and maintenance of the irrigation districts to Water User Associations in Mexico, a big training and technological program began. Two large irrigation districts started their remote operation projects with unfavorable results. Poor equipment selection, based on extremely limited experience, and the absence of a supervisory system to verify the performance of the components were the root causes. The Mexican Institute of Water Technology (IMTA) is making headway in the use of SCADA systems for canal operation in Mexico. Studies include testing of the control algorithms required, development of the supervisory schemes, evaluation and adaptation of control elements available on the market and training of user association personnel. Two laboratory canals were used for these purposes. Since 1997, the Institute, supported by the National Water Commission (CNA), the Mexican federal agency responsible of water reclamation, worked with the farmers' association in the Carrizo Irrigation District to develop a remote flow monitoring system and remote control of four control structures

INTRODUCTION

In 1989, The Mexican government began the transfer of operation and maintenance of irrigation districts. This transfer was associated with a training, financial and technology program. In Mexico, water is a limiting factor for development. The marked competition between the municipalities, industry and agriculture is pushing toward more efficient use of this limited natural resource. Agriculture, the largest water consumer, requires new technologies to improve water and soil conservation. SCADA systems are one of these technological alternatives under analysis in Mexico.

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With the transfer process, a modernization program was started with limited results. The principal problem was that system operation (Plusquellec et al., 1994), the main aspect of modern project development, was not considered during design. New infrastructure and remote monitoring control systems were installed without considering well-defined and realistic operational plans based on the service concept. These problems and the lack of qualified staff doomed the modernization project to failure. These considerations and the limited experience with modern flow and level control alternatives caused two SCADA projects to fail.

PREVIOUS SCADA EXPERIENCES

In 1989, the National Water Commission (Comisión Nacional del Agua, CNA, the Mexican federal agency responsible of water reclamation) created two automation projects in the central planning area, "El Canal Alto" in the Yaqui River Irrigation District and "Bachimba" in the Delicias Irrigation District.

Río Yaqui Project

In 1994, IMTA carried out an evaluation of equipment and operating conditions in the Yaqui Project to determine why a recently built remote monitoring system had never been used and had been partially dismantled. The evaluation showed that an operation analysis had not been carried out, equipment was removed in two control structures, electronic components were faulty, and the communications components was inadequate for heavy-duty telemetry systems. These problems made the system very dangerous to use as it was. In the following years, the Users Association and CNA did not have the resources or desire to continue testing remote monitoring systems.

Bachimba Project

Bachimba project had a similar fate. The CNA's central office developed a project without the participation of personnel in charge of canal operations. When the project was finished, no one at the irrigation district knew how to use the new system or the purpose of the project. The proposed system involved the use of an unreliable communication system and a Remote Terminal Units (RTU) incapable of operating the control structure if communications with the master station were broken, a frequent occurrence with the communication equipment selected.

The reliability and performance of the equipment and the project architecture required for canal operation were underestimated. The lack of experience and interest in remote monitoring resulted in poor technical specifications in the request for proposals. Consequently, the projects were unreliable and useless. The cheapest solutions were taken while ignoring the contractors' lack of experience in canal operations.

IMTA RESEARCH PROJECTS ON REMOTE MONITORING AND CONTROL

IMTA has been involved in three aspects of remote monitoring and control of canal operation: 1) development of control and supervisory algorithms, 2) evaluation of control equipment and software and; 3) training of water users association personnel. The first component of this research was conducted with the simulation model SIC from the CEMAGREF, France. In 1995 and 1996, with the collaboration of the ITRC CalPoly, three slide gates were installed on a zero slope laboratory canal. Last year, with the assistance of the USBR Provo Office, a slide gate was installed on a trapezoidal canal.

Research Project On The Zero Slope Canal

Canal description. Three slide gates were installed (Fig. 1) in a zero slope canal, 60 cm wide, 40 m long and 1 m high at IMTA laboratory facilities. The canal inflow is regulated with a servo valve controlled by the RTU located at the slide gate. At the downstream end of the canal, the level is regulated by an overshot gate. Each slide gate is equipped with a linear actuator, two pressure sensors (upstream and downstream water level), a potentiometer for gate position and limit switches (maximum and minimum gate opening). The system was designed to allow manual operation and RTU operation. The RTU can be operated in the manual or local automatic mode. The linear actuator has a 12 Volt DC motor, controlled by an operation box that allows manual or RTU operation. Inside the box, a set of electromagnetic relays is controlled by the digital outputs of the RTU that specifies the direction of the motor. Two limit switches cut the power supply to the motor when the gate is at the upper and lower positions. The pressure sensors and gate position potentiometer are relayed to the analog inputs of the RTU. The RTUs used are the MODICOM PLC E984-245 and the SCADAPack from Control Microsystems. At the Pentium PC master station, the man-machine interface (MMI) was designed using the Lookout as SCADA (Supervisory Control and Data Acquisition) software. The master station and the PLC communicate using a cable communication called MODBUS+ or radio.

Control algorithms. With the control equipment installed, some control algorithms were evaluated. The initial tests were with a Proportional-Integral (PI) regulator in an upstream control application. The PI regulator performance changed with the head across the structure. The control parameters (KP and KI) had to be readjusted to maintain the desired closed loop performance. Burt et al. (1998) proposed a correction factor to account for the non-linearity of the upstream water level response to gate movement. The new algorithm is the PI with the universal factor (UF). This control algorithm is a gain scheduling PI regulator (Aström and Wittenmark, 1990).

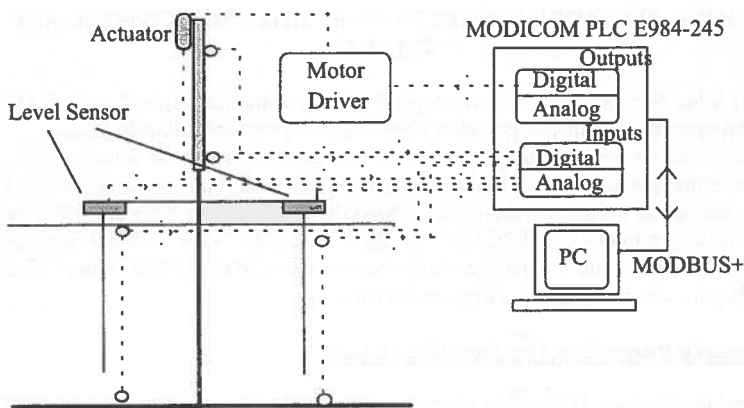


Figure 1. Slide gate with control and supervisory components.

The performance of a PI control algorithm in the regulation of the water level upstream of the gates at the laboratory canal is presented in Fig. 2. The flow at the head of the canal was changed 25% in each case. The sampling time was 10 seconds, the control parameters were $K_P = 0.8$, $K_I = 0.24$ (gate one), $K_P = 0.4$, $K_I = 0.08$ (gate two), and $K_P = 0.43$, $K_I = 0.04$ (gate three). The references (y_{ref}) for gate 1, gate 2 and gate 3 were 70 cm, 55 cm, 40 cm, respectively. The ability of the PI - UF to maintain the performance of the control algorithm under different operating conditions can be clearly observed in Fig. 3.

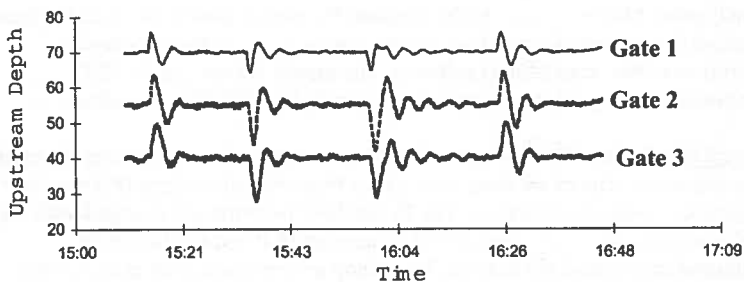


Figure 2. Evolution of the water depth upstream of the laboratory canal slide gates with a PI regulator when the flow at the head of the canal change 25 % (20 l/s)

Last year, a multivariable optimal regulator (Linear Quadratic Gaussian, LQG), was tested in simulation and in on the laboratory canal, as an alternative to canal

control. The LQG regulator was introduced in the SCADA systems, using the Windows DDE options, the SCADA software Lookout was connected with Matlab where the control algorithms were developed. Fig. 4 shows the downstream level responses (outputs), when an inflow perturbation acts on the canal with the LQG regulator. The Fig. 4 presents the opening evolution of the control gates (inputs), and inflow variation (perturbation) (Begovich et al, 2002).

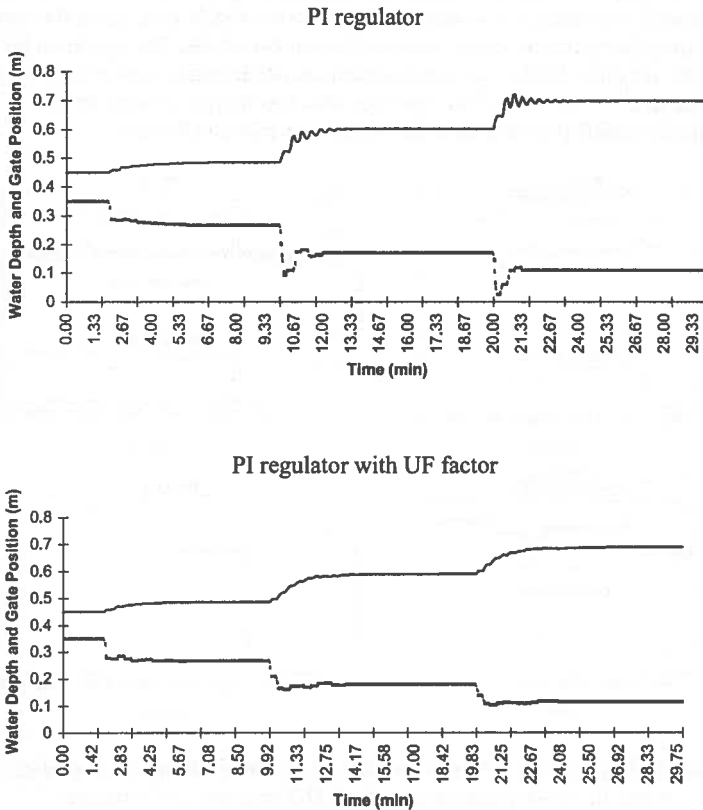


Figure 3. Evolution of the water level (continuous line) tracking a reference profile with different PI regulators. The gate position is presented in the dotted line.

Research Project On The Trapezoidal Canal.

Canal Description: A slide gate was installed, with water level sensors, gate position sensor and gate actuator, on a trapezoidal canal 25 m long, 0.0005 bottom slope, 1:1 slide slope,. The low cost sensors and actuator were provided by the group of Roger Hansen from USBR, Provo, USA. The canal also has scaled-down models of real regulators (AMIL gate, overshoot gate) and turnouts (metering gates and distributor). The inflow to the canal is regulated by a manual valve. An X2 distributor (120 l/s max.) is located upstream from the slide gate. As in the zero slope canal, the operation system was divided on two boxes. The operation box drives the actuator. All the electronic equipment (RTU, radio, power supply, etc.) is located in the control box. The operation box was designed based on the example the USBR provided us with components found in Mexico.

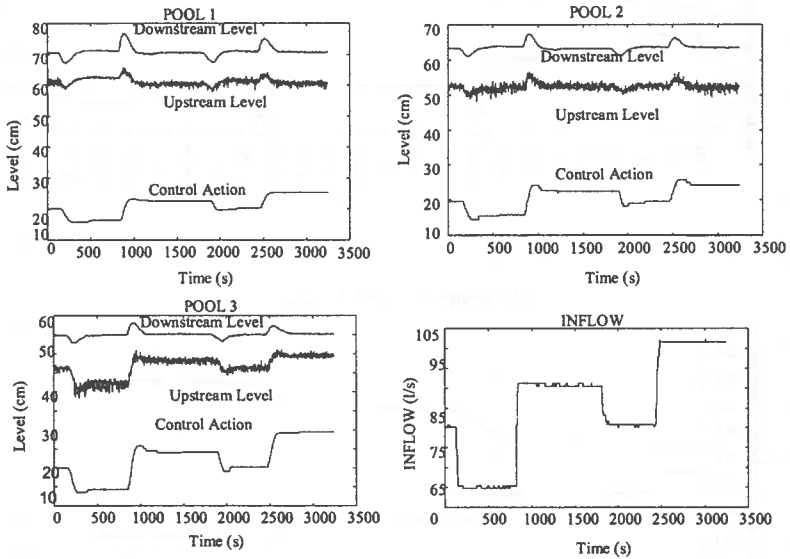


Figure 4. Responses of both downstream levels and positions of control gates when an inflow perturbation acts (LQG regulator performance).

Regulator test. As a first step, the PI block of the Telepace ladder logic was used for upstream control. The level was regulated at 35 cm from the bottom of the canal, the nominal level of the X2 distributor (Nerpyc Alsthom). Downstream of the distributor the discharge was free. The evolution of the level upstream the gate and gate position when the flow through the distributor changes is shown in Fig. 5.

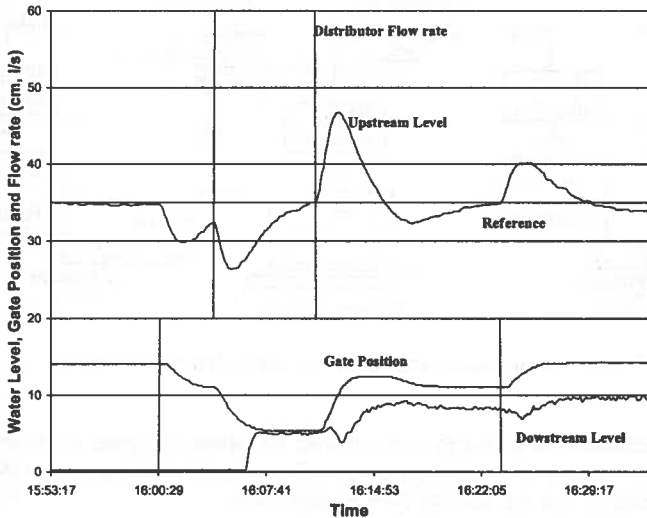


Figure 5. Performance of the PI regulator on the upstream water level in the laboratory canal

IMTA FIELD EXPERIENCE

Remote Flow Monitoring. The farmers' association in the Carrizo Irrigation district, under a drought assistance program financed by the Ministry of Agriculture (SAGAR), asked IMTA to help them develop a remote flow monitoring system (Fig. 6). Long-throated flumes were built at the head of the main canals and secondary canals, and at the beginning of the irrigation sections controlled by different farmers' associations. The water depth in the flume is measured at a stilling well using an ultrasonic sensor. From the water depth, a 2100 Badger Meter determines the flow and totals the volume passing through the flume using the flume calibration equation. The measured information is sent to the master station using a radio-modem transceiver (MDS 4310). The communication protocol used is MODBUS. At the master station, a man-machine interface (MMI, Lookout) program presents the flow information and the accumulated volume. The MMI displays on a district map the sites and the measured flow. There is a screen display for each flume that presents all the flow and volume information required by the water master.

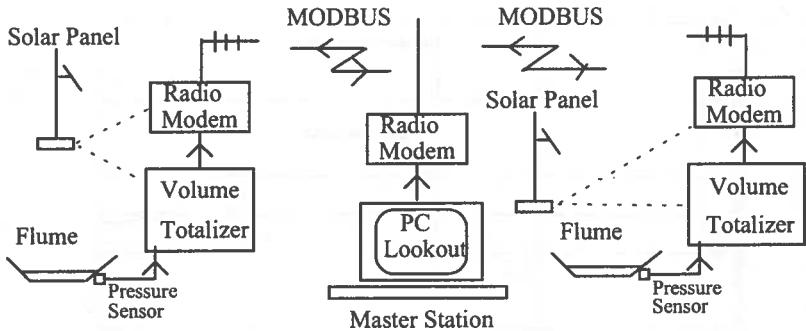


Figure 6. Flow measurement at the Carrizo Irrigation District.

Problems encountered during this project were all solved. The main problem for 3 years was the quality of the field equipment. This original field equipment (MGV from Hidronica) was replaced by 2100 Badger Meter.

Remote Operation. In November of 1999, IMTA began to work on the remote operation of control structures at the Carrizo District. The project is financially supported by CAN. Given the Carrizo District's experience with remote flow monitoring, IMTA considered that this could be a good place to test control equipment. Today, four control structures have remote monitoring and control. Two of the remote flow monitoring sites are based on the equipment tested on the trapezoidal canal. The two other sites are based on technology developed at the National Autonomous University of Mexico. Figure 7 shows the upstream level and gate movements requested since it started operation at the control structures located at the head of the North Canal.

CONCLUSIONS

SCADA equipment is an alternative for canal operation. Special care must be taken in the development of the project. Equipment maintenance, training programs, user capacity and social conditions must be carefully considered. Pilot projects, involving important remote monitoring but not crucial canal operation, can provide an estimate of the capacity of those responsible for building and operating the system.

After the experiences on canal operation and the possibilities Lookout gives to supervise operation through Internet and Intranet, CNA is very interested in the development of SCADA projects to supervise Water Users Association operation. This year some districts have requested IMTA to help them develop their remote monitoring system as part of the federal program to improve flow measurement at the control point where the water is provided to the water user associations. Until

today the remote control projects have been supported 100% by CNA.

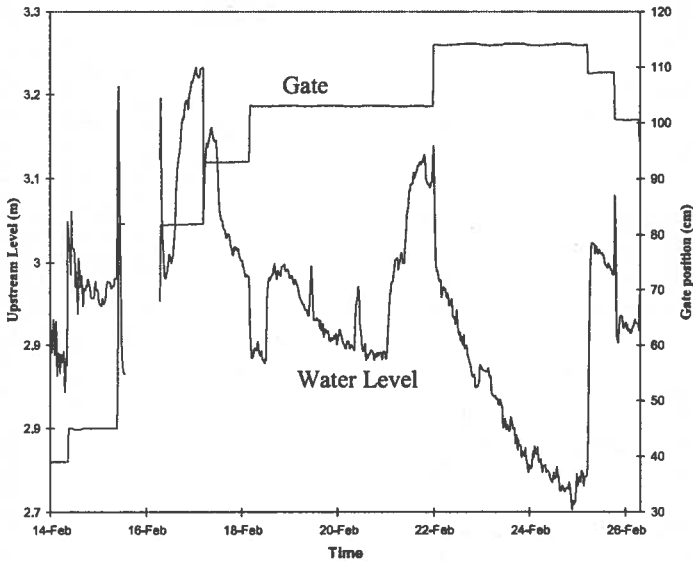


Figure 7. Evolution of the water level upstream and gate position at the head of the north main canal in the Carrizo Irrigation District.

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