SCADA APPLICATION ON A DIVERSION DAM

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ABSTRACT

This paper describes a flow control regulator application in a diversion dam at the Irrigation District 097, "Lázaro Cardenas", Michoacan, Mexico. A Hydropower Company has started to produce electricity during high demand peak hours releasing the daily volume for irrigation in few hours. Downstream of the storage dam, a Diversion dam stores the water released for power and delivers the water as the irrigation district requires under controlled conditions. Because of these changes in operations at the diversion dam a SCADA systems was installed. The measurement and operation equipment integrated for this application consisted in a SCADAPack, the Probe ultrasonic level sensor, gate position sensor and Horizontal Doppler Current Profiler Channel Master as flow meter. The SCADAPacks at the flow meter and diversion dam were connected by low cost radios called Maxstream. To improve the reliability of the systems redundant equipment was installed on gate position, upstream level sensor. For flow measurement reliability the gate equation, calibrated with the H-ADCP data, was used. As a first step a set of rules were introduced to adjust the gate opening to keep the flow at the head of the main canal constant as the level on the diversion dam change. Since the end of 2006 the system is being transferred from a manual system to an automated system.

INTRODUCTION

The Mexican water law promotes the "Integral use of Water". A water source can be used for different water users while its profit does not affect the rights of the other users. Since Federal Company of Electricity, "Comisión Federal del Electricidad" (CFE) is not interested to produce electricity at small storage dams, small Hydropower companies have started to install hydropower facilities because they have smaller operation costs. The main constraint for the Hydropower companies is that they can only use the volume used for irrigation each day.

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With different water requirement in time and flow the Hydropower Company (HC) and the irrigation district required to modify the operation of the hydraulic infrastructure on their operation boundaries to make compatible their water requirement. The HC request large flow rates during the peak hours of electricity every night, taking all the volume for irrigation in some hours while irrigation district needs a constant flow rate all day. In the case of the “Chilatan” storage dam at the Irrigation District 097 “Lazaro Cardenas” in the state of Michoacan the only hydraulic infrastructure to make possible the profit of water for both water users is the “Piedras Blancas” diversion dam. The diversion dam stores the water used to release for power at storage dam and release it as the irrigation district request under controlled conditions. In front of these new operation conditions some modifications were made, the storage capacity of the diversion dam was increased and the gates and its actuators at the head control structure of the Left Bank Main Canal (LBMC) were rehabilitated. For the control system for the diversion dam operation the HC contacted Dr. C. Burt. Dr. Burt suggested that the Mexican Institute of Water Technology (IMTA) could make the project. Finally the “Comisión Nacional del Agua” (CONAGUA), Federal Agency in charge of water reclamations in México, responsible of diversion dam management, requested to IMTA a turn key solution for the control of the diversion dam (Fig. 1).

This paper describes the solution proposed for the operation of the Diversion Dam, the equipment used for it implementation, the typical manual operation made at the Diversion Dam and some simulation obtained with the control algorithms and the future works to finish the control project.

Figure 1. Piedras Blancas Diversion Dam

CONTROL PROBLEM DESCRIPTION

CONAGUA and HC reviewed the operation of the diversion dam considering the water users requirements. The storage capacity of diversion dam was increased, the spillway was raised 1.5 m. The seal of the emergency gates of the Diversion Dam were rehabilitated and motor actuators were installed. At the control structure of the LBMC on the Diversion Dam the seal of the gates were changed and motor actuators were installed.

For the gates at the head of the LBMC a flow control systems was requested to keep the flow constant for the irrigation requirements when the level on the diversion dam change. The control structure at the diversion dam has three radial gates three meter tall and four wide. In all the gates measurement and control equipment were installed for flow control. The original control project considered that the flow at the head of the canal could be measured with a Replogle flume. The hydraulic conditions presented in the canal and the diversion dam made impossible to install a flume without and important reduction of the storage capacity at the diversion dam. To avoid this problem and Horizontal Acoustic Doppler Current Profiler (Channel Master RD Instruments, H-ADCP) was installed. With the change on flow measurement device, the flow measurement problem became more complicated. The canal dynamics, volume changes and wave propagation were added to the flow measurement problem.

For reliability of the flow control system to design, the redundancy of all the sensors, level, gate opening and flow was considered

IMPLEMENTATION EQUIPMENT

For the operation of the Diversion Dam a SCADAPack RTU was used. For level sensors the ultrasonic sensor “The Probe” from Milltronics Siemens were installed upstream and downstream. The gate position was measured with a potentiometer connected to the gear box of the gate actuators. Transpack T752 transducers were used to transform the resistance of the potentiometer on a 4-20 current loop. For the operation of the three gates an electric circuit of electromagnetic relay was made. This circuit advice the RTU when the gate in on manual operation or RTU operation and activate the gate actuator function of the digital outputs signals of the RTU. The circuit panel used for manual operation was not modified. On RTU the procedures for gate operation was programmed on Leader Logic and the procedures for sensor calibration, level and gate opening, on “C” lenguage.

To measure the flow a Channel Master was installed. The Channel Master was calibrated considering four different flow conditions that cover the flow operation range in the LBMC. During the calibration procedure the flow was measured using the mobile ADCP Steam Pro. From the calibration procedure, velocity index equation obtained had only one coefficient. The H-ADCP was configured to send every five minutes the average data collected of flow, volume, velocity, Pitch, Roll, Temperature, to a SCADAPack RTU. The SCADAPack using a “C” program reads the ASCII code sent by the H-ADCP.

Low cost radios from Maxstream allowed the data exchange between the RTUs on the H-ADCP and the Diversion Dam.

Redundant sensors were considered on all the collected data, for upstream level and gate position two sensors were installed at the diversion dam and on each gate. For flow measurement the H-ADCP data will be compared with the gate equation, actually under development. For downstream level sensor the level was measured by an ultrasonic level sensor and the ultrasonic level sensor of the H-ADCP.

For security on the operation, difference of two centimeters was allowed on the gate opening and upstream level sensor. If the difference was grater than the tolerance the leader logic program stop the operation of the gate and turn on an alarm. The alarm is reseted when the difference was eliminated and the reset alarm switch is activated.

For this simple application of a control structure, the master station was integrated using a PC and Lookout as Man Machine Interface. The RTU of the diversion dam and the master station were in the same office and were connected by wire.

H-ADCP Diversion Dam

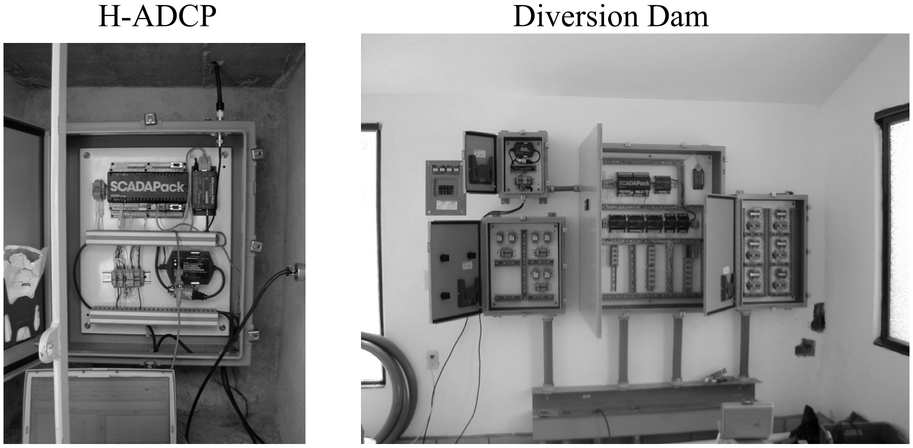


Figure 2. RTU at the H-ADCP and Diversion Dam

Level Gate Opening Channel Master H-ADCP

Figure 3. Level and Gate Position Sensors

In the integration of the systems the protocol used was MODBUS. The RTU installed has the possibility to change to DNP3 when more measurement and operation points will be added to the SCADA system.

MANUAL OPERATION

Until now the operation of the Diversion Dam were made manually. The level on the diversion dam rises as the water coming from the Storage Dam arrives and decreases as the flow from the storage dam stop. As it can be seen on Fig. 4 the gate adjustments were made mainly between 7 am to 3 pm when the diversion dam is draining and the head on the control structures decrease and between 7 pm to 11 pm when the water used during the peak demand hours of electricity production 6 pm to 10 pm arrives. After review some weeks of operation, the results show that the operation made by the ditchrider was not the same all the days of the week. On Friday and Saturday the quality of the irrigation service decreased. On Sunday the peak hours of electricity generation decreased. In general with manual operation more water than requested was given to the user association in charge of the LBMC management.

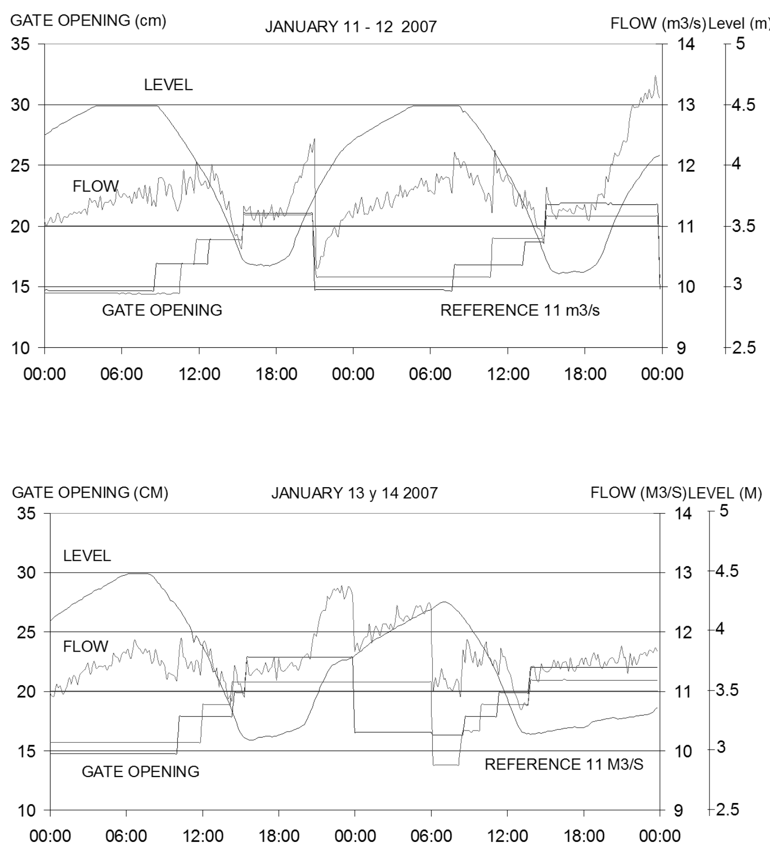


Figure 4. Performance of the Diversion Dam on Manual Operation.

CONTROL ALGORITHM

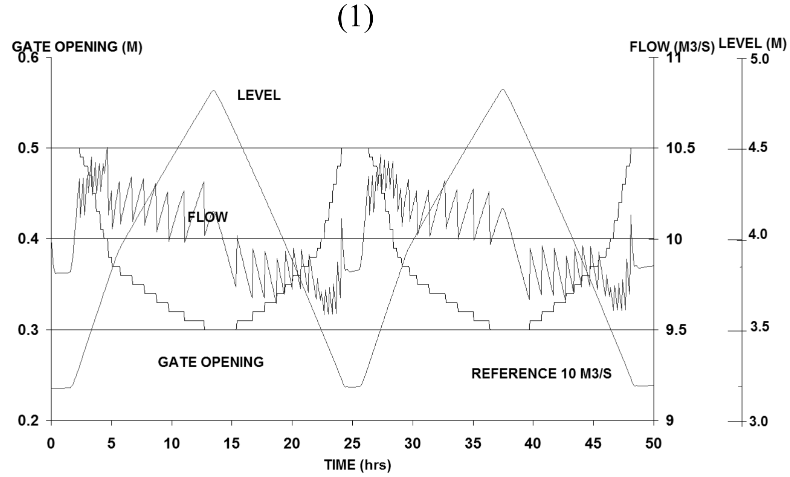
Dr. C. Burt showed the data collect by the system on its first months of manual operation and suggested that we use simple rules to drive the canal rather than a Proportional Integral Regulator (PI). In general PI regulator presents overshoots not recommended for flow control. Dr. Burt suggested some simple rules to drive the canal:

IF your flow error is greater that the tolerance :
  If flow is grater than the reference: (1)
    Close the gate 90% of the error/reference
  If flow is smaller than the reference:
    Open the gate 110% of the error/reference

make control decision every 30 minutes.

The rule proposed by Dr. Burt was tested on simulation using the SIC canal model simulator developed by the CEMAGREF. The SIC model was configured to approximate the data collected on the field. On Fig. 5 the performance of the rules were tested on two days of operation. Two cases are presented in the first one the percentage factors (1) were the proposed by Dr. Burt on the second one the factors are 120 and 150 respectively. With a higher percentage a better response was obtained since not only the present error was considered in the correction, also the future evolution on the dam's level was considered. The higher percentage reduced the number of movement in the gate. In this simulation the regulator dead zone was 0.25 m3/s and the sampling time was 20 minutes. Fig. 6 show the results when the regulator dead zone changed from 0.25 to 0.4 m3/s and the percentages of correction were the original ones (1) and 150 and 200 respectively. As seen in the above simulation results as the regulator dead zone increase and the percentage factor increase the maximum operation error in the flow was higher and the number of gate movements was reduced.

(1)



(2)

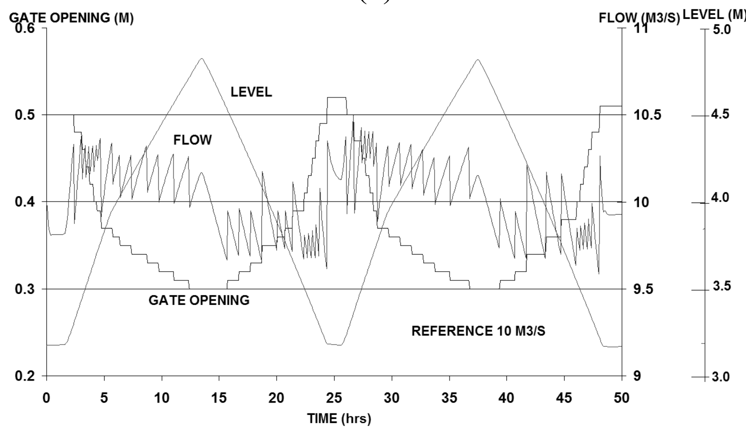
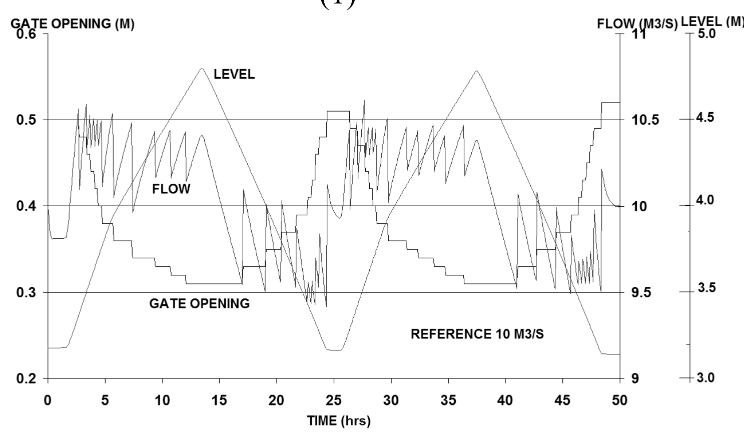


Figure 5. Evolution of the Diversion Dam with Different Control Rules
(1) Percentage 90 and 110, (2) Percentage 120 and 150

(1)



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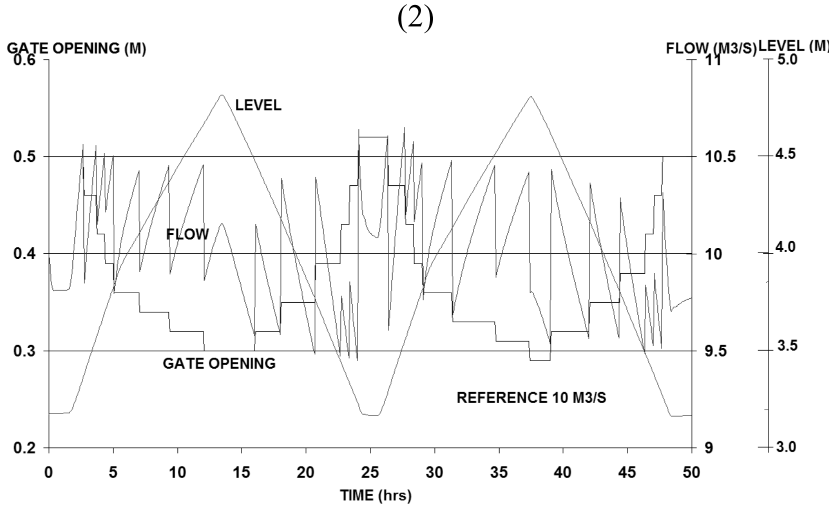

Figure 6. Evolution of the Diversion Dam with a Dead Zone of 0.4 m3/s
(1) Percentage 90 and 110, (2) Percentage 150 and 2000

Finally, a one day SIC- simulation was done, looking for the control action that produced the smallest flow error in front of the level variation present on the diversion dam (Fig. 7). As in the other simulation the control decision were made every 20 minutes. On the simulation result (Fig. 7) almost every 20 minutes a gate movement of 1 cm was done, the number of gate movements increased. To reduce the flow difference to the reference flow the perturbation introduced by the fill and empty of the dam needed to be included on the control algorithm. The rules only consider the past, the effect on the flow at the head of the LBMC, feedback, and it should include the future that it is more or less known, volume change on de diversion dam, Feedforward.

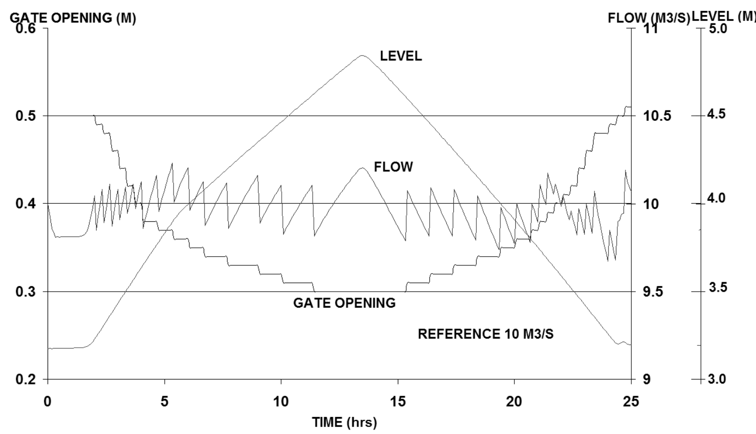

Figure 7. Evolution of the Diversion Dam Under Manual Operation Considering the Evolution of the Level on the Diversion Dam

WORK ON DEVELOPMENT

To complete the control system two aspects are needed to be done: a simple flow gate equation for the canal control structure on the diversion dam and the integration of the known perturbation on the control algorithm.

The main control problem on the Diversion Dam operation is the rejection of the perturbation, level variation, which is known. In this condition it is necessary to use a control algorithm that includes the information of the known perturbation in the operation of the Dam. Predictive control is a strategy that will be evaluated to incorporate the known perturbation as a feedforward component.

The data collected from levels, gate opening and flow will be used to obtain the flow equation of the gate. As a first step all the scales, level and gate openings, must be checked in both dam and canal. With data verified the equation will be determined and used to improve the reliability of the flow measurement.

CONCLUSIONS

The use of SCADA system for the flow control at the Piedras Blancas diversion dam is the only feasible solution to attain a reliable irrigation service at the head of the LBMC, since with Manual operation it is impossible to obtain the desired service. With Manual operations more water than requested is supplied to the Water Users Association.

With the automated control system on the diversion dam the safety on the canal will also be improved. This is the result of less water level fluctuations which damage structures and canal lining.

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