SCADA APPLICATION IN CENTRAL ASIA

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ABSTRACT

This paper presents an application of Supervisory Control and Data Acquisition (SCADA) in three countries of Central Asia: Uzbekistan, Kyrgyzstan and Tajikistan. The project is financed by the Swiss Development Agency for Cooperation (SDC). The objectives of this project are to stabilize the flows diverted for irrigation downstream from large hydro-power plants and to monitor the equity and reliability of water diverted to secondary canals. This application provides an example of a promising success story in irrigation modernization in developing countries. Three factors may contribute to this success: i) the existence of a regional automation company, ii) the use of factory-made control equipment and iii) the rapid intervention of the local industry when repairs or corrections to control equipment are needed. The project also demonstrates that modernization of irrigation systems can be completed at a reasonable cost. The paper presents the results of the first series of tests of the SCADA system and highlights some of the differences in the design of SCADA projects between developed and developing countries.

INTRODUCTION

Over 7 million hectares are irrigated in the five countries of Central Asia, mostly through diversion of the large Amu Darya and Syr Darya rivers flowing into the Aral Sea. Since independence from the Soviet Union in 1991, these countries are now responsible for the management of large irrigation systems that are aging and would need considerable investments in massive rehabilitation works and adaptation of the on-farm works to the on-going policy of privatization of lands.

The Swiss Agency for Development and Cooperation (SDC) is not the major lending agency in Central Asia. However it has developed an original strategy to optimize the technical assistance and limited financial assistance provided to these countries for the agriculture sector. This strategy is based on the evidence that chaos is inherent to all large-scale delivery systems (Clemmens Lecture at ICID Congress, Beijing, 2005). Chaos was defined by Clemmens as the fact that a small

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deviation in the upstream part of a canal system from a target delivery flow would result in large variations in water delivery further down. Clemmens rightly argued that neither improved management nor water measurement was the answer to that chaos: "*Improved management alone may result in small increments in the productivity of systems, but not in substantial gains. Water management is a key component of water, but it is not sufficient for significantly improving productivity by itself.*"

In 2001, SDC signed a protocol with the Scientific Information Center (SIC) of the Inter-State Commission for Water Coordination (ICWC), an international Organization of the five central Asia countries, to assist in the modernization of irrigated agriculture in the Fergana valley. The Protocol includes assistance for: i) integrated water resources management (IWRM) in the valley to contribute to the reform of irrigated agriculture through the creation and strengthening of water associations and ii) Canal automation and monitoring. This paper describes the SCADA and automation projects installed in the Fergana Valley under SDC assistance. A first project installed at a large diversion dam on the Naryn River in 2002 is now operational. A second on-going SCADA project, initiated in 2003, included a number of discrete structures on the large conveyance canal systems and three pilot irrigation canals.

Geographic Background and Irrigation Development

The Fergana Valley is a large inter-mountain plain, about 300 km long, encircled between the Tian Shan Mountains in the north and an extension of the Karakoram Mountains in the South. The plain has been irrigated since time immemorial. The URSS government built a large scale irrigation system beginning in the late 1940s that transformed the Fergana Valley into one of the most populated valleys in central Asia. The total irrigated area is now estimated at about 1,375,000 ha, with 911,300 ha in Uzbekistan, 330,700 ha in Kyrgyzstan and 133,900 ha in Tajikistan. The central plains of the valley are in Uzbekistan, and the surrounding piedmonts and mountainous areas are in Kyrgyzstan. The western part of the valley opening on the arid steppe of Central Asia belongs to Tajikistan.

Agriculture in the Fergana valley is heavily dependent on diversion of water from the Syr Darya River and its tributaries. Agriculture accounts for 92 percent of water use. Water use efficiency is very low since about 70 percent of water diverted is wasted due to aging of infrastructure and mismanagement. Most of the valley has very favorable soil conditions compared to downstream areas in the Aral Sea Basin which are largely affected by salinization and waterlogging. Nearly 85 percent of the lands in the valley are non-saline or weakly saline with only 15 percent of the lands unfavorable to irrigation due to high groundwater table or salinity.

The Fergana Valley is drained by the Syr Darya River formed by two main branch rivers draining the high mountain areas: the Naryn River and the Kara Darya River. The annual total volume of water available in the valley is estimated at about 14 billion m^3. The large hydropower potential of the Naryn River was developed through the construction of the 170-m high Toktogul dam creating a reservoir of 11 billion m^3 and a cascade of five medium and low head hydropower plants, all located in Kyrgyzstan.

The Naryn-Karadarya irrigation system is divided into a number of interconnected canals originating from the Naryn River and its two main tributaries.

Figure 1

The first structure (1) on the Naryn River in Uzbekistan just downstream from the border is the Big Fergana Headwork (submerged weir and side intake) which diverts water to the Big Fergana Canal (BFC) with a design capacity of 300 m^3/s. A few kilometers downstream (A), there is the Uchkurgan diversion dam which supplies water to the North Fergana Canal (NFC) with a capacity of 70 m^3/s and to the Feeder Canal (150 m^3/s). BFC flows are supplemented by the Feeder Canal. Two structures(2 and 3) exist on the BFC at 2.5 and 6 km from Uchkurgan dam to supply Hakulabad and the Big Andijan canal (BAC). The BFC then conveys Naryn water to the Kara Darya River just upstream of the Kuyganyar diversion dam (B). The 105-meter high Andijan dam creating a reservoir of 1.7 billion m^3 was built on the Kara Darya River. This reservoir supplies three irrigation canals including the Sharhikanzai canal, which in turn supplies the South Fergana Canal (SFC).

Earlier Automation Projects

The first SCADA project at Kuyganyar diversion dam (A) on Kara Darya River was implemented with USAID assistance in 2001. A second project under SDC assistance was implemented at Uchkurgan diversion dam (B) at a cost of US$187,000 in 2002. The objective of these two projects was to stabilize the discharges into the irrigation canals despite the large and not always scheduled variations of the flows released from the power plants located in Kyrgyzstan. These two projects were implemented by SIGMA, an integrator company specializing in automation.

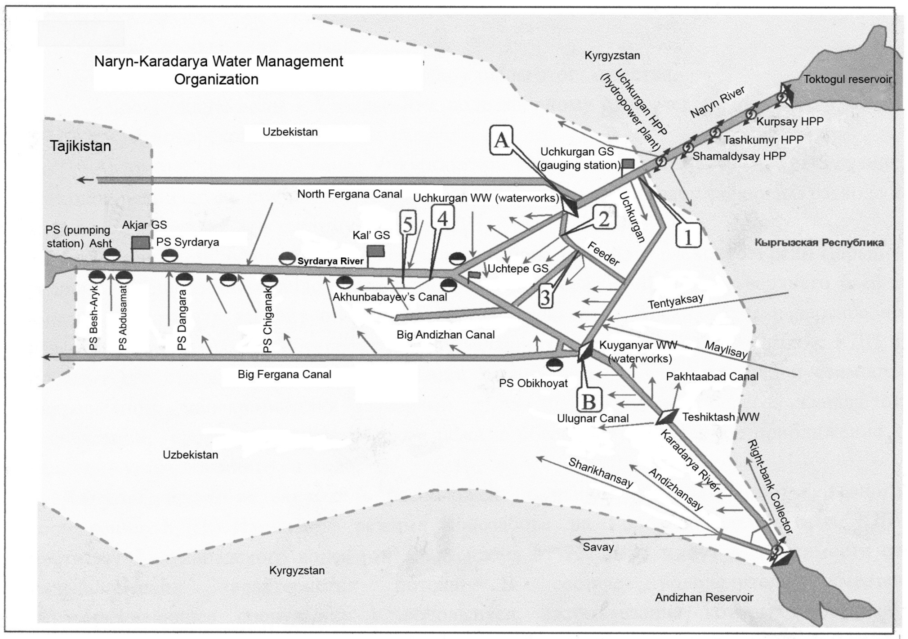

Figure 2
(A) Uchkurgan Waterworks on Naryn River.-(B) Kuyganyar Waterworks on Karadarya River.- (1) Big Fergana Canal Headwork on Naryn River.-(2) Khakulabad Divider at DP 15 of BFC Feeder-(3) Waterworks at DP66 of Feeder (Big Andizhan Canal Headwork)-(4) Headwork on Akhunbabayev Canal-(5) Spillway on Akhunbabayev Canal.

The Uchkurgan SCADA project was designed to provide target flow releases into the NFC and BFC canals and to control as much as possible the water level upstream of Uchkurgan dam, despite the variations of flows released from the upstream power plants on the Naryn River located in Kyrgyzstan. Flow data at Uchkurgan are collected and stored every 10 minutes. Data are processed to calculate hourly, daily, 10-day and monthly average flows and can be presented in graphic form.

Monitoring of the water discharges into the NFC and BFC canals during the period April 2004-April 2005 indicated that the intakes of the NFC and BFC were working under automatic control regime about 270 days during that one-year period. The average deviations between the actual flows and the target flows in automatic control regime for the entire irrigation season did not exceed 2 percent (1.61% and 1.69% for NFC and Feeder canal respectively). However the maximum deviations between actual daily flows and set flows were 6.17 m^3/s (or 11.22%) for the NFC and 11.01 m^3/s (or 1.77%) for the Feeder canal. Although these variations are still substantial, the SCADA system has considerably improved the stability of the flows released into these two canals. The Uchkurgan project has successfully proved that a considerable impact can be achieved in improving system operations with a small investment and within a limited time frame.

ONGOING FERGANA VALLEY CANAL AUTOMATION PROJECT

The objective of the ongoing SCADA project, initiated in 2003, is to introduce local automated control and remote automatic monitoring to ensure optimal allocation of water. The project includes i) four discrete structures on major conveyance canals under the responsibility of the Syr Darya Basin Organization (BVO) and ii) three irrigation pilot canals under the responsibility of local agencies: the South Fergana Canal (SFC) in Andijan and Fergana Provinces of Uzbekistan, the Aravan-Akbura Canal (AABC) in Osh Province of Kyrgyzstan and the Gulya-Kandoz canal in Soghd province of Tajikistan.

BVO Structures

The ongoing SDC canal automation project is the continuation of the previous automation project of Kuyganyar and Uchkurgan diversion dam. It includes automation of four main structures in the Naryn/Karadarya system: the intake of the BFC (1 on figure 2), two structures on the Feeder Canal (2 and 3 on figure 2), and the intake of Akhunbabayev canal on the Syr Darya River (4 and 5 on figure 2).

All BVO inter-link canals, as irrigation canals, are operated under upstream control. The first two reaches of the Feeder Canal are short and with gentle slope. Thus flow measurements by gauging stations are not reliable. Therefore canal operation was converted from upstream to downstream control during SCADA implementation. Downstream control will ease operation of the first two reaches.

Gates: There are 46 sluice gates already equipped with electric motors. These electro- mechanical devices have been checked, repaired or replaced and equipped with end switches and gate opening sensors. Electric supply and standby generators are available at the 4 locations, except at Akhunbabayev where a standby generator is planned to be installed soon.

Water level measurement: Nineteen ultrasonic level sensors have been installed upstream and downstream from each cross regulator or automated outlet**.** In some cases, hydro posts (flow gauging stations) have also been equipped with water level sensors.

Type of control: All structures are composed of a cross-regulator with upstream or downstream water level control and outlets supplying inter-link canals equipped for flow control. All gates can be operated either by automatic control or manually by the operators.

Electronic equipment**:** gates are controlled by programmable local controllers (PLC) (one PLC for 4 gates) with separate I/O modules and interfaces (analog and digital input, digital output). The PLCs are programmed to send the following 6 alarms to the supervisory software:

- Torque overload (closure or current relay in control panel)
- Error or no reading from gate position sensor
- Reading of erroneous value from gate position sensor (e.g. off-limits values, such as height greater than gate dimensions)
- Gate movement opposite to the requested movement, mostly in the early testing phases in case of inversion of cables.
- Commands that cannot be executed by the gate. This can have several origins, including electrical and mechanical problems.

One PLC is dedicated to control the other PLCs and is connected with the operator PC where all data are displayed and set points are input. PLCs are of model DECONIT 182 and are installed in tight cabinets close to the gates or in the control room. PLCs are also connected to the telecommunication system.

Telecommunication: A General Packet Radio Service (GPRS) system has been selected for the communication between new automated control structures (except between Kuyganyar and Uchkurgan dispatchers, where conventional radio was already installed and operated). This choice has some advantages:

- the maintenance of the communication network will be performed by a specialized communication company
- no authorization to use frequencies needs to be obtained from the authorities (such authorization is difficult to obtain in Uzbekistan)
- allows future expansion (e.g. link to Tashkent is possible with no additional hardware).

However, the quality of communication relies on the service provider (MTC) who has just completed installing the GSM+GPRS network in the Fergana valley (a GPRS network is already operating in the Tashkent region) and some problems were observed during the preliminary tests. Fortunately, these problems did not affect automatic control (there is only local automatism), but only the data transfer.

Software: Use of a commercially available supervisory and control software package is desirable to allow easier customization and maintenance and avoid site specific and lengthy development. SIGMA has chosen an intermediate solution between a readily available program and a totally custom-made application. The supervisory and control software was built using libraries (existing application for operator interface, archives, PLCs, …etc.) supplied by the provider of the PLCs and specific programs developed for BVO, such as flow computation using hydraulic laws of existing hydro posts.

Preliminary tests: Tests were performed on the four new automated structures in October 2006. Some problems were observed related to calibration of water level measurements, and some gates were randomly faulty and could not be operated. These problems did not affect the performance of the control that was found accurate and stable. Since October, all gates have been checked and repaired when necessary and level sensors have been adjusted and tuned.

Figure 3 presents the measurement of discharge and the openings of the five gates recorded by the SCADA system at Akhunbabayev headwork. The discrepancy between set point and controlled flow is less than 1.5%, 30 minutes after starting the control. Stability of flow is excellent.

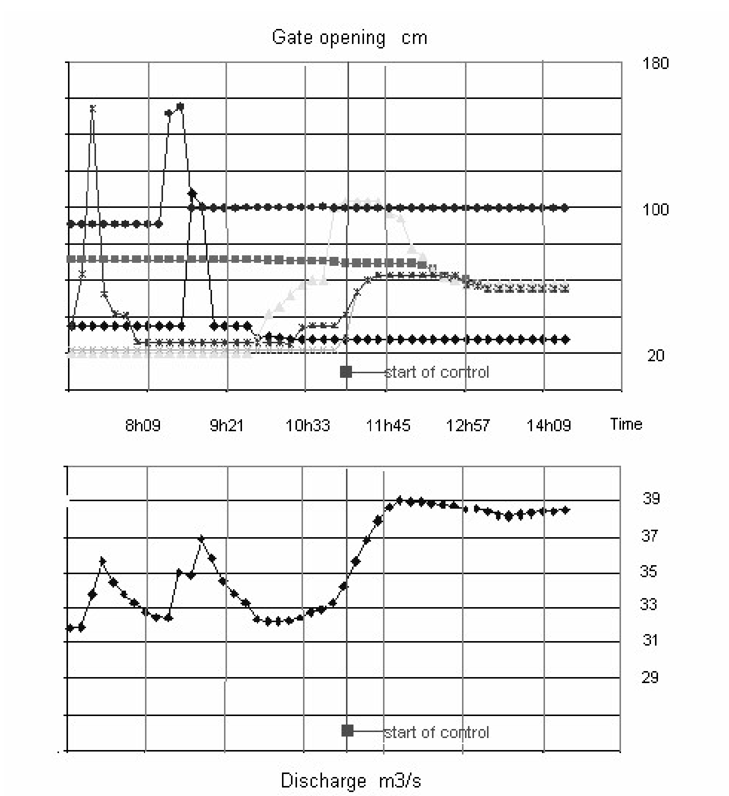

Figure 3

Pilot Irrigation Canals

a. The 120 km long South Fergana Canal with a design capacity of 100 m^3/s constructed in 1935 irrigates about 87,000 ha in the provinces of Andijan and Fergana in Uzbekistan and 2500 ha in Kyrgyzstan. This canal receives uncontrolled receives uncontrolled waters from a number of tributary rivers. At about half its length, a branch canal enables the diversion of excess water into the Karkidon compensation reservoir, which is a very favorable layout for canal operation. Design of this automation and monitoring project is not yet completed but will be very similar to the BVO automation project

b. The 21-km long Aravan Akbura canal diverts water from Akbura River about 7 km downstream of the Papan storage dam. AAB canal supplies irrigation water to about 9,000 ha in Kyrgyzstan. Design of this automation project has been completed and gate repairs and motorization are finished. The main characteristics are:

- 3 control structures with 17 gates will be automated and monitored;
- 2 remote balancing stations will be equipped with automatic level measurement;
- Equipment will be very similar to BVO project;
- Data transmission system will use VHF radio (2 frequencies are required);
- One additional VHF frequency will be used for voice communication.

c. The Gulya-Kandoz Canal diverts water from the unregulated Khokabirgan River to irrigate about 8100 ha in Tajikistan. Design has just started.

Present operation

The three pilot irrigation canals are presently operated under upstream control with a minimum number of check structures. Some of the bays found at check structures are not equipped with gates, making impossible precise control of water level. The three canals have a steep longitudinal slope on average. Several chutes and drops are found on the SFC. A unique feature common to these three canals is the very high number of direct outlets supplying small tertiary canals providing water to former collective farms. For example, over 135 gravity outlets and 68 small pumping units are found on the SFC and 80 outlets on the Khojabakirgan canal. Some sections of the canals are lined. However lining is in poor condition.

Hydro posts (gauging stations) exist along the three canals at about 10 km intervals to determine the flows through stage-discharge curves at regular intervals. The volumes of water diverted between measuring stations, known as balancing sites (i.e. water accounting sites) are then analyzed to determine the equity of water distribution among balancing sites and the gap between planned, requested and actual volumes of water delivered. Several field teams for each balancing site are responsible for monitoring and adjusting, if needed, the openings of the numerous individual outlets diverting water from the main canals three times a day to meet the agreed target flows.

In spite of efforts made by the field teams, sharing of water remains rather inequitable as shown in figures 4 and 5 (water distribution along the South Fergana canal and inside one balancing section). The SCADA project is designed to improve the equity of water distribution between balancing sites and between outlets within a site.

Figure 4

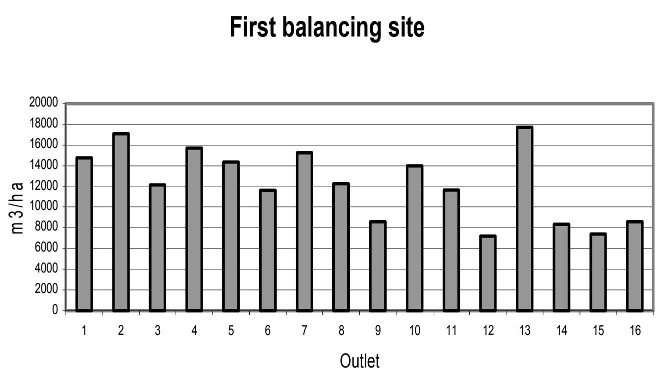

Figure 5

Costs of Automation

The total amount of automation contracts is about $1.3 million (US), divided as follows:

- BVO works: $ 305,000
- South Fergana canal: $ 667,000
- Aravan-Akbura canal: $ 337,000
- Khojabakirgan canal: $ 104,000

The unit cost for the pilot canals range from about US$ 6/ha for the SFC canal to US$ 30/ha for the Aravan-Akbura Canal, which is very low compared to other rehabilitation cost. This is another example of the fact that modernization itself is not necessarily as expensive as often argued. The cost of rehabilitation of many irrigation projects could reach a few thousand US dollars for the reconstruction of dilapidated infrastructure and lining of canals. A number of these rehabilitation projects do not give appropriate attention to the modernization of the irrigation delivery service. The canal automation project in the Fergana valley demonstrates that considerable improvement can be achieved with a small investment.

CONCLUSIONS

In developed countries, the main objectives of irrigation modernization are; i) to improve the flexibility of canal in order to meet the variation of water demand (on demand or pre-arranged demand), ii) to increase the accuracy and the reliability of irrigation water service to users, iii) to reduce management costs and labor costs, and iv) to alleviate negative effects of irrigation on environment, in some cases.

The main objectives of the SCADA project in the Fergana valley are to reduce the negative impact of the operation of the power plants and to improve and control the equity of irrigation water allocation. Labor cost in Central Asia is so low that reduction of staff is not yet a consideration in modernization of irrigation projects.

There is still limited confidence in local automatic control and telecommunications. Consequently each local control station is equipped with a computer for local intervention and staffed 24 hours per day. In case of failure, instructions and reporting can still be done through telephone lines and operation of gates can still be manually done.

The factors that have contributed to the success of the earlier SCADA projects in the Fergana valley are: a) the existence of a regional automation company, ii) the use of factory-made control equipment produced in Kyrgyzstan or European countries and iii) the rapid intervention of the above company when repairs or corrections to the control equipment are needed. These conditions are not yet found in the poorest developing countries. However there are a number of emerging market countries that have developed computer and telecommunications industry to a level sufficient to provide the technical assistance for the maintenance of SCADA equipment in large irrigation districts. These countries should take advantage of the present available modern technologies to improve the performance of their irrigated agriculture.

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