CRITICAL SUCCESS FACTORS FOR LARGE SCALE AUTOMATION EXPERIENCES FROM 10,000 GATES

Tony Oakes[1]
Gino Ciavarella[2]
Remy Halm[3]

ABSTRACT

Canals have been the principal means of distributing irrigation water since the early civilisations. However, the performance of irrigation systems, which use approximately 70% of the available water world-wide, is being called into question. The technology used to control canals and hence their performance changed little until the second half of the nineteenth century when the early work on performance enhancement started with the first generation of activities focussed on automatic monitoring and regulation. This paper provides an overview of the experiences gained over the last 20 years in the application of technology to enhance the performance of large scale irrigation systems through improvements to monitoring and control. Improving the productivity of irrigated agriculture is seen as a critical initiative to double world food production by 2050. Improving the performance of irrigation canal systems is seen as a critical requirement to meet the future world food needs.

INTRODUCTION

Automation is defined as "The act of implementing the control of equipment with advanced technology; usually involving electronic hardware; "automation replaces human workers by machines"[1]. Numerous papers have been devoted to various aspects of automation of irrigation systems at previous USCID forums and likewise there is a plethora of information published in the academic literature about irrigation system automation.

This paper seeks to provide an overview of the author's collective experience gained over the last 20 years in the development and application of automation technology to the open channel irrigation sector, primarily in Australia but more recently in the USA, China, New Zealand, India, Vietnam, France and Italy. The focus is primarily on a holistic approach to transform irrigation systems from pre biblical design principles to be fast, flexible, responsive and efficient to provide a platform to sustain food production against a global background of declining water, agricultural land, energy and nutrient availability. The paper generally follows the directions documented in [2] and discusses the following topics

[1] Rubicon Systems Australia Pty Ltd, 1 Cato Street, Hawthorn East, 3123, Australia (Anthony.Oakes@rubicon.com.au)
[2] Rubicon Systems Australia Pty Ltd, 1 Cato Street, Hawthorn East, 3123, Australia (Gino Ciavarella@rubicon.com.au)
[3] Rubicon Systems Australia Pty Ltd, 4563 Denrose Court, Fort Collins, CO 80524, USA (Remy.Halm@rubicon.com.au)

- Automation Conceptualisation
- Instrumentation
- Gates Actuation and Flow measurement
- Communications
- SCADA System Engineering and Control
- Human Considerations
- Performance Measurement

For a more detailed discussion on the business benefits of automation technology refer to Reference 3.

AUTOMATION CONCEPTUALISATION

The process of automating a single gate to meet a local objective such as maintaining an upstream or downstream water level or constant flow is a well documented and understood process. Invariably this process involves instrumentation to monitor water levels, usually on the upstream and downside side of the gate, some instrumentation to measure the position of the gate, a motor to drive the gate, and some electronics usually in the form of a commodity Programmable Logic Controller (PLC) or Remote Terminal Unit (RTU) to make the decisions about how to position the gate as a function of time to meet the underlying objective. Installations of this type require an energy source to drive the automation equipment with solar being a popular choice due to the remote location of installations, and communication to a central environment and/or other gates is becoming increasingly common practice.

For this simple standalone example there are many choices to be made about the technologies to best meet the automation needs with accuracy, stability, reliability, responsiveness, durability and total cost of ownership being key considerations. However, a more overriding consideration is usually how this automation equipment “fits” with the channel system and the “demands” the system places on the automation technology. In the case of a single standalone piece of equipment heuristic methods to configure and tune the automation are generally satisfactory.

However, the approach to automating large systems where there are potentially thousands of automated gates is a more demanding academic and practical challenge. In a network of automated gates the impact of control action at one gate can potentially impact on the control outcomes at many other gates. For moderately large systems it may be possible to compute the best position to set many gates to meet an overall control objective but in general with communication system constraints it is not practical to transmit these values to the field equipment at the required frequency given their remoteness. For these reasons we have chosen to distribute the control logic to the field equipment on the basis of the conceptualisation of a canal system as many concatenated blocks of the form depicted in Figure 1.

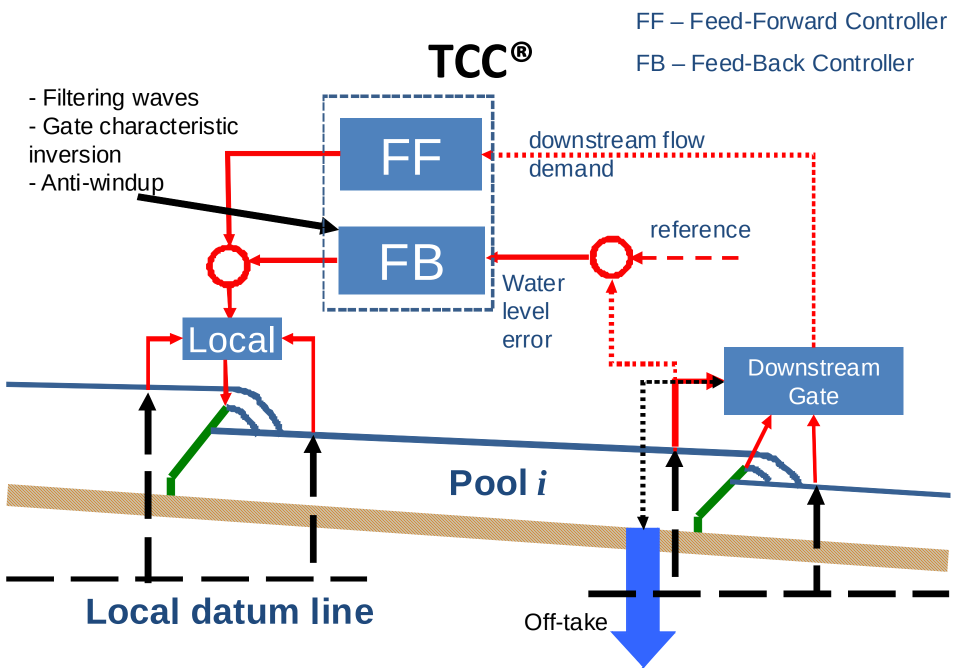

Figure 1. Conceptual Structure of a Pool

The authors contend that this conceptualisation of large networks is a critical factor in successfully deploying automation on a large scale.

INSTRUMENTATION

There is much to be said for the old adage that if you cannot measure it then you cannot manage it. The availability of cost effective and accurate measurement instrumentation has in our view hampered the development of large scale automation technology. An implication of the conceptual structure shown in Figure 1 is that flow leaving the pool at the downstream gate must be accurately measured if there is to be accurate control. It is contended that to accurately measure flow it is necessary to be able to accurately measure water levels, with millimetre precision. For this reason and in the absence of alternatives in the market Rubicon has developed unique water level measurement instrumentation based on acoustic technology, as depicted in Figure 2. The unique feature is the use of a precision calibrated reference mark that reflects the sound wave before the reflection from the water level surface. By processing the return signals and using the relationships shown in Figure 2 it is possible to precisely measure water level.

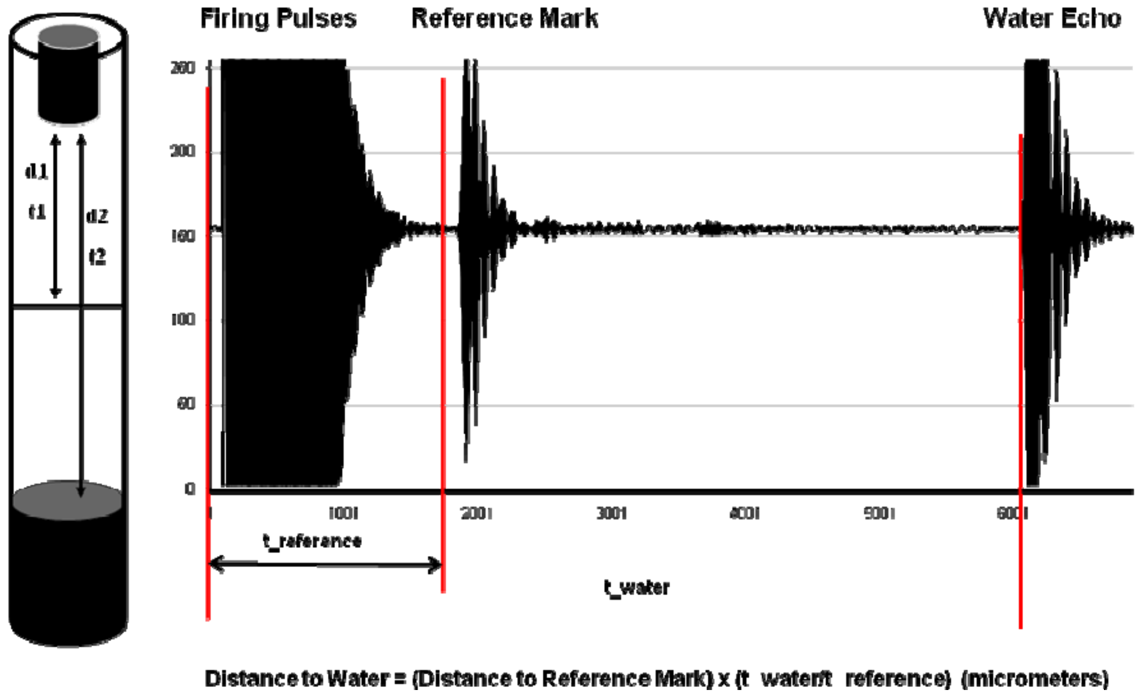

Figure 2. Self Calibrating Ultrasonic Water Level Instrument

This instrument in packaged as a standalone device but also embedded within the FlumeGate products as shown in Figure 4.

GATES ACTUATION AND FLOW MEASUREMENT

Rubicon has a generic gate control software product. This product been progressively developed since the company's formation in 1995 and has been implemented on hundreds of gates mainly in Australia, with a handful of sites in the USA. The design intent was to be able to retrofit to instrumentation and actuation equipment using industry standard interconnection methods like 4-20mA, 0-5 Volt, MODBUS and relay technology. Figure 3 shows an example from the USA. In this case the application was to automate a standalone spill gate site to "dump" water on the basis of high canal levels, utilising existing gate and lifting mechanisms but retrofitted with a Limitorque actuator, solar power supply, RTU and radio. This approach required extensive on site equipment installation and configuration and the software configuration requires the gate elevations to be surveyed and various calibration parameters computed and configured in the field for incorporation in the software.

Figure 3. Retrofitted Automation – New Cache La Poudre, Colorado, USA

Our experience is that this approach is really only viable when contemplating a small number of sites when the duty is primarily focussed around coarse control objectives where the errors associated with water level and gate position measurement are consistent with the capabilities of the plant.

However, when contemplating large scale automation of complete irrigation systems such as the Northern Victorian Irrigation Modernisation and Renewal Project [3] a more systematic approach to the control infrastructure is considered to be warranted. For this project FlumeGate technology was used to replace the existing in channel manual regulating equipment. The FlumeGate is a precision manufactured control and measuring device that has been specifically designed for network based control strategies such at that shown in Figure 1.

Critical Success Factors for supporting this strategy are

- High Duty cycle – the unique actuation and drive chain mechanism is designed for precise control and long life.
- The water level instrumentation is located within the gate frame providing stable and repeatable water level measurements.

- The flume nature of the gate design combined with precision instrumentation enables accurate flow measurements across free and submerged flow conditions.
- Standardised electronics and software featuring solid state fusing, digital instrument marshalling, encoder based gate positioning, motor soft starting combined with local keypad and display interface.

Figure 4. 9 FlumeGate™s at the CG No 8 Channel Offtake, Tatura, Australia

COMMUNICATIONS

Reliable communication is a clearly a critical success factor for reliable automation. The systems we have deployed are based on the following design principles;

- Most of the communications traffic is based on *report by exception* where the site broadcasts a message when a parameter value changes by an amount that is uniquely configured for each key variable at a site. An event driven communication architecture is a critical requirement for addressing scalability.
- Each control site communicates with its neighbouring site, independently of the central server – so called Peer-Peer communication.
- Each site must be capable of being solar powered and is typically configured with a 75 watt solar panel.
- For redundancy reasons, there are alternate communication paths to link the distributed communication nodes to the central office environment. Figure 5 shows a solar powered communication node.

Frequency Hopping Spread Spectrum (FHSS) radio systems are the technology of choice for most applications primarily because

- There is no requirement for licensing, as they operate in the 915MHz – 928MHz ISM band
- High speed air interface typically running at 19,200bps
- Low maintenance requirements
- High sensitivity -116 dbm
- Designed for robust communications in an unlicensed band
- Ease of deployment
- Total cost of ownership

Figure 5. Communications Node Site

SCADA SYSTEM ENGINEERING AND CONTROL

Our experience from managing large scale rollouts is that the following are critical success factors;

1. Standard software needs to be developed and maintained based on well understood IT system design and implementation methodologies. Our preference is to use standard programming languages like C/C++ and Java across the product range rather than RTU specific languages that are difficult to manage using code revision control systems.

2. The software needs to closely couple demand and supply i.e. it is considered essential that the demand imposed on the control system never exceeds the capacity. This Demand Management System is considered to be a critical aspect of any canal automation solution.
3. The systems must be able to be incrementally configured to support the transition from manual to automated operation.
4. The ability to configure systems dynamically without the need to shutdown or interrupt system operations.

HUMAN CONSIDERATIONS

The management of change is clearly a critical aspect of any transformation project such as canal automation. Firstly for irrigation district staff moving from manually planned and controlled systems to complete automation is a huge change. The skill sets for supervising and maintaining the automated systems are completely different and this needs to be formally addressed through a structured change management program. For irrigation district customers automation can deliver huge improvements in services. However, again because the extent of the changes can be dramatic, particularly for older farmers, it is essential that they be lead through this process and supported by informed and positive staff.

PERFORMANCE MEASUREMENT

Quantifying and measuring the performance of an automated canal system is not trivial. Control Engineers often like to measure performance within a framework like that shown in Figure 6. However, these principles are difficult to communicate to irrigation district staff and to incorporate into contract acceptance criteria.

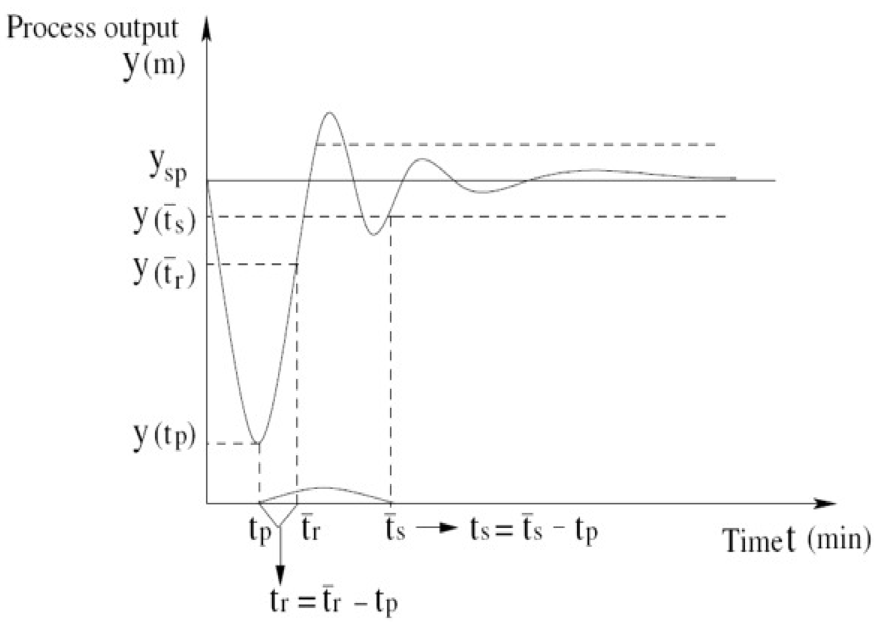

Figure 6. Characteristic Control System Process Response

Our experience for these purposes is that simpler measures shown below are more practical;

- Time water level deviates from set point
- Volume of water spilt from system
- Availability of plant (i.e. benchmark on down time)
- Deviation between time customer requires water and when it is delivered
- Deviation between requested and delivered flow rate

LEASONS AND CONCLUSIONS

Quite clearly the technology used for automating irrigation systems needs to be first class, well designed, robust, stable and cost effective. In developing evolutionary solutions for canal automation, a critical focus has been placed on technological innovation and standards. However, as the footprint of the implementations expands increasing focus is being placed on the human aspects associated with moving from a manually operated data poor situation to one that is automatic and data rich. It is absolutely critical for Boards of Management and Irrigation District managers to be able to define to customers what the costs and benefits of implementing canal automation may be and how such an investment will be assessed, measured and evaluated. A key success factor in a smooth transition to an automated irrigation system is preparing and implementing a sound Education/Information/Training program for both staff and customers in the use and maintenance of the systems. It is our experience that whole of life costs are a more significant consideration for customers than the initial capital cost of a system.

Irrigation in most parts of the world is under growing pressure to “lift its game” to perform better and use more productively, the large proportion of water allocated to it. There is now demonstrated experience that full automation can be successfully implemented to deliver significant performance improvements and enhanced customer services.

REFERENCES

1. Webster Dictionary

2. Water Management Technology – The Australian Experience, Tony Oakes, Garry Smith, Barry Duncan, Mark Bramston and David Watts, USCID Workshop on Modernisation of Irrigation Water Delivery System, Phoenix, Arizona, October 1999.

3. Making large gravity irrigation systems perform, G Spencer, Third International Conference on Sustainable irrigation Management Technologies and Policies, June 2010, Bucharest, Romania

4. Rising to the Climate Challenge, Murray Smith, Upgrading Technology and Infrastructure in a Finance-Challenged Economy, USCID Conference, Sacramento, March, 2010