AVOIDING PITFALLS IN CANAL AUTOMATION

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INTRODUCTION

Canal automation has come to age and is now a proven method of ensuring efficient water distribution in large irrigation systems in many countries. It is often opined by some engineers in the water management field that such efficient management of water can minimize the dire effects of droughts on farmers. Automation, if properly designed, can ensure such efficient water management. Automation is defined as "a procedure or control method by which a water system is operated by mechanical and/or electronic equipment that replaces the human observation effort or decision".

Canal automation is a coordinated application of several fields of engineering disciplines such as:

- Canal Designs
- Canal Structures
- Canal Hydraulics
- Hydraulic Transients
- Gates and Hoists
- Automation of Gates
- Telemetry
- Communications
- Electronics
- Computers/Microprocessors

AUTOMATION CONCEPTS AND METHODS

Confusion usually occurs in understanding due to indiscriminate use of terminology without clear definitions. Canal automation primarily involves two basic tasks: operation and control. Each of the tasks is based upon a concept to be followed and a method to implement, as outlined below:

		Concept	Method
A.	Operation	Upstream	Constant U/S Depth
		Downstream	Constant D/S Depth
			Constant Volume
			Controlled Volume

		Concept	Method
B.	Control	Upstream	Local Manual
		Downstream	Local Automatic
			Supervisory
			Combination

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a. Operation Concepts

It should be noted that operation concepts and methods entirely deal with water, whereas, control concepts and methods deal with instrumentation, data acquisition, control gates and their response. An upstream operation concept is used when conditions or constraints upstream of the system govern. Collector systems typically represent upstream operation concept. Downstream operational concept bases operation upon downstream conditions or demands. Most irrigation systems are based upon downstream operation concept.

b. Operation Methods

Operation methods refer to the operation of the canal pool between check structures, based upon the location of a pivot point on the water surface at which the canal depth is maintained constant. Thus, in the constant downstream method of operation, the pivot point is kept at the downstream end of the pool and in the constant upstream depth of operation, the pivot point is maintained at the upstream end of the pool. In the constant volume method, the pivot point is at the center of the pool. In the controlled volume method of operation, pivot point can vary on the pool surface anywhere between the check structures.

However, the difference between upstream control and downstream does not always relate to pivot point. A downstream pivot point can be used for either. In upstream control, the gate immediately downstream of the pivot point is used in maintaining a constant depth. In downstream control, the gate at the upstream end of the reach is used to maintain a constant depth.

It is good to note that a constant downstream method of operation permits the canal banks to slope downward along the canal length, resulting in overall economy. This method, therefore, is more common. However, with the advent of modern techniques of supervisory control methods, controlled volume method of operation is becoming increasingly popular as it offers greater flexibility.

c. Control Concepts

A downstream control concept refers to response of gate(s) at the check structure based upon information of instruments located downstream of the gated structure. Similarly an upstream control concept refers to response of the gate(s) based upon information from instruments located upstream of the gated structure. It must be noted that a downstream control concept is entirely incompatible with upstream operation method. Similarly, an upstream control concept is inefficient with downstream operation concept although may not be impractical.

d. Control Methods

Control methods refer to method of controlling the gates at the check structures in order to implement the selected operation concept and method. The four primary control methods are: local manual, local automatic, supervisory and combination. A detailed discussion of the various control methods are beyond the scope of this paper and the reader is referred to References 1 and 2. The following are typical cases of automation for canal systems:

Case 1

Downstream operation concept plus downstream constant depth operation method plus upstream control concept using local automatic or semi-automatic supervisory control method.

Case 2

Downstream operation concept plus downstream control method plus upstream control concept using semi or fully-automatic supervisory or combination control methods.

Local manual control method is the historical method of operating the gates manually by a ditch rider. Local automatic control methods use Littleman, Colvin or El-Flo type equipments. While Littleman and Colvin basically fulfill upstream control concept, El-Flo fulfills the downstream control concept. The author has come across many books referring to Littleman and Colvin as suitable for upstream "operation" method which is not a correct statement. It should read as upstream "control" method. The Northern Colorado Water Distrist effectively uses a Littleman controller for the control of their canal system.

e. Manning's Coefficient

It is a known fact that canal lining roughness, which can be described as Manning's n, plays a key role in canal hydraulics. It is almost impossible to pin down the exact value of n during the design stage, as the value can lie between a significantly wide range of values. For example, the value of n can be anywhere between .011 and .016 for concrete lined canals. Several factors influence the roughness and the asociated n value, such as workmanship, type of forms and type of lining, vegetation, growth of algae, concrete abrasion, and lining deterioration. Thus, the roughness can also vary during canal operation. It is, therefore, necessary to establish the probable range of values of n appropriate for the lining proposed for the canal during design stage. While the canal size and discharge depths should be based upon maximum probable value of n, it is a safe practice to use lowest probable value of n for computing hydraulic transients including the rate of rise and fall of water depths. The author has come across some designers assuming maximum value of n for hydraulic transient computations as well. Such practice may fail to predict rapid transients with potential to overtop canal banks or pull down the canal lining.

f. Method of Characteristics vs. Implicit Method

The partial differential equations-continuity equation and momentum equation involved in determining hydraulic transients can be solved using either method of characteristics or implicit method. The USBR program, like USM (unsteady state model), uses method of characteristics. Programs have been developed using implicit method. Some engineers are of the opinion that implicit method may give unreliable results when applied to simulation of emergency flows in the canal if the Courant condition for stability is ignored. The usual condition required is:

$$dt \leq dx/c + u$$

where	dt	=	time interval assumed in computations
	dx	=	distance of canal reach in computations
	c	=	wave velocity
	u	=	canal flow velocity

It usually will be found necessary to use smaller time intervals or shorter reaches for a given flow velocity to satisfy the stability criterion when using implicit method to satisfy the above criterion.

g. Gates

Various types of gates have been used in canal systems of which the fixed-wheel, slide and radial gates are the most common. As the gate slots tend to collect silt with consequent increase in friction and uncertain gate response, radial gates should be preferred over fixed-wheel and slide gates for canal automation, as the radial gates need no gate slots and result in overall economy requiring relatively less maintenance. Although gate discharge coefficients are not constant and are not always accurately predictable by algorithms, the discharge coefficients for radial gates can be calculated to a reasonable degree of accuracy by the computer programs using algorithms developed by USBR. While using such algorithms, however, it is important to ensure that the bottom seal configuration of the proposed gates is identical with those used in the USBR standard designs (Figure 1). Flat rubber seal strips should be used for bottom seal of the gate and not other shapes like music note. Otherwise, considerable error could result. Also, care should be taken to locate bottom horizontal beam high enough above the gate bottom seal avoiding flange protruding into flow which will cause flow disturbance and consequent discharge variation. Such a situation can also contribute to gate vibrations and downpull resulting in improper gate response during automation.

h. Gate Hoists

While slide gates necessarily require hydraulic hoists, radial gates permit operation by electric motor operated rope drum hoists, which are environmentally more acceptable since no oil leakage of hydraulic system is involved. Rope drum hoists also respond excellently to automation requirements if variable speed motors are used. Prestretched ropes are desirable to eliminate any potential errors in gate position indication which may be possible due to rope stretch or creep.

Fiber Optics vs. Metallic Cable

For telemetry and supervisory control and data acquisitions (SCADA) systems, the fiber optic case is performed in modern designs over the metallic cable. The following are the advantages and disadvantages.

I. Fiber Optic vs Cable Communication Systems

Advantages

a. Immunity to electromagnetic and electrostatic fields.

b. Wide band width for high bit rate capability.

c. No cross talk between fibers.

d. Unaffected by lighting or electrical storms.

e. No government licensing required.

f. Small size, weight, flexibility and ease of handling surpasses that of multipair metallic cable.

g. Suitable for continuous data scanning supervisory control and data acquisition systems.

h. Voice and data can be transmitted simultaneously.

i. Excellent channel expansion capability.

j. Long life (35 years).

k. User has complete control over communication system.

l. High security against undesired monitoring of communications.

Disadvantages

a. Short transmission distance without repeaters.

b. Power is required at repeater locations. If not available, must be provided over metallic wire within fiber optic cable.

c. Additional electronic equipment is required to convert the electrical signals into light and back to electrical signals.

d. Special splicing equipment is required.

e. Special termination and connector equipment is required at termination points.

f. Repair to buried cable installation is costly and complicated.

II. Twisted Pair Metallic Cable Communication Systems

Advantages

a. Medium band width and bit rate capability.

b. No government licensing required.

c. Suitable for continuous data scanning supervisory control and data acquisition system.

d. One pair can be used for voice communications.

e. Additional pairs allow for easy channel expansion capability.

f. Long life (35 years).

g. User has complete control over communication system.

Disadvantages

a. Buried cable susceptible to damage.

b. Lightning protection for each pair is required.

c. Special design and filtering is required to reduce cross talk between cable pairs.

d. Special grounding is required near high voltage lines.

Microwave and Radio Communication Systems are also used in certain conditions where fibre optic or metallic cable is too expensive.

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