Supervision and Water Depth Automatic Control of an Irrigation Canal

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Abstract: A supervisory and control system developed for a Portuguese irrigation canal system equipped with motorized sluice gates and buffer reservoirs is presented. The article discusses the development and tuning of the canal system's controllers: manual controllers for direct control of gate position and gate flow controllers, which maintain discharge at predefined values; automatic controllers for water depth control upstream from check structures. System hydraulics was simulated using an unsteady flow open-channel model based on the complete Saint-Venant equations. After field calibration and validation, the model was used for tuning the water depth controllers. The automatic upstream water depth control is based on local proportional-integral controllers. Controller gains were determined using optimization tools provided by the hydraulic simulator. These procedures tune the controller parameters globally, considering a given set of inflow variations. Finally, the paper presents simulated control tests results and an analysis of controller performances. Under the test conditions, the controller was able to drive water levels back to their setpoint rapidly and without instabilities and also guaranteeing stable gates movement.

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Introduction

The paper presents the supervisory and control system of the Main Canal of the Infra-Estrutura 12 (MC12 Canal) of the Multipurpose Alqueva Project (MAP) in Portugal. MC12 Canal is the first canal built for this large hydraulic project that will be, in the near future, the main water source for the region of Alentejo, in Southern Portugal.

Local upstream control (Fig. 1) is the most used irrigation canal control method in the world and the only one used in Portugal. With this control strategy, canals can be sized to convey the maximum steady flow at normal water depth for the designed flow. This simplifies both the design (constant cross section along the canal) as control system requirements (Rijo 1999).

Fig. 1 presents a canal pool under local upstream control. The controlled variable is the water depth upstream from the check structure, i.e., the water depth at the downstream end of the pool (Yd). The input to the controller is the deviation of the measured water depth (sensor) from its target value (usually the normal depth for the canal design flow) and the controller output is the gate $G2$ movement that will return the controlled variable to its target value. The water surface profile pivots around the established constant Yd value, according to the flow. A storage wedge is created between consecutives steady-state flow profiles (Fig. 1 represents the maximum storage wedge, between maximum and null flow surface profiles). When flow rate increases, the water stored in the canal pool also increases.

Because of water storage volume variations inside each canal pool, this control system is particularly effective when associated with programmed delivery methods (supply oriented operation), like rotation (Clemmens 1987). However, this method has disadvantages when combined with water flexible delivery methods (demand oriented operation) because pool storage must change opposite to the natural tendency (Buyalski et al. 1991). The inflow must be changed by an amount grater than the desired outflow in the pool, until the new steady-state profile is achieved. When the outflow decreases, the pool wastes water to downstream and when demand increases, the necessary amount of water must be supplied from upstream (Buyalski et al. 1991).

Water delivery performance can be improved changing the control logics, from upstream control to downstream control (Rogers et al. 1995) or by building control and buffer reservoirs between the conveyance system and the delivery system. Buffer reservoirs can reduce water losses and improve the system's ability to satisfy the expected and unexpected water demands.

MC12 only supplies three large reservoirs, each of them located upstream of an irrigation block. So, for the above reasons and considering that the MC12 Canal is a distributor of the Odivelas Main Canal (see next point), the chosen control option was the local upstream control. The buffer reservoirs reduce control needs, being possible to borrow water from storage when demands increase unexpectedly and store when demands decrease. Simple local upstream control can perform adequately under these conditions, not being necessary to wait for changes to arrive

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