8th IFAC Symposium on Fault Detection,
Supervision and Safety of Technical Processes (SAFEPROCESS)
August 29-31, 2012. Mexico City, Mexico

New Fault Isolation Architecture for Irrigation Canals

João Lemos Nabais * Luís Mendonça ** Miguel Ayala Botto ***

* *IDMEC, Department of Informatics and Systems Engineering, Setubal School of Technology, Polytechnical Institute of Setúbal, 2910-761 Setúbal, Portugal (e-mail: joao.nabais@estsetubal.ips.pt).*
** *IDMEC, Department of Marine Engineering, Escola Superior Náutica Infante D. Henrique, Av. Eng. Bonneville Franco, Paço d'Arcos, Portugal (e-mail: luismendonca@enautica.pt)*
*** *IDMEC, Instituto Superior Técnico, Technical University of Lisbon, Dept. of Mechanical Engineering, Av. Rovisco Pais 1049-001 Lisbon, Portugal, (e-mail: ayalabotto@ist.utl.pt)*

Abstract: Irrigation is one of the most consuming water resources in human activity. As water conveyance systems are commonly spatially distributed and crossing large regions it is important to guarantee their best efficiency. A fault diagnosis architecture is an important tool to increase efficiency in water conveyance systems. In the presence of leaks, unauthorized water extractions or water level sensor faults, the service level can be severely compromised. Recent literature deal with these situations as a unique fault of water extraction type. Isolating correctly each fault is important to access the real current state of the irrigation canals and proceed in accordance to restore its nominal conditions. This paper proposes a fault diagnosis architecture to distinguish common faults in water canals, considering either unexpected water extractions, gate faults and downstream water level sensor errors. The architecture is based on geometric and hydraulic parameters and therefore can be extended to existent irrigation canals. The proposed fault isolation architecture is an important tool to support maintenance services and be extended to fault tolerant controllers.

Keywords: Fault Diagnosis, Fault Isolation, Distributed Fault Isolation, Irrigation Canals.

1. INTRODUCTION

More than 80% of world fresh water consumption is distributed through irrigation canals. Irrigation canals are mostly open channels to convey water from sources to end users. The main concern on designing irrigation canals is to obtain higher performant systems with the best product quality. However canal faults suffer from unpredicted disturbances which may result in severe consequences to the end user as well as to the overall environment. Safety and reliability of irrigation canals then becomes an important system requirement that must be addressed in the design phase, usually requiring sophisticated control systems that must be able to automatic supervise, detect and isolate any fault as earlier as possible. Irrigation canals are normally managed manually with large water losses leading to poor system performance. It is widely accepted that automation can improve water distribution and reduce operational water losses Plusquellec et al. (1994).

Actuator or sensor faults may affect the controller performance in as many as 60% of industrial control problems Harris T.J. (1999). As the irrigation canal used in this paper includes a large number of actuators and sensors the use of a fault diagnosis architecture becomes inevitably.

A system that includes the capacity of detecting, isolating and identifying faults is called a fault diagnosis and isolation system (FDI) Chen and Patton (1999). Different approaches have been developed in FDI. One of the first was the *failure detection filter*, which is applied to linear systems Beard (1971). After that, different methods and approaches were developed such as the application of identification methods to the fault detection of jet engines Rault et al. (1971) and the correlation methods applied to leak detection Siebert and Isermann (1976). Some years later, Isermann (1984) introduced process fault detection methods based on modeling parameters and state estimations. Model-based methods for fault detection and diagnosis applied to chemical processes were presented in Himmelblau (1978), the first book about this approach. In the frequency domain, FDI is applied using the frequency spectra as criterion to isolate the faults Ding and Frank (2000). Other FDI approaches are based on residual generators, including physical or hardware redundancy methods, or analytical or functional redundancy methods Chen and Patton (1999).

Physical or hardware redundancy methods are a traditional approach to fault diagnosis which uses multiple sensors, actuators and components to measure and control a particular variable. The major problems encountered with these methods are the extra equipment and maintenance cost, as well as the additional space required to accommodate this equipment. This disadvantage increases the necessity of using other methods, easier to use and with smaller costs.

Analytical or functional redundancy methods can be used instead. These methods use redundant analytical relationships among various measured variables of the monitored system Kinnaert (2003). In the analytical redundancy scheme, the resulting difference generated from the comparison of different variables is called *residual* or *symptom signal*. These variables are measured signals with estimated values, generated by a mathematical model of the considered system. When the system is in normal operation the residual should be zero, and when the fault occurs the residual should be different from zero. This property of the residual is used to determine whether or not faults have occurred.

The fault diagnosis architecture proposed in this paper allows for simultaneous isolation of offtake, gate and sensor faults, which represents an innovation for irrigation canals. This is an important feature as usually different faults are treated as a unique fault of water extraction type, see Bedjaoui et al. (2006). The operating controller is designed to reject offtakes and accommodate gate faults. Although the fault is accommodated the system is no longer on nominal conditions and for example the maximum flow across the system can be compromised and with it the interactions with neighbor irrigation canals. Concerning the sensor fault the operating controller is insensitive to an existent fault. This fault is of extreme importance as the service level is normally based on this information, but also security problems may arise. The present work makes a direct contribution on how to isolate these different faults.

The proposed architecture has the following distinctive features over current ones:

- it allows for simultaneous isolation of offtake, gate and sensor faults;
- the sensor faults can be isolated with a minimum configuration of three water level sensors along a canal pool, and for some existing canals at the cost of one extra water level sensor this functionality can be implemented;
- it is easy to apply in existent irrigation canals as it is based on canal and gate geometry information, the only parameters needed to identify are the gate discharge coefficient and the Manning-Strickler coefficient;
- it is specially suited for incipient faults as the fault isolation is not based on explicit models or observers and therefore no learning mechanism is present;
- it has a modular feature as it is the fusion between two algorithms, one dedicated to isolate sensor faults with a local character and a second dedicated to isolate offtakes with a distributed nature, that can operate separately;
- it is a useful tool for establishing the current canal status namely the existence of bottlenecks responsible for imposing a bound on the maximum flow across the canal.

The paper is divided into the following sections. In section 2 the typical faults for irrigation canals are presented and grouped in different categories accordingly to the impact in the system behavior. The fault isolation architecture is presented in section 3 in particular its structure composed by two algorithms: the Distributed Fault Isolation (DFI) and the Sensor Fault Isolation (SFI). The architecture performance is analyzed in section 4 based on a simulator developed for the experimental canal property of NuHCC – Hydraulics and Canal Control Center from the Évora University. In section 5 final comments and future directions are pointed.

2. FAULTS IN IRRIGATION CANALS

In irrigation canals the water delivery to clients is based on the water level at the extraction location. Therefore the controlled variable is typically the water level. In Bedjaoui and Weyer (2011) the following typical faults in irrigation canals are found,

- *Offtake fault:* this fault accounts for client offtake, unauthorized offtakes and existing leaks in the canal structure;
- *Water level sensor fault:* depending on the sensor location this type of fault has different impacts on the system behavior. When the sensor is used exclusively for monitoring issues the impact is reduced but when the sensor is used for feedback the impact is critical.
- *Gate fault:* the gate obstruction by sediments or external objects, gate leakage or break are the only faults considered. The gate elevation sensor fault is not considered since current gates are electronically advanced components with this functionality available.

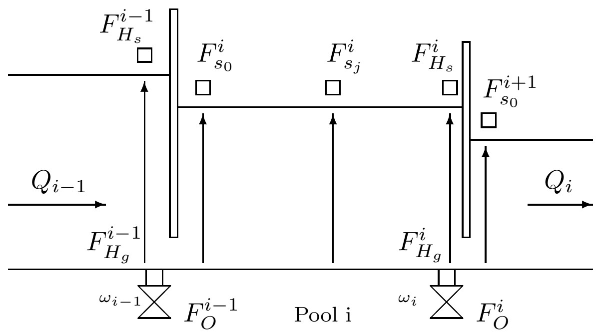

Fig. 1. Fault location for a generic pool i.

In Fig. 1 these faults are indicated for a generic canal pool. It is interesting to classify the considered faults into groups concerning the nature and impact on the canal behavior. Hence we consider three major fault groups, Fig. 2: the *offtake fault* F_O, the *hardware fault* F_H and *sensor fault* F_{s_j}. The new approach is based on the hardware fault that accounts both for gate fault F_{H_g} and water level sensor faults F_{H_s} used for gate flow estimation. These two faults have a similar impact locally as they are responsible for a bad flow estimation across the gate. The operating controller can accommodate the gate obstruction by opening the gate but is unable to react adequately to the sensor downstream sensor fault.

3. FAULT ISOLATION ARCHITECTURE

The fault diagnosis architecture presented is decomposed in two modules responsible for isolating different faults, Fig. 2,

Download English Version:

https://daneshyari.com/en/article/709634

Download Persian Version:

https://daneshyari.com/article/709634

Daneshyari.com