MODERNIZATION PROJECT AND SCIENTIFIC PLATFORM ON THE GIGNAC CANAL

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ABSTRACT

Theoretical progress in the domain of open channel automatic control has been achieved in the last decades. Controllers are generally designed with the help of mathematical software and tested on computer simulation models. Nevertheless, a phase of real-time testing appears to be necessary before the full validation allowing wide spread implementations of given automatic controllers. This helps taking into account and solving problems linked to the physical limits of sensors or actuators or to usually neglected phenomenon such as communication delays, faults and model errors.

The Gignac canal project aims at addressing this issue and sharing a research platform with diverse industrial and academic partners. It involves mainly the equipment of the canal with sensors and actuators, and an opened SCADA system. It has been designed to make possible the test of a wide range of control architectures and algorithms.

The equipment also helps the canal manager facing strengthening management constraints. They appear with the strict application of new legislations which lead to diminish intake withdrawals and to modernize parts of the secondary network. The project associates in a scientific committee: the canal manager, research teams, engineering companies, Universities and Colleges. It helps transferring academic knowledge and focusing the experiments on problem solving and end-users' requirements. Universities and Colleges take benefit from the facilities for practical work for teaching programmes in hydraulics and automatics.

INTRODUCTION

The project of scientific platform on the Gignac canal was initiated by the TRANSCAN team of Cemagref, which studies hydraulic modelling and automation for open channels. After several years of theoretical research in

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automatic control applied to wide hydraulic systems and particularly to irrigation channels, an experimental laboratory appeared more and more necessary. Indeed, with the exception of a few experimental channels of small dimension (of the range of tens of meters) existing in France, Mexico, Portugal or the USA, such facilities, aiming at this kind of specific testing, did not exist to our knowledge. The existence of an open channel not far from Montpellier (see **Figure 1**) and financial opportunities enabled us to materialize this idea.

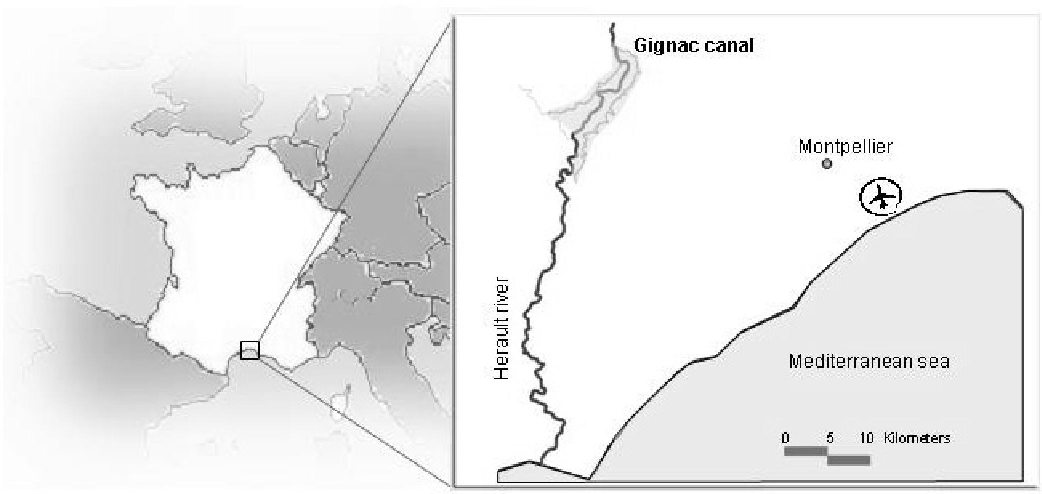


Figure 1. The Gignac Canal - Location Map

Stakes and Scientific Objectives

Stakes: In most regions of the world, diminishing available water and limited investment capacities of stakeholders and funding agencies lead to favour water savings through improved infrastructure and operations rather than investments for the development of alternative water resources. Those questions are particularly acute in southern France and, more generally, in the Mediterranean countries.

In France, growing conflicts around the use of water and the progressive introduction of contractual management of water resources at the basin level make this question essential for the agricultural sector and for emerging water uses in suburban areas.

Beside demand management, modernisation of irrigated schemes through an improvement of transport and delivery channel management appears to be the main way to achieve water savings. Indeed, manually operated open channels are characterised by a low efficiency (30 % in some cases), which can reach 70 % or more on fully automated systems.

The creation of an experimental laboratory follows this logic and aims at:

- demonstrating that modernization can lead to water savings,
- setting facilities enabling researchers to develop, test and evaluate new control methods and algorithms, and,
- promoting new techniques among engineering companies, canal managers and educational establishments.

Scientific Objectives: From a scientific point of view, the control of irrigation open channels is complex. This complexity is due to multiple factors like: delayed and non linear dynamics, complex topology of networks, interactions between control devices, unpredicted perturbations.

Like the Gignac canal, many systems in France and around the world are still manually operated, with upstream regulation, and a low on-line storage capacity. Those systems are particularly difficult to manage and modernize.
Improved hydraulic management can lay on two groups of control methods of growing complexity:

- local monovariable automatic control, sometimes associated with manual operational rules at some devices,
- multivariable control, generally centralised, and associated with robustness analysis.

Those methods can be tested on hydraulic models but they need a real-size validation before being industrialized. In this aim, the Gignac canal laboratory has a double interest:

- for the evaluation of the first group of methods, which could be of particular importance in developing countries,
- for the development and the *in situ* tests of the second group of methods.

Why the Gignac Canal?

Numerous reasons lead to the choice of the Gignac canal for becoming an experimental laboratory. On the one hand, its size is comparable to many irrigation channels, in France or abroad, and it is sufficient for achieving representative experiments. On the other hand, a modernisation programme initiated by the canal manager and the possibility to lead experiments in the fall-winter time when the canal is not in function are interesting opportunities. The improvement of the hydraulic management and efficiency of the canal itself has a particular importance because of the scarcity of the water resource in the basin. Lastly, this canal is located close to Montpellier, where Agropolis Research Complex hosts several research institutes dealing with water issues, attracting several national and international events (2003 54th Executive Council of ICID and 20th European Regional ICID Conference, 2008 XIIIth World Water Congress) and many delegations from all over the world interested in thematic visits.

PRESENTATION OF THE PROJECT

The Gignac Canal

Description and Main Figures: The Gignac canal is the main work of an irrigated area managed by the "ASA[4] du canal de Gignac", and was built in 1890. It is located about 35 km west from Montpellier (south of France). The resource comes from an intake in the Hérault River, which has a very pronounced Mediterranean regime, with severe lows in summer. The main canal is 50 km long, with a common trunk (8 km) and two branches on the left and right banks of the river (resp. 27 and 15 km). The nominal flow of the common trunk is 3.5 m^3/s. The dominated area is about 3,500 ha wide, out of which 2,800 ha are irrigable.

Water Delivery: For a bit less than 90 % of the surface, the water delivery is done through the open channel secondary network with a fixed rotational schedule, allocating 35 l/s during 5 hours per week per ha, which represents 63 mm/week. The remaining 10 – 12 %, essentially in suburban zones, receives water through pipe networks, with or without additional pumping.

Crops and Irrigation Techniques: Vine is the dominant crop with about 58 % of the surface. Other crops are cereals, orchards, and market and private gardens with respectively 6.3, 4.7 and 7.3 %. Non irrigated surfaces (waste land, gravel extraction, forests) accounts for about 24 %.

Traditional furrow irrigation is the most used technique in the area, especially in vineyards. Market gardens and orchards are mostly irrigated with drip and spray irrigation respectively, even if the water is delivered through open channels to the plots. In these cases, farmers have their own pressure devices.

Urban gardens are mainly supplied through low - or high- pressure networks and use spray irrigation.

Equipment

The project consisted mainly in installing sensors and actuators, and building an opened SCADA system for the canal, enabling supervision and local or remote automatic control. It has been designed to make possible the test of a wide range of control architectures and algorithms. Level, gate position and flow velocity sensors have been installed on the whole main canal at strategic locations.

Equipment Rationale: Transforming the canal into a laboratory consisted in permitting the centralisation of the measurements and the commands. More

[4] ASA : Association Syndicale Autorisée = association of landowners, under public administration control

precisely, it has been build around a supervisory system, located in the ASA's head office, and distant devices like sensors and motorised gates.
Because of the high cost of the equipment, choices had to be made. They were done according to the following constraints:

- command and measure discharges upstream of the 3 main branches,
- command outlets for security reasons and for enabling perturbation simulation,
- command four reaches in a row, in order to take interactions into account,
- get measurements on a "sufficient" number of points,
- guarantee a collection time of the variables compatible with the dynamic of the system, and,
- have at disposal a SCADA system enabling the integration of any control modules.

The choices also took into account various constraints linked to the topography, the possibility to reject important discharges, to the proximity of the power supply network, etc.

<u>Equipment Description:</u> Those criteria led to retain the following equipments (see Figure 2):

- measures and commands on some points of the common trunk and of the right branch,
- measures only, on the left branch.

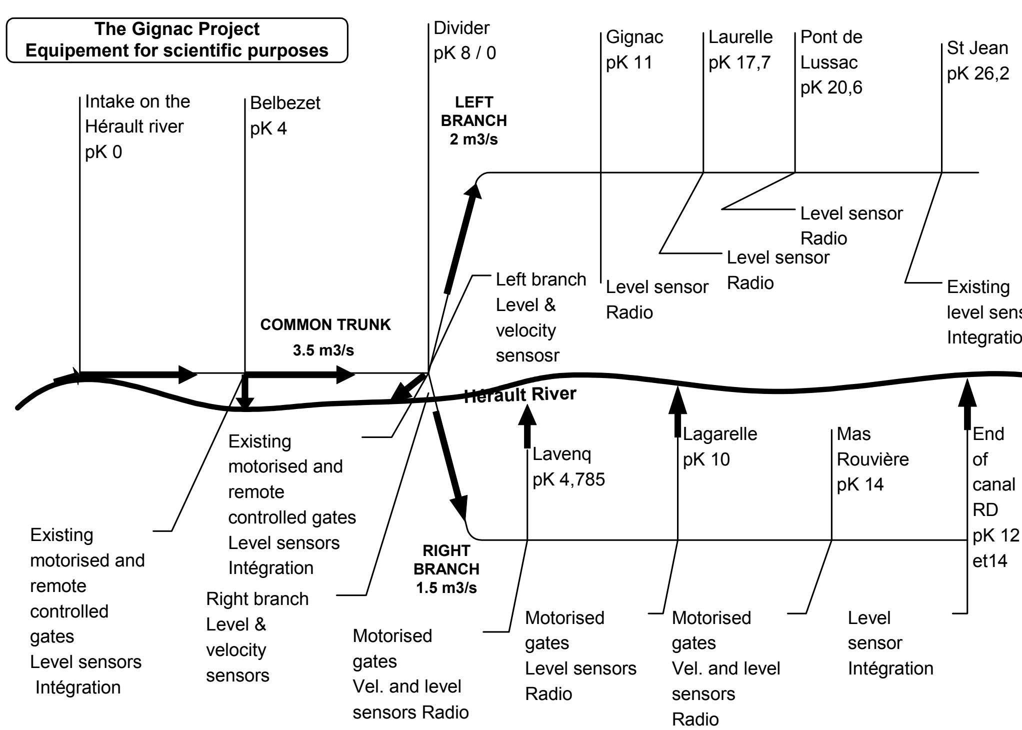


Figure 2. Installed Equipment on the Gignac Canal

Variables and Types of Sensors: Measured variables are:

- water levels, with piezoresistive sensors,
- discharges, with ultrasonic velocity sensors, and,
- gate openings.

Discharges can also be evaluated with indirect methods, with the measurement of water levels over freeflow weirs, the measurements of water levels upstream and downstream in addition to the gate openings at cross devices, or the establishment of discharge rating curves on some interesting locations. Three rain gauges give additional information on the meteorological situation.

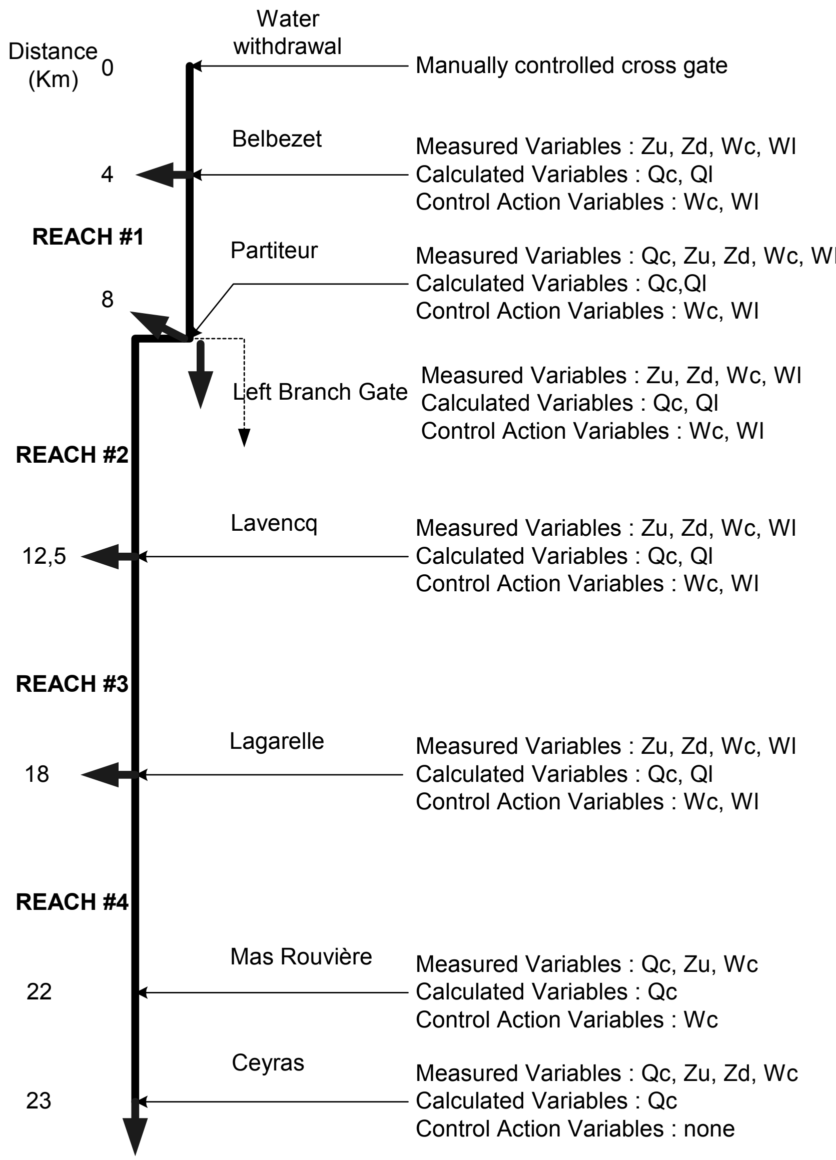
Control Action Variables: Control action variables are the gates openings, which can be cross gates, for level or transient discharge control, or lateral gates for perturbations generation and security outlets discharges.

Communications: Some sites were already equipped with remote measurements and control through the landline telephone network. This transmission method presents the disadvantage of being slow and expensive. The time for the scanning of eleven remote sites would have been of about ten minutes, which appeared too long regarding the dynamic of the system, and especially near the gates.

Hence, a 470 MHz radio system has been chosen, even if some location could not be equipped due to the topography. They were equipped with the telephone, and the central had to be designed to be able to communicate through both media.

SCADA and Control Modules: One of the main constraints in the conception of the supervisory devices was to enable the operator to link any control module to the SCADA system. The solution adopted is presented in a separate paper (mala et al., 2007).

GIS: A Geographical Information System has been added to the equipment. It includes the existing database of the ASA and various layers of data (primary and secondary network, land ownership, land occupation, soil reserve, etc.). The GIS is useful to the ASA for its day-to-day management and to the scientific teams for diverse studies.



NOTATIONS :

Z = water leval
Zu = upstream water level (gate or weir)
Zd = downstream water level (gate or weir)
Qc = discharge in the channel
Qd = lateral discharge (outlet)
Wc = cross gate opening
Wl = lateral gate opening

Figure 3. The Gignac Canal (Common Trunk + Right Branch): Measured, Calculated and Control Action Variables

Finance and Partnership

Financial Aspects: The total cost of the programme reaches 900 k€ (1170 k$), including about 510 k€ (660 k$) of investments. Local institutions (*Conseil Général de l'Hérault* and *Conseil Régional du Languedoc-Roussillon*) and the Water Basin Agency (*Agence de l'Eau Rhône-Méditerranée et Corse*) funded the project, partly because the investments were also a means to help modernizing the canal.

Partnership: The partnership includes the canal managing institution (ASA du canal de Gignac), 3 scientific laboratories, 3 engineering companies and 3 engineering Colleges. It is settled with a main M.O.U., the *Scientific Interest Group*, which includes all partners, and 2 M.O.U.s between the scientific leading institution (Cemagref) and the canal manager, which regulate the use of the canal for scientific purposes.

ACHIEVEMENTS AND RESULTS

Experiments

The experiments are conducted mainly before and after the exploitation period of the canal, which starts generally at the beginning of March and ends in mid-October. During those two periods, the canal can be completely dedicated to measurements and experiments.

Some tests may also be achieved during the exploitation period, as soon as they do not disturb the water delivery.

Research Topics

The various topics studied with the canal can be represented in the perspective of their automation (see Figure 4).

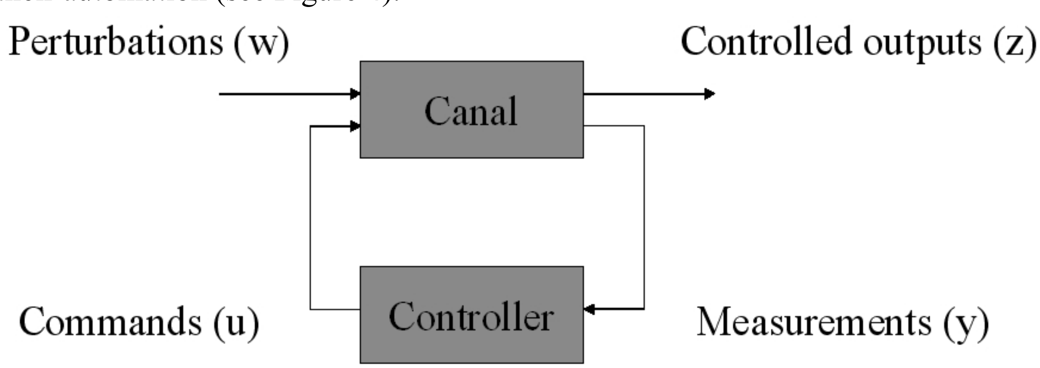


Figure 4. Automatic Control of a Canal - Studied Topics

Canal Model

A hydraulic model of the primary canals has been build with the SIC software, which allows simulation of one-dimensional steady and transient flows. The large amount of precise data enabled us to have a fine appreciation of the precision of the model. It is used for testing scenarios and control modules before their implementation on the real system.

Perturbations

Demand Study: Due to the inherent time delays of the system it is interesting to make a prediction of the water demands and to use it in a feedforward controller added to feedback controllers.

Evolutions in the Perimeter: Some former lands are converted to urban areas where the new inhabitants keep the ancient water right associated with the land. A low pressure piped network is then constructed providing raw water for gardening, swimming pools and some domestic uses. This change, although still limited, has an impact on the water demand and therefore on the canal operations that is currently studied.

Observation : Measurements and Controlled Outputs

Canal Supervision: As soon as real time measurements are used for real time control the issue of data validation, data reconciliation and fault detection is raised. Several studies have been conducted on this aspect leading to scientific publication, a PhD thesis and software tools.

Flow measurement: several options are available to measure flows in a canal, such as calibrated rating curves, ADCP techniques, and device equations. The quantity of data that are measured and saved in the database allowed us to evaluate and compare several alternatives for these measurements.

Commands

Several control action variables are possible as outputs of a controller. The main classical ones are the discharge Q or the gate position W. These alternatives could be further tested and compared on the real system. This work was presented in scientific publications and is still under investigation.

Controllers

Several SISO and MIMO controllers have been studied in the frame of several research projects leading to scientific publications and PhDs. Some of these controllers are presented in a separate paper (litrico et al., 2007).

CONCLUSION

The first phase (2002-2007) of the scientific project of the Gignac canal will be achieved in 2007.

For the scientific teams involved, it has been an essential element for the validation of various control algorithms and supervision methods. It enabled the teams to publish several articles and two PhDs, which include real-size test results.

Those results are now available for engineering companies, which also take benefits of the know-how gained during the installation phase of supervision and command system.

Several Colleges organized visits and conferences around the Gignac canal, practical works in hydraulic simulation and automation have been backed on data taken from it and about ten students worked on Gignac during training periods.

The canal manager has also improved its knowledge and comprehension of the system behaviour through the modelling and the various experiments and studies conducted on the canal. As it is now facing new environmental constraints, this knowledge will help making decisions on a modernizing plan.

Lastly, a second phase of experiments and testing has to be discussed in 2007 between the scientific teams potentially involved in the field of canal automation.

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