# SCADA INTERFACE OF THE SIC SOFTWARE FOR EASY REAL TIME APPLICATION OF ADVANCED REGULATION ALGORITHMS

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## ABSTRACT

An increasing number of irrigation canals are following modernization projects to improve their hydraulic efficiency, their quality of service to users and to face new operational constraints. The Gignac Canal has been specifically modernized in order to be used during certain periods of the year as an experimental platform for several partners. A SCADA system has been installed with display screens at the manager's office and a SCADA interface has been developed into the SIC hydrodynamic software allowing testing of any type of control algorithm. This testing can be done first on the SIC hydraulic simulation model, and then switched onto the real canal without any code rewriting or parameters change. This SIC SCADA interface is communicating with the SCADA system developed by DSA Company exchanging data forth and back through simple ASCII files. The features of this approach are described in this paper. This SCADA module is now included into the standard library of the SIC software. This tool has been intensively tested on the Gignac canal that will be used for illustration.

## INTRODUCTION

### Context

The project of scientific platform on the Gignac canal was initiated by the Transcan Research Team of Cemagref in 2000. Funds have been obtained for the period 2000-2006 from different partners including the State (Federal funds and Cemagref), the Region (Languedoc-Roussillon), the Department (Hérault) and the Water Agency (Rhône Méditerranée Corse). The rational of this project is described in a separate paper (Vion et al., 2007). Some important equipment have been installed on the canal including sensors, hydraulic devices, actuators, and a SCADA system allowing to observe and control remotely the main canals from the manager's office. The innovative aspect of this project was, in addition to modernizing the canal for its traditional irrigation objectives, to make this real irrigation system a scientific platform that can be used by several partners for scientific purposes. The 12 partners of this project are gathered in a "Groupement d'Intérêt Scientifique" (Scientific Interest Group). It includes 3 consultant

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companies, 4 automatic control laboratories, 3 engineering schools and Universities, the Canal Manager and Cemagref.

## Terms of References of the SCADA System

-   The first objective of the SCADA system was the classical one, i.e. collecting real-time data, storing them into a structured database, displaying then in user friendly standards, managing the defaults and alarms, and allowing remote control of some devices.
-   The second objective of the SCADA system, less classical, was to allow testing of any automatic control algorithm, from simple ones such as SISO PID controllers, to very advanced ones such as multivariable LQG, $H_{inf}$, $l_1$ controllers.
-   Due to the complexity of some of these controllers, the third objective was that this testing could be done with as limited sources of errors and as little efforts as possible.

It was decided that the second objective would be attained if all the controllers already programmed into the SIC regulation module library including those than can be written using the open Fortran, MatLab or Scilab interfaces, could be tested as it.

It was decided that the third objective would be attained if any given controller could be tested first on the SIC hydraulic numerical model (offline), and then on the real canal (online) without any code rewriting or parameter editing.

The experiments protocol imposed within the partners of the project was then to test first the studied controller onto the SIC simulation model using the Gignac data files provided by Cemagref, and then, when validated by the canal manager and Cemagref on the selected scenarios, to run the experiment on the real canal, on line.

The two next chapters describe, first the general features of the SCADA software developed by DSA Company, and second the SIC-SCADA interface principles allowing fulfilling the above terms of references. A last chapter gives an illustration of use of this interface.

## SCADA SOFTWARE PRINCIPLES

The SCADA software installed on the Gignac Canal is proprietary software developed by DSA Company. It is nevertheless based on standard software solutions such as SQL database, PCView for the graphical displays and Java components for the management of the data and the communication devices. A web interface is available for users in order to monitor and control the plant using a secure Internet access.

Different users' profiles are defined into the SCADA software allowing different functionalities to different users. The canal manager has the full access to all options including visualizing the canal hydraulic state, the alarms, acknowledging the alarms status, changing RTU parameters, activating some local controllers, sending manual gate movements or operational objectives in terms of discharges or water levels, etc. The research-student login allows visualizing the canal state and to operate one or several gates as authorized by the canal manager.

After the login procedure, a general display screen (Figure 1) allows visualizing general information on the canal at 13 different local field stations: the main canal intake on the Hérault River, the partition between the right bank and the left bank, 4 stations along the right bank main canal and 4 stations along the left bank main canal corresponding to 8 cross devices, the radio communication station and a moveable station that can be used to monitor any location depending on the experiment. This moveable station is based on a small trailer with safety protections and includes data logger, sensors, and a radio communication system. This screen displays information on the alarm status for each station, on the communication status and most of the hydraulic and device position data.
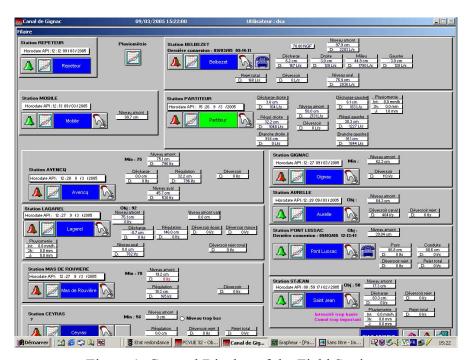


Figure 1. General Display of the Field Stations

More detailed information and a synoptic drawing is displayed if a given station is selected (Figure 2).
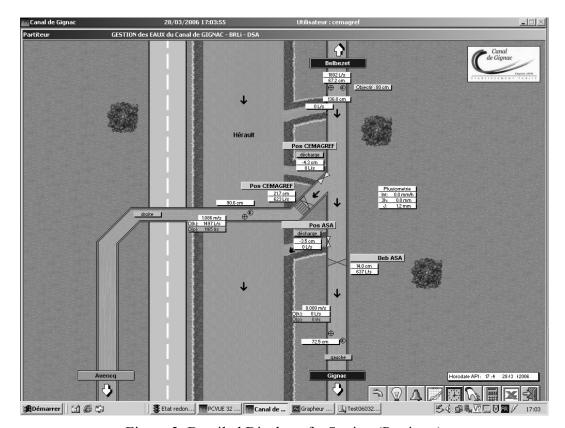
Figure 2. Detailed Display of a Station (Partiteur)

Each hydraulic device (cross regulator or lateral offtake gate) can be switched into 4 different modes:

- "position Cemagref": a user logged under the Cemagref login for field experiments can change the position of the device.
- "discharge Cemagref": a user logged under the Cemagref login for field experiments can change the discharge target at the device and a local slave controller (programmed into the local RTU) will calculate the position of the device to get this discharge.
- "position ASA": only the manager can change the position of this device.
- "discharge ASA": only the manager can change the discharge target at this device and a local slave controller exists as above (with possibly different parameters).

The management of these 4 modes was imposed in the terms of the reference of the SCADA system in order, during the field experiments, to limit the operation at the selected devices and to prevent unwanted operations at other devices.

## SIC-SCADA INTERFACE

Except a specific management of several modes for the operations at the cross or lateral structures as described in the previous chapter, the SCADA system in itself

is following a standard framework. DSA Company has an extensive experience of similar applications in several industrial domains going from the supervision of a shampoo plant to an integrated flood alert system. The most innovative aspect, as imposed by the terms of references, was to have an opened software structure allowing, as easily as possible, the test of any simple or advanced automatic control algorithm on any hydraulic device. Several options where possible for this software component.

## Several possible options

The first option is to program the algorithms to be tested directly into the SCADA software when it allows such option (ex.: in proprietary, in Java or in c programming language). The advantage of this method is that being incorporated into the SCADA software the computational speed is optimized and no interaction is necessary with any third party software. The drawbacks of this method are:
- only PID and predictive controller are sometimes present in the commercial SCADA packages,
- programming of other algorithms needs lots of efforts, in languages offering few specialized libraries,
- if the algorithm has to be tested first on the SIC simulation model the programming has probably to be done twice: in the SCADA software and in the SIC software,
- since different partners can propose algorithms, the management of the SCADA source and executable version (existing on several computers) has to be managed carefully.

The second option is to program a specific software interfaced with the given SCADA interacting through files (ex.: ASCII files) or in memory (ex.: DDE link). Compared to the previous method the advantage of such approach is to have more flexibility in the choice of the programming language and therefore to be able to use specific mathematical or control libraries or links with specialized software such as MatLab or Scilab. It would have been also possible to reuse some existing Fortran code of the SIC Regulation Module Toolbox. The drawbacks of this approach are the same as the 2 latest of the previous option: redundant programming and management of the source files as a new project with several programmers.

Transcan research team of Cemagref used a third option consisting in developing a SCADA interface into its SIC hydrodynamic software. This SIC SCADA interface is communicating with the SCADA software developed by DSA exchanging data forth and back through simple ASCII files. The great advantage of this approach is manifold:

- All control algorithms available into the SIC software library can be used on the real canal (simple PID controllers, auto tuned robust PID, any State

Space controller such as LQG, $H_{inf}$, $l_1$, Open Loop controller, user's defined controller through the simple Fortran interface or through the DDE link with MatLab or Scilab).

- It is possible to test first the controllers on the SIC simulation model, and then just by switching on the SCADA option to use exactly the same controllers and parameters on the real canal.
- The SIC unsteady flow program can be automatically synchronized with the real time data allowing checking the calibration of the model, by comparing the simulated data with the real-time measured data.
- This SIC SCADA interface allows using SIC interfaces for example to check the operation of the gates, to compute performance indicators, etc.
- If an advanced controller needs some unmeasured hydraulic data, these data are available into the hydraulic model (for example for an advanced conversion between the gate discharge and opening).

## Description of the SIC-SCADA Interface Principles

The "Digesteur" is the name given by DSA to the SCADA module managing the communication between the database located in the 2 frontals (in redundancy) and the Cemagref tools described hereafter allowing testing control algorithms in real-time on the Gignac canal. The SCADA module of the SIC software named "Scada_Sic" hereafter is the name given by Cemagref to the software component managing the communication between the files of the Digesteur detailed hereafter (csg.txt, data.txt and the parameters file) and the unsteady flow calculation module of SIC, including the standard regulation module library.

The Scada_Sic module is in fact a regulation module of SIC with a similar structure of the classical ones. It has been programmed by Cemagref but using the open Fortran interface of SIC it could have been programmed by any SIC user. Before describing the principle of the Scada_Sic module, let us first recall the principle of the SIC regulation modules.

A regulation module as defined in the SIC software is composed of several elements:

- a selection of the measured variables,
- a selection of the controlled variables,
- a selection of the control action variable,
- a control algorithm,
- parameters for the algorithm.

The first 3 type of variables are selected using a user's friendly editor among a large type of variables at all possible locations along the canal. The control algorithm can either be selected among a list of pre-programmed algorithms such as PID, state space feedback controllers, open loop controllers or can be

programmed in Fortran, MatLab or Scilab programming language. The parameters of the controllers depend of course on the selected algorithm. These data are saved into a .reg file.

During an unsteady flow simulation the corresponding module of the SIC software is then collecting the measured and the controlled variables, provides these values to the control algorithm, gets the output of the algorithm and apply the values to the control action variables.

The general principle of the Scada_Sic regulation module is the same. It has 3 parameters:

- Name of the algorithm to be used (among the list of the regulation modules, including the MatLab, Scilab and the Fortran ones).
- Flag indicating that the measured and controlled variables must be taken from the data.txt file (i.e. from the field real-time values) instead of the unsteady flow calculation.
- Flag indicating that the control action variable calculated by the algorithm must be written into the csg.txt file (i.e. to be applied to the field in real-time) or/and applied to the variables in the unsteady flow calculation.
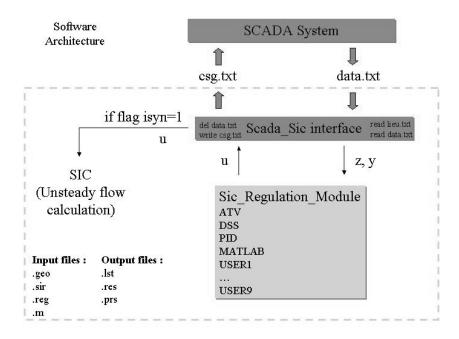


Figure 3. Software Architecture of the SIC SCADA Interface

**Variables managed by the Digesteur and the Scada_SIC module**

The SQL database of the SCADA system for the Gignac canal contains several hundreds of variables. Each of them is described using several fields. One of them

is named "ItemRegulateur". If this field is nil the corresponding variable will not
be considered by the Digesteur. If a name is given in this field, this variable will
be managed by the Digesteur. When the name starts by "data", then the variable
will be written in the data.txt ASCII file at a regular time step. When the name
starts by "csg", then the variable will be looked for in the csg.txt ASCII file at a
regular time step and, if found, applied on the field in real-time. The names given
in the "ItemRegulateur" field can be for example: Data.Avencq.DebitAmont for
the discharge upstream of the Avencq station, or Csg.Avencq.PosVanneReg for
the gate position at the Avencq cross device.

### Data Sub-Directory

A sub directory named Data contains the data.txt files generated periodically by
the Digesteur at a given time step indicated in a config.txt file. These data.txt files
will be read by the Scada_Sic module and then deleted, to leave room for the next
iteration.

A data.txt file contains several sections including a header with the time of the
creation of the file, an index that is incremented during the simulation for each
new file and then the data with their name, date and time of latest field collection
and value. The units and offsets are specified in the database.

### Exemple of Part of a Data.txt File

```
[Header]
Horodate=26/10/2004 17:03:02
Index=01
[Data]
DATA.AURELLE.DEFPIEZZO;    20/03/2004 10:31:16;   0.0000000000E000
DATA.AURELLE.DEFSURVERSE;  20/03/2004 10:31:16;   0.0000000000E000
DATA.AURELLE.NIVPIEZZO;    26/03/2004 15:51:07;   7.0000000000E001
DATA.AVENCQ.DEBITAMONT;    26/03/2004 15:51:27;   5.3100000000E002
DATA.AVENCQ.DEBITAVAL;     26/03/2004 15:51:27;   5.3100000000E002
...
[End]
```

## ILLUSTRATION OF SOME USES

Several experiments of control algorithms have been carried out on the Gignac
Canal by several partners of the project. We present hereafter some results
obtained testing an auto-tuned PID algorithm using an improved ATV method.
This experiment is further detailed in a journal paper (Litrico et al., 2007). Figure
4 displays the screen interface of the SIC SCADA module during the experiment.
We can check the parameters of the module and all input data (measured and
controlled variables obtained from the field stations via the data.txt files) and
output data (control action variables as calculated by the tested algorithm as
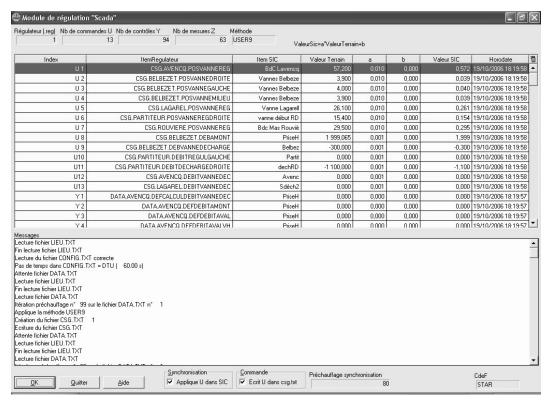written on the csg.txt file before being sent to the field stations).

Figure 4. SIC SCADA Display During the Experiment

Figure 5 shows a real-time field experiment using the standard ATVPID regulation module of the SIC software and the SIC SCADA interface. We can see a first phase during which a relay experiment is carried on. Then using the result of this experiment as described in (Litrico and Malaterre, 2007) the PID parameters are automatically calculated and the PID is activated. We can see that the tracking of a new target is followed very quickly. All this is done without any human input during the experiment. It can be used and was tested for any local upstream, local downstream and distant downstream PID controllers.

## CONCLUSION

The SCADA software installed for the supervision and control of the Gignac canal followed terms of references including classical features for a SCADA systems plus specific features in order to allow extensive tests of all types of automatic controllers from simple ones to the most advanced we could imagine. This should also be done reducing the time taken by the users to do these tests and to limit the risks of problems occurring including operations at wrong locations or operations damaging the system.
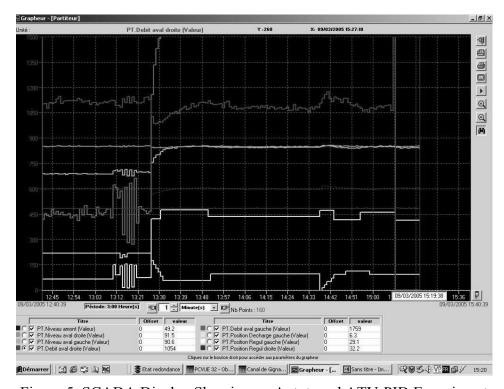
Figure 5. SCADA Display Showing an Autotuned ATV-PID Experiment

The SIC SCADA module has been used routinely for many experiments for 3 years now. It proved to be very powerful and flexible.

The fact that the controller can be tested first in simulation mode using the classical SIC software offline, and then switched in real-time onto the real canal without any code rewriting or parameter re-entering is a very simple, fast and safe procedure. The fact that the SIC SCADA module is a regulation module incorporated into the SIC program is also very powerful since it is possible, if needed, to use the unsteady flow calculation for some advanced control algorithms or to check if the field data are matching the simulated data. Using this feature it is also possible to test auto calibration algorithms for example to calibrate friction coefficients or gate coefficients using real-time measurements without manual data entry on extended period.

The fact that this SIC SCADA module is incorporated into SIC also enables it to benefit directly from all the SIC improvements such as new interfaces, new installation procedures, new regulation modules, etc.

## REFERENCES

Litrico X., Malaterre P.-O., Baume J.-P., Vion P.-Y., Ribot-Bruno J., 2007. Automatic tuning of PI controllers for an irrigation canal pool. ASCE Journal of Irrigation and Drainage Engineering, Jan./Feb. 2007, Vol. 133, n°1, p. 27-37, ISSN 0733-9437.

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