SCADA System for Monitoring Water Supply Networks

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Abstract: - Water supply represents a vital problem for people, and this imposes the need to know the information regarding consumptions, resources and production. This implies a continuous supervision of the water supply process in order to allow any problem that could appear to be solved, and in the same time, to maintain normal functioning parameters. Proper solutions imply automation and monitoring architectures which contain: a supervision and control system for the real time installation, programmable logic controllers with basic functions (communication, adjusting, measuring, etc.) libraries, communication systems, standard interfaces or dedicated ones with sensors, electrical drive elements, measuring devices, etc. The informatics systems present the possibility of preventing some phenomenon, by analyzing and processing the data, leading to an optimum functioning and to important financial economies. In this way, the paper presents a SCADA system for the monitoring and control of the technological parameters in the water distribution stations, which will allow the optimum functioning of the pumping system, safety and endurance growth in the equipments and installations exploring, and so obtaining efficient energy usage and optimum administration of the drinkable water.

Key-Words: - SCADA, data acquisition, analysis, monitoring, control, PLCs, data transmission.

1 Introduction

A modern management, based on the economical performance, imposes, in principal, the knowledge, in every moment of the report between costs and profits, and of the control level that can act on this report to bring him to a subunit value. The implementation of modern solutions in an efficient functioning of the pumping stations within the public water supply services implies the existence of some proper systems based on computational technology. In this way, to obtain this information, based on analyses of the technological process, of the driving and exploiting mode, there is proposed an DMS/SCADA type informatics system which to allow an optimum drive of the technological process and a greater safety regarding the drinkable water distribution with the purpose to continuously improve the quality of the services offered to people [1], [2], [9], [14], [16], [17], [18].

In the making of the architectural model for the DMS/SCADA system, the following principles have been considered:

- distributed processing open systems;
- principle of modularity;
- principle of autonomous and integrated working of equipment;
- principle of mutual settlement of the equipments to provide the essential working of the system;
- principle of transparency in using and working;
- principle of best cost/performance ratio;
- principles destined to provide:
  - effective monitoring, control and management of real-time and extended-time installations, based on the data acquisition from installations;
  - management of installations besides the real-time;
  - the required information for analyzing the behavior in operation and working out the statistics related to the working of the existing networks, installations and equipments, for establishing the technical and economic solutions to improve the technical conditions of installations, equipments and development strategies;
  - the information for the superior dispatcher levels.

The proposed system uses a distributed architecture, in which there are distinguished two levels:

- a local level corresponding to the water distribution stations;
- a central level corresponding to the dispatcher.

The local level is based on the usage of the programmable logic controllers and of computers, and the central level contains high speed PC computers for the supervision or operative drive of remote processes. The communication between the dispatcher and the local monitoring and control systems is done by the help of some data sending techniques, according to the type of the communication environment between these points (cable, optical fiber, telephone line, radio channel/wireless, GSM). Considering a base characteristic of the SCADA systems – flexibility, the main concept fallowed in the development of this system is modularity, in the idea of an easier configuration and maintenance and to assure ulterior extension possibilities of the system.

2 The Architecture of the SCADA System

The information tracking in real time and the range enlargement of this information, the tracking of the working parameters comparatively with the accepted limits, storing the data from the process and its continuous processing, examining the technical state of the equipments and early preventing the future averages, automatic providing of the parameters settings and last but not least, providing the linking with the dispatch level for possibilities of two-sided data and controls transmission, make it necessary the large-scale introducing and distribution of the digital technologies.

From an architectural point of view, the system will be developed on a equipments distributed network model based on the present standard level of computational technique, in order to fulfill the requests for fast processing of an important quantity of information, the requests for high viability and the necessity of open access to the informatics system.

2.1 System functions

The monitoring and control system has the role to supervise the evolution of the technological process, to measure exactly the consumptions and production, respectively to optimize the technological process, assuring the fallowing functions:

- acquisition of data taken from the transducers and their process;
- framing between the technological limits of the acquisitioned data, warning in case of crossing these limits;
- pumps command, the regulation being made according to the debit or pressure in the drinkable water supply network;
- realization of the supervision bulletin and of the specific reports;
- assuring the informational support by creating and maintaining a secure and complete database;
- elaboration of synthesis reports using data from the databases and from archives and presenting them on display or printer, with the possibility of completion or modification by the user;
- presenting the measures taken from the dispatcher, by:
  - synoptic, general or on sectors schemes, for rapid evaluation of the momentary process functioning situation;
  - virtual instruments (bar-graphs, instruments with pointing needle);
  - evolution diagrams on selectable time ranges.
- informing the decision factors in order to take the optimum measures that impose;
- system centered administration;
- interfacing possibilities with other existing informatics systems.

2.2 System components

The informatics system (Fig.1) uses a distributed architecture hierarchical [4], [6], [10], [11], which contains the following blocks:

- Transducers signals adapting block.

This block realizes the bringing of the signals taken from the process through the transducers in the unified signals range compatible with the inputs of the computing systems interfaces.

- Local data acquisition and command equipment - Programmable Logic Controller (PLC).

Each local water distribution station is provided with a data acquisition and command equipment (PLC) associated with a PC which does:

- automat acquisition of the specific parameters;
- primary processes (filtering, validation of the values from the transducers, framing between limits);
- local display;

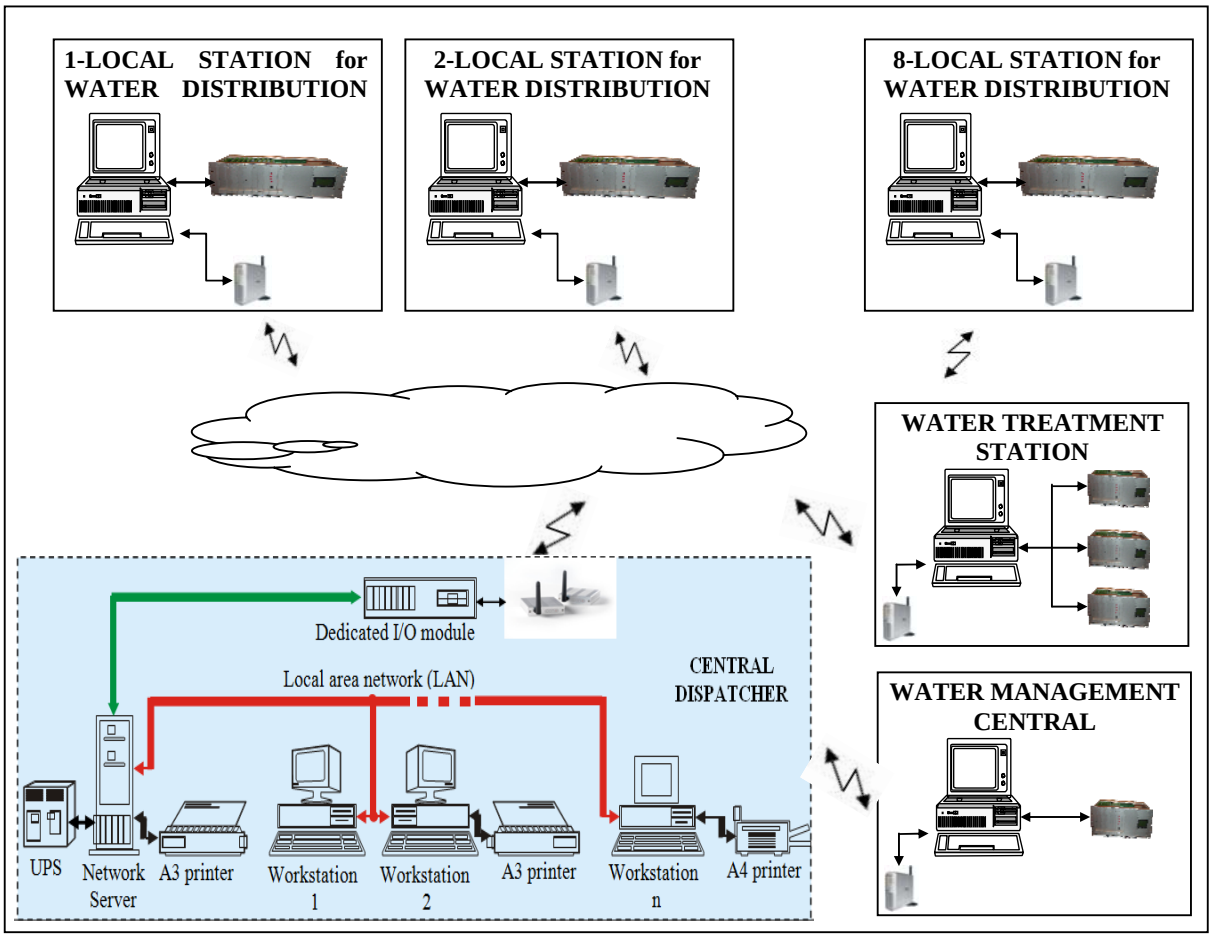


Fig.1 The Block Diagram of the SCADA System

- warnings in case of crossing the limits;
- communication with the superior hierarchical level.

• Dispatcher

At the Water Staging level there is the Dispatcher which does:

- supervising the entire system;
- superior data process;
- displaying the system's scheme;
- displaying the synoptic schemes with real time supervision for each local equipment;
- elaborating the general monitoring bulletin.

The communication between the dispatcher and the local systems is done through telephone modems or radio.

The technological parameters that are monitored are:

- pressures;
- debits;
- levels;
- pumps state;
- electro-vane state;
- filters state;
- active/reactive energy.

2.3 System functioning

The SCADA system assures the acquisition from the transducers of the characteristic parameters of the functioning of the technological installations within the water distribution stations, the monitoring and command of the pumps at the local stations level, the taken of the acquisitioned data, sending the data to the central dispatcher level, monitoring the stations functioning through the synoptic schemes, elaborating the monitoring bulletin and stations balance sheets, sending the results to the decision factors. In this way, each station has its own data acquisition and command local equipment which has associated a local PC and which communicates with the dispatcher PC. The equipment is questioned at a constant period of time fixed by the local PC and so all the analogical/digital inputs and outputs are registered at the level of the local computer. The equipment

realizes the drive of the pumps driving engines within the respective station, through soft - starters/invertors (Fig.2).

Usually, there are used soft-starters until the engine reaches the nominal revolution, and through

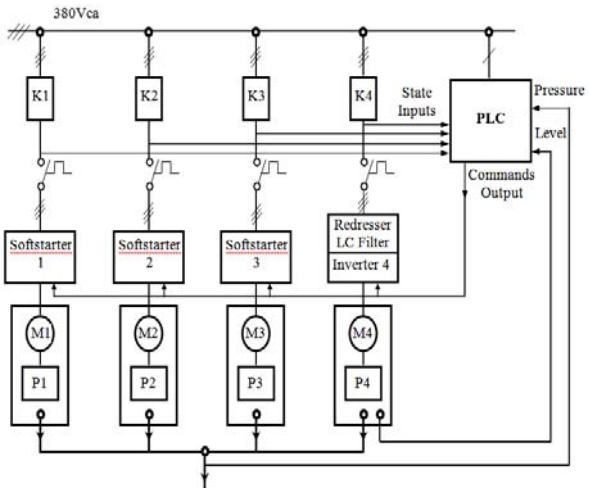


Fig.2 The Block Diagram of a Water Distribution Station

the inverter the evolution is adjusted according to the measured pressure. The invertors supply with variable voltage and frequency the asynchronous water pumps drive engines, and so assuring the change of the evolution between zero and the nominal voltage [5], [7], [12], [13], [15].

The local computer realizes the following functions:

- questioning the data acquisition and command equipment;
- data register in the local database;
- generating states of warning/pre-warning;
- communication with the superior hierarchical;
- local display of the functioning parameters in a format specified by the user;
- access to the general database within the central dispatcher for obtaining reports and statistic information at request.

The automation box (Fig.3) within the local stations communicates with the automatic logic controllers using a RS485 communication bus of type Modbus.

Water flow and quality information are acquired directly by the local stations.

In each station there were defined the following general alarms:

- for functioning (box supply flaw, battery flaw, internal flaw, PLC internal flaw);
- for acquired information (acquired measures warning boundaries);
- for pumps functioning (time boundaries for functioning of a pump in accordance with scheduling maintenance operations);
- for water quality measures (conductivity, Ph, temperature, etc.);
- for flow and level measures (instant flow, level, volume – by the help of the volume contact provided by the flow meter).

Fig.3 Automation Box

All local computers are questioned by the central dispatcher regarding the stored data, until it receives the necessary data (through a communication protocol that assures 10 questions).

In case a local computer detects the warning/pre-warning state, in generates a special message which is sent to the dispatcher in order to inform about the special state.

The warning/pre-warning state refers to the crossing of some limits imposed by the system's user on analogical channels or the activation/deactivation of some digital inputs.

The special events are stored in a local archives (at the local computer) and in a general one (at the dispatcher). The general and special data (warning/pre-warning) are used by the central dispatcher to generate different functioning reports or for generating of evolutions in time of some parameters requested by the user.

Also there are acquired and sent by the central dispatcher (Fig.4), the following states:

- information regarding the motors, acquired by the help of the existent programmable logic controller (Pump Start/Stop, Pump Auto/Manual behavior, pump thermal flaw, pump motor boundary temperature, lift pump pressure, pump functioning time, start count, flaw count, vibration boundaries);
- vane information;
- station consumption information (acquired also by the help of the Modbus communication bus within the energy measuring centers mounted in the general electrical panel).

Fig.4. Central Dispatcher

Water quality measures, flow, level and pressure are packed in the local station at a fixed period of time and at their each variation with more than 10%.

The goal of the central dispatcher is to assure the management of a station network composed of local stations and industrial programmable logic controllers.

Various information collected by the local stations are sent to the supervision centers installed in the water treatment station and to the central water management area, the place where there is supervised the entire network of the city. The information is packed in a database within which there can be issued exploitation reports and graphical charts.

The Microsoft Windows operating system has support for applications independent of hardware equipments and peripherals and also supports different applications which allow interfacing with PCWin through standard mechanisms of data sizing.

The centralized information within the stations can be processed directly with the PCWin application (station parameters, visualization of synoptic schemes, alarm reports, etc.), or using different Windows applications (table of chart generation within EXCEL, etc.).

Remote access to the application and information acquired by PCWin is possible through a Web browser by passing through a local network of through dedicated RTC/GSM modems.

The number of synoptic schemes, of charts and of EXCEL reports is not limited and depends only on computer's hard drive available space.

PCWin offers the possibility of creating an unlimited number of annual calendars which allow the schedule of actions which will be automatically executed (local station queering, EXCEL reports editing, etc.).

For communicating with the stations, PCWin uses one or more communication channels. Each communication channel is defined by a name, a communication protocol, a communication port, the number of the central station (if the associated stations communicate with more central stations), access settings, alarm management, setting up the clock hour for all the stations associated with this communication channel.

PCWin exposes the data (current state, history, etc.) to external applications using an OPC Server interface.

3 Data Processing Software Tables and Diagrams Obtained Experimentally

The data processing software specific to the SCADA system implemented in Water Staging Craiova [3], [7], [8], [9], [11], is developed on a model of a distributed network composed of equipments and contains the following application software packs:

- Software packs for acquisition and control – run at the local level: PLC and inverter;
- Software packs for local monitoring – run at local level: PC;
- Software packs for communication – assure communication: PLC–inverters, PLC–local PC, local PC–dispatcher PC;
- Software packs for dispatching – run at PC level and at PC dispatcher level.

The SCADA system offers information to the compartments which participate to the operative

drive, supervision and decision making of the technological process.

The software programs suits assure a large set of features, like:

- Real time process monitoring and control, through:
  - synoptic schemes, hierarchies, for fast evaluation of the current functional state of the process;
  - virtual instruments (bar charts, indicator instruments, etc.);
  - evolution diagrams on selectable time intervals;
  - alarms.
- Real time presentation of the information necessary for the user in computer assisted operative drive, through:
  - graphical and/or digital presentation of the relevant parameters tendency, on certain time intervals;
  - evolution curves of the parameters vs. their reference values;
  - dynamic computation of the deviation and presentation of actions to be taken;
  - warning in case of exciding the working boundaries.
- Recording the changes in process state in ordered event journals and presentation on screen or to the printer of these journals.
- Operative reports issuing and their presentation on a display or to the printer, allowing the user to complete/change them.
- Elaboration of synthesis reports using the data within the database and/or within the archives and their presentation on a display or to the printer, allowing the user if needed to complete/change them.
- Presentation of the content of the database and the archives, with the possibility of their completion/changing.
- User assistance in technical analysis and post analysis.

The program consists in a "Main post" and a number of operator posts.

When launching the "Main post" program, on the screen there is displayed a window with the following buttons: Acquisition start; Domain establishment; Synoptic scheme; Reports; Events report.

3.1 Synoptic scheme

For configuring the connection to an local station there is available a window (Fig.5) within which there are set some parameters like: Station ID, Time Out, Analogical Inputs, ADC Min, ADC Max, UM Min, UM Max, Alarm Validation, etc.

Synoptic scheme (Fig.6), is used for rapid evaluation of the current functional state of the process. This highlights a number of parameters,

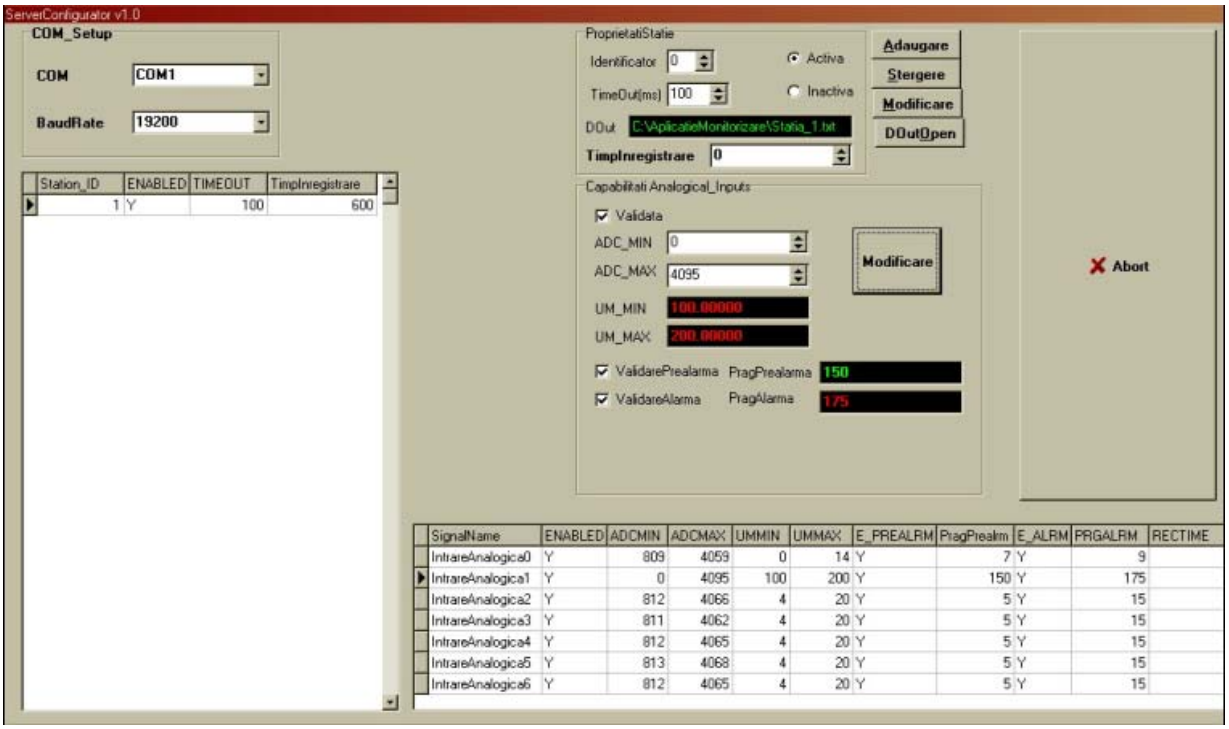


Fig.5. Connection Configuration – Local Stations

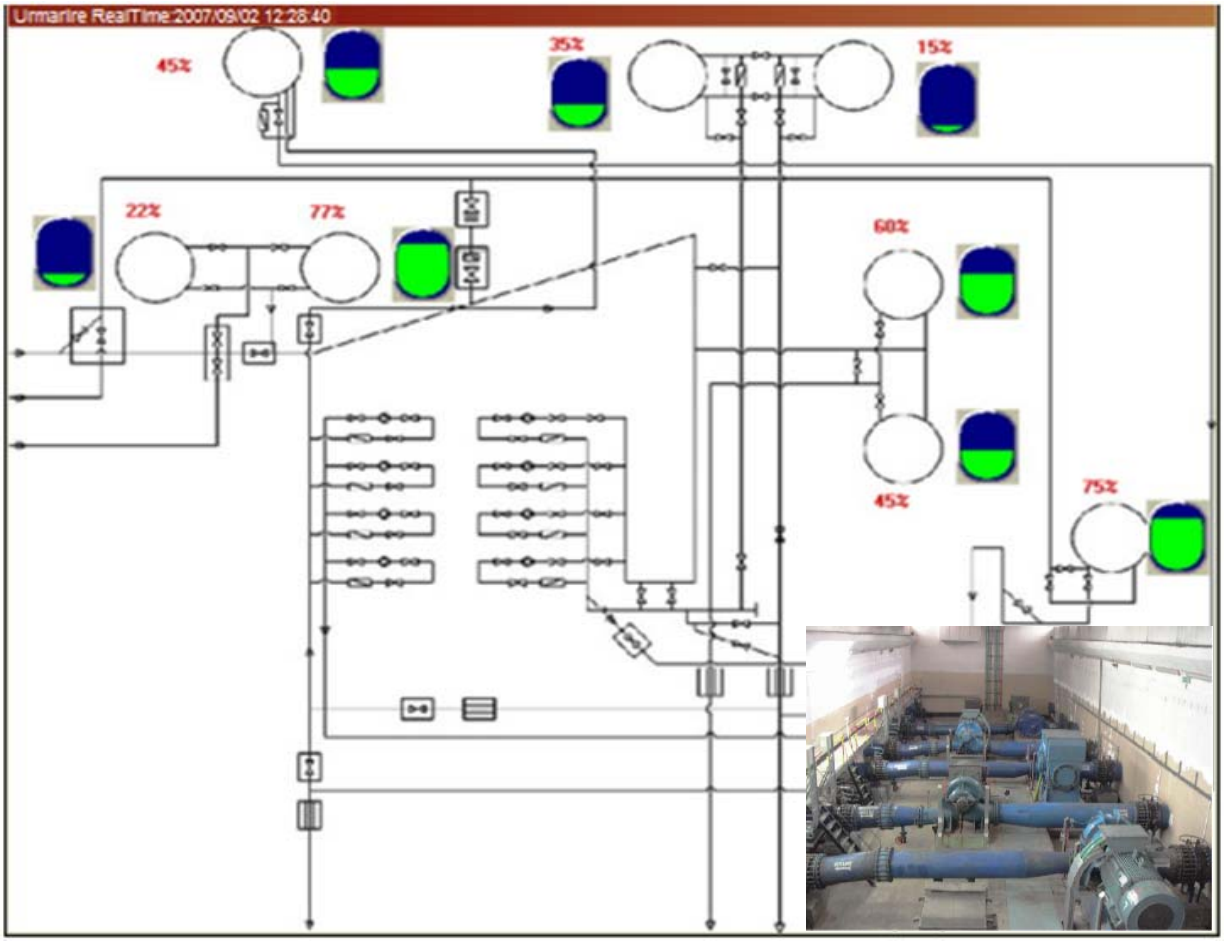


Fig.6. Synoptic Scheme for the Water Level in Tanks

considered essential, with the name and value. When placing the mouse over the tags, a message appears describing the position of the transducer used for measuring the respective parameter.

The synoptic scheme allows:

- visualization of the hydraulic scheme of the respective station;
- displaying information regarding the functioning of the pumps;
- displaying information regarding the vanes state;
- water level information in the water tanks of the station.

Flaws occurred in pumps or vanes functioning are visually and acoustically notified.

Details regarding the functioning mode of the pumps, occurred flaws in pumps functioning, working pressures, can be known using table reports which have rows which contain information about:

- pump state: stopped, started;
- functioning mode: auto, manual;
- vanes state: open, closed;
- alarms which come from the protection relays of the pumps' motors;
- alarms which come from the protection relays of the aspiration pressure values and lift pump pressure;
- number of times the pump stated, functioning time of the pump, flaw count.

3.2 Reports

Reports that underline the tabular or graphical evolution of the parameters selected, using the data from the database and/or from archives and displaying it on screen or printer, the user having the possibility to complete/modify it. In this way there is called a window that allows selection from a list of a parameter and for this there is established the visualization channel (Fig.7) and respectively the corresponding period selecting the year, month, day and hour (Fig.8).

Fig.7 Channel 0 and Channel 4 Selection for Report Visualization

Fig.8 Setting a Year, Month, Day for Report Visualization

There is presented the evolution in a table style mode (Fig.9), graphic mode (Fig.10) and instruments with needle indicator (Fig.11) for the selected parameters.

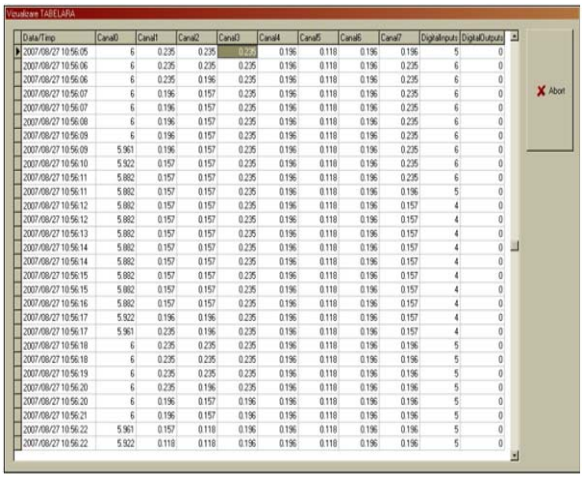
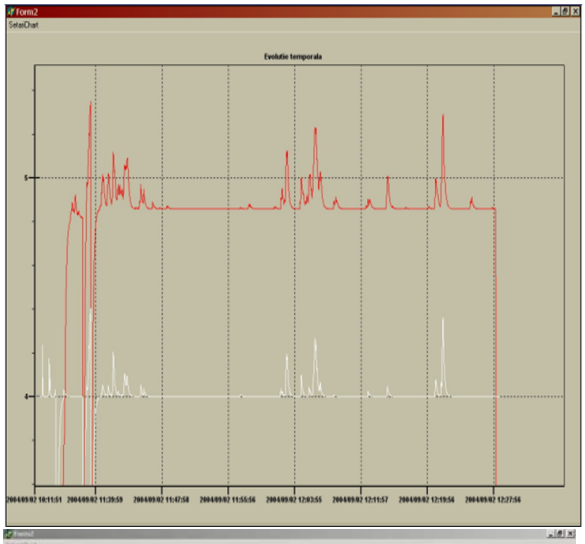


Fig.9 Table Style View of the Selected Parameter



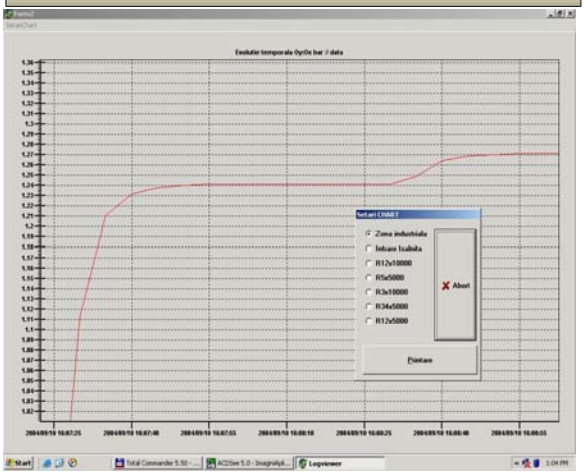


Fig.10 Graphic Visualization of the Temporal Evolution of the Fig Selected Parameter

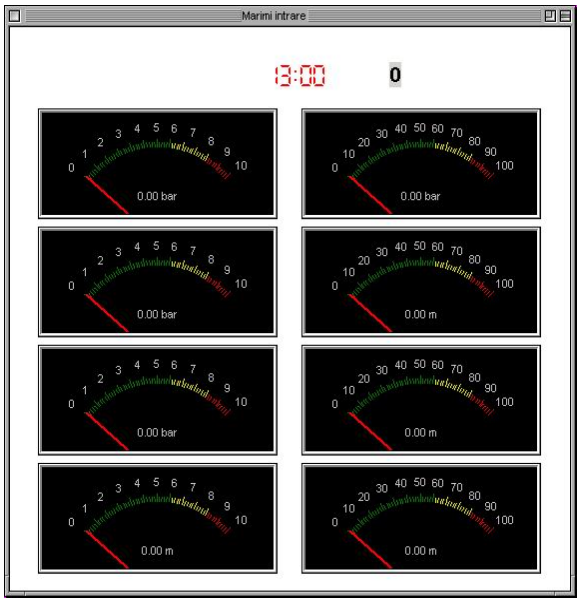


Fig.11 Input Measures Visualisation

Events report allows the recording of the changes of the process state in event journals ordered and shown on the screen or sent to a printer (Fig.12).

4 Conclusion

The SCADA system presented in the paper is a complex monitoring and control system for the water supply parameters, implemented in Craiova.

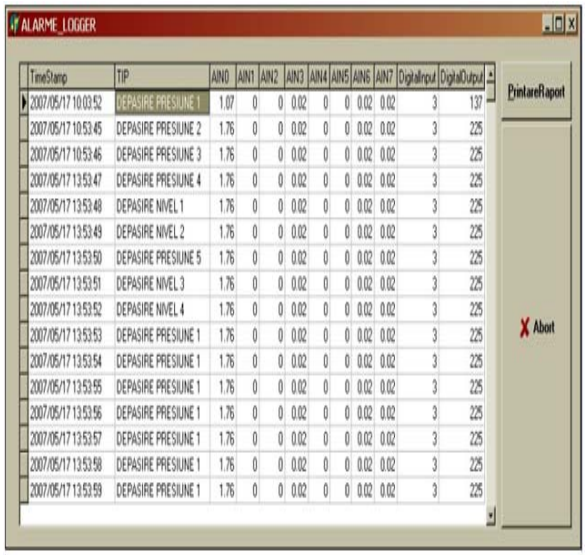


Fig.12 Events report

The monitoring and command system enforces the beneficiary with a powerful working instrument which allows:

- growth of productivity in functioning of the pumping stations;
- pumps command and energy consumptions reduction;
- performance levels and water quality improvements;
- continuous functioning in supplying water to the population;
- permanent real-time monitoring the technological parameters state and the energy consumptions;
- user assistance in elaborating technical analysis and post analysis;
- offering information to the decision factors for taking optimum decisions;
- assuring informatics flows needed for management.

Through the features that it offers, the system can work interconnected with other monitoring system and also with computing systems from the network and so allowing access to information, at different decisional levels.

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References:

[1] D. Bailey, E. Wrigh, *Practical SCADA for Industry*, Elsevier, ISBN:0-7506-5805-3, 2002.

[2] M. Dobriceanu, *Data Acquisition Systems and Microprocessors* (Ro), Ed. Universitaria Craiova, 2003.

[3] M. Dobriceanu, A. Bitoleanu, M. Popescu, Practical Aspects Concerning the Monitoring of the Machines Drives in Industrial Processes, *12th International Symposium on Power Electronic – Ee 2003*, Novi Sad, Serbia & Montenegro, November 5 - 7, 2003, pp. 49.

[4] M. Dobriceanu, A. Bitoleanu, M. Popescu, M. Lincă, The Dispatching of the Energetic Activity in Industrial Processes using Data Acquisition Equipments, *International Aegean Conference on Electrical Machines and Power Electronics– ACEMP 2004,* Istanbul, Turkey, May 26-28, 2004, pp.492-497.

[5] M. Dobriceanu, A. Bitoleanu, M. Popescu, M.Lincă, Energetic data acquisition equipment in industrial processes, *Symposium on Power Electronics, Electrical Drives, Automation & Motion, - SPEEDAM 2004,* Short Papers Proceedings, 2nd Volume, June,16 – 18, 2004, Capri, ITALY, page.TID-5…TID-8, ISBN 88-89389-00-1.

[6] M. Dobriceanu, A. Bitoleanu, M. Popescu, G. Vlăduț, System for Monitoring the Energy Flow in Electrical Stations, *5-th WSEAS International Conference on Power Systems And Electromagnetic Compatibility–PSE 05*, August 23-25, 2005, Corfu, GREECE, (CD: 498-398), ISBN 960-8457-34-3**.**

[7] M. Dobriceanu, A. Bitoleanu, M. Popescu, G. Vlăduț, Practical Aspects Concerning the Monitoring of the Electrical Stations, *WSEAS Transactions on Information Science and Applications*, Issue 11, Volume 2, November 2005, GREECE, page.1897-1904, ISSN 1790–0832.

[8] M. Dobriceanu, A. Bitoleanu, M. Popescu, G. Vlăduț, Automated Data Acquisition System for Monitoring Electrical Stations, *12th International Power Electronics and Motion Control Conference – EPE-PEMC 2006*, August 30- September 1, 2006, Congress Centre Bernardin, Portoroz - SLOVENIA,

Proceedings (CD: 1271 T7-201), IEEE Catalog Number: 06EX1282C - ISBN 1-4244-0121-6, Library of Conference 2005938592.

[9] G. Clarke, D. Reynders, Wrigh, E. *Practical Modern SCADA Protocols*, Elsevier, ISBN: 0-7506-5799-5, 2004.

[10] M. Kezunovic, Data Acquisition and Communication Requirements for Advanced Monitoring, Control and Protection, *CIGRE Symposium on Integrated Control and Communication Systems*, Helsinki, Finland, August 1995.

[11] Y. Wu, M. Kezunovic, T. Kostic, Cost Minimization in Power System Measurement Placement, *International Conference on Power System Technology (POWERCON 2006)*, Changqing, China, October 2006.

[12] J. Stokoe, T. Cumming, B. Hood, W. Carr, Development of a Strategy for the Integration of Protection, Control and Monitoring Equipment. *Session 2002 CIGRE*, pp. 34 - 102.

[13] R. Bárcena, A. Etxebarria, Real-Time experimentation environment for digital controllers applied to industrial processes, *12th WSEAS International Conference on SYSTEMS*, Heraklion, Greece, July 22-24, 2008.

[14] V. Matz, T. Radil, P. Ramos, A. C. Serra, Automated Power Quality Monitoring System for on-line Detection and Classification of Disturbances, *IEEE IMTC 2007 – Instrumentation and Measurement Technology* Conference, Warsaw, Poland, May 2007.

[15] N. Zhang, M. Kezunovic, A Real Time Fault Analysis Tool for Monitoring Operation of Transmission Line Protective Relay, *Electric Power Systems Research Journal*, Vol. 77, No. 3-4, pp. 361-370, March 2007.

[16] V. Matz, T. Radil, P. Ramos, Multifunction Power Quality Monitoring System, *Conference Technical Computing*, Prague, 2006.

[17] M. Rizzi, M. Maurantonio, B. Castagnolo, A wireless sensor network for security systems adopting the Bluetooth technology, *WSEAS Transactions on Circuits and Systems*, vol. 5, n.5, 2006.

[18] I. Zolotová, L. Landryová, Knowledge model Integrated in SCADA/HMI System for Failure Process Prediction, *WSEAS Transaction on Circuits and Systems*, Issue 4, Volume 4, April 2005, pp. 309-318, ISSN 1109-2734.