SCADA Systems in Water Supply: Kragujevac Case Study

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Abstract: *The population of Kragujevac is supplied with drinking water from the following sources:Water supply system Gruza, water supply system Grosnica, water supply system Morava and alternative water sources. SCADA system covers these systems and pumping stations, too. SCADA system provides 24 hours monitoring .It contributes maximal profit and minimal consumption like water loss, consumption of electrical power, overtime work of pumps and so on. If the situation in system changes , the signalization will be shown with flashing red lights on the central screen for monitoring. In that way, the warning is (maximal level in chamber, minimal level in chamber, break of communication, damage on chlorine sensor , damage on pump). Besides monitoring of water supply system, SCADA system has a role to control with it. For example : prohibition of pump work, definition of regime of pump work (regular and cyclic), pump reset, protection of locations and so on.*

Keywords: *water, supply system, SCADA*

1. INTRODUCTION

According to a number of participants and the complex dynamic relations between them , water supply is a complex system. In the previous period ,for a sake of quality of life and balanced regional development ,some aspects mostly relating to reliability, capacity, quality of water, development of the network ,are analyzed.

Today, the citizens in Kragujevac are supplied with drinking water from:

1 .sources in water system JKP Water Supply and Sewerage including:

- Gruza water system,(artificial lake Gruza with plants for technological processing of water),
- Grosnica water system (artificial lake Grosnica with plants),
- Morava water supply(the country of Brzan well system close to The Velika Morava River)

2. alternative source for water supply including:

- local water supply,
- individual wells in some households,
- public drink fountains and
- springs.

Sources in water system JKP Water Supply and Sewerage are assigned by their own significance . Monitoring program of hygienic and biological accuracy applies to these sources which are a subject of many researches.

3.1. Sources in Water System JKP Water Supply and Sewerage

Source Gruza water system,(the artificial lake of Gruza with plants for technological processing of water), Sources in Water System JKP Water Supply and Sewerage are:

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In this paper the wather supply system of Kragujevac will be presented with special emphasiye on SCADA systems in water supply.

2. WATER SYSTEMS FOR SUPPLY OF KRAGUJEVAC

2.1 Gruza Water System

The name Gruza derived from old-serbian word 'gruze' .It means flood .That name is valid, because bed-river of the Gruza River has short banks and in time of middle and high water level , the river causes floods.

'Gruza' system was built for intensive development of the town and industry ,when the need for water was continually growing. Thus, in the eighties, it began with building of dam and accumulation of 'Gruza' on the Gruza River with plants for filtration of the water and other plants for operating of the system. After filtration of water, it is pushed with pumps to broken chamber ' Vuckovica' and then gravitationally transported to Kragijevac, the reservoir R-14.

Gruza system provides Kragujevac (60-70 percent), parts of Knic and Kraljevo with drinking water. All of three sources provide about 250 000 people with drinking water.

The River Gruza is placed into the center of Serbia and belongs to the Montenegrin watershed. It is one of the longest river(its length is 77 kilometers) in Sumadija. The River Gruza springs up on the south slopes of mountain Rudnik ,and flows into The West Morava River close to the country of Cukujevac ,eastern from Kraljevo, bringing 2.2 m^3 /s of water. The elevation of the Gruza River is 560 mnv ,and its delta is at the height above sea level of 82 meters.

The elevation of Gruza at the place where the dam is built is 240 mnv. The highest elevation of watershed is on the furthest northern part with the height of 1098 meters. Upper flow of The River Gruza is a running water with lacking flow rate (about 10 l/s),because the source part of the river consists of a lot of streams which unite down the river and make the flow of the river. The flow of this part of the river is erosive and in time of snow melting and rainfalls ,it comes to flowing down of large torrents. It is a water current with large oscillations of water regime.According to average water level bulletin (from 1962), the flow of The Gruza River is 120 l/s , and the velocity of the river is 1.6 m/s. The width of the river is 3-5 meters in upper course and 8-10 meters in lower course. The average depth is from 0.75 cm to 1.5 m. The oscillation of temperature regime of the river is variable ,it amounts to 0 C in winter and 22 C in summer.

The artificial lake of Gruza (Figure 1 - *The map of Gruza*) is made by damming the middle course of the river for the next demands:

- water supply of citizens and industry,
- flood conservation,
- sediment retention,
- correction of small water regimes at downstream line of The Gruza River in extreme bad hydrology conditions.

Figure 1- The map of Gruza

Building of the dam began in 1979. and finished in 1985. The dam is about 20 kilometers south-eastern from Kragujevac, at height above sea level of 238-269 meters, at the 32nd kilometer from delta of The Gruza River into The West Morava River. The building height of the dam is 51.50 meters, but the chord in the dam crown is 207.89 meters. The ratio of chord in the dam crown to the dam height is 4.04 meters. The length of dome in the dam crown is 230.30 meters. The arched dam leans with upper parts of its contour on the rock . Total length of the dam is 300 meters. Four limbs of ø1300 mm with axle at the elevation of 245 000, are set on the dam. Besides these four limbs, there is one more of ø200 mm. The water from accumulation are scooped from three levels : the first one is the highest at the elevation of 265 mnv, the second one is at the elevation of 257.50 mnv ,the third one, the lowest is at the elevation of 250 mnv.(Figure 2 and Figure 3 - *The dam of the artificial lake Gruza*).

Figure 2- The dam of the artificial lake Gruza

Figure 3-The dam of the artificial lake Gruza

Accumulation of Gruza guarantees delivery water of 816 l/s average per a year, with theoretical security of 99.0 percent. Besides that , it is anticipated that guaranteed minimal flow of 200 l/s continually is let out of accumulation. Total average flow per a year is 1000 l/s. The mean time of water keeping in accumulation is 1.8 year.

Unlike to the accumulation of Grosnica, the accumulation Gruza is considerably less exposed to danger by sediment covering and belongs to less exposed to danger accumulations, where is g <400 m^3 /km2 per a year.

2.2. Water System Grosnica

Grosnica system consists of the dam and accumulation 'Grsnica' on The Grosnica River which was built in period from 1930. till 1937. and repaired in period from 1960. till 1962. (Figure 4- *The dam of Vodojaza*)

Figure 4 - The dam of Vodojaza

The volume of accumulation of 3 200 000 m3, with two plants for filtration drinking water(one plant is from 1937., the second one is from 1962.).The water is transported to reservoir 'Cava' (4 200 km3) through pipelines of ø 350 mm and ø 500 mm and of the length of about 8,5 km . This system provides the parts of settlements in Kragujevac with the water. Raw water from river basin being processed is not polluted, so it is of good quality. The water from 'Grosnica" system is provided by gravitation of capacity of (80-150 l/s)

2.3 Morava water system

'Morava' system was built for increased needs of citizens and industry in water supply in period from 1964. till 1975. This system is accomplished by scooping underground waters of the Velika Morava River in the area of Batocina,in the country of Brzan. Morava water system consists of 14 wells(Figure 5 – *Well „Morava" system*). The water is transported to filtration plant 'Kosutnjak' (3 800 m3) in Kragujevac through pipelines of ø700 mm and the length of 27,5 km.

This system provides the city of Kragujevac and the parts of Batocina with the water of capacity of 130-200 l/s.

Figure 5 – Well „Morava" system

However, large part of citizenship in the area of Kragujevac(16,44 percents) doesn't belong to city water supply. They are supplied with water from local country water supply ,from individual wells or from public fountains.

According to gathered data, about 26 000 citizens in 44 settlements of Kragujevac aren't covered with city water system. The alternative sources for water supply in these settlements are 7270 wells,562 local water supplies, 87 springs and 56 public fountains.

3. SCADA AND TELEMETRY

3.1. Definition of SCADA Systemand Telemetry

SCADA (Supervisory Control and Data Acquisition) system refers to the combination of data acquisition and telemetry. It consists of collecting information, transferring it back to a central site, carrying out necessary analysis and control, and then displaying this data on a number of operator screens. Total modular construction and programmability of device enable its adaptation to monitoring, control and management of plants for special purpose ,power stations in electric distribution ,water supply, rails, medicine, sections in industry, like in other branches where remote monitoring of plants is necessary.

In each system of automatic management, SCADA system is on the top of pyramid.

Tasks of SCADA system are :

- visualization of process
- HMI (Human Machine Interface)
- events logging
- alarm handling
- data archiving
- production of report and trend charts (graphs)

Telemetry is a technology that allows remote measuring and reporting of information. The word is derived from Greek roots 'tele'=remote and 'metron'=measure. The information can be some measurements, such as voltage, speed or flow. Telemetry typically relates to wireless communications ,for example: radio-frequent systems for transmitting of data .Also ,telemetry can relate to transmitting of data to another location through a medium such as cable, telephone or radio. Information may come from multiple locations. A way of addressing these different sites is incorporated in the system.

3.2. Overview of SCADA system

The earliest gadgets related to remote command and monitoring appeared in the end of 19. century. Those early electromechanical systems are very often used only for monitoring or only for control ,but rarely for both of them at the same time. During twenties and thirties, the various commercial systems for monitoring and control appeared. These systems were appropriate for remote transmission ,more measuring in a canal and they supported an elementary operation of remote control. Also, they are used for remote simple commands like turn on/ turn off. Measures taken from remote stations were indication of equipment state, in fact the sum which has just two possible values turned on /turned off.
The first commercial systems were completed by usage of electromechanical relays. Solutions based on electromechanical relays, because of their complexity and unreliability of such equipment, made transmission of large number indications and analogous measuring impractical. These systems were used for remote control and acquisition of small number of measuring information. These systems are called systems for ‘ supervisory control ‘ . Later, in sixties , as a results of development of telecommunication , measuring equipment and appearance of mini-computers, the first computer systems for remote monitoring and management were appeared. They had all important components and functions of system which are called SCADA SYSTEMS, today. The computer technology and SCADA system developed at the same time.
There are 3 generations of SCADA system :

- centralized SCADA systems,
- distributed SCADA systems,
- networked SCADA systems.

3.3.Components of SCADA for water sypply systems

Essential components of SCADA system are (Figure 6 – *Components of SCADA system*) :

1. Field instrumentation
2. Remote Stations - RTU
3. Central Monitoring Station - MTU
4. Communications Network

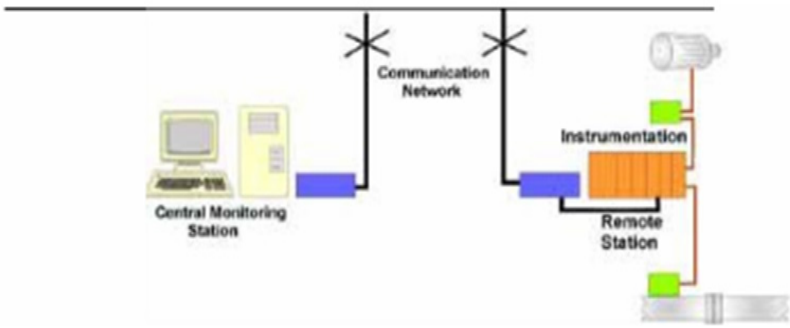

Figure 6 – Components of SCADA system

1.Field Instrumentation refers to the sensors and actuators that are directly interfaced to the plant or equipment. Devices like measures of level ,flow, pressure, temperature and others acquire data on the basis of which experienced operators may estimate state of system . Signals are also conditioned to make sure they are compatible with the inputs/outputs of the RTU or PLC at the Remote Station. Outputs can either be in analog (continuous range) or in digital (discrete values).Some of the industry standard analog outputs of these sensors are 0 to 5 volts, 0 to 10 volts, 4 to 20 mA and 0 to 20 ma. Digital outputs are used to differentiate the discrete status of the equipment. Usually, <1> is used to mean EQUIPMENT ON and <0> for EQUIPMENT OFF status. This may also mean <1> for FULL or <0> for EMPTY. Actuators are used to turn on or turn off certain equipment. Likewise, digital and analog inputs are used for control. For example, digital inputs can be used to turn on and off modules on equipment. While analog inputs are used to control the speed of a motor or the position of a motorized valve.

2.Remote stations (RTU-Remote Terminal Units) are used for performing the functions like remote monitoring and management .Information which are received from sensors and actuators must be transformed in shape which is compatible to SCADA 'language'. Remote stations are robust industrial computers which take data (measuring and indication) from measuring equipment ,primarily process data, manage and communicate with superior center. They are used in situations where communications are more difficult. RTUs hold data gathered in their memory and wait for a request from MTU to transmit the data. (Figure 25-Input and output information from RTU). One of RTU's disadvantages is a bad programmability. However, modern RTUs offer a good programmability comparable with PLC.

The functions of superior centers are very often performed by Programmable Logic Controllers thanks to their good programmability. (Figure 7 – *Architecture of SCADA system*)

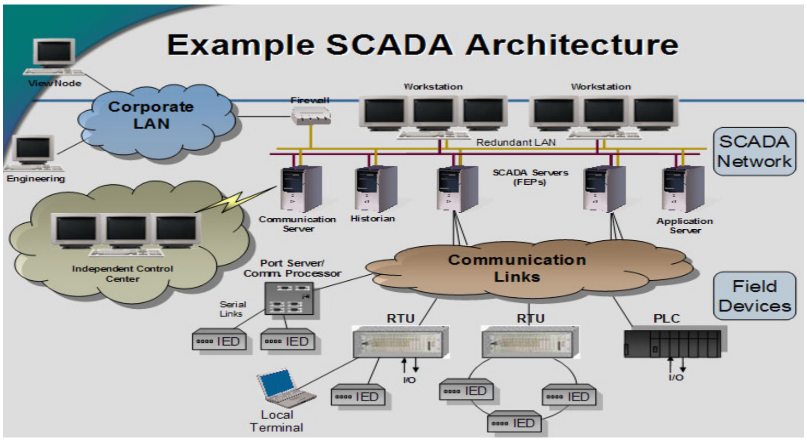

Figure 7 – Architecture of SCADA system

3.Central Monitoring Station (Master Terminal Units) represents the host processor of SCADA system where all acquired and telemetric data are received. At the heart of the system is the master terminal unit (MTU). The master terminal unit initiates all communication, gathers data , stores information ,sends information to other systems, and interfaces with operators. The major difference between the MTU and RTU is that the MTU initiates virtually all communications between the two.

The MTU also communicates with

other peripheral devices in the facility like monitors , printers, and other information systems. The primary interface to the operator is the monitor that portrays a representation of valves, pumps, water level in reservoirs ,etc. As incoming data changes ,the screen is updated.(Figure 8 - *Central Monitoring*)

Figure 8 - Central Monitoring

4.Communication network (WAN, LAN, GSM networks) is the medium for transferring information from one location to another. SCADA system for transferring information uses different communicative media like optical fibers, directed radio lines,telephone lines, and local computer networks in area of plant. Remote management or monitoring of SCADA system often relates to telemetry.

SCADA protocols are designed to be very compact and many are designed to send information to the master station only when the master station polls the RTU. Standard protocols are IEC 60870-5-101 or 104, IEC 61850 and DNP3. These communication protocols are standardized and recognized by all major SCADA vendors. Today, it is possible to transmit data and manage the plants which are a few hundreds kilometers away thanks to GSM network and cell phone. (Figure 9 - *Shows position of a reservoir and pump on cell phone*)

Figure 9 - Shows position of a reservoir and pump on cell phone

The system, which allows transmission of data through the network ,is called GPRS (General Paket Radio Service). GPRS is shortcut for the latest technology for transmission of data by means of present GSM network.

Benefits of GPRS communication :

- No need for receiving the license from authorized organs for usage of frequency

- Unlimited signal coverage of the area
- No need for expensive antenna
- Average (constant) speed of communication
- Low price of installation
- Easy broadening of system by adding of pages

PLC-Programmable Logic Controller

Programmable Logic Controllers is a digital computer used for automation of electromechanical processes.

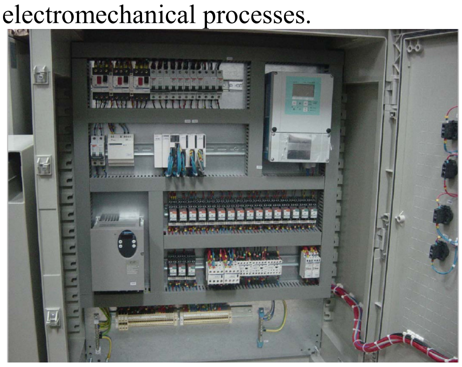

Figure 10 - Interior of control locker with PLC computer

Typical tasks of PLC mean acquisition of more tens or hundreds analog and digital values, in fact measurements from system , processing of these measurements and formation of control analog or digital outputs in real-time. (Figure 10 -*Interior of control locker with PLC computer*)

PLCs are used in industrial environment. It means that there are electromagnetic interference , exposure to corrosive evaporations, but sometimes an exposure to atmospheric conditions. Thanks to fast development of computer , telecommunicative technology and increasing of processor ability of micro-computer systems at modern implementation of remote sites and programmable logic controllers, mentioned classification of activities is not severe any more. Modern RTU also may perform control activities, typical for PLC, but modern PLC are expanded with communicative interfaces which allow transmission of gathered information to remote , central site MTU.(Figure 11 - *SCADA system management by PLC*) Really, differences between modern implementation s RTU and PLC are minor so that the term 'RTU' is used for identical devices with different configurations , when we talk about remote field interface device. When we talk about the device which has control program, then the term 'PLC' is used.

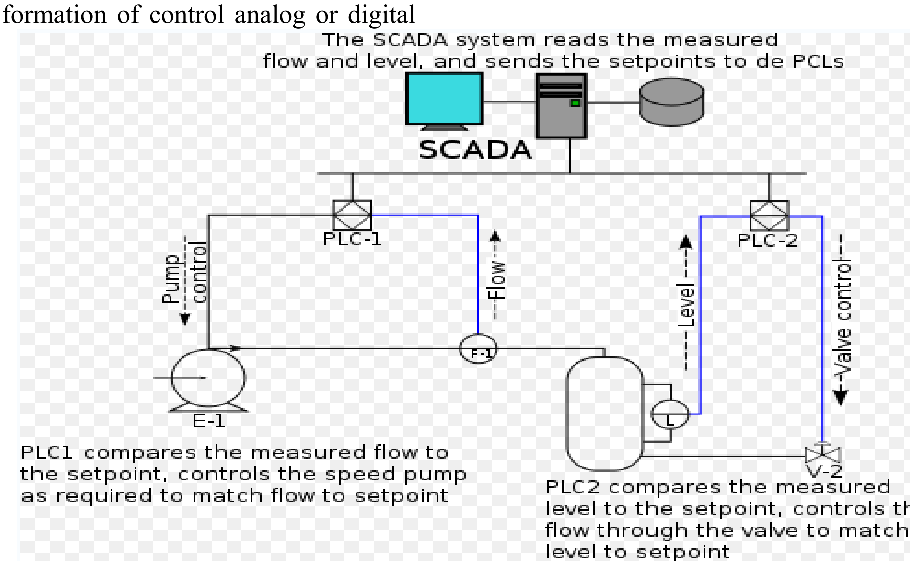

Figure 11 - SCADA system management by PLC

Alarm

Alarms may be generated by an equipment at remote location and transmitted from relevant RTU to MTU. Alarm handling is based on the edge and state which is checked and accomplished in data of server.

Generating and processing of alarm are one of the most important function of each SCADA system. Real-time presentation of alarm situations allows the real-time corrective actions and removing the situation which led to alarm situation to an user (operator, dispatcher)(fall of absorbing, pump reset, break of communication, maximal level in chamber , minimal level in chamber, damage on chlorine sensor, damage on pump, fire in plant, burglary, etc.)

When SCADA system is used for control the large waterpower systems, the alarm indications have a various significance for security and accuracy of system works and they occur very often.

On the monitors of an operator (dispatcher) , alarms are displayed like flashing red light and in that way ,they show that it came to the changes of state in the system.(Figure 12 -*Graph of SCADA parameters*).

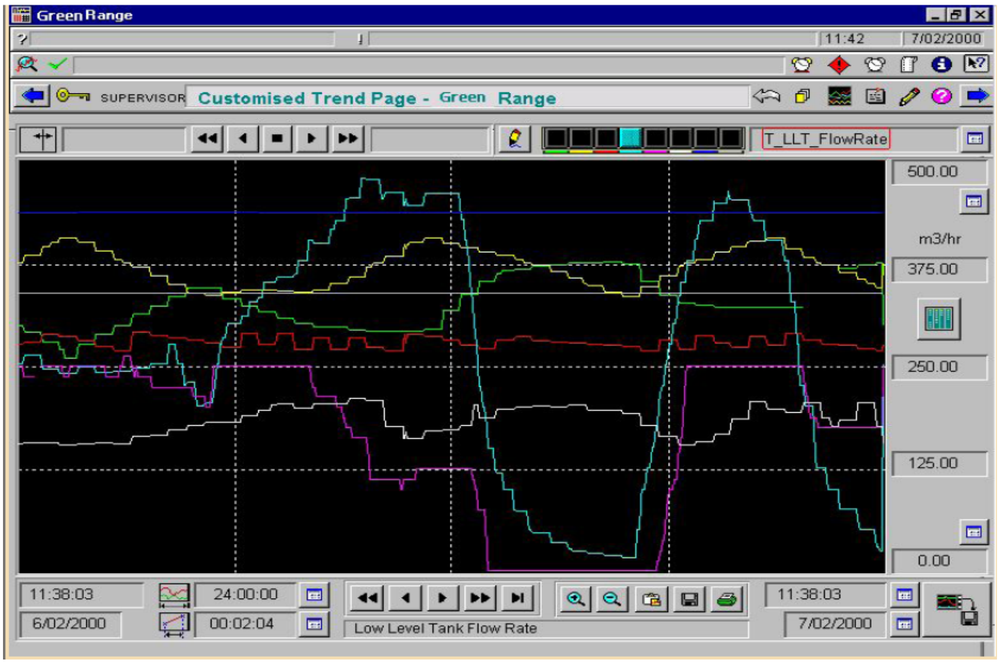

Figure 12 - Graph of SCADA parameters

In order to avoid situations in which the users of system are not capable of right acting and to recognize the real cause of problem (saturation with alarm messages), there is a additional processing in SCADA systems :

- **Alarms are classified according to its priority and field of responsibility.**

The classification according to the priority helps to user to easy recognize the alarms show a risky situation , when the one should primarily act. The classification according to the field of responsibility determines the users to whom will be shown a certain group of alarms . In that way, the user is responsible for a certain group of alarms.

- **Various automatic procedures are added to the certains alarms.**
  Various software procedures, which perform automatically , can be added to a certain set of alarm messages. In that way, performing of necessary activities for removing of alarm state can be automated.
- **The Intelligent Alarm Processors are used :**
  Intelligent Alarm Processors are software applications in SCADA system which task is to interpret set of alarm messages and to give information about real problem in system to the user instead of a large group of alarm messages with the same cause. In modern SCADA systems The Intelligent Alarm Processors recognize the combination of an alarm and an event the in system and on the basis of that, they determine 'collective event' and represent it to the user. In analysis of alarms, the various software techniques (based on expert systems, artificial intelligence, logic phrase) are used very often.

This work shows water supply systems of Kragujevac with alternative sources and significance of SCADA system. User's interface of SCADA system provides :

- monitoring of various analog and discreet measures,
- the graphs of structure of control system,
- giving of commands and conrol orders,
- review of alarm messages,
- review of events,
- connection with other users of SCADA system.

On the basis on results in the field of usage of these systems, we may conclude that monitoring and control water supply systems are inconceivable without SCADA system.

4. CONCLUSION

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