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WATER SUPPLY SYSTEM RELIABILITY MANAGEMENT

The necessity of using modern techniques of monitoring, supervision and protection of particular subsystems and elements of the water supply system (WSS) in order to improve its reliability has been analysed. It is common that during WSS functioning various undesirable events (failures) may occur. They can cause losses of water, breaks in water supply and secondary water contamination in water-pipe network, which might seriously threaten consumers' safety or even their lives. The main purpose of the work was to present new methods of the water supply system operation and safety reliability management utilizing information techniques. The paper also describes the modernization of an existing WSS in order to improve its functioning in terms of technical, economic and reliability aspects.

1. INTRODUCTION

Water supply systems (WSS) belong to critical infrastructure of cities and their reliable operation has an important impact on water consumers' safety. This system is characterised by continuous work, which forces the usage and professional management of complicated supervisory systems. Complex reliability and safe management of the WSS operation require the collection of information concerning the operation of particular WSS elements, transferring it to a system operator in a real time, archivising this data, and alerting appropriate maintenance services to all disturbances in system work. The WSS operator should receive current data on possible failures, which would system his response time to the failure. Automatic control systems and supervisory systems of processes occurring in the whole WSS are the basis of system reliability management. Nowadays such systems use programmers and computer operator stations, which play the role of computer supervisory systems. They belong to a group of different SCADA (supervisory control and data acquisition) software and they perform the functions of data collecting and processing, process state visualisation, superior control, raising alarms and event registration, data archiving, and ac-

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cessing information about process in computer networks. The main purpose of this work was to present new methods of water supply system operation and safety reliability management utilizing information techniques.

2. WATER SUPPLY SYSTEM RELIABILITY MANAGEMENT

The WSS reliability is the probability that different groups of consumers will continuously receive a required amount of water, with specific pressure and quality, in accordance with consumers' demands in specific operating conditions, at any or a specific time, and at an acceptable price [1], [2], [3], [7]. The WSS safety is the probability that consumers will get drinking water at a tolerable risk level connected with the possibility of poor quality water consumption or breaks in water supply that will be longer than the acceptable and specified time (most often assumed to be 2 hrs) [4]. An important problem concerning the WSS statistic reliability analysis is a system of collecting, processing and archiving data on all the disturbances in the system operation. The correct system of collecting data on failures should contain information about:

- the date and type of failure (the undesirable event),
- precise data allowing the identification of a given object,
- failure repair time,
- the possible cause of failure,
- existing and probable consequences,
- the number of affected people.

The WSS reliability management was defined as a decision assistance process by means of complex and integrated technical and organizational actions for the reliable and safe WSS operation. The correct WSS reliability management process should contain:

- suitable organizational procedures within the framework of regular waterworks' activity,
- the WSS operation technical control and supervisory system,
- a system of automatic transfer and data processing on the operation of WSS elements.

The key role in this process is played by a system operator, whose main purpose is:

- to implement the reliability and safety management system (RaSMS),
- to operate the WSS according to valid regulations in a way which ensures its long and reliable operation,
- to execute a program of undesirable events prevention,
- to develop failure scenarios for water supply in crisis situations,
- to develop a complex system of information about the possible threats for water consumers.

3. INFORMATION SYSTEMS OF WSS RELIABILITY MANAGEMENT

The extended systems of the WSS reliability and safety management forced the usage of both technical systems and information systems. It not only enables us to control water production processes in a fluent way but also enables us to locate failures in the system quickly, resulting in the possibility of repairing them quickly and efficiently. When the WSS operator analyses the data recorded, he has the possibility of remote controlling particular subsystems and the WSS devices. He can also make suitable decisions on system operation, such as starting repair or failure control. Simultaneously he makes a decision to send the proper repair team to the place of possible failure. A property of the WSS is that the particular system elements are, as a rule, some distance away from one another. The standard visualization and control systems in the majority of industrial facilities use the control and communication electric cables or fibre optic cables to transfer data. In the case of the WSSs which are scattered across long distances, located very often on highly urbanized terrains, most often the usage of such solutions is impossible. Because it is not possible to use wire data transfer from the particular SWW elements, the following solutions are applied [5]:

- data transfer between the particular WSS elements by digital transmission, using circuits leased from the telecommunication operators (the most often TP S.A.),
- data transfer between the WSS components by radio, in the frequency band open to the public, thanks to special radio modems,
- communication using the GSM cell telephony network, established in two ways:

a) event – alarm is sent to a system operator by means of a text message,

b) ON-LINE – constant connection between system elements, using the GPRS technology (package data transfer using the GMS network),

- data transfer through the Internet.

In practice, in order to perform a complete system telemetry, all or several of the above-mentioned transmission methods are used, taking into account local possibilities, the shape of the terrain, the GSM range, the access to the Internet, the possibility of using circuit, the economic possibilities, etc. Data collection from the controlled process, data transfer to the central computer and visualisation of the whole process are most often made by means of the software from SCADA group [8], [9]. Such systems allow constant supervision of water production parameters, they signal the state of alarm, inform about current state of devices and visualize their operating parameters, as well as allow archiving, data transmission measurement and processing. Such type of the WSS reliability management optimises operation of particular WSS devices (e.g. parameters of operation of water pipe pumping stations which cooperate with network tanks) and the work of the whole system. Figure 1 presents the diagram of the WSS information reliability and safety management.

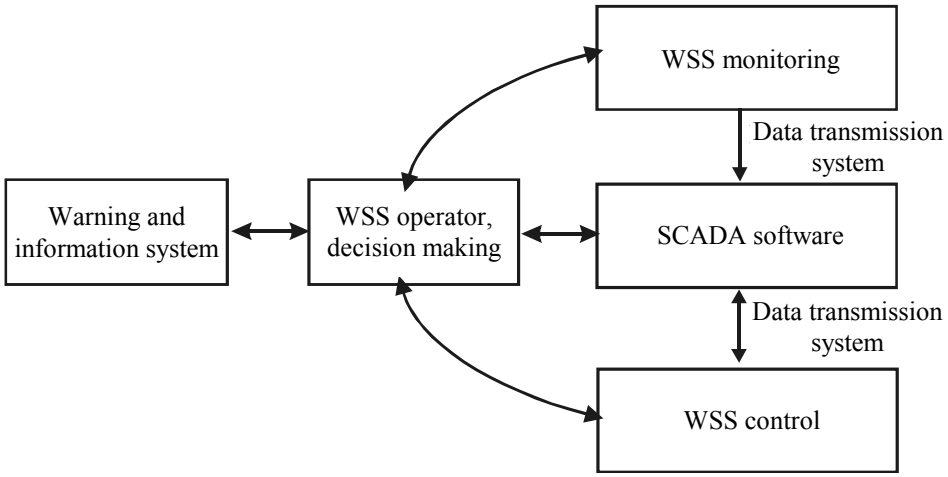

Fig. 1. Information system for WSS reliability and safety management

4. EXAMPLE OF MODERNIZATION OF WATER INTAKE AND PUMPING SUBSYSTEM

The example presented shows the modernization of the water intake and pumping subsystem (WIaPS) for a town with population of about 20000. A typical surface water intake is located about 600 m away from the water treatment plant (WTP). Water is taken from above a weir, it flows through the gate valves and a settling tank to the main pumping station which consists of four pumps, and is then pumped to the WTP. The intake operation and the pumping station are controlled manually. A decision to turn particular pumps on or off, to lift the weir gates, and to open or close the gate valves is made by an operator in the WTP. This decision is transferred by an internal telephone line to the water intake staff and there the operator implements the proper settings for the elevation of the electric switching station [6]. The WIaPS modernization, within the framework of the proposed reliability and safety management system of the whole WSS, comprises:

- visual monitoring of raw water intake (cameras) together with visual signal transmission to the WTP,
- visualisation of pump operation, the weir gates and the gate valves, before the settling tank and in the pumping pipeline behind the pumps, together with transmission of the suitable information to the WTP,
- remote control of pumps, gates and gate valves located on the intake from the WTP control room.

The main controller will be able to control the following devices:

- gates on the weir,
- gates in the well on the pipeline,
- gates in the settling tank,
- gates in the pumping pipelines,
- pumps.

The first controller will communicate with the second controller located in the WTP in order to enable control and visualisation of the above-mentioned devices. The pumps should be equipped with a frequency converter so that smooth control will be established not by means of throttling particular pumps but by changing the drives' rotational speed, with the use of a frequency converter. The visualisation of the WIaPS operation by means of the SCADA software should be carried out in the operator stand, located in the WTP dispatch room. Every alert should be displayed in the form of a red window with an information about the type of failure. The alert should be written in the computer disc together with the following information:

- beginning of alert,
- end of alert,
- alert priority,
- person who confirms alert,
- time of alert confirmation,
- possible comment.

The operator should be able to see and print the previous alerts at any time, with any priorities. Alerts with a high level of threat for the subsystem operational reliability and safety should be promoted by an acoustic signal. All information about the operation of the devices (standstill, operation, failure), the measured parameters of pump operation, and the stage of the gates opening should be conveyed, registered in the computer and displayed on its monitor. For the purpose of visualisation, the following displays should be shown on the computer screen:

- drawing of raw water intake,
- drawing of central pumping station,
- drawing of weirs,
- drawing of the settling tank,
- charts from the measuring data,
- history of alarms.

Operation control should be possible from the computer keyboard.

In figure 2, the diagram of the WIaPS modernisation for the example presented is shown.

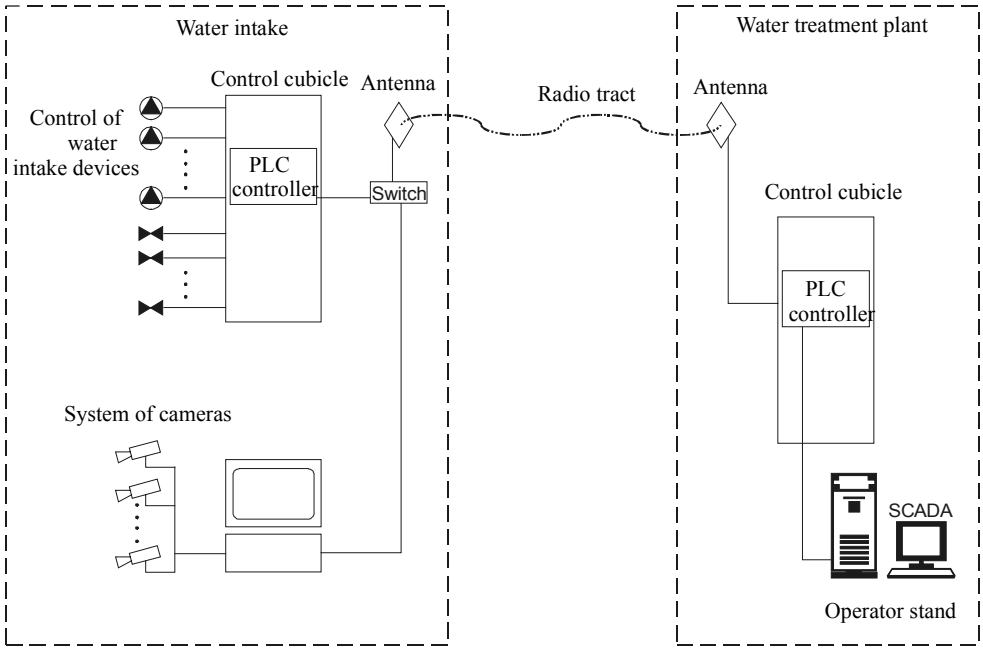

Fig. 2. Water intake and water pumping modernisation

5. CONCLUSIONS

• In order to improve technical, economic and reliability aspects of the existing WSS and their subsystems, their modernization is performed. The changes include: upgraded automatic and control systems, visualisation of processes and states of the operation of particular units, as well as modern supervisory and management systems.

• In the era of information systems, the correct water supply system reliability management should include a complex system of collection, processing and data visualisation for all operating states of particular devices.

• In extraordinary situations, including incidental threats (e.g. incidental raw water pollution), it should be possible to immediately shut down the water intake.

• With regard to safety, supervisory control systems comprising water intake facilities, treatment stations and network objects (e.g. tanks) should be extended by visual supervisory systems (cameras) installed in the unmanned objects.

• Correct failure recording plays a very important role in the reliability analysis procedures, especially in order to determine particular reliability indexes. The credibility and reliability of information, as well as a precise data base on operation, have a significant impact on the correctness of the chosen methods, assumptions and the final result of the reliability analysis.

REFERENCES

[1] KWIETNIEWSKI M., ROMAN M., KŁOS-TRĘBACZKIEWICZ H., *Niezawodność wodociągów i kanalizacji*, Arkady, Warszawa, 1993.
[2] MAYS L.W. et al., *Reliability analysis of water distribution systems*, published by the American Society of Civil Engineers, New York, 1989.
[3] RAK J., *Niezawodność systemu uzdatniania wód powierzchniowych*, Zeszyty Naukowe Politechniki Rzeszowskiej, nr 111, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów, 1993.
[4] TCHÓRZEWSKA-CIEŚLAK B., *Method of the identification of the areas of risk of failure in water-pipe network*, Polish Journal of Environmental Studies, 2007, Vol. 16, No. 2A, 774–776.
[5] TCHÓRZEWSKA-CIEŚLAK B., KUCHARSKI B., *Komputerowe systemy nadzoru i sterowania wybranych elementów systemu zaopatrzenia w wodę*, Instal, 2004, 12, 54–57, Wydawnictwo Ośrodka Informacji „Technika instalacyjna w budownictwie", Warszawa.
[6] TCHÓRZEWSKA-CIESLAK B., CIEŚLAK R., *Sterowanie i wizualizacja pracy podsystemu ujmowania i pompowania wody*, Instal, 2008, 5, 38–42, Ośrodek Informacji, „Technika instalacyjna w budownictwie".
[7] WIECZYSTY A., *Niezawodność systemów wodociągowych i kanalizacyjnych*, tom I i II, skrypt, Wydawnictwo PK, Kraków, 1990.
[8] www.wasko.pl
[9] www.controlengpolska.pl

ZARZĄDZANIE NIEZAWODNOŚCIĄ SYSTEMU ZAOAPTRZENIA W WODĘ

Obecnie powinno się stosować nowoczesne techniki monitoringu, nadzoru i ochrony poszczególnych podsystemów i elementów systemu zaopatrzenia w wodę (SZW), aby zwiększyć jego niezawodność. W funkcjonowaniu SZW zawsze mogą pojawić się różnego rodzaju niepożądane zdarzenia, których skutkiem są przerwy w dostawie wody, jej brak, a także wtórne zanieczyszczenie wody w sieci wodociągowej. Zdarzenia tego typu powodują, że konsumenci wody tracą poczucie bezpieczeństwa. Głównym celem pracy jest przedstawienie nowych metod zarządzania niezawodnością funkcjonowania i bezpieczeństwa systemu zaopatrzenia w wodę z wykorzystaniem technik informatycznych. Przedstawiono również przykład modernizacji istniejącego SZW, co poprawiło jego funkcjonowanie pod względem technicznym, ekonomicznym i niezawodnościowym.