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INTELLIGENT DECISION MAKING IN WASTEWATER TREATMENT PLANT SCADA SYSTEM

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Abstract. *In this paper a SCADA system for a primary wastewater treatment control system with fuzzy controller is presented. As local controllers Programible Logical Controllers have been used, special attention has been dedicated to connection with SCADA. The main problem considered in this paper is the development of remote monitoring and controlling of systems for wastewater treatment and its improvement by adding a module for intelligent decision making. The usage of intelligent sensors and actuators, as well as the control of the dislocated facilities and transportation systems for wastewater treatment is discussed. Furthermore, a simplified system for web control is developed, which is an excellent basis for further improvement in order to develop a complete system of control and supervision of wastewater. The problem of communication between local controllers and central SCADA system, which is located in the dispatch center, was solved in several ways using modern wireless technologies. The developed intelligent module of SCADA application based on Sugeno type fuzzy algorithm makes decisions at a higher control level, while the local PLC controls the appropriate dislocated facilities. The PLC used in this work has no fuzzy module or software. The proposed fuzzy-SCADA system is flexible and applicable in other industrial applications and it is characterized by an optimal system performance and faulty safety.*

Key words: *intelligent control, fuzzy logic, SCADA, wastewater treatment, wireless communications*

1. INTRODUCTION

Modern technology allows for the measurement of a large number of process parameters. For wastewater systems, the following parameters are important: physical (flow, water level, etc), chemical (pH), biological (presence of microorganisms in the system).

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The control of all parameters in all the points of the system, even the most important one, is obviously impossible, while it is even less possible to process all the data and transmit it to the remote center. It is not only that the price would be too high, but the problems of handling all the information would also appear. Therefore, the need to sort the data according to its importance and set priorities becomes obvious.

The alarm and monitoring system is of the highest importance. It covers the most significant facilities of the wastewater treatment plant (Fig. 1), pumping stations, reservoirs and supply lines and shows whether the plant as a whole works well. If something unexpected happens – such as a failure or a malfunction of a vital facility – the system should register and alert the staff who work there.

Here, reliable and precise measuring devices must be used, and secure transmission of information and high quality accessories must be provided [7].

The introduction of remote control is just one phase in the implementation of an energy-efficient integrated information system [3]. Therefore, the pursuit in the area of development of the wastewater treatment plant should be the establishment of an integrated information system through which everyone can get any necessary information, while not interfering with other participants. The application of sophisticated technical systems in wastewater treatment systems represents a suitable basis for further application of new scientific and technological achievements in order to increase the energy efficiency of the system. The key technology, in this sense, is provided from the area of system control, which itself is experiencing a renaissance through rapid development, falling prices and very fast progress of microcomputer systems and telecommunications [1] [5].

Fig. 1. The wastewater treatment plant

Fuzzy logic is a powerful methodology for solving problems with many applications in control and information processing. The use of a fuzzy controller has significantly changed the approach to control problems. Conventional controllers adjust the control sizes of the system based on a set of differential equations that represent a model of a dynamic system. In fuzzy controllers, the control values are obtained on the basis of fuzzy rules, which are similar to the model of human reasoning [6].

2. SCADA APPLICATION FOR THE WASTEWATER TREATMENT PLANT

The wastewater entering the treatment plant includes items like wood, rocks, and even dead animals. Unless they are removed, they could cause problems later in the treatment process. Most of these materials are sent to a landfill. If the plant is built above the ground level, the wastewater has to be pumped up to the aeration tanks. From here on, gravity takes over to move the wastewater through the treatment process. One of the first steps that a water treatment facility can do is to just shake up the sewage and expose it to air. The wastewater enters a series of long, parallel concrete tanks. Each tank is divided into two sections. In the first section, air is pumped through the water. Bubbling oxygen through the water also keeps the organic material suspended while it forces 'grit' to settle out. The grit is pumped out of the tanks and taken to landfills. The wastewater then enters the second section or sedimentation tanks. Here, the sludge (the organic portion of the sewage) settles out of the wastewater and is pumped out of the tanks. Some of the water is removed in a step called thickening and then the sludge is processed in large tanks called digesters. As sludge settles to the bottom of the sedimentation tanks, lighter materials float to the surface. This 'scum' includes grease, oils, plastics, and soap. Slow-moving rakes skim the scum off the surface of the wastewater. Scum is thickened and pumped to the digesters along with the sludge. The treated water is then discharged to a local river. Another part of treating wastewater is dealing with the solid-waste material. These solids are kept for 20 to 30 days in large, heated and enclosed tanks called 'digesters.' Here, bacteria break down (digest) the material, reducing its volume, odours, and getting rid of organisms that can cause disease. The finished product is mainly sent to landfills, but sometimes can be used as fertilizer [7].

In the wastewater treatment plant the following process parameters are continuously measured: air and water temperature, pH value of wastewater [13], water flow, the flow of mud and sludge, precipitation, humidity [12]. These data are acquired by the central computer, and they are stored in electronic and printed form.

The proposed automation solution for wastewater treatment plant involves the use of a series of small control systems that run the facility, or intelligent terminals (Remote Terminal Unit) and PLC (Programmable Logic Controller). The intelligent terminals continuously monitor the operation of pumps, closures and other devices, collect and execute commands coming from the higher levels, while programmable controllers (PLC) are used to control various processes based on the data and the built-in algorithm [5] [8] [9].

According to the given specifications, a control panel (Fig. 2) was created in a suitable SCADA software [15]. Only the part of the application responsible for controlling the valve and first three pumps that regulate the flow of water entering the purification system is represented.

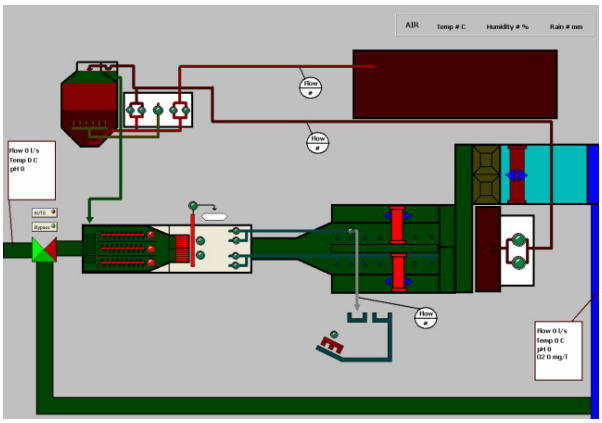

Fig. 2. The control panel of the wastewater treatment plant

For the control and monitoring of wastewater treatment facilities, the communication between the SCADA application and local PLC controller is necessary. A program that provides the appropriate behavior of the valve placed at the entrance and the control of the pumps was written in a ladder diagram (Fig. 3).

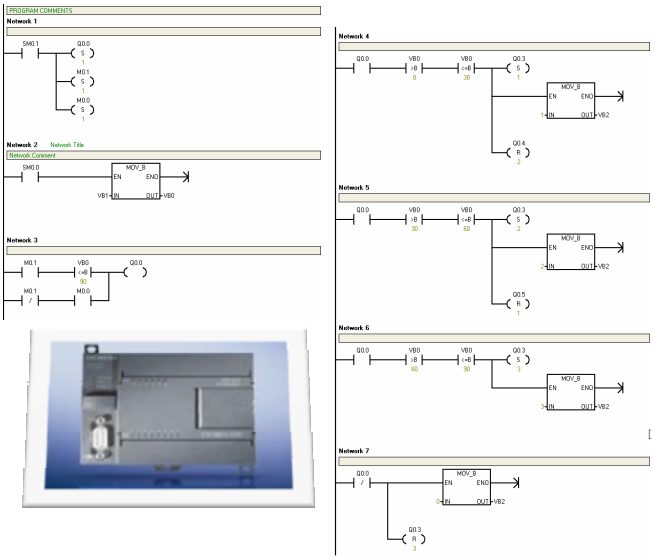

Fig. 3. The ladder diagram for the control of the valve and pumps placed at the entrance

This program consists of seven ranks, as follows [15]: Network 1 – which sets the initial values; Network 2 – a simulation part – which copies the value of the water flow at the entrance to a new block for the purpose of simulation, using SCADA software; Network 3 – which controls the valve; Network 4 – Network 6 – control of pumps according to the current flow of water; Network 7 – if the valve is closed, then it is not necessary to run the pump.

3. FUZZY LOGIC FOR DECISION MAKING IN A DEVELOPED SCADA SYSTEM

In the wastewater treatment system, it is necessary to control the pumps, liquid levels, and flow regulation. In this paper the control of the valve and the pumps behind the valve is developed using SCADA applications and standard PLC based on fuzzy logic. The control is realized without any additional phase logic modules/software on the PLC controller, thus reducing the cost of control equipment and retaining all the advantages of fuzzy control [10].

Furthermore, a fuzzy SCADA system, which is implemented in this way, can be applied without difficulty in the control of various industrial processes. Simulation software is used as a tool for fuzzy control of the system and the simulation of a system in laboratory conditions. Fuzzy membership function parameters are determined using expert knowledge [2]. Membership functions are triangular and are applied in fuzzy algorithms of Sugeno type. As shown in Figure 4, the fuzzy controller has two input variables: h (t) presents the level of water in front of the valve, and dh (t) / dt is the rate of the change of the water level, while the output variables are the position of valve and the number of the active pumps behind the valve.

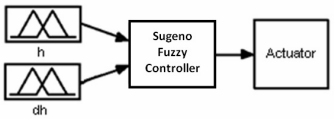

Fig. 4. The structure of the fuzzy controller

As long as the water level in front of the valve is less than critical, the entire amount of wastewater enters the plant, and fuzzy logic controller determines the number of pumps that will transfer wastewater to further processing. The consequence of this predictive control is the increase in the energy efficiency of the plant, as well as the work of the plant in harsh conditions. The block scheme of the control system [15] is shown in Fig. 5.

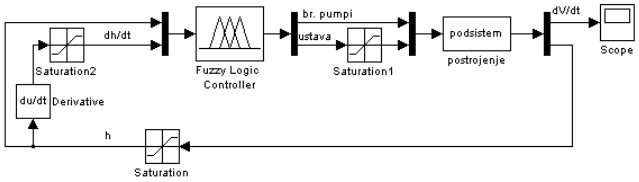

Fig. 5. The block scheme of the fuzzy control system

Namely, in the towns of Serbia, rainwater sewerage is most often directly connected to the sewerage system, and at higher precipitation, especially in spring when the snow melts, the amount of wastewater coming to the treatment plants is significantly increased [5] [7] [9]. If the wastewater level is higher than critical, the valve only diverts a part of the wastewater away from the plant, instead of diverting all wastewater directly away from the plant, while the plant continues to operate at full capacity.

The standard PLC (Siemens Simatic S7-200 without the fuzzy module) is used to control the work of the subsystems at the entrance of the plant. The data on the water level is transmitted to the PLC by means of an analog input module. This data, which is in the range from 4 to 20 mA, is transferred to the computer where it can be converted so the value of the water level in cm is determined. The measured level and rate level changes are inputs of the fuzzy controller which is implemented as a subprogram of SCADA applications. The outputs from the fuzzy controller that are brought to the PLC are referent position of the valve and the number of active pumps. The proper flow of wastewater is achieved by the proper position of the valve and proper number of the active pumps. The PLC controls the state of the valve actuator depending on the reference flow values, i.e. the position of the valve, finally achieving the appropriate work regime of the system. The purpose of this control is the increased work stability of facilities and the increased energy efficiency of the system.

4. WEB CONTROL OF THE SCADA SYSTEM

In the control of dislocated facilities, and due to their remoteness and the insufficient development of the local Internet infrastructure and economic aspect, Internet communication can be achieved by an independent Web server and the SCADA server (Fig. 6) [4]. The use of this solution allows for the connection of wastewater treatment subsystems with the dispatch center via GPRS, 3G or 3.5G technology (which can reach speeds of up to 14.0 Mbit/s for download and 5.8 Mbit/s for upload of data) as the most favorable technical solution without building local networks. Some wastewater treatment subsystems are connected to the main center via wireless Wi-Fi communication, which enables faster data transfer [3] [5] [7].

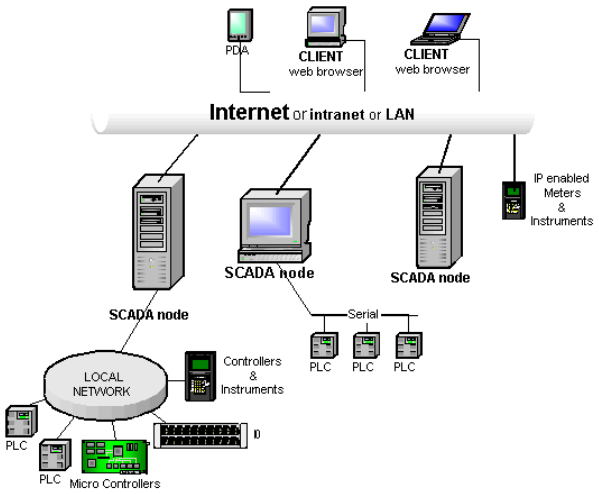

Fig. 6. Automation system using SCADA nodes and Web Browser Clients

The prices of equipment for wireless Internet communication have rapidly dropped in recent years, thus making the construction of local wireless networks for the wastewater system a reasonable investment, which would pay off in the long term. It also allows for a relatively easy Web control by establishing the Internet connection only in the dispatch center, thus increasing the security of the system and enabling the control of the water supply system and wastewater treatment from anywhere in the world either via a PC or a "thin client" [11].

To access a remote SCADA system, Apache web server and MySQL database are used. The used SCADA software has embedded protocols for exchanging data with ODBC, and this technology is often used to write / read data from the database. On the other hand, reading / writing the data from mySQL database using PHP is very simple. The software package WAMP – Windows-Apache-MySQL-PHP, containing all the necessary components for creating a web server in a very simple way, is used [14]. To control the database a simple web application is used and it is developed for this purpose.

To access the database for experimental purposes, a very simple Web pages is created using PHP, from which it is very easy to read the data from the database, while a user can change the state of the input valve and its way of work. The water flow can be read from the website and the modes (automatic or manual) can be set, as well as the state of the valve for the manual mode. The number of currently active pumps at the entrance can also be seen. Further development includes the development of the web portal and the improvement of the user interface which would be intuitive, clear, and easy to use. It is necessary to introduce a number of different users with different privileges, depending on the data that they can view, or whether they can change certain control parameters of the process and make changes to the Web portal itself. Web portal administrators would simply extend the database by adding new tables of data directly from the Web portal user interface, in accordance with the expansion and improvement of water supply and wastewater networks.

5. CONCLUSION

The presented concept of development of the remote monitoring and control of the wastewater treatment system has energy efficiency as one of its main aims. It is based on the local PLC controllers located in the dislocated facilities which communicate with the central dispatch SCADA system using a Web server that allows for the access to data on the system over a local network or the Internet.

In addition to the SCADA server which functions as the central data acquisition and remote control server, the control of liquid level in front of the valve based is developed on the basis of fuzzy logic, which significantly improved the energy efficiency of the system. This approach, which is focused on the expert knowledge operator and not on the process, shows better performance than conventional controllers, in terms of response time, settling time, and especially robustness. The control is achieved without any additional fuzzy logic modules / software on the standard PLC controller, thus reducing the cost of control equipment, and retaining the benefits offered by the application of fuzzy logic. The standard simulation software was used as a tool for fuzzy control part of the system, as well as for the simulation of the system.

The implemented fuzzy-SCADA system is flexible and applicable in other industrial applications, and is characterized by a relatively low price, with optimal power consumption and achieving maximum system performance.

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INTELIGENTNO ODLUČIVANJE U SCADA SISTEMU POSTROJENJA ZA TRETMAN OTPADNIH VODA

Vlastimir Nikolić, Žarko Ćojbašić, Ivan Ćirić, Emina Petrović

U ovom radu predstavljen je SCADA sistem za nadzor i upravljanje postrojenjem za tretman otpadnih voda primenom fazi upravljanja. Za lokalno upravljanje korišćeni su PLC kontroleri, a posebna pažnja je posvećena njihovom povezivanju sa SCADA sistemom. Razmatran je problem razvoja daljinskog nadzora i upravljanja sistemom za tretman otpadnih voda i njegovog poboljšanja dodavanjem modula za inteligentno odlučivanje. Upotreba inteligentnih senzora i

aktuatora za upravljanje udaljenim objektima i transportnim sistemima je takođe razmatrana. Osim toga razvijen je jednostavan sistem za web upravljanje koji predstavlja odličnu osnovu za dalje unapređenje u cilju razvoja kompletnog sistema za upravljanje i nadzor tretmana otpadnih voda. Komunikacija između centralnog dispečerskog SCADA sistema i lokalnih kontrolera ostvarena je na više načina korišćenjem savremenih bežičnih tehnologija. Inteligentni modul SCADA aplikacije zasnovan na Sugeno fazi algoritmu donosi odluke na višem nivou upravljanja dok lokalni PLC kontroleri upravljaju odgovarajućim dislociranim objektima sistema. PLC kontroler koji je korišćen u ovom postrojenju ne poseduje fazi modul ili softver. Predloženi fazi-SCADA sistem je fleksibilan i primenljiv u drugim industrijskim aplikacijama, a karakteriše ga ostvarivanje optimalnog učinka sistema i povećana sigurnost.

Ključne reči: *inteligentno upravljanje, fazi logika, SCADA, tretman otpadnih voda, bežične komunikacije*