CHEMICAL ENGINEERING TRANSACTIONS
VOL. 66, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216
DOI: 10.3303/CET1866166

Monitoring System of Sewage Treatment Based on PLC

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The purpose is to achieve a more intelligent sewage detection in the process of sewage treatment, and further improve the accuracy and immediacy of monitoring data. This paper takes the PLC platform produced by Allen-Bradley Company as the main research object and basic monitoring instrument to detect the PH value and COD value in the treated sewage. Through the optimal design of DCS structure and communication network level in sewage treatment system with PLC as platform, a better sewage monitoring effect has been achieved.

1. Introduction

With the increasing shortage of water resources and the rapid development of industrialization, efficient and reliable sewage treatment has become an important link to realize sustainable development and the intelligent upgrading of sewage monitoring system has become essential in the process of sewage treatment.
On the basis of studying and expounding the mechanism of sewage treatment process, according to the actual operation needs of each treatment link, the DCS structure of the whole sewage treatment monitoring system is comprehensively designed, and the control technology discussed in this paper.

2. Literature review

The large-scale sewage treatment in human history began in 1950s. At that time, the vigorous development of industry brought serious environmental pollution problems. By the end of 1970s, the developed countries such as Britain, France and Germany invested a huge amount of funds to build a large number of sewage treatment plants, which improved the water quality of the countries in which they are located. It played a huge role and accumulated a great deal of valuable experience in sewage treatment.
Developed countries have made great achievements in the field of sewage treatment technology and monitoring technology. In the early stage, in the field of sewage treatment and control system, the sewage treatment plant of developed countries used single chip machine (SCM) as a lower machine applied in the sewage treatment monitoring system. After that, Baldovino and Dadios studied the better performance and more stable programmable logic controller (PLC). PLC has gradually replaced the SCM in the sewage treatment and control system. Tablet machine is still widely used in modern sewage treatment monitoring system (Baldovino and Dadios, 2017). In the field of sewage treatment equipment and instruments, developed countries have developed a variety of efficient, intelligent, and well-integrated sewage treatment equipment and instruments. At the same time, the industrial computer technology is introduced and achieved good results in practical applications. In sewage treatment monitoring system, communication network plays a role as a link. The early monitoring system is widely used in communication with optical fiber, cable and other cable media. It is still widely used in modern small and medium-sized sewage treatment plants. In recent years, with the expansion of the scale of new sewage treatment plants and the enhancement of remote control requirements, all kinds of unlimited communication technologies are rapidly popularized and applied.
Because sewage treatment is a typical time-varying, nonlinear, uncertain and prolonged industrial process, the traditional proportion integral derivative (PID) control methods cannot meet the requirements of high precision, high efficiency and high stability of the sewage treatment and control system. It can enhance the anti-interference ability of the system, improve the quality and efficiency of the system operation, and reduce the production cost. Ma is working to improve the intelligence of the monitoring system (Ma, 2017). Dange and

Please cite this article as: Wang H., Zhang F., 2018, Monitoring system of sewage treatment based on plc, Chemical Engineering Transactions, 66, 991-996 DOI:10.3303/CET1866166

Lad realized the full automatic control of the key or all sewage treatment processes by introducing fuzzy control and neural network control technology, or combining the two, and used various high performance digital equipment and instruments and advanced network communication technology (Dange and Lad, 2017). Elleuch and so on adopted the open loop fuzzy control strategy based on the combination of principal component analysis, Takagi-Sugeno algorithm and proportional integral control. It has a good inhibition effect on the disturbance produced by the feeding in the process of anaerobic sewage treatment, and achieves good results in the actual operation (Elleuchi et al., 2017). Alattabi and others used neural network algorithm to classify and store the data of sewage pH, oxygen redox potential (ORP) and dissolved oxygen (DO), such as "vertex", "turning point", "step" and so on. They also took these historical data as the basis to deal with the current events and changing trends and realized autonomous learning and intelligent control (Alattabi et al., 2017). Kalaitzidou and others realized the automatic and efficient monitoring of desalination with the application of PLC and the technology of permeable membrane in the process of desalting in sewage treatment (Kalaitzidou et al., 2016). Sushree and others analyzed the process flow in the common sewage treatment plant, and put forward the distributed PLC monitoring station layout scheme and the communication network scheme based on industrial fiber redundant Ethernet. Meanwhile, the time cycle control, the level difference control, classic and fuzzy PID control and other strategies are put forward in view of the mechanical grille, the pump, the aeration and so on. The plan is realized and applied in Yuncheng second sewage treatment plant (Sushree et al., 2017). He and so on, in the sewage treatment and control system, selected the SIEMENS S7-300 series PLC, and applied the closed loop PID control algorithm and the fuzzy self-tuning PID control algorithm to control the dosage and pH value, and the quality and reliability of the sewage treatment is greatly improved (He et al., 2017). However, there is still a great gap in current sewage treatment monitoring system between China and the developed countries.

In recent years, with the rapid development of urbanization, industrialization and agricultural modernization in China, a lot of domestic sewage and industrial wastewater are discharged to the outside water directly without processing. The water pollution caused makes the contradiction between supply and demand of water resources more prominent. Secondly, with the improvement of people's living standards and environmental protection requirements, the standard of treatment of industrial wastewater and domestic sewage is becoming increasingly stringent. The monitoring system is used later in the sewage treatment plant in China. Before 1980s, the instruments of the sewage treatment plant in China were mainly thermal instruments, and the equipment was checked and controlled manually. Since 1990s, the disperse control system (DCS) has been introduced into some sewage treatment plants, and the analytical instruments have been applied in these systems. In twenty-first Century, with the substantial improvement of the demand and requirement of sewage treatment in China, along with the progress of domestic computer and industrial control technology, a large number of newly built sewage treatment plants have introduced or developed the sewage treatment monitoring system. In these systems, PLC is widely used as the core controller, and the digitalization instrument is introduced at the same time and achieved good results in practical operation.

To sum up, in the above research work, the process flow of the sewage treatment plant, the control function and parameters of the main equipment instrument are mainly analyzed, and the design principle and function orientation of the monitoring system are determined. In addition, the type of the monitoring system is determined and the PLC control system software is developed. Aiming at the characteristics of uncertainty, nonlinearity and time-varying aeration of the core processing technology of the sewage treatment process, the fuzzy PID control method is used to establish the control strategy of aeration process. The monitoring of the biological aerated filter of the core process facility in the sewage treatment process is completed. Therefore, based on the above research status, a set of sewage treatment monitoring system is designed and developed for sewage treatment process and plant layout. The system can realize the automatic real-time monitoring and control of the important parameters and the main equipment running status in the sewage treatment process.

3. Sewage Treatment Methods

3.1 Classification of sewage treatment methods

In modern times, different sewage treatment methods are adopted for different pollutants, which are usually divided into three types:

Physical treatment is to achieve solid-liquid separation through physics, with such commonly used methods as screening, filtering (coarse grids), centrifugation (using grit tank). It belongs to the pretreatment stage of sewage treatment.

Chemical treatment is to transform the water soluble and colloidal organic matter into the stable inorganic matter through chemical reactions. The most commonly used method is the addition of chemicals. Through the addition of certain amount of FeCl3, the sewage is neutralized, so that the microbial enzyme can keep high activity. Besides, other methods such as disinfection and oxidation are also used.

Biological treatment belongs to the secondary treatment, which is the core of the whole sewage treatment process. Through the degradation of microorganisms, organic matters such as proteins that are not easily precipitated in water are transformed into stable inorganic matters so as to eliminate pollution. According to the demand of oxygen for microbial degradation, the biological treatment methods can be divided into aerobic biological method and anaerobic biological method.

3.2 Sewage treatment gradation

Primary treatment, also known as pretreatment, refers to the purification process of removing floating and suspended matter in sewage, while adjusting its pH value, reducing its degree of degradation and subsequently treating technical load. Its specific treatment process is shown in Figure 1.

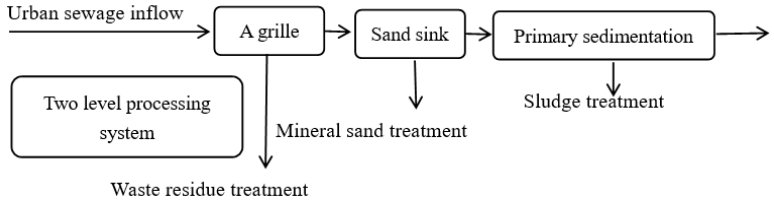

Figure 1: First grade treatment process of sewage

Secondary treatment refers to the use of biochemistry to further treat wastewater based on primary treatment. It is a purification process of continuing to remove the colloids and dissolved organic matter in sewage, mainly BOD and COD matters, by using biological treatment methods, with a removal rate of up to 90%, so that organic pollutants can meet discharge standards.

Tertiary treatment of sewage, that's, advanced treatment of sewage (also referred to as deepened treatment), is the last of the three levels of sewage treatment. After secondary treatment, the sewage still contains very fine suspended substances, phosphorus, nitrogen and organic substances, minerals and pathogens which are difficult to biodegrade and need further purification treatment.

To sum up, the current process of sewage specific treatment is shown in Figure 2.

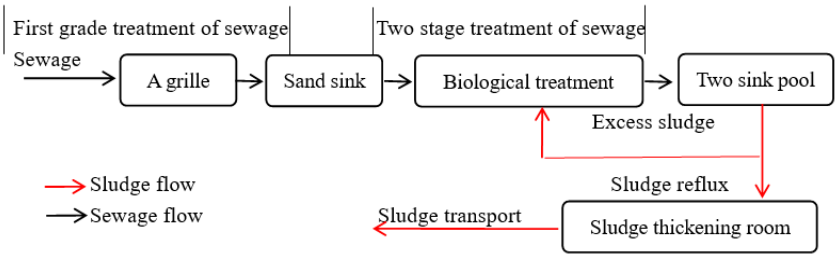

Figure 2: Flow chart of sewage treatment

4. Study on Sewage Treatment Monitoring System Based on PLC

4.1 Overview of programmable logic controller (PLC)

The PLC is usually divided by the number of I/O points and structure. According to the number of I/O points, PLC can be divided into three types, large PLCs, which are above 2,048 points, medium PLCs, which are between 512 and 2,048 points, and small PLCs, which are below 512 points (PLCs below 64 points are Micro).

According to the structure form PLC is divided into the integrated and the modular.

1) Integrated PLC, is also referred to as unitry PLC or cabinet PLC, which integrates the power supply, I/O components, and CPU in a chassis. Its advantages are low price, small size and compact structure. This type of structure is commonly used for small PLCs. The basic units and expansion units with various I/O points form an integrated PLC. The base unit contains power supply, CPU, and I/O, while the expansion unit only contains power supply and I/O. They are usually linked via a flat cable.

2) Modular PLC means that various parts of PLC are separated into to several independent modules, such as CPU module, power supply module, I/O module and various function modules. Modular PLC is a multi-module framework. Some PLCs lose frames, while various modules are installed at the bottom. Large and medium-

sized PLC is usually suitable for the use of modular structure. With such advantages as flexible configuration, easy installation, it is easy to be expanded and repaired.

4.2 Introduction of RSlogix5000 control system of Allen-Bradley PLC platform

As shown in the information flow chart of the RSlogix5000 control system in Figure 3, the control system collects the information of the controlled objects in the production process, analyzes the current process control status according to the established program, and outputs the corresponding control instructions to the objects to achieve the purpose of control.

The RSlogix5000 system can design different control strategies according to different on-site process control requirements, which basically includes the following four types:

1. Sequence control completes sequential logic control, with the complete set of command system ported from enhanced PLC5.
2. The process control completes the process control, with a functional block ported from a small DSC system.
3. The drive control completes the drive control. In the Drive Logix controller, special function blocks and configuration are used to realize the specific control mode of the frequency converter.
4. The motion control completes the servo control, which realizes the control of the physical quantity of the moving axis, by programming of operation and control instructions.

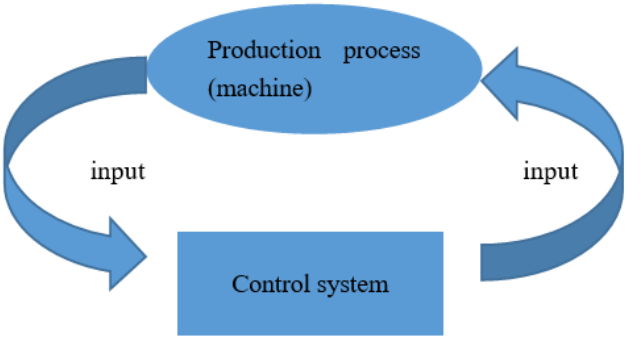

Figure 3: RSlogix5000 Control system information flow chart

4.3 Performance index of water quality after sewage treatment

The influent water quality such as BOD, COD and NH3-N should meet the requirements of national environmental protection after the wastewater is treated by A2 / O biochemical pool technology. The inlet and outlet water quality indexes of the sewage treatment plant are as follows:

Table 1: Water quality index of sewage plant

Water quality index	inlet	effluent	Removal rate
BOD	300mg/L	≤10 mg/l	≥88.7%
COD	1000mg/L	≤50 mg/l	≥95%
SS	400mg/L	≤10 mg/l	≥97.5%
TR	30mg/L	≤5 mg/l	≥87.5%

4.4 Overall design of automatic control and network system

The PLC1 control main station is set in the power distribution room of the sewage plant, which is responsible for monitoring and controlling the process parameters of the oxidation ditch, sludge reflux pump room, A2/O biological reaction tank blower room, secondary sedimentation tank and other structures and equipment. The PLC1-I01 control sub-station is set in the pre-treatment power distribution room, and is responsible for monitoring and controlling the process parameters of the inflow pump room, grid system, rotational flow grit chamber and other structures and equipment.

The PLC2 control main station is set in the sludge dewatering room, which is mainly responsible for monitoring and controlling the process parameters of sludge dewatering system and mud cake preparation.

The PLC3 control main station is set in the chlorination and dosage power distribution room, which is responsible for monitoring and controlling process parameters of CLO2 generator, PAC flocculant configuration, dosing pumps and other equipment.

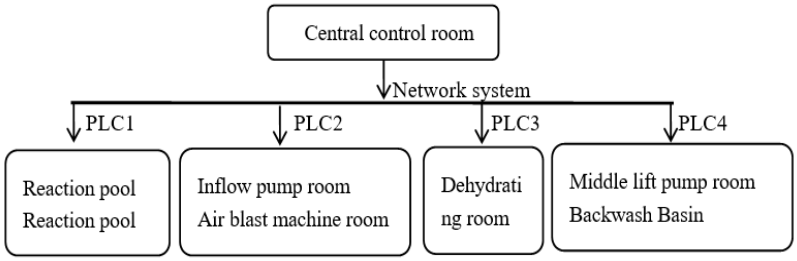

Figure 4: Structure diagram of self control system for sewage treatment

The PLC4 control main station is set in the filtering operation room, which is responsible for monitoring and controlling the process links such as active sand filtering, backwashing, flocculation sedimentation tank, ex-factory water detection and metering.

According to the actual on-site situation of sewage plant, distributed control system (DCS) is selected for plant automation, consisting of a central control room, PLC1 control main station in power distribution room, pretreatment PLC1-I01 control sub station, PLC2 control main station in sludge dewatering room, PLC3 control main station in dosage room and PLC4 control main station in filtering operation room. Each control main station uses COMPACTLOGIX 1769-L3X series controllers of AB company, while PLC1-I01 control substations adopt I/O substations of FLEXI / O 1794-AENT series remote of AB company and PLC1 control main station, which are connected through Ethernet communication. CPU of the main station supports Ether Net / IP, Control Net, Device Net protocol, each PLC main station is equipped with a programmable operator terminal HMI, and each PLC control station and third party equipment with PLC and communication interface are connected with the central control station by Ethernet or PROFIBUS-DP bus to ensure stable and reliable communication. The system structure is as shown in Figure 4.

The engineer station and operator station (industrial grade PC) of the central control room are normally located in the management building. The former operates the configuration software of the upper computer for monitoring and remote control of the equipment within the jurisdiction, while the latter realizes remote debugging and remote diagnosis through software programming to PLC. Independent control is often used for automatic control of production processes, that is, The PLC control station of the equipment control layer and the upper monitor computer are independent of each other, and can operate independently without relying on the upper computer, thus ensuring the independence and safety of the production process. The central control room is equipped with a projector, so that the monitoring process flow and monitoring images can be put on the projector in real time, which is intuitive and convenient. In addition, the corresponding I/O point table formulated according to the process links and related equipment monitored by the PLC1 control main station is as shown in Table 2, and the hardware configuration of the PLC shall be carried out accordingly.

Table 2: Water quality index of sewage plant

Structure	Device name	Detection content	Number
AAO	Reaction pool	sludge concentration meter	12
Oxidation	ditch propeller	Sludge pump reflux pump	8
Two sink dredger	Mud suction machine	Function/Stop it	6

The scheme is designed according to the planning principles of the distributed automatic control system, which meets the following requirements:

(1) The instruments and testing equipment shall be installed according to the relevant operation requirements of the field process, and an overall monitoring system shall be set up.

(2) With decentralized control and centralized management, he central control room with the central control system shall be established in the office area of the sewage plant, so as to manage the production process of the whole sewage treatment plant.

(3) The central control system shall adopt an open and computer-controlled network that conforms to the Ether Net / IP protocol and can be linked with the superior management system, the database system and other peripheral systems.

(4) The control of main process equipment shall adopt three-tier control mode, including local control, on-site control and central control room control. On-site PLC control station shall be provided with operation human-machine interface such as touch screen.

(5) Other equipment shall adopt two-tier control mode, including on-site control and central control room control.
(6) The control station (main station or sub station) based on PLC control system shall be set up in every process. The high speed data communication network --- Ether Net / IP, is used for the connection between stations and that between the control station and the monitoring computer in the control room.

5. Conclusions

(1) The time sequence control is adopted in the sewage treatment control system in the present paper. The water treatment control is ideal, but there is not enough consideration of the energy consumption.
(2) Sludge reflux and discharge control. Sludge control is also an important research topic in sewage treatment. A large number of microorganisms are attached to the sludge, and the sludge control can ensure that microorganisms in the biochemical pool reach a certain concentration. If sludge reflux is less, the concentration of microorganism in biochemical pool will be low, and the growth rate of bacteria will be decreased, which affects the effect of sewage treatment. If sludge reflux is excessive, the eater inflow of sedimentation tank will increase, which will raise the hydraulic impact of sedimentation tank and affect the solid-liquid separation effect of sedimentation tank.

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