Design and application of sewage treatment technology in fieldbus control system

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Abstract. At present, most sewage treatment plants in China generally have low sewage treatment automation and low operating efficiency. In order to solve this problem, this article takes a sewage treatment plant in Hangzhou as an example to analyze the functions and control requirements of each process in detail. Adopting three-level sewage treatment process and multiple disinfection technology at the same time, a set of sewage treatment field bus automatic monitoring system for SBR comprehensive process is designed, and the overall structure of the control system, control system hardware, control program and host computer monitoring system are given. The system adopts siemens S7-300 as the main control station, and uses industrial ethernet to complete the data exchange between the bus control and the control station on the network configuration. With various testing equipment, the inverter and MCC serve as the slave stations form a profibus control network, and complete functions such as automatic control of sewage treatment equipment and dynamic process monitoring through Wincc7.4 and Step7 V5.5. At the same time, automatic online monitoring and sampling are adopted, and video monitoring replaces manual inspection. Practice shows that the system The operation is in good condition, the effluent indicators, reliability, safety, etc. have reached the design requirements, and good economic and social benefits have been achieved. It is an integrated control system with strong practicability and high degree of automation, which is useful for further improving the automation of sewage treatment. The degree has important reference value. At the same time, the technical achievements of automatic sewage control and comprehensive treatment can fully support the sewage treatment needs during the new coronavirus epidemic, and have a wide range of application prospects.

1. Introduction
In the 21st century with rapid economic development, severe water pollution has become a major factor restricting the sustainable development of cities. At the same time, my country is a country with relatively lack of water resources. Wastewater reuse has great potential. Wastewater treatment has become an indispensable part of the economic development process. An indispensable part [1], water treatment technology can treat sewage and wastewater to the level of drinking water, and can also be processed to the level of non-drinking water, for toilet flushing, green land watering, road cleaning, etc. [2]. Developed countries abroad have accumulated relatively mature experience in dealing with
wastewater treatment problems brought about by industrialization and economic development. At present, the wastewater treatment capacity of the Netherlands, Germany, and Japan is at the world's leading level. These countries attach great importance to the research of sewage treatment automatic control systems [3]. After more than 30 years of development, China’s sewage treatment technology has formed its own technology while absorbing and learning from the sewage treatment technology of developed countries such as Europe and the United States. However, compared with foreign advanced technology, our research on automatic control systems is still There is a long way to catch up. The country is stepping up its efforts in sewage treatment, and the research of sewage treatment automatic control system is imminent [4].

The project covers an area of 1 million square meters, with a daily treatment capacity of 200,000 cubic meters. The total scale of the sewage treatment plant is 400,000. Based on the actual research on the sewage treatment process, the SBR three-level integrated sewage treatment technology suitable for urban sewage treatment is designed. On the basis of the existing equipment, a three-level field bus control system composed of industrial computers, plc and intelligent equipment is introduced. The field bus uses industrial ethernet and profibus, the controller uses siemens S7-300, and the central control level is divided into engineer stations. And the operator station, using wincc as the man-machine interface to display the real-time process of sewage treatment, practice has proved that the system can accurately automatically control the various processes of the SBR integrated process, and the sewage treatment field bus control system is a huge society The research direction of benefits, environmental benefits and economic benefits.

2. Design of sewage treatment process

Sewage treatment is a combination of system engineering, the design of the process plan should be determined according to comprehensive factors such as water quality and treatment scale. The process plan of this project is designed for the treatment of urban sewage. A three-stage sewage treatment process is adopted, and physical methods are first adopted. Chemical methods and biological methods are used again, combined with activated sludge method and biological contact oxidation method, as the advanced treatment method of refractory organic sewage, the use of strong oxidants to disinfect, decolor and deodorize the sewage, while introducing ultraviolet light In the biochemical treatment system, the process flow of the sewage treatment control system is shown in Figure 1.

![Wastewater treatment process diagram](image)
3. Scheme design of fieldbus control system

3.1. System design ideas

This control system is a sequential control for the SBR comprehensive process. In order to improve the control accuracy of the system, more sensors are added, such as DO detector, ORP detector, Miss measuring instrument and other related detection equipment. At the same time, industrial Ethernet is adopted. The fieldbus technology combined with profibus can not only reduce costs, but also improve the reliability and real-time performance of the system, making the system easy to expand and maintain.

3.2. Control system structure

The system adopts a three-tier structure and a two-tier network. The three-tier structure includes a process equipment layer, a field control layer, and an operation monitoring layer. The process equipment layer includes smart sensors, actuators, and analytical instruments that conform to the fieldbus communication protocol. Each device is partitioned MCC, frequency converter, field detection instruments, etc. are connected by profibus; the field control layer completes basic control functions and executes various control algorithms; the operation monitoring layer includes operation stations and engineer stations, which are mainly used for monitoring and control systems of the production process configuration and maintenance [5]. The secondary network includes management information network and real-time control network. The management information network adopts the form of optical fiber ring network to realize the communication between the field control layer and the operation monitoring layer. The communication between the control station and the control unit adopts the profibus DP mode, and the structure of the control system is shown in Figure 2.

3.3. Network topology

The sewage treatment control system adopts the master-slave structure of the upper and lower computers, and uses the industrial ethernet based on TCP/IP to realize the communication between the upper and lower computers, thereby realizing the integrated control of the entire sewage treatment plant. The central control room consists of an engineer station and two operator stations as the upper computer. It forms a wired data communication network with the four field control stations through industrial ethernet, and is connected to the lower computer through an ethernet switch. The lower computer is selected with an open for the S7-300 series of network structure, the topological structure of the control network is shown in Figure 3.

![Figure 2. Structure of sewage treatment field bus control system.](image1)

![Figure 3. Ethernet topology.](image2)
4. Step7 software system design

4.1. Hardware configuration and address allocation
The control system adopts simatic step7 V5.5 software for hardware configuration, completes the address and station address allocation and program design and development, and realizes the processing of process data by plc. Siemens S7-300 is used as the master station and profibus-DP is the field bus. ET200M series and various inverters, actuators, etc. are used as slave stations, and the IM365 module provides its expansion interface. According to the needs of the process and control requirements, the system is equipped with 4 plc stations, 12 analog input SM331 modules, 2 analog output SM332 modules, 28 digital input SM321 modules, and 15 digital output SM332 modules, as shown in Figure 4. Shown is the hardware configuration of the biochemical processing sub-station.

4.2. Communication program design

4.2.1. Ethernet communication between plc. The ethernet communication between S7-300 is realized by calling FB14/FB15 function block [6], the communication addresses of the 4 S7-300 are w#16#1, w#16#2, w#16#3, w#16#4, timed to read once in 1 second, read two bytes to the start address of DB4, part of the procedure of ethernet communication is shown in Figure 5.

4.2.2. Communication design between frequency converter and plc. The siemens inverter is connected to the Pprofibus network through the DP interface as a slave station. The master station CPU315-2DP and the inverter slave station perform cyclic data exchange. It is necessary to call the function blocks SFC14 and SFC15 [7], the S7-300 and inverter the DP communication program is shown in Figure 6, laddr is the starting address of the process data W#16#100 (that is, 256), the length is 4B, and record represents the address of the slave data area in the data block, when M0.1 is 1 state At the time, call SFC15, package the control word and speed setting value in MW30 and MW32 and send it, and call SFC14 at the same time, unpack the received data and save it in MW4 and MW6.
4.3. Control program design

Step7 software programming adopts a modular structure. According to the actual situation of the controlled equipment, the entire sewage treatment is divided into several sub-processes. Each sub-process corresponds to a function or functional block, which combines various control functions and communication data between each site. Written in different subroutines respectively, the main control program calls each function through the organization block.

The design of the control program adopts the form of modular structure and subprogram calling. The functions of each main function block are as follows: FC1 is an analog quantity processing program block, FC11~FC15 are respectively pH value control and adjustment program blocks, and the sewage pH value is controlled by the function block FB41 Realize continuous pid control. FC181~FC193 function blocks respectively complete the monitoring of circulating pumps, flow meters, pressure sensors, and temperature sensors. FC201~FC223 function blocks realize other functions, such as agitator control, high and low limits of liquid level gauges. For pH value control and fault alarms, FC1 calls the function block FC32 to convert the input analog quantity. The sensor converts the actual value of the analog quantity into a 4-20mA signal, which becomes a 0~27648 signal after A/D conversion. The number of internal codes, the actual value of the internal code is sent to the host computer for display through programming, and the field instrument reading is processed as follows: field instrument reading = (reading value/27648) × (actual maximum range value-actual minimum range value) +The actual minimum range value [8], the analog quantity processing program is shown in Figure 7.

Take the temperature sensor as an example. The signal transmitted on site is an analog quantity of 4-20mA. The PIW address of this signal is 256. The analog quantity processing program block FC1 is
called through the main program OB1 to process the temperature signal from the scene and convert it to the engineering quantity readable by plc, Figure 8 is the ladder diagram program called by analog quantity.

![Ladder Diagram](image)

**Figure 7.** Analog quantity conversion subroutine.

**Figure 8.** Analog quantity calling program.

5. **Wincc monitoring system configuration**

5.1. **Selection and function of configuration software**

According to the actual needs of the sewage treatment control system, the upper computer selects the dedicated Advantech industrial computer for the industrial site, and the graphical interface selects the Wincc V7.4 of Simence to centrally monitor the operating conditions of the entire plant's process equipment. Wincc has the powerful process automation control, it also has a very cost-effective SCADA-level operation and monitoring system, and has complete monitoring and management functions [9]. The engineer station and the operator station use the full user version and the running version respectively.

5.2. **Configuration realization of monitoring system**

The sewage treatment monitoring system is equipped with multiple real-time monitoring screens, including process screens, alarm screens, report screens, event screens and operation record screens, among which the process screen can display the process flow of the entire system, as shown in Figure 9, through the button below different functional areas can be entered. The instantaneous values of equipment parameters are marked on the general process drawing according to the actual installation position, and the real-time data and historical data are made into corresponding sub-screens.

The process flow picture truly reflects the operating conditions of the field equipment, and is presented in the monitoring system in the form of animation. The left part is the three-way water inlet pipe, the distribution tank and the primary sink, and the data frame is set above the distribution tank. To display the liquid level from the site, a data frame is set in the inlet pipe and the dilution pipe of the sedimentation tank to display the real-time flow. The middle part is the H+DN tank and the contact
oxidation tank. The data frame above each reaction tank is used to display Temperature, acid valve opening degree, alkali valve opening degree, oxygen content, flow rate and other information. The acid-base valve is controlled and adjusted by the PID loop. The output value of the acid-base valve is a percentage (range 0-100%), PID parameters need to be determined by on-site debugging. The treated sewage is discharged in the rightmost discharge channel, and the sludge enters the lowermost sludge treatment channel. PV is the pH feedback value of the sedimentation tank, and SP is the pH setting value.

Figure 9. Wincc monitoring system process flow overall screen.

6. Debugging and maintenance
System debugging is generally divided into two steps: static debugging, dynamic debugging and running. Static debugging mainly uses running programs to check the logical relationship of various hardware interfaces. Program debugging mainly uses s7-plcsim and step7 through signal generators. Simulate field signals to debug the hardware in the plc control cabinet. First, debug the subprograms and function module programs, then debug the initialization program, and finally debug the main program. The dynamic debugging adopts manual and then automatic debugging methods until the process control requirements are met. After the system has been debugged separately and on-line, the effluent quality meets the testing requirements of the "Urban wastewater treatment plant pollutant discharge standard" GB18918-2002 class a standard.

7. Conclusion and discussion
Aiming at the problems in sewage treatment, this paper analyzes and studies the entire process flow of sewage treatment according to the characteristics and requirements of urban sewage treatment [10], designs the SBR three-level integrated sewage treatment process [11], and designs the industrial ethernet and profibus phase according to the process requirements. Combined with the overall architecture and control plan, the system selects four s7-300 as the field control station, which realizes the industrial Ethernet communication between the lower computer plc and the upper industrial computer, the lower computer and the field equipment profibus real-time communication [12], and the use of modular I wrote the step7 control program and designed the host computer monitoring interface.
using wincc configuration software [13], which realized the remote monitoring and fully automatic operation of the system, and also realized the data transmission with the environmental protection department. The entire control system can be adjusted according to the process requirements. The parameters are especially suitable for the situation of insufficient water in the Longmen sewage treatment plant and unstable influent water quality, thereby effectively ensuring the discharge of sewage treatment standards.

Since the system was actually put into operation in October 2019, the control system has been operating stably and reliably, and all indicators have met the design requirements, solving the problem of scattered, complex, and difficult to control sewage treatment plant equipment, and greatly improving the efficiency of sewage treatment. The effluent index has reached the national first-level discharge standard, which is of great significance in solving the increasingly serious water pollution problem and saving investment [14]. More importantly, as the automation of the entire system increases, it will lay the foundation for future system transformation and expansion. A solid foundation is of great practical significance under the background of relatively backward domestic sewage treatment control technology and has a wide range of application prospects.

References

[1] Li Qianzhen 2018 Design of PLC control system for sewage treatment based on PROFIBUS. Dalian Jiaotong University
[2] Wang Jinren 2019 J. Automatic control system based on SBR sewage treatment process. Mechanical Design S1 26-28
[3] Li Ming and Kang Kai 2019 J. Application of PROFIBUS and PROFINET field bus in sewage monitoring system. China Instrumentation 6 26
[4] Sun Jing 2019 Experimental study and feasibility analysis of Angang's sewage treatment system. Harbin: Harbin Institute of Technology 28
[5] K J Hidalgo, T. Saito, R S Silva, Tiago P. Delforno, Iolanda C S Duarte, VM de Oliveira and Dagoberto Y. Okada 2020 J. Microbiome taxonomic and functional profiles of two domestic sewage treatment systems. Biodegradation 3 35
[6] Rui Wang, Li Jiaqi and Gao Xianbin 2020 J. Design and Simulation of an Ozone Catalytic Oxidation System Based on Programmable Logic Controller. Journal Européen des Systèmes Automatisés 53 4
[7] Meng Xiaoxi 2019 Research on technical transformation of ultraviolet sterilization technology in sewage treatment plant. Harbin: Harbin Institute of Technology 50
[8] Chuan Zhang 2020 J. Oilfield sewage treatment technology and improvement countermeasures. International Journal of Education and Economics 3 4
[9] Abdel Shafy Hussein I., Mansour Mona S. M. 2020 J. Rehabilitation and upgrading wastewater treatment plant for safe irrigation reuse in remote area. Water Practice and Technology 15 4
[10] Li Zhanying 2018 Distributed Control System and Field Bus Control System and their engineering design. Electronic Industry Press 237
[11] Wang Shanbin 2018 Configuration software application guide. Chemical Industry Press, 315
[12] Tang Haifeng 2019 Siemens PLC Mastery Case Course. Publishing House of Electronics Industry 277
[13] Sunit Kumar Sen 2020 Fieldbus and Networking in Process Automation. CRC Press 12
[14] Zhang Wei, Ma Tao 2019 Proceedings of the 31st China Control and Decision Conference. Northeastern University Chinese Society of Automation 566