



## Design of electric automatic control water treatment system based on LabVIEW

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### ABSTRACT

How to establish an effective electrical automation control water treatment system, optimize the operation effect, reduce cost investment, of great significance. The design of an electric automatic control water treatment system based on LabVIEW is proposed. Siemens industrial computer is used as the upper computer, and the S7-300 series of Siemens is used in a programmable logic controller (PLC) system. Based on the LabVIEW development platform, the OPC server is set up by Siemens SIMATIC. NET, which can connect with PLC to realize real-time communication. SQL Server is used as a backstage database to realize basic monitoring functions such as data collection, equipment control, real-time curve display, history record, fault alarm, etc. The experimental results show that the system can predict the biological oxygen demand concentration online and compare it with the measured value. It can adjust the control strategy in time, reduce the fault, save the dosage and reach the goal of economical operation.

*Keywords:* Electrical automation control; Water treatment system; Data acquisition; Equipment control; Real-time curve display; History record; Fault alarm

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### 1. Introduction

The rapid development of industrialization in modern society and people's pursuit of material, while ignoring the resulting adverse changes in the earth's environment, especially the slow depletion of water resources [1]. At the same time, the rapid development of urbanization has also caused the acceleration of water pollution, which seriously affected people's normal lives and sustainable economic development. The reduction of water resources and how to reduce water pollution has become an important problem and a major challenge for human beings.

Regional development and urbanization with the city as the development goal have become the inevitable direction of economic and social development, but the water pollution problem has also become a major hidden danger. As far as the construction and operation of urban sewage treatment projects are concerned, it is a very arduous task to upgrade the discharge of effluent from sewage treatment

plants from the general secondary discharge standards to fairly stringent A discharge standards [2]. Therefore, the sewage treatment system for the rapid development of countries more important. With the rapid development of urbanization, environmental problems have become increasingly important. Sewage is an important factor in destroying the environment. At present, the automatic control system of sewage treatment is relatively backward, the cost of sewage treatment remains high, and the quality of treated sewage discharged from a sewage treatment plant is unstable. Therefore, it is of great significance to establish an effective automatic control system, optimize the operation effect and reduce the cost investment.

It is of great significance to improve the quality of people's life and living environment and to promote the harmonious and sustainable development of society. Based on LabVIEW (virtual instrument), this paper puts forward the design of an electric automatic control water treatment

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system, establishes an OPC server on a LabVIEW development platform by Siemens SIMATIC. NET, connects it with programmable logic controller (PLC) to realize real-time communication and uses SQL Server as the backstage database to realize the basic monitoring functions such as data collection, equipment control, curve real-time display, history record, fault alarm, etc., greatly improves the precision and automation level of electric automatic control process, and greatly improves the water treatment efficiency.

## 2. Hardware design of electric automatic control water treatment system

### 2.1. Analysis of the sewage treatment process and control requirements

#### 2.1.1. Sewage treatment process

The process uses the activated sludge process, which is mature in the industry. The influent of sewage treatment system is lactic acid fermentation wastewater and washing wastewater from the dairy factory. The effluent from the plant is low in contaminants, but the fermentation effluent is a high concentration of organic wastewater with a high concentration of contaminants [3]. The concentration of organic pollutants in wastewater is high and easy to be biodegraded. The electric automatic control water treatment system is used in the various process units as shown in Fig. 1.

The sewage from the production workshop is piped into the catchment well (TK01), then lifted by the submersible lift pump installed in the catchment well, and entered into the regulation pool (TK02) after the larger suspended substance is intercepted by the rotary screen. Water quality, such as water quantity, temperature and pH, is balanced by regulating submersible mixers and air stirring systems in the tank [4]. After the wastewater in the regulating pool is regulated by pH, the submersible lift pump installed in the regulating pool is lifted to the air flotation system. The solid waste intercepted by the rotating screen enters the dustbin, and the landfill leachate returns to the collecting well. The wastewater from the accident enters the pool and is treated slowly later.

Although the development of sewage treatment technology is relatively rapid, the process of sewage treatment is not a great change, there are many in common. The most common sewage treatment process, for example, sewage entering the system (including sewage ditch, discarded waterway, inlet pipe, etc.) → physical treatment with coarse grids → sewage lift pump, reflux pump station → physical treatment with fine grids → desander tank → oxidation tank (including important sewage treatment processes such as anaerobic tank, anoxic tank, aerobic tank, etc.) → sedimentation tank → disinfection outlet tank → sludge external transportation and discharge of clean water [5].

#### 2.1.2. Control requirements analysis

According to the equipment and data acquisition of each process unit, in-depth analysis of process requirements, we can sum up its control mode [6].

#### 2.1.2.1. Water collection well (T4101)

The equipment consists of two sewage pumps (4101-P01/2) with 1 use and 1 spare; the model is 100WQ80-10-4 with each power of 4KW. Hydrostatic level gauges (4101-LIT01), 1 set; electromagnetic flowmeters (4101-FIT01), 1 set; float (LFT), 1 set [7].

*Control mode:* Sewage pump can be set up in the upper machine standby, failure or operation of the state, standby is not subject to level control, the other by level control. High open and low stop, high level and low level can be adjusted at any time on the upper machine, the liquid level can be displayed on the upper machine, and the total working time of each pump or motor can be displayed on the upper machine. The flowmeter on the upper computer can analyze and display the instantaneous flow and can display the cumulative flow on the upper computer. All data are stored separately in graphical and EXCEL form, and all equipment is available on site and under PLC control [8].

#### 2.1.2.2. Accident pool (T4141)

The equipment consists of 1 sewage pump (4141-P01), model 80WQ 50-10-2.2, power 2.2KW; 1 submersible mixer (4141-SMX01), model MA1.5, power 1.5KW; hydrostatic level gauge (4141-LIT01), quantity 1; float (LFT), quantity 1.

*Control mode:* Sewage pump can be set in the upper machine suspension, failure or running state, the suspension is not subject to the level control, the other by the level control. High open and low stop, high level and low level can be adjusted at any time on the upper machine, the liquid level can be displayed on the upper machine, and the total working time of each pump or motor can be displayed on the upper machine. Submersible mixer in the upper machine set suspension, failure or running state, according to the level or time to start, and can choose to set up, can be displayed on the upper machine working time [9]. According to the level of calculation and display at any time in the pool water, and can be set each pump sewage water, each numerical display and cumulative. All data are stored separately in the graphical and EXCEL form [10]. All the equipment can be on-site and PLC control.

#### 2.1.2.3. Regulation pools (T4121)

The equipment includes sewage pumps (4121-P01/2), 2 sets, 1 set, model 80WQ 50-10-2.2 power 2.2 KW; submersible mixers (4121-SMX01/2), 2 sets, model MA 1.5, power 1.5 KW; hydrostatic level gauges (4121-LIT01), 1 set; on-line pH meters (4121-PH01), 1 set; electromagnetic flowmeters (4121-FIT01), 1 set; on-line T meters (4121-TI01), 1 set; and floating ball (LFT), 1 set.

*Control mode:* Sewage pump can be set up in the upper machine standby, failure or operation of the state, standby is not subject to level control, the other by level control. High open and low stop, high level and low level can be adjusted at any time on the upper machine, the liquid level can be displayed on the upper machine, and the total working time of each pump or motor can be displayed on the upper

machine. Online monitoring of the pH, the analog signal of the pH meter input to the PLC, and then the PLC to control the operation of the alkali metering pump (4711-P01/02, 4741-P01/02), dynamically adjust the pH value of wastewater until the requirements of the process [11]. The temperature is measured online and the instantaneous value is displayed on the upper computer. The flowmeter on the upper computer can analyze and display the instantaneous flow and can display the cumulative flow on the upper computer. The analog signal of the flowmeter is input to the PLC, and the rotational speed of the sewage pump or motor can be automatically adjusted by the frequency converter according to the flow rate; the submersible mixer can be set to suspend, malfunction or running state on the upper computer, and can be adjusted at any time on the upper computer, and the accumulative working time of each pump or motor can be displayed on the upper computer [12]. All data can be stored and output in graphical and EXCEL form respectively. All equipment can be controlled by field and PLC.

## 2.2. Structure of control system

The whole sewage treatment system is controlled by PLC. Except for manual operation, most of the work is controlled automatically. Basically, nobody is on duty [13]. The industrial control computer shall be used as the engineer station (concurrently as the operator station) to monitor and control the process of sewage treatment. The main parameters such as dissolved oxygen (DO), pH, temperature, motor speed and so on shall be monitored online, and the feedback of liquid level, flow and temperature shall be monitored and controlled simultaneously. Select intelligent instruments and high-performance transducer to ensure the accuracy of regulation [8].

According to the requirements of water treatment process control, the system control can be divided into three levels, including field control level, centralized control level and remote control level. Among them, the field control level is the highest and the Internet remote control level is the lowest. Onsite water collecting wells, regulating pools, accident pools, mobile bed reactors, anaerobic reactors and other units shall install sensors to collect relevant parameters. The data collected by sensors and the status parameters of various equipment shall be transmitted to the upper computer through PLC and 485 bus. The upper computer and the internal program of PLC shall analyze and process the data collected, send control instructions to the submersible pumps, mixers, air floats, blowers, dosing pumps and other executive parts, and realize the centralized control of each unit [14].

The whole control system mainly consists of three parts, namely, the core part of a PLC system, the field instrumentation part and the upper computer monitoring part. The operator can operate the keyboard by PC in the control room to control the field equipment remotely, and also can control all kinds of equipment manually by button box in the field. I/O module completes data scanning, data sets, digital input/output, linearization, process point quality judgment, engineering unit conversion and so on. All I/O modules have LED status display and other diagnostics display, such as module power indicator. All control and protection

loops digital input signals are guaranteed to be scanned and updated at least 4 t/s, and all analog signals at least 2 t/s.

In the control room to add a PLC cabinet, a set of low-voltage electrical cabinets. In addition, an operation table is added, and a PC monitoring machine is arranged for the operator to operate and control. The control cabinet and wiring shall meet the following requirements: the cabinet door shall be sealed with a conductive door pad to improve the ability to resist radio frequency interference. The design of the cabinet meets the requirement that the cable is introduced from the bottom of the cabinet. For PLC cabinets, forced heat dissipation is used to provide exhaust fans. Each terminal row and terminal in the cabinet shall be clearly marked and shall conform to the drawing and wiring list.

## 2.3. PLC programming

The programming software is STEP 7, which adopts the integrated and unified architecture of SIMATIC software, and provides a powerful and consistent software platform for the easiness and friendliness of PLC programming configuration and the integration with the upper unit state system [15].

Firstly, according to the hardware configuration of the PLC module in the STEP 7 development environment, the power module, CPU module, communication module and I/O module are inserted into the corresponding guide rail.

After completing the hardware configuration, click the download function button, and download the hardware configuration to the current PLC. If the fault red light on the panel is not lit, the model and parameters of the current hardware configuration and the actual PLC module are matched. The current CPU 315-2 DP is CPU 315-2dp with a maximum power-down hold area of 2048Kbyte, since the program is not very large, basically, all data can be stored without power. The programming method adopts the commonly used LAD (trapezoid diagram) method, and the trapezoid diagram and the circuit diagram are very similar, and the symbols adopted are similar to the symbols used in the electrical design, such as contacts, coils, etc. This programming method is suitable for technicians familiar with the contactor control circuit.

## 3. Software design of a monitoring system based on LabVIEW

The upper computer monitoring software is developed and generated by the LabVIEW programming platform of the National Instrument Corporation of the United States of America and completes data collection, automatic control of equipment, fault alarm, parameter trend display, historical data query, Internet network monitoring, Global System for Mobile Communications wireless Short Messaging Service query and control and other functions.

### 3.1. LabVIEW development platform

#### 3.1.1. Virtual instruments and LabVIEW

The concept of a virtual instrument system is a breakthrough to the traditional instrument concept and is the product of the combination of instrument technology, computer software and hardware technology, network and communication technology. In recent years, the technology of virtual

instruments represented by LabVIEW has developed rapidly. With the powerful computing function of the computer and the corresponding hardware, the limitation of the traditional instrument in data processing, display, transmission and processing has been broken through, so that users can maintain, expand and upgrade it conveniently [16]. At present, LabVIEW has some successful applications in the field of fermentation process monitoring and automatic control.

LabVIEW is a G language, a graphical programming language. Using data flow programming, the data flow between nodes in the block diagram shows the VI and the execution order of the function vividly. It is quite different from the traditional text programming language in that the sequence of statements or instructions determines the execution order of the program. LabVIEW provides many appearance controls, and traditional instruments such as oscilloscopes, multimeters and other similar controls, making it very convenient to create a user interface.

In LabVIEW's block diagram, with icons and wires, you can programmatically control the object in the front panel, which is the graphical source code. LabVIEW was originally designed for testing. Up to now, it has unparalleled status and advantages in the field of testing and has been widely recognized. Today, many mainstream data acquisition devices are equipped with LabVIEW drivers, and users can easily find a variety of LabVIEW toolkits for the testing and measurement field. It is much easier for users to build on these toolkits, which cover almost all of the functionality they need. Sometimes even a few functions in the toolkit can be simply called to form a complete test and measurement application. So that users can use LabVIEW convenient control of the operation of equipment, and high precision, high-speed data acquisition.

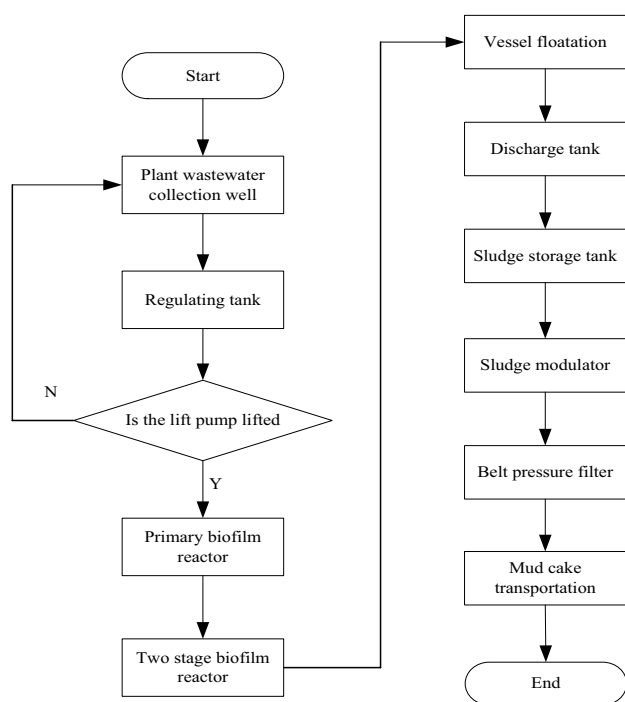


Fig. 1. Flow chart.

### 3.1.2. Development of monitoring configuration software

Monitoring and control configuration software is an important part of industrial application software. Its development is restricted by many factors. In the final analysis, it is driven by the application. The industrial process of foreign developed countries is relatively early, its industrial automation technology is relatively mature, configuration software products of the following companies occupy a large share in the market.

The use of LabVIEW in control is very widespread. Control and testing are two highly correlated areas, and LabVIEW, which started in the field of testing, naturally expanded to the field of control first. LabVIEW has modules dedicated to the control domain – the LabVIEW datalogging and supervisory control. In addition, the commonly used devices and data lines in the industrial control field usually have corresponding LabVIEW drivers. LabVIEW can be used to program various control programs very conveniently.

## 3.2. Functional design of the monitoring system

### 3.2.1. Establishment of a communication connection between LabVIEW and PLC

The NI LabVIEW platform can communicate with any PLC in various ways, and this paper adopts the OPC model. OPC is a process control technology based on Microsoft Object Linking and Embedding, Building Object Model and Distributed Component Object Model. Using OPC technology, the seamless integration of field equipment, process management and information layer can be realized conveniently. OPC server is suitable for almost all PLCs and production activity control.

The system adopts Siemens S7300 series PLC, which is widely used in industrial process control. For this series PLC, there are two ways to set up the OPC server in the upper computer. One way is to set up OPC. SIMATIC. NET server for S7300/400 PLC through Siemens' SIMATIC. NET software. The precondition is to install Siemens CP communication card for IPC, which is divided into three steps, the flow is shown in Fig. 2.

First, after installing SIMATIC. NET, configure the site name, address, communication method, and parameters in the Station Configurator for the OPC server you want to establish. After PC installs SIMATIC. NET, open the site configuration window, select the OPC server in the add component window, add CP5613, assign MPI address, baud rate and other parameters. In the interface configuration interface, point S7 ONLINE to PC internal, and then set CP5613 interface parameters, compile and store configuration [17]. Then confirm in the Configuration Console that the mode of the module is Configured mode, and in the access points set the interface parameter for S7 ONLINE to CP5611 (MPI). Under the project management directory of SIMATIC Manager, create a new SIMATIC PC site with the same site name as the one configured in the Station Configurator. In the network configuration, further, configure the address of the object to be connected according to the actual situation. Confirm all configurations. The established S7 connection will be displayed in the current connection table, then compiled and saved, and downloaded to the PC

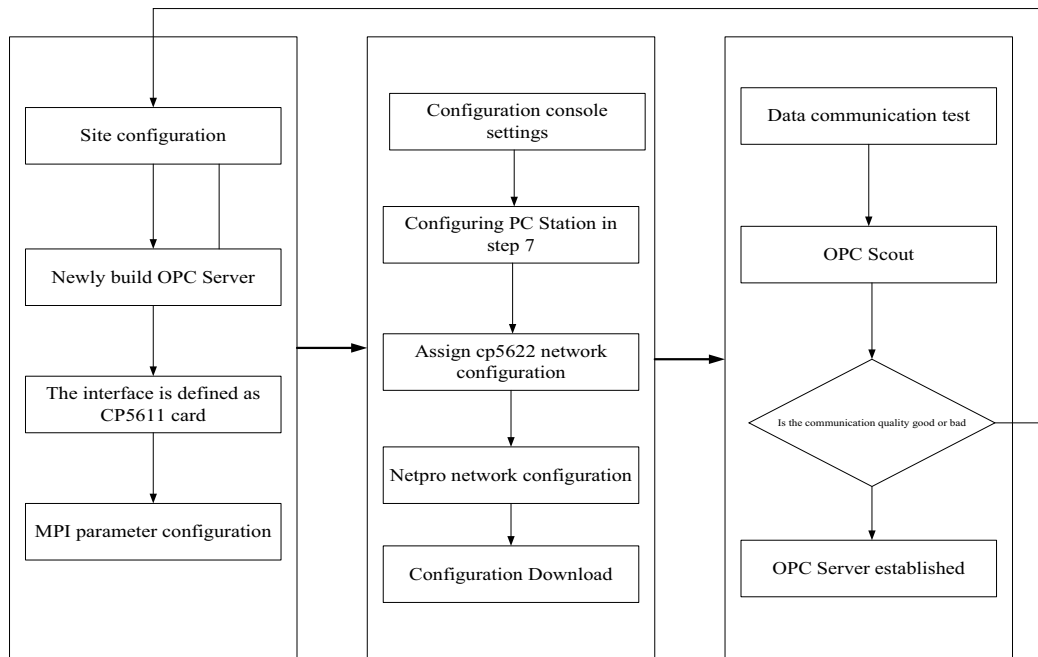


Fig. 2. OPC server setup process.

Station. Finally, in the Local Serves in OPC Scout, select OPC. SimaticNET, add a new group (Group) and add the desired target item (item) within the group. If the quality of communication is good after the completion, the communication is successfully established.

The built-in DataSocket library in LabVIEW has the functions of opening DataSocket, reading DataSocket, writing DataSocket, selecting URL and closing DataSocket. The program starts by establishing a connection with the data register that opens the DataSocket function and the corresponding OPC server to which the specified address string points, or by using the DataSocket chosen URL function if the specific address of the target data is not previously found. If you establish a 51-byte connection from IB0 in the digital input module of S7-300 PLC, change to localhost so that the program can connect to the PLC regardless of the hostname of the software.

### 3.2.2. Access to the SQL database by LabVIEW

When using the LabVIEW platform to develop applications, it is unavoidable to interact with the database. Users can use the database to store, read, induce and analyze information.

LabVIEW is an open programming platform that provides various interfaces for users to access databases and provides good support for current mainstream databases such as Microsoft SQL Server, ACCESS, Oracle, DB2, etc.

This system uses two methods to connect to the SQL Server database.

- Make use of the LabVIEW SQL Toolkit function toolkit provided by NI Company for database access, including common sub-functions such as database connection, table

creation, data selection, data insertion, data deletion, etc., as well as some advanced functions through which users can perform various operations on the target database.

In addition to using the official NI toolkit, there are some LabVIEW enthusiasts who have developed their own toolkits, LabSQL is one of the most widely used. Copy the subroutines from the toolkit into the user.lib folder in the LabVIEW installation directory, and you can call them directly from the LabVIEW programming environment. In order to compare the communication rates between the two connection methods and the database, two double-precision values are selected to write into the corresponding two columns of the target table of the SQL Server database [18]. Compare the communication time, as shown in Table 1.

As you can see from Table 1, the time taken to write to the database once is essentially the same, with the primary time used to establish the connection channel, and the advantage of LabSQL communication time becomes more and more obvious as the number of communications increases. However, LabVIEW SQL Toolkit contains many security and fault-tolerant mechanisms, which can prevent the client from competing with each other, protect

Table 1  
Connection to SQL Server Communication Time (ms)

Tool	LabVIEW SQL Toolkit	LabSQL
1	1,014.38	936.45
100	1,152.36	1,014.26
1,000	2,295.56	1,577.14
10,000	14,420.25	6,467.25

the connection and ensure the stability of communication. Therefore, the two methods cannot be generally concluded which is better and which is worse, so it is necessary to choose the method of accessing the database according to the actual situation.

If the user is familiar with the low-level code of Microsoft ADO, he can call Microsoft ADO control with ActiveX function in LabVIEW, or write a DLL program with C, C+ and other languages, access the internal program of LabVIEW through its internal DLL interface, and access the database file indirectly. These two methods need to have a deeper understanding of the database and related programming languages, and the programming workload is larger, it is not easy for most designers to implement, generally rarely used [19–21].

### 3.2.3. Development of monitoring software

The system is developed for a sewage treatment plant of a dairy group in Shanghai. The whole process includes grid wells, water collecting wells, accident pools, regulation pools, moving bed biofilm reactors, primary sedimentation pools, air flotation, secondary sedimentation pools, sludge pools and other treatment units. The equipment includes mechanical grid, mixers, submersible pumps, multiple dosing pumps, roots blowers, dissolution devices, sludge screw pumps and other electrical equipment, and the whole process of water treatment is monitored by the upper computer. The operation interface of the upper computer is divided into process flow, equipment control, real-time trend, historical data and curve, fault alarm and report output.

First is the password login system, the user in the login, the system can edit the user and authority. In the login page can change the user name and password, add or delete users, change user permissions and so on. Double-click on a row to change its name, password, and permissions. Only the administrator has permission to add or delete users.

In the interface of process flow, the whole process of water treatment can be seen intuitively. Each equipment has three indicator lights: running, stopping and failure. The operator can detect the current running state of the equipment in the monitoring room. The data collected by the field sensor such as liquid level, temperature, pH and DO are displayed in this interface.

In the equipment control interface, the user can set up parameters such as the upper and lower limit of the liquid level, motor speed, etc. Each equipment control function block is provided with the button of an automatic switch, start and stop, and the user can set the equipment control mode according to the actual control requirements. At the same time, the system accumulates the running time of the motor in the equipment and stores it into the database for convenient maintenance and inquiry.

In the real-time display interface, the system parameters such as temperature, pH, DO, flow can be displayed through the curve chart, the operator can adjust the control mode according to the curve trend chart.

In addition to the above interface, the system also includes a user management interface, alarm interface, history data query interface and report interface. Because LabVIEW has a powerful development function, developers

can flexibly add functions according to the needs of operators. MPI bus is used for communication between IPC and PLC, the transmission rate is 187.5 kb/s. A large amount of data transmission will result in slow response and slow program response, which will affect the control speed and accuracy of the system.

## 4. Electric parameter calculation and energy-saving optimization design of the control system

### 4.1. Scope of design and requirements

The technical standard of sewage treatment plants can be divided into two types of municipal engineering facilities. In the actual construction process, two 10 kV power sources are used as the external power sources, and the voltage of the external power sources is 380 V. Through such treatment, the standby power sources can continue to supply power when any power source of the whole system fails. Therefore, the line capacity is arranged according to the technical standard needed for the long-term scale.

Usually, a single 400/230 V is used as the load voltage level of the tailrace depth treatment plant. The control voltage load of the tailrace depth treatment site is composed of two parts, one is auxiliary electric load and the other is dynamic load. The main power equipment shall calculate the power load according to its working capacity, the small equipment shall calculate the power load according to the method of demand coefficient, and the auxiliary power for production shall calculate the power load according to the method of power consumption index per unit area. If the concurrent coefficient of the whole sewage treatment plant is considered as 0.9, the compensated power factor shall be about 0.95. Reactive power compensation in the plant is used in the general distribution room 0.4 kV side of the capacitor compensation cabinet centralized automatic compensation. The power factor at the 10 kV side of the compensated backfield area shall not be lower than 0.95. According to the requirements of the general sewage treatment system, the electric system of the urban sewage treatment plant is composed of a 10/0.4 kV transformer, 10 kV power distribution organization in the substation and distribution house, special low-voltage power distribution control equipment, and a large number of motors, cables and other process equipment distributed throughout the sewage treatment plant. From the test results, it can be known that the main source of the electrical loss of the system is the above equipment. In view of the above factors, the energy-saving design focuses on the following aspects to improve, the most important is the location of the main transformer distribution room, key transformer performance matching, cable losses, low-voltage distribution mechanism reactive power compensation processing and the motor selection and control to further improve the treatment.

### 4.2. Energy saving measures for transformers

The optimization of the energy saving of the transformer in the system is to speed up its operational efficiency and reduce its power loss fundamentally in the actual design. The active power loss of the transformer

includes two aspects, one is a short-circuited loss and the other is a no-load loss. Through qualitative calculation and analysis, it is found that the short-circuit loss is proportional to the square of load current. The load current is usually defined as a copper loss at rated value, also called short-circuit loss, and its magnitude can be calculated by formula 1. However, the no-load loss is only closely related to the material of the iron core used in the transformer and has little to do with the value of the load. If the system is in a normal state, it is a constant normal value.

$$\Delta P = P_0 + K_T B_2 P_K \quad (1)$$

where  $\Delta P_K$  is the active power loss;  $P_0$  is the transformer no-load loss;  $P_K$  is the transformer short-circuit loss;  $B_2$  is the transformer load rate.  $K_T$  is a load fluctuation loss coefficient. In general, the following measures are taken by the sewage treatment plant in terms of transformer energy saving:

- Selection of transformers is generally based on load loss and no-load loss at a relatively low value, such as transformer S9, S11 series can meet the technical requirements.
- Load rate of transformers shall match the design requirements of the sewage treatment plant as a whole.

When calculating the load factor of the optimal efficiency of the transformer, the average load factor of the load curve is usually multiplied by a multiple greater than 1, but it should not be too large, about 1–1.3, and then the loss ratio of the transformer can be easily calculated. In the treatment of the scheme, we make a reasonable calculation of its capacity according to the load rate when the transformer has the highest efficiency. According to the experimental data, it can be concluded that when the copper loss and iron loss of the transformer are the same, its energy consumption is the lowest. At this time, the output power  $P_0 = K_T \times B_2 \times P_K$  of the transformer, due to the  $P_0/P_K = 1/3 \sim 1/4$  of the general transformer, when the load rate is around  $B_2 = 50\% \sim 60\%$ , the energy consumption of the transformer is also the minimum value. However, if the selection of the transformer is based on  $B_2 = 50\%$ , the cost of investment, land occupation and transportation will increase sharply. Based on the above consideration of transformer selection, in the actual implementation, many factors need to be balanced, such as initial installation cost, land construction investment cost, operation and operation cost, etc., not only that but also should be retained in the service life of the transformer. Therefore, in order to make the transformer in the most energy-saving state, its load rate should be between 75% and 85%.

- Handling of reactive power compensation for low-voltage distribution systems

Through a large number of measured data, it is shown that the power factor of the low-voltage line and the low-voltage network can be improved to a certain extent by connecting a matching capacitor in parallel on the whole load of the system, thereby reducing the loss of the line and stabilizing the terminal voltage fluctuation.

Because of the stability of the system operation, the compliance of the sewage treatment plant is generally located in a relatively concentrated area. Therefore, if the geographical location of the low-voltage distribution house is in the center of the load, the compensation method of the low-voltage distribution centralized is preferred. Only through such treatment, the 10 kV side power factor can meet the design requirements, that is, not less than 0.95, achieving the goal of energy saving.

#### 4.3. Transformer power load calculation

In general, 0.4 kV low-voltage side with the compensation method for reactive power load compensation processing. After this treatment, the 10 kV side power factor can meet the design requirements of not less than 0.95.

Conversion of low-voltage side-load to high-voltage side load of the transformer:

- Transformer loss

Active power loss:

$$\Delta P_r = \Delta P_0 + \Delta P_K = 0.84 + 4.14 \times \left(\frac{471}{500}\right)^2 = 4.51(\text{kW}) \quad (2)$$

Reactive power loss:

$$\begin{aligned} \Delta Q_r &= S_N \times \left[ \frac{I_0}{100} \% + \frac{U_K}{100} \% \times \left( \frac{S_{30}}{S_N} \right) \right] \\ &= 500 \times \left[ \frac{1.0}{100} + \frac{4}{100} \times \left( \frac{471}{500} \right)^2 \right] = 25.74(\text{kvar}) \end{aligned} \quad (3)$$

where  $S_N$  is the apparent power of transformer load.

- High-voltage side load of transformer

$$P_i = P + \Delta P_r = 397.96 + 4.51 = 402.47(\text{kW}) \quad (4)$$

$$Q_i = Q + \Delta Q_r = 162.29 + 25.74 = 188.03(\text{kvar}) \quad (5)$$

$$S_i = \sqrt{P_i^2 + Q_i^2} = \sqrt{402.47^2 + 188.03^2} = 444.2(\text{kVA}) \quad (6)$$

where  $P$  and  $Q$  represent the equipment power of the electrical equipment group respectively, and  $\Delta Q_r$  and  $\Delta P_r$  represent the tangent value of the power factor angle of the equipment respectively.

Power factor:

$$\cos \phi_1 = \frac{P_i}{S_i} = \frac{402.47}{444.2} = 0.906 \quad (7)$$

Load rate of transformer:

$$B = \frac{S_i}{S_N} = \frac{444.2}{500} = 88.8\% \quad (8)$$

## 5. Experimental results analysis

Take membrane bio-reactor (MBR) control station as an example, its control scope includes: membrane water production system, maintenance line cleaning system, restorative cleaning system, air duct backwashing system, surplus sludge system, mixed liquid reflux system, instrument air system. Traditional control of the MBR membrane unit of the water production pipe flowmeter and pump inverter for Proportional-Integral-Derivative Controller (PID) control, constant flow water, according to the water situation manually set the membrane unit water production. In fact, the inflow of municipal wastewater treatment plant is unstable, especially at night, which causes the team operators to pay attention to the inflow at night, and manually adjust the output of each MBR membrane unit according to the inflow, so the operation intensity is very large. Based on the constant flow control of each MBR membrane unit, the inlet channel level of the membrane pool is controlled so that the inlet channel level of the membrane pool is controlled within a set range. According to the liquid level PID curve, the set liquid level value is consistent with the feedback value of the liquid level transmitter, which can meet the actual operation requirements.

The specific control method is as follows: the inlet channel level of the membrane pool shall be set at 3.9–4.1, and the value of the inlet channel level meter shall be collected at regular intervals (liquid level judgment cycle). In the judging period of liquid level, if the liquid level is higher than the set range, the water production pump will increase the flow rate according to the set flow increment value, otherwise reduce; if the liquid level is within the set range, the flow rate of the water production pump will not change. On the contrary, when the change of the inflow water is small, the increase and decrease of the inflow water yield should be small, and the judging period of the inflow water level should be prolonged.

In the process of sewage treatment, the representative parameters are influent flow  $Q$ , pH, temperature  $T$ , DO, turbidity suspended solids, chemical oxygen demand (COD), biological oxygen demand (BOD) and other major indicators. In addition to BOD, other parameters have been online monitoring equipment on the market, including COD. In recent years, Hash Company has developed online monitoring equipment, and now many sewage treatment plants have purchased and used it. But the online monitoring equipment of BOD parameters has not appeared on the market yet. At present, the monitoring means is the laboratory biological culture, the average time needs about 5 d, the time is long.

A total of 30 d of data were selected, respectively, 5, 10, 15, 20, 25 and 30 d of data, the specific results as shown in Table 2.

The data of the first 25 d in the table are selected as the training samples of the neural network, and the last 5 d are used as the test samples to verify the prediction results, as shown in Fig. 3.

As shown in Fig. 3, the real-time curve shows the real-time monitoring data in curve form. There are three curves, which show the important data of liquid level, pressure and turbidity. Transverse foot time scale, the longitudinal axis for the actual value of the scale maximum value of 100.

The history curve shows the historical values of the monitoring data through the variation curve. In order to query, the query criteria can be set on the screen to query the history curve, so as to obtain the information needed by the query. First of all, we need to set the time period of the query. After the query parameters are set up, the numerical curves to be queried are represented by different colors. You can also check the curves you want to display, and the selected curves are displayed in the plotting area.

The alarm system includes a fault alarm and an over-limit alarm. When the alarm system, the corresponding parameters or equipment in the corresponding screen flashing alarm, until the restoration of normal conditions, at the same time the alarm time and the actual situation of storage, send out the alarm signal. According to the alarm function, the “reset” button is designed, its role is to eliminate the alarm, through the operation of the “reset” key, so that the interface signal disappeared, return to its normal state. Click on the “night screen” button, enter the alarm interface, you can see the name and type of the report, as well as the date of production and specific. According to the actual situation of the site and customer requirements, classification of the newspaper. According to the type of inquiry, the alarm is generally divided into two types: historical alarm and real-time alarm. They have confirmed alarms and unconfirmed alarms. Plant personnel may perform specific operations according to actual requirements.

Network output data regression analysis as Fig. 4, target for the network output value, the graph R represents the regression coefficient, the value of about 1, the better regression coefficient.

As can be seen in Fig. 4, the R correlation coefficient is 0.98826, which shows that the model has good generalization ability and is reliable for predicting BOD parameters in water treatment. Let's select the last 5 d of data to verify the established model, as shown in Fig. 5.

From Fig. 5, we can see that the estimated value of the network is very close to the measured value, which can reflect the actual operation effect. Table 3 shows the statistics of the estimates.

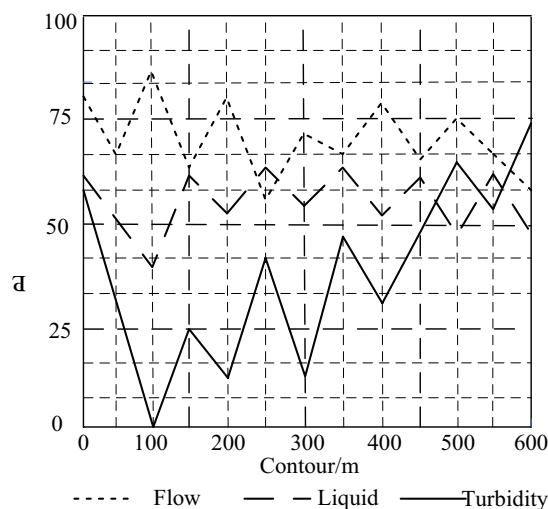


Fig. 3. Real-time trend curve.



From Table 3, we can see that the error range is within 2%, and the fitting precision of the model is high. Therefore, the network can reflect the actual operation of sewage treatment and the prediction results have high credibility. The experimental results show that the system is close to the real measured value, with small error, high stability and high practicability.

### 6. Conclusion and expectation

#### 6.1. Conclusions

Based on a sewage treatment plant and combined with the sewage treatment technology, an automatic control system for sewage treatment is designed. Using LabVIEW virtual instrument development platform, OPC server and Siemens S7-300 PLC are established through SIMATIC. NET. SQL Server is used as the backstage database to realize the data collection and equipment control, and the system is released to the Internet through the WEB tool embedded in LabVIEW to realize remote online monitoring. Global System for Mobile Communications wireless communication module is used to query the real-time data of the system by Short Messaging Service. The application shows that the system runs stably and reliably,

and can realize the centralized and remote monitoring of the water treatment process. By using the RBF neural network and many related parameters in the process of water treatment, a set of a soft-sensing model for predicting BOD parameters is established.

#### 6.2. Expectation

With the rapid development of modern internet technology, we can look forward to the day when we can have direct access to the electrical automatic control system of sewage treatment plants through the internet, and remote monitoring and control of sewage treatment plant equipment

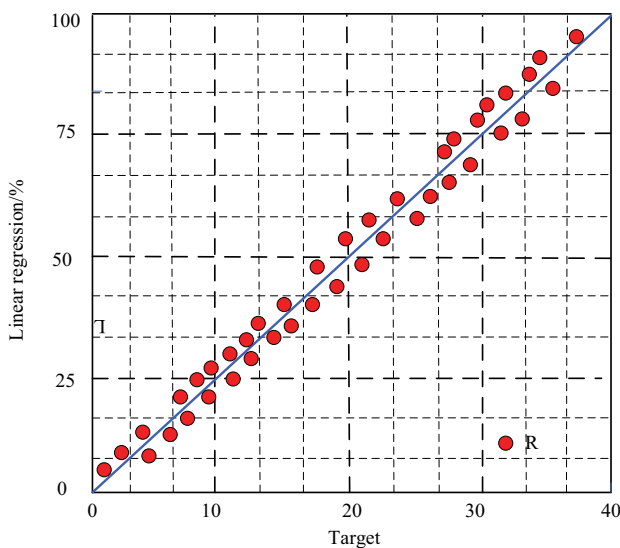


Fig. 4. Linear regression analysis of model training.

Table 2  
Samples of water treatment parameters

Sample number	Q (m <sup>3</sup> /h)	COD (mg/L)	TSS (mg/L)	DO (mg/L)	PU: sterilization strength value	T (S°C)	BOD (mg/L)
5	110.69	214.09	196.75	1.15	7.73	18.55	9.13
10	199.01	150.64	96.93	1.80	7.92	22.76	8.05
15	200.34	111.12	152.26	2.34	8.15	21.85	7.18
20	188.34	207.66	166.79	2.22	7.53	21.90	9.04
25	184.21	156.98	84.24	1.53	8.16	21.74	8.13
30	184.86	144.78	30.76	0.45	8.15	21.75	8.15

TSS – total suspended solids; DO – dissolved oxygen; BOD – biological oxygen demand.

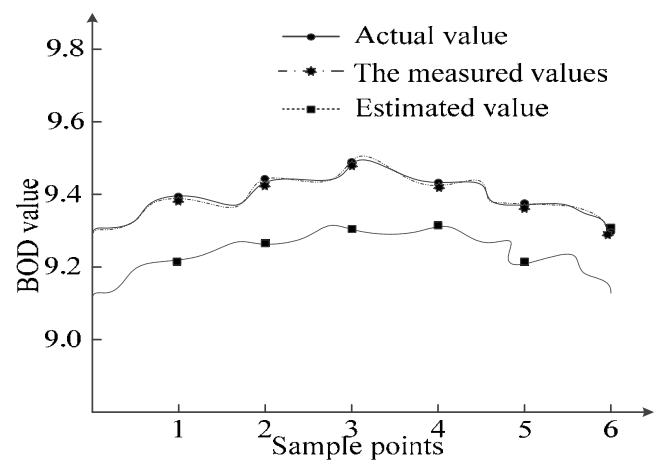


Fig. 5. Sample test results.

Table 3  
Relative errors

Sample number	Q (m <sup>3</sup> /h)	COD (mg/L)	TSS (mg/L)
5	8.34	8.21	1.63
10	7.47	7.53	0.73
15	8.81	8.68	1.47
20	9.32	9.38	0.63
25	8.11	8.17	0.77
30	9.18	9.05	1.05

COD – chemical oxygen demand; TSS – total suspended solids.

can be achieved by requiring only authorized user names and log-in passwords. The real-time sewage treatment data can be reported to the superior department through the internet to facilitate the management of the superior department in a timely and accurate manner.

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