Research Journal of Applied Sciences, Engineering and Technology 6(16): 2988-2992, 2013
DOI:10.19026/rjaset.6.3683
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: January 08, 2013 Accepted: January 31, 2013 Published: September 10, 2013

Research Article

The Study on Integrated Control System of A/O Sewage Wastewater Treatment Process

Jiangzhong Yu, Jihong Shan, Lijun Sheng and Yi Sun
Key Laboratory of E and M, Zhejiang University of Technology, Ministry of Education, Zhejiang Province, Hangzhou 310032, China
Hangzhou Hengda Environment Protection Industrial Company Limited, Hangzhou 310032, China

Abstract: Aim to solve problems of the low automatic level, high energy consumption and high labor intensity in the process of sewage treatment and combing with the actual control requirements of the worksite, this study introduces an integrated control system of sewage treatment. The system bases on the S7-300PLC, inverter and KINGVIEW software. The methods of controlling, testing and management in the process of sewage treatment via the integrated control system which consists of PLC, KINGVIEW and PC were presented. The study also discussed the content of sewage treatment process, the component structure of control system, the control principle and the design of hardware and software in detail. Finally, the results proved that the system can operates reliably and effectively.

Keywords: Inverter, PLC, sewage treatment

INTRODUCTION

As we all know, it is not suitable for workers to operate the equipments in the field because of the harsh environment, the complex condition and so on in the sewage treatment plant (Wang *et al*., 2011). So it becomes a development tendency of modern sewage treatment industry that the process of sewage treatment can be achieved via automatic control and remote monitoring. This study presents an energy-saving and integrated automatic control system of sewage treatment which bases on the MPI network. The system is designed for the production process wastewater of a new material factory. The system consists of host computers and lower machines respectively, which include IPC (Industrial Personal Computer), KINGVIEW and S7-300 series PLC of siemens, smart instrumentations and connected the components together via KINGVIEW software (Taira *et al*., 2003). This system can carries out real-time monitoring and centralized management of the collected data such as the field, screen monitor, parameters setting, command control and other functions. It is convenient for workers to check any time.

THE PROCESS OF SEWAGE TREATMENT

The sewage treatment plant uses the improved A/O (Anoxic/Oxic) sewage treatment process as the biochemical treatment process (Zhu *et al*., 2005). Some of processed sewage is reused and the other is discharged into river after it satisfies sewage discharge standards. The process flow is shown as Fig. 1. The sewage flows into catchpit through bar screen machine and then it is sent to floatation tank by sump pump and flows into hydrolyzation and acidification pool after floating later. The PH (Potential of Hydrogen) of sewage is adjusted. The sewage is lifted to anaerobic jar by high-concentration sewage lift pump next. And the sewage flows into mixed regulation pool after anaerobic treatment and then it is lifted to A/O biochemical pool by mixed lift pump for aerobic treatment. Some sewage flows into mixed regulation pool and some flows into radial flow sedimentation tank. The supernatant water of sedimentation tank flows into the water effluent pool after disinfecting. The bottom sludge of sedimentation tank flows into anaerobic jar partly for reusing by return-sludge pump and the other flow into the sludge dewatering room to dispose for sinotrans.

Integrated control system for the sewage treatment: The structure of system is shown as Fig. 2. The key of this control system is the PID aerating system which bases on the inverter. The system acquires data of various sensors by connecting with the real inspect equipments. S7-300 PLC and the host computers are connected together by CP5611 communication card to achieve the deliveries of equipments working states, sensors' working parameters and control commands. According to HTTP protocols, web service interface of the system is established by utilizing the function of

Corresponding Author: Yi Sun, Zhejiang University of Technology, Hangzhou 310032, China, Tel.: 13515816690

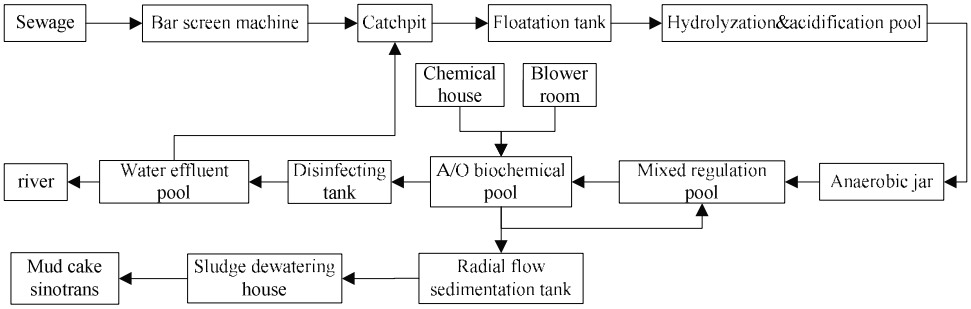


Fig. 1: The process flow of sewage wastewater treatment

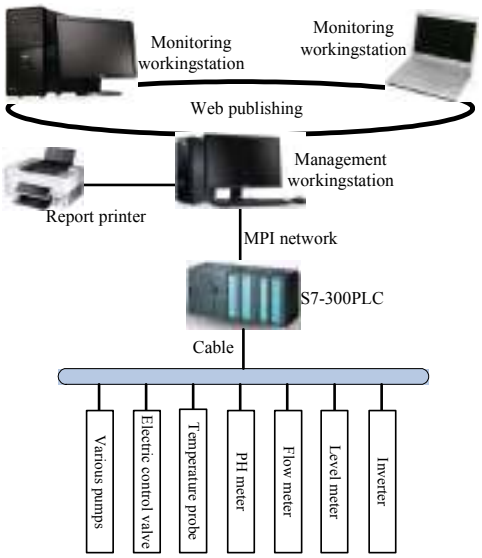


Fig. 2: The structure of system

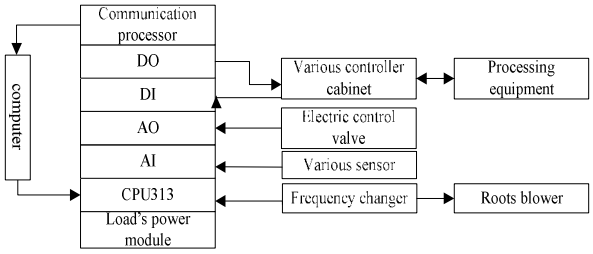


Fig. 3: The system hardware configuration

KINGVIEW'S web publishing so that the remote network terminals can call conveniently. In order to communicate with sewage treatment equipments via remote control, the remote terminals must be able to call the web service or web explorer.

THE HARDWARE CONSISTS OF SEWAGE TREATMENT INTEGRATED CONTROL SYSTEM

According to the control objects and system's design commands, the system adopts siemens-313C as the working host computer and the relevant modules are chosen to configure the system hardware. The S7-300 system hardware configurations are shown as Fig. 3.

The hardware consists of KINGVIEW monitoring system: In the system, the monitoring computer is Dell OptiPlex390MT CPU, 2G RAM. King view and S7-300PLC are connected by MPI drive. It can realizes the following functions by combining with PLC control program (Su *et al*., 2011):

- It can display the running states of the equipments and sensors' parameters in this system. The main picture provides a better system monitoring interface for managers and workers, which can display the whole process of sewage treatment, the work states of pumps and valves, liquid level, quantity of flow, temperature, PH, frequency of inverter and so on.
- It can display equipments failures and warning function. This system can automatically disposes the events and alarms. While failures happen, for example the thermo relay is overload protection or the breaker trips, the event can be clearly shown in the picture. When alarms happen, for example the excessive liquid level and temperature, this system can quickly detect and pop up the alarm prompt picture. And the corresponding alarm text can be shown or printed and an alarm sound ring out to prompt workers' attention.
- **Checking the run report, operating record, real-time curve and accident record:** The numerical value of various analog quantities of the controlled objects can be recorded and displayed on the pictures by curves or data list. At the same time, the worker' operation for equipments can be recorded into the access database in order to freely query for managers.
- Some equipment can realize automatic control by operating on the interconnected control picture. Here the interconnected control can be set the interconnected control and the pumps can start or stop when the floater moves up or down based on the signal of liquid level in the pool. If the liquid

level is lower than the setting value, the pump stops and when liquid level is higher than the first setting value, only one pump runs and when liquid level is higher the second setting value, two pumps run automatically.

- **The user management functions:** In order to control the equipments, the users should log in firstly and according to the users' authority, the system automatically judges the users' authority to control the equipments.
- **The web publishing functions:** Other users can load the monitoring pictures by web explore if the host computer publish the pictures.

THE SOFTWARE DESIGN OF THE SYSTEM

The control strategies of hardware equipments in the system:

The PID closed-loop for opening of electric control valve: In the sewage treatment integrated control system, the opening of electric control valve and steam control valve are controlled by PID closed-loop so that the regulation pool can has a relative temperature by controlling the flow velocity and flow quantity of hot water. Here, the position-type PID control algorithm is:

$$u(k) = K_p\{e(k) + \frac{T}{T_1}\sum_{j=0}^{k} e(j) + \frac{T_D}{T}[e(k) - e(k-1)]\}$$

By using PID unitary parameter tuning method, the above formula is:

$$\Delta u(kT) = K_p\{2.45(kT) + 3.5[(k-1)T + 1.25e(k-2)T]\}$$

By setting one parameter like KP instead of setting four parameters like T, K_P, T_1, T_D, it can simplifies the problems and the closed-loop control scheme is shown as Fig. 4.

The temperature of regulation pool is acquired by S7-300 and the analog signal is converted to digital signal by A/D. Compared with the temperature setting value, the error can be calculated. The opening of electric control valve can be controlled by outputting control signal of PID regulator. The temperature eventually can be maintained between 30 and 40°C.

The inverter controls the speed of fan: In this system, fan is one of the main energy-consumption equipments. However, considering the energy-consumption factor, the concentration of dissolved oxygen of A/O biochemical pool can be controlled by adjusting the speed of fan. So the speed of fan is adjusted by inverter. According to the dissolved oxygen in sewage, this system adopts quadratic rate load for inverter to adjust the speed of fan (Li *et al*., 2011). The characteristics of blower's torque and power are:

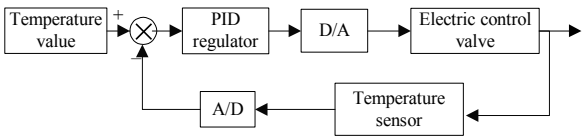


Fig. 4: The closed-loop control scheme

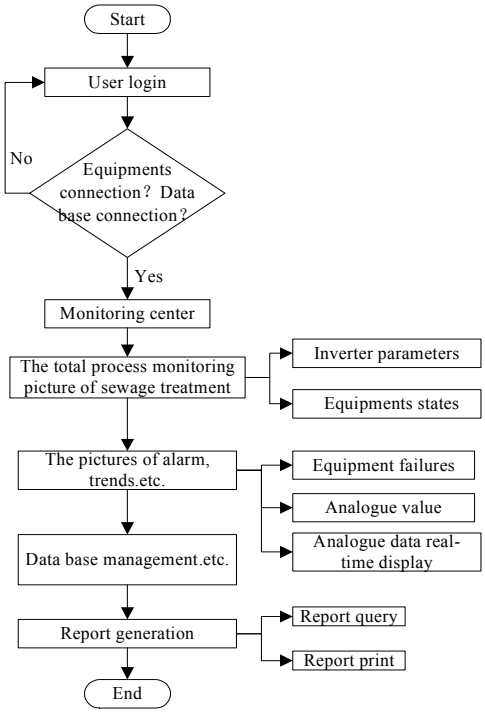


Fig. 5: The design flow of KINGVIEW

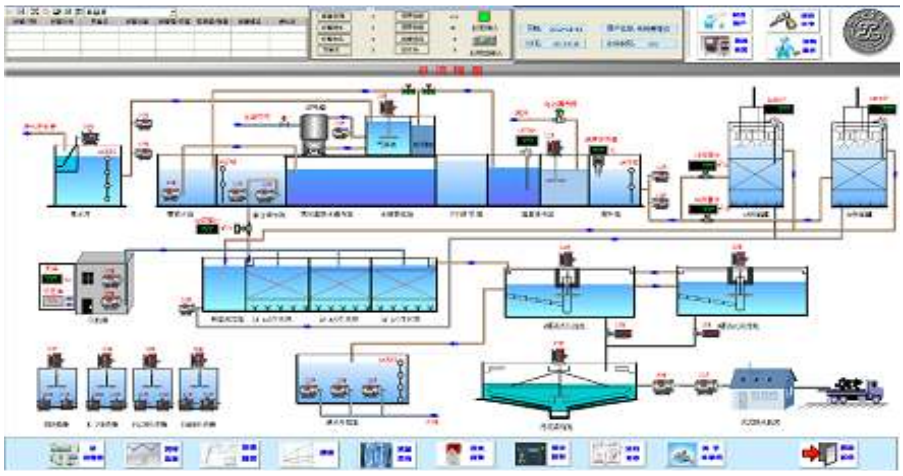
$$T_L = K_T n_L^2 \quad P_L = K_T n_L^2 n_L / 9950 = K_P n_L^3$$

where,

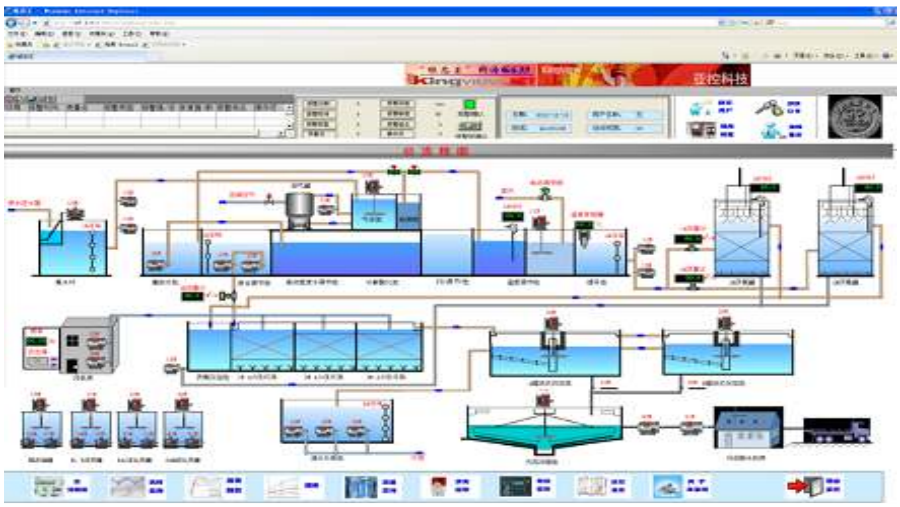
T_L = Quadratic rate load torque
P_L = Quadratic rate load power
n_L = Quadratic rate load speed
K_T = Quadratic rate load torque constant
K_P = Quadratic rate load power constant

In the above formula that the torque is proportional to the speed's square and the power is proportional to speed's cube. So when the oxygen requirement is decreasing, the line frequency can reduce the speed of blower by inverter. The torque and power can be more greatly reduced and the energy-saving target is achieved (Bae *et al*., 2003).

The monitoring software design: The design quality of monitoring software is closely reponsed to control result and the safety of user and equipment (Gustaf, 2012). So it is extremely important to develop a set of perfect function and high reliable software. According to the actual requestments and condition, the design flow of the software is shown as Fig. 5.



(a)



(b)

Fig. 6: (a) The main picture of monitoring system, (b) the web publishing page

Firstly, the user should enter into the login interface and input correct username and password. While passed user check and equipment and data base connected successfully, the monitoring center will be shown. Otherwise, it will return the login window. In the monitoring center, users can click the bottoms at the below of the desktop to switch the different pictures. If the current picture is the whole flow picture of sewage treatment, users can view the running state of equipments and set the running parameters of inverter and so on. The alarm, trend curve, running log and other information can be seen via changing the pictures by users.

RESULTS AND DISCUSSION

The main monitoring picture of the system is shown as Fig. 6(a). In the picture, the running states of equipments, running parameters and the reasons of equipment's failure can be got clearly in the picture. And the on-off control of motors and inverter parameters can be controlled. The web publishing pages is shown as Fig. 6(b) and it runs basically stable. Even though it has a bit of delay when you change the picture, this doesn't affect the monitoring result. And image transmission and real-time control can synchronously process. Because the web publishing doesn't support active controls, data and curves can't be scanned expediently. The information of data list and related curves' information can be scanned on IE.

CONCLUSION

This system is designed for the sewage treatment plant of the new material factory. Now, the system has been running more than six months and the control system runs stable and reliable. Various indexes of water can reach depend on the design requirements after

the sewage is processed, the equipments run well and maintain expediently. The problems of scatter, complexity and uncontrollability of equipments are solved in sewage treatment plant. And this system reaches the advanced level in the same industry automation and satisfies the demands of saving energy and lower maintenance cost. The goals of unattended operation in worksite and fewer workers in central station are achieved in this sewage treatment plant.

ACKNOWLEDGMENT

The authors acknowledge to be supported by Zhejiang Province Science and Technology Development of P.R. China (Grant No: 2012C13006-1) and Advance Manufacture and Design Funding of Zhejiang University of Technology.

REFERENCES

Bae, H., M.H. Lee, Y. Kim and C.W. Kim 2003. Knowledge-based unmanned automation and control system s for SBR wastewater treatment process [J]. Artif. Life Robot., 7: 107-111.

Gustaf, O., 2012. ICA and me- A subjective review [D]. Water Res., 46(6): 1585-1624.

Li, J., 2011. Discussion on the application of control system of energy saving fan based on PLC and inverter [J]. Manufact. Automat., 33(12): 127-129.

Su, J. and Y. Hong, 2011. Research of remote monotoring and control system of energy saving control station based on PLC and king view [J]. Ind. Mine Automat., 37(2): 21-23.

Taira, H., T. Hiroshi, *et al*., 2003. Advanced treatment of sewage by pre-coagulation and biological filtration process [J]. Water Res., 37(17): 4259-4269.

Wang, Y., S. Chen, *et al*., 2011. Design of remote monitoring system for sewage disposal plant [J]. Comput. Measur. Control, 19(10): 2433-2436.

Zhu, Z., Y. Hu, *et al*., 2005. The application of the variable frequency drives for fan [J]. Coal Mine Mach., 7: 5-6.