Journal of Scientific Research & Reports

23(2): 1-10, 2019; Article no.JSRR.48476
ISSN: 2320-0227

Design of Domestic Sewage Treatment System Based on Programmable Logic Controller

Jinjin Dang[1], Yuxi Gu[1], Juncheng Zhou[1], Hexiu Huang[1] and Lijun Wang[1*]

[1]School of Mechanical Engineering, North China University of Water Resources and Electric Power, Zhengzhou, China.

Authors' contributions

This work was carried out in collaboration among all authors. Author JD designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors YG, JZ, HH and LW managed the analyses of the study. Author HH managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2019/v23i230119
Editor(s):
(1) Dr. Mahmoud Nasr, Sanitary Engineering Department, Faculty of Engineering, Alexandria University, Egypt.
(2) Dr. Prinya Chindaprasirt, Professor, Khon Kaen University, Thailand.
Reviewers:
(1) Ali Saber, University of Nevada, USA.
(2) Hen Friman, Holon Institute of Technology, Israel.
Complete Peer review History: http://www.sdiarticle3.com/review-history/48476

Original Research Article

Received 04 February 2019
Accepted 11April 2019
Published 20 April 2019

ABSTRACT

This paper focuses on the design of software and hardware for the purification and recycling of domestic sewage discharged from a residential area. According to the characteristics of domestic sewage, the process used in this paper is determined to be Sequencing Batch Reactor (SBR) process and the allocation of system input/output (I/O) port. According to the determination of the process flow to select appropriate instruments, sensors and other equipment, using Programmable Logic Controller (PLC) to design the system in manual mode and automatic mode of the program respectively, to achieve the function of sewage treatment.

Keywords: Domestic sewage; SBR; PLC; sewage treatment.

1. INTRODUCTION

Urban sewage mainly comes from residents' living and industrial production. Generally speaking, domestic sewage is the water discharged from people's daily life. With the rapid development of the social economy, the urbanization process is accelerating, which

**Corresponding author: E-mail: wljmb@163.com;*

makes the discharge of domestic sewage in the city gradually increase and the problem of water pollution is prominent. It is necessary to do a good job in sewage treatment to achieve sustainable urban economic development and protection of water resources. The centralized treatment of sewage needs to be completed in the treatment plant. However, the situation of emissions from the failure of domestic sewage treatment plants and treatment technologies is severe. And it is urgent to improve relevant laws and regulations and increase rectification efforts. Through the introduction of advanced treatment technology, optimization of existing processes, improvement of emission standards and other measures to reduce environmental pollution of urban sewage and improve the living environment of residents [1-2]. Automatic control of sewage treatment has great advantages in efficiency, capacity, cost and it can save costs in a wide range. When the economy and environment can balance each other, the application of programmable controller to master all the processes of domestic sewage treatment system will undoubtedly give a shot in the arm to economic development, social and environmental benefits. This paper is mainly aimed at the design of how to purify and reuse the domestic sewage discharged from a residential area. After selecting the appropriate technological process, the PLC is selected as the appropriate model, the automatic and manual mode implementation program are written.

2. INTRODUCTION AND SELECTION OF PLC

2.1 Introduction of Programmable Controller

The history of programmable controller began at the end of 1960s. In the process of the development of science and technology, PLC gradually replaced the relay control circuit in the past [3-4]. The first PLC developed in 1969 was used to control the automobile production line and the use of this let people get unexpected results. In the late 1970s, the relatively large scale integrated circuit appeared in people's field of vision, which led the PLC technology to the direction of large scale and high performance gradually. By the 1990s, PLC has developed very mature. It can communicate with equipment, generate reports and it has the function of self-diagnosis [5]. PLC is very different from computer. The characteristics of PLC are mainly shown in the following aspects [6]:

(1) The hardware has high reliability;
(2) Users can grasp quickly and easy to use;
(3) No complex wiring;
(4) Can be used as control network system;
(5) Simple installation and convenient maintenance.

2.2 Hardware Structure of PLC

The structure of programmable controller is the same as that of computer, including CPU (Central Processing Unit), memory and input/output (I/O) interface, etc. [4]. Its hardware structure can be divided into three categories. Among them, the unit structure is mainly suitable for small system. The characteristic of modular structure PLC is that each module has no relation with each other, which is mainly suitable for large system. The PLC of the stacked structure combines the characteristics of the unit type and the module type so that the unit type is compact and the modular configuration is flexible [7]. Fig. 1 is a simplified block diagram of PLC hardware system.

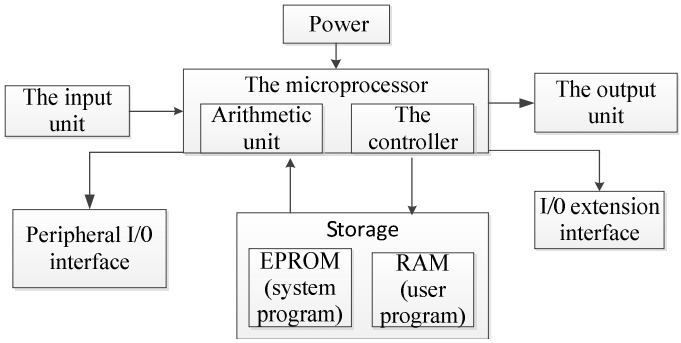

Fig. 1. Simplified block diagram of PLC hardware system

Table 1. I/O allocation table

The I/O allocation table			
Input		**Output**	
X0	Start	Y0	Grille cleaner
X1	Catchment high water signal	Y1	Sump feed pump
X2	SBR1 pool high water signal	Y2	SBR1 pool inlet valve
X3	SBR1 pool low water signal	Y3	SBR2 pool inlet valve
X4	SBR2 pool high water signal	Y4	SBR1 pool decanter
X5	SBR2 pool low water signal	Y5	SBR1 pool blower
X6	SBR pool manual feed switch	Y6	SBR2 pool blower
X7	Low water signal in the catchment	Y7	SBR1 pool outlet valve
X10	Emergency stop	Y10	SBR2 pool outlet valve
X11	Starting blower	Y11	Sludge pump
X12	Manual/automatic switch	Y12	High water level in the catchment
X13	Turn on the decanter	Y13	Low water level in the catchment
X14	Start the mud pump	Y14	High water level in SBR1 tank
		Y15	SBR1 pool low water level
		Y16	High water level in SBR2 tank
		Y17	SBR2 pool low water level
		Y20	SBR2 pool decanter
		Y21	Sludge pump

2.3 I/O Port Allocation of PLC

A total of 13 input interfaces and 16 output interfaces are used in the control system. Specific allocation information is shown in Table 1.

3. OVERALL DESIGN OF SBR PROCESS

3.1 Common Sewage Treatment Process

Commonly used sewage treatment processes are A^2/O process, A/O process and SBR process.

A^2/O process, A^2 represents anaerobic organisms and anoxic organisms respectively and O represents aerobic organisms. The process is mainly used for nitrogen and phosphorus removal. It has the combination of dephosphorization, denitrification and degradation of organic matter. However, this process can not achieve good results in nitrogen and phosphorus removal. If the concentration of dissolved oxygen is suddenly increased during the process, the effect of nitrogen and phosphorus removal will be poor. What's more, the A^2/O process requires a large land occupation. Therefore, it is more suitable for cities with large sewage water and high management level.

The A/O process consists of an A_1/O process for denitrification and an A_2/O process for dephosphorization, which is modified with an activated sludge process to combine anaerobic conditions with conventional activated sludge processes. The reaction cells are reciprocated in an anaerobic and aerobic staterespectively. A/O wastewater biological treatment technology will be a suitable choice when the wastewater to be treated requires only denitrification or dephosphorization.

SBR is the abbreviation of Sequencing Batch Reactor, which is an activated sludge wastewater treatment technology that completes the treatment process in continuous feeding, intermittent drainage and reciprocating intermittent aeration [8]. The SBR process has the following advantages: The push-flow process increases the driving force of the biochemical reaction and the efficiency is improved. The anaerobic and aerobic conditions in the pool are in an alternating state and the purification effect is good. The operation effect is stable and the sewage is precipitated in an ideal static state. What's more, it requires short time, high efficiency and good effluent quality. Thus, this paper takes the residential sewage as the design object. SBR process is the most suitable process under considering the local water quantity, economy and treatment effect. Therefore, the use of PLC to control the process involved in the motor valve and other equipment trend in order to achieve the purification of domestic sewage. Fig. 2 is the basic flow diagram of SBR process:

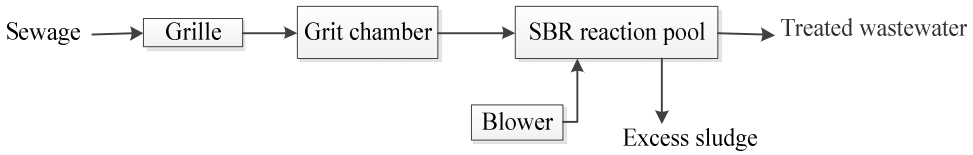

Fig. 2. SBR basic process flow chart

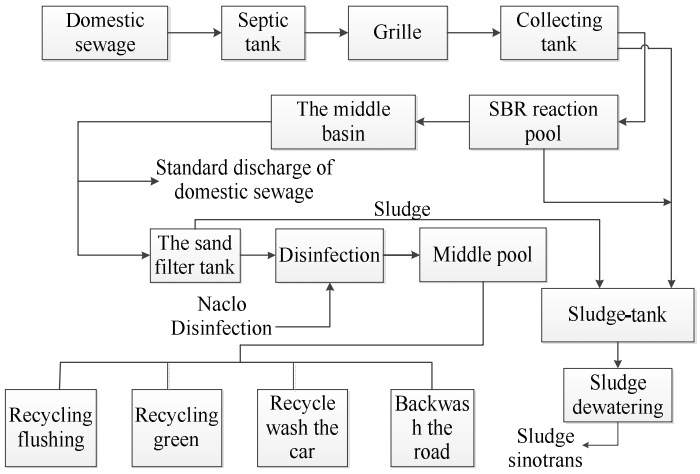

Fig. 3. System process flow chart

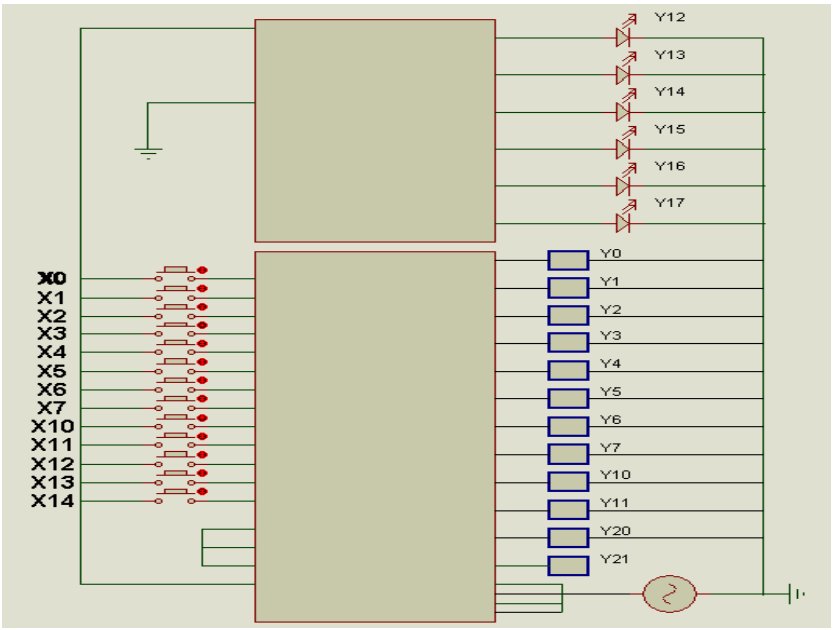

Fig. 4. SBR sewage treatment system PLC control external circuit diagram

3.2 System Process Flow

The effluent from the community first enters the septic tank built in the community; then it goes through the grille decontamination machine to remove a large number of suspended

substances. Because the design of this paper combines the grille machine and the collecting pool together, the inflow of sewage only depends on the intermediary effect of the inlet pump between the collecting pool and the grille machine. When the level of the collecting pool reaches the upper limit, it enters into the SBR pool and the decanter conducts water inflow, reaction and other related operations in turn. After the precipitation, the upper clarifying fluid flows into the middle pool with the help of the decanter. The discharged water goes through the sand filter tank to remove the colloid and solid particles in the water; then it enters the disinfection pool for NaClO disinfection. The discharged water is discharged into the middle pool for flushing and greening. Finally, the remaining sludge is discharged into the sludge tank, and the dehydrated sludge is used as other sludge after applying the sludge dewatering technology. The process flow is shown in Fig. 3.

3.3 PLC Control Circuit Design

We need to understand each object is driven to achieve the conditions when design PLC control circuit, such as: how much should be set the driving voltage, driving load should be set to the appropriate number and so on. Besides, when designing the controlled object, the specific number of I/O ports should be determined. In addition, the model used by the PLC and the connected peripherals must be determined to complete the circuit design. Design and manufacture the schematic diagram of the PLC control circuit as needed. Fig. 4 is the PLC control system external equipment control diagram.

3.4 Equipment Configuration and Model Selection

3.4.1 Contactor configuration selection

Feedback value is the PLC used to control the start and stop of the necessary amount of equipment. But these feedback values are provided by the contactor, so it needs to be applied to various contactors, such as grille machine and solenoid valve contactor. When selecting a contactor, it is necessary to take into account the life, suitability and versatility of the contactor, so that a contactor with a long life and adaptability to a harsh sewage treatment environment is the best choice.

3.4.2 Configuration and type selection of liquid level meter

The level gauge is an essential water level detector for the sewage treatment plant, which is used to display the water level of the pool [9]. The liquid level meters commonly used in sewage treatment plants mainly include the following types: float type, input type, ultrasonic type and so on. The float type liquid level gauge is simply referred to as a float switch. It is a fully sealed liquid level detector that can be completely immersed in water. It has the advantages of good sealing, corrosion resistance, long life, large buoyancy and the big switch movement back difference. Magnetic steel float level gauge is a liquid level sensor floating with the change of liquid level. The dry reed pipe is set in the pipe. When the float is close, the dry reed pipe will send out the liquid level signal under the influence of magnetic force line. Static pressure gauge has the advantages of simple installation and continuous measurement. But it is rarely used in engineering practice due to its poor measurement accuracy and stability. The input type liquid level gauge is a pressure sensor that needs temperature compensation during the conversion signal process. It is widely used in several industries including metallurgy, water supply and drainage, environmental protection, etc. In addition, the structure of the input type level gauge relative to other liquid level meter is relatively easy to install and easy to debug which enables users to quickly grasp the using method. The ultrasonic liquid level sensor estimates the distance between the ultrasonic wave and the liquid level gauge by the difference between the emitted wave and the received reflected wave. Since the liquid level meter has the advantages of high measurement accuracy, good stability and strong adaptability. It has been widely used in the practice of large-scale sewage treatment projects.

3.4.3 Configuration and selection of water decanter

In the SBR reaction tank, in order to let the clarified water flow out of the reaction tank with the change of water level, the decanter became the product of the development of technology, which is a kind of water decanting device. Water decanter usually consists of three parts. Among them, the main function of the water collecting device is to collect the settled clarifying fluid to the decanter and discharge it from the SBR pool through the catheter. The connecting device

must ensure the decanter runs freely and its sealing in water must be ensured. The decanter needs to run normally in water and the main function of the transmission is these. The siphon water decanter with PLC control solenoid valve was selected to decant the water with consideration of the quantity of water, economic cost and suitability of the designed sewage treatment.

3.4.4 Selection of aeration device

There are two main aeration modes of SBR process. Among them, mechanical aeration can be generally divided into surface aerator and submerged impeller aerator. The surface aerator has the advantage of simple equipment and is used as a common aerator, but in the SBR process, it is used relatively less [10]. Blast aeration is a common aeration method in the blast aeration method. The most efficient aerator in SBR process is the microporous aerator. Microporous aerator has the advantages of fine air bubbles and high oxygen use degree, but the deficiency of the aerator in use process cannot be ignored. Its disadvantage is that a lot of air pressure will be lost in the aeration process and it is easy to block the porosity. At present, dual-use aerator has been gradually used and developed in a wide range, which plays a great role in the application of SBR process in sewage treatment and also improves the purification effect of sewage treatment. Therefore, the dual-purpose aerator in blast aeration is used in this design.

4. SBR PROCESS PLC PROGRAM DESIGN

4.1 System Flow Design

According to the system design requirements in this paper, the control types can be summarized into the following two types: manual and automatic. Therefore, it is necessary to design the program of manual operation mode and the program of automatic operation mode according to the start and stop conditions of each button in SBR process. When the system is running in manual mode, separate operation buttons need to be set to complete the start and stop of the action. In addition, this mode can also be used as the basis for device debugging. Automatic mode is to let the button according to the design of the program to automatically achieve the order of action and stop. The system flow is shown in Fig. 5.

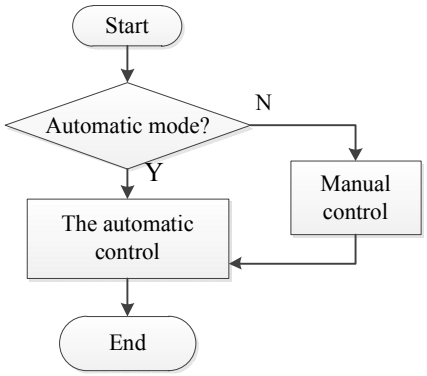

Fig. 5. PLC control system flow chart

4.2 Manual Control Program Design

In the manual operation mode, users can perform the operation of a single button, which helps the debugging of the device. When the device fails, a single test can be performed to find the fault location, which is convenient for maintenance and overhaul. In the manual mode, the switch decanter can be controlled by the button switch, whether the sump inlet pump is closed, whether the SBR pool inlet valve is opened, how long after the blower is turned on, etc. At the same time set the associated lights to show the operating status of the device. Manual mode control diagram is shown in Fig. 6.

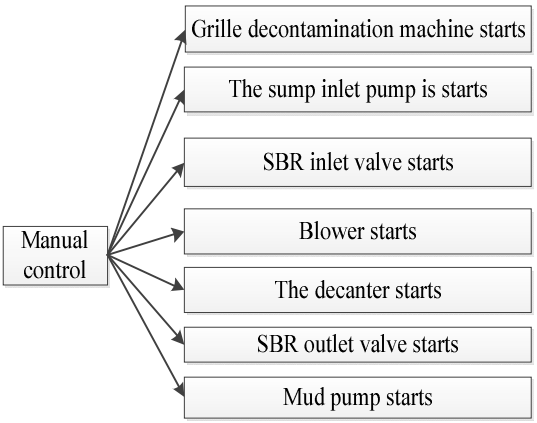

Fig. 6. Manual mode control chart

4.3 Automatic Control Program Design

The flow chart of the automatic operation mode of the system is shown in Fig. 7. The following work is to write programs according to the flow chart and use PLC to control each variable.

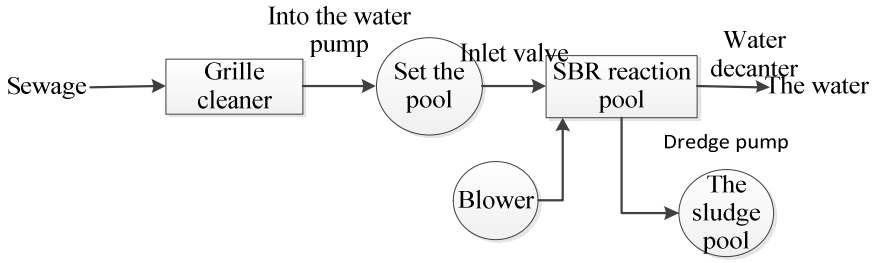

Fig. 7. Automatic mode control flow chart

In this design process, the following processes are mainly experienced: (a) The sewage flows out of the septic tank before entering the SBR process. The sewage passes through a grille desulper, which removes a large amount of suspended material and large pieces of waste. (b) After a period of time, when the liquid level of the collecting pool rises to the set upper limit value of water level, the water inlet pump stops and the upper limit light of water level is on. At the same time, the SBR pool water inlet switch is opened to make water flow into the SBR reaction pool. (c) When the water level drops to the lower limit of the collecting pool, stop draining water to the SBR pool and start the water inlet pump again after the lower limit lamp is on for 2S. (d) When the SBR tank reaches the upper limit of the level, the water inlet valve closes and the blower turns on. After a delay period, the blower is shut down and a delay period of sedimentation is run. When the time reaches the preset value, the decanter runs and the upper clarifying fluid is discharged from the SBR pool to the middle pool. (e) When the SBR tank reaches the low water level, the low water level indicator light will be on and the sludge discharge pump will be started to clear the remaining sludge into the sludge tank. SBR process includes the process of water inlet, precipitation and idling. It is necessary to design two SBR tanks for intermittent operation to treat sewage.

4.3.1 Grille design

A grille decontamination machine is set before the collecting tank. In order to facilitate the test equipment, the switching time of the grille decontamination machine can be set as 10s on and 10s off, and the cycle continues until the collecting tank meets the liquid level requirement. Before the grille machine is started, let the sewage water continuously enter 40s. After 40s, turn on the grille machine and the water inlet pump of the collecting tank for circulating operation. The flow is shown in Fig. 8.

4.3.2 The design of the catchment basin

When the start switch is turned on, the sewage passes through the grill and reaches the sump feed pump.When the 40s water enters the upper limit set by the program, the inlet pump will be turned on. When the water level of the switch is turned on, the sewage will pass through the grille machine and reach the inlet pump of the catchatchment pool rises to the upper limit set by the program. The upper limit light will be on. When the level of the collecting pool reaches the preset low level, the low level light will be on and all the valves connected with the outlet of the collecting pool will be closed and no more water will come out. Its operation flow chart is shown in Fig. 9.

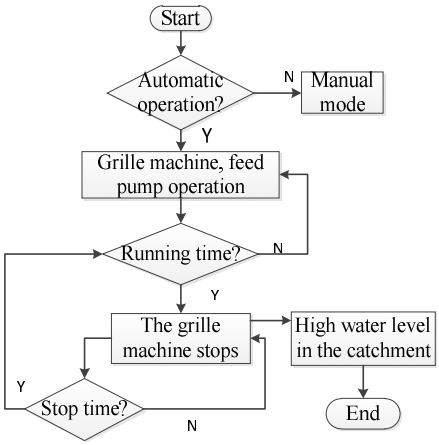

Fig. 8. Grid design flow chart

In the design of this paper, the grille and collecting pool are taken as a whole. The flow trapezoid diagram of their operation is shown in Fig. 10.

4.3.3 Design of SBR reaction tank

The design consists of two SBR pools. When one of them reaches the upper limit of the liquid

level, the other reaction pool begins to fill and the cycle operation runs. The main processes include: (a) When the catchment reaches the preset upper limit of water level, the SBR pool inlet valve opens. (b)When the liquid level of SBR pool rises to the preset value in the program, the inlet valve is closed and all equipment before SBR pool is closed. After closing, the inlet pipe of SBR pool is opened and the blower starts to work. After working for a period of time, the inlet valve is closed. (c)After the sewage is allowed to settle in the tank for 40s, the decanter is turned on to operate and the upper clarified liquid is discharged into the SBR pool. (d)When the level of SBR pool reaches the lower limit, the low level light turns on. Then the decanter stops running, the sludge is discharged to the sludge tank after the sludge is removed by the sludge discharge pump and the SBR pool starts to fill again. The program design flow chart of SBR reaction pool is shown in Fig. 11.

Although SBR reaction pool is divided into 1 and 2, but two of the pool operation process is the same. That is, when the first tank is full then the second tank is going to start filling, so they're all going to have the same trapezoid diagram. The ladder diagram of Fig. 12 represents the operation flow of SBR advanced water. Fig. 13 is the trapezoid diagram of the second pool starting to fill when the first filling tank is at high liquid level.

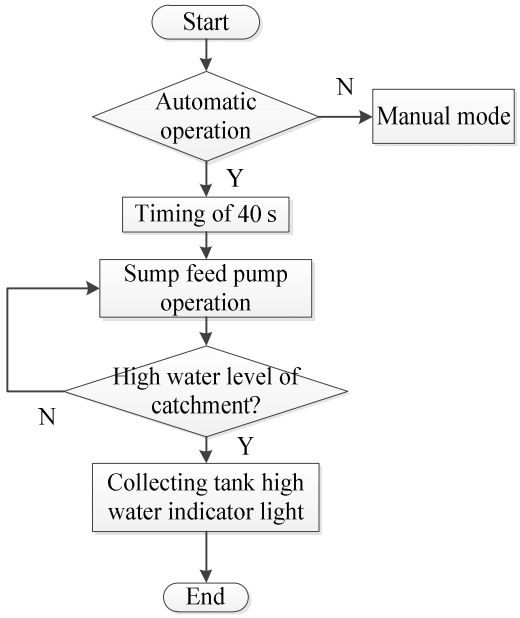

Fig. 9. Pool programming flow chart

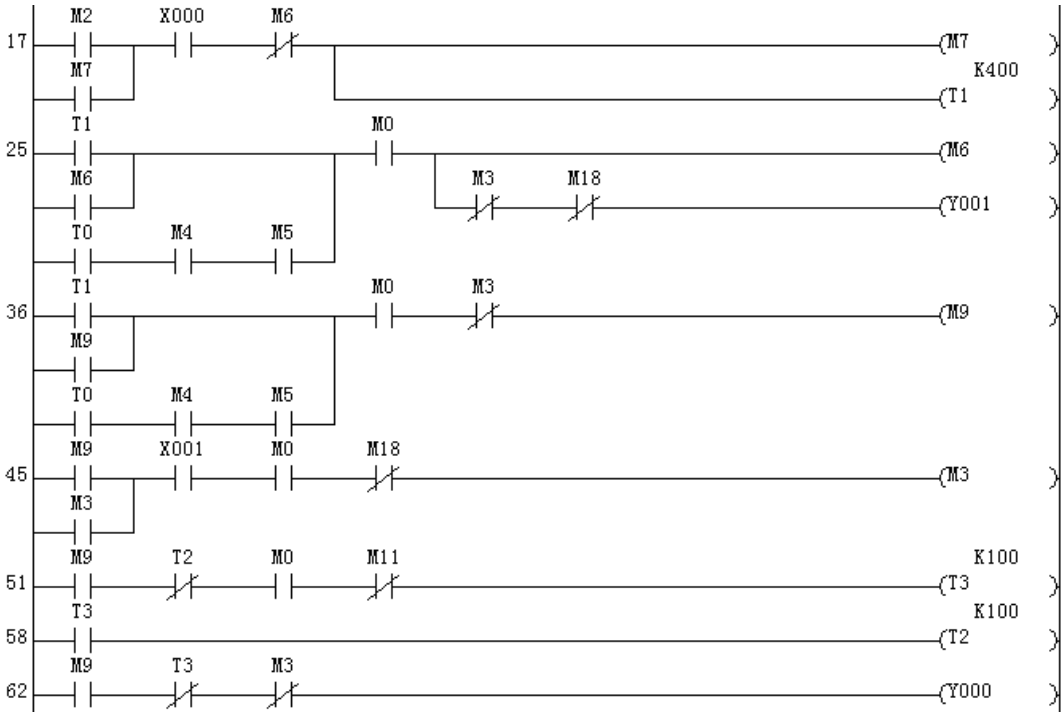

Fig. 10. Grille, gathering pool ladder diagram

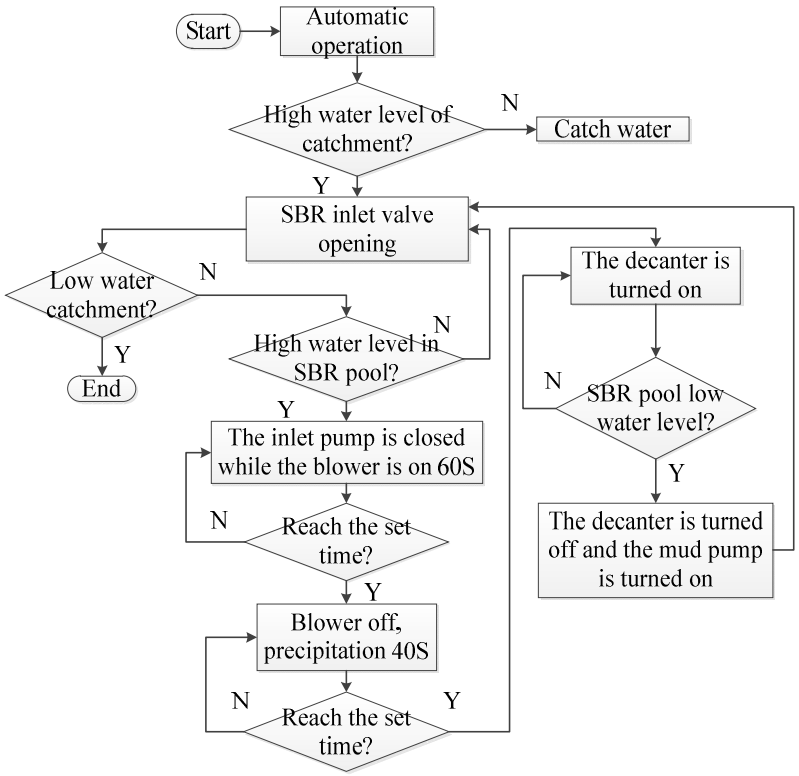

Fig. 11. SBR reaction pool program design flow chart

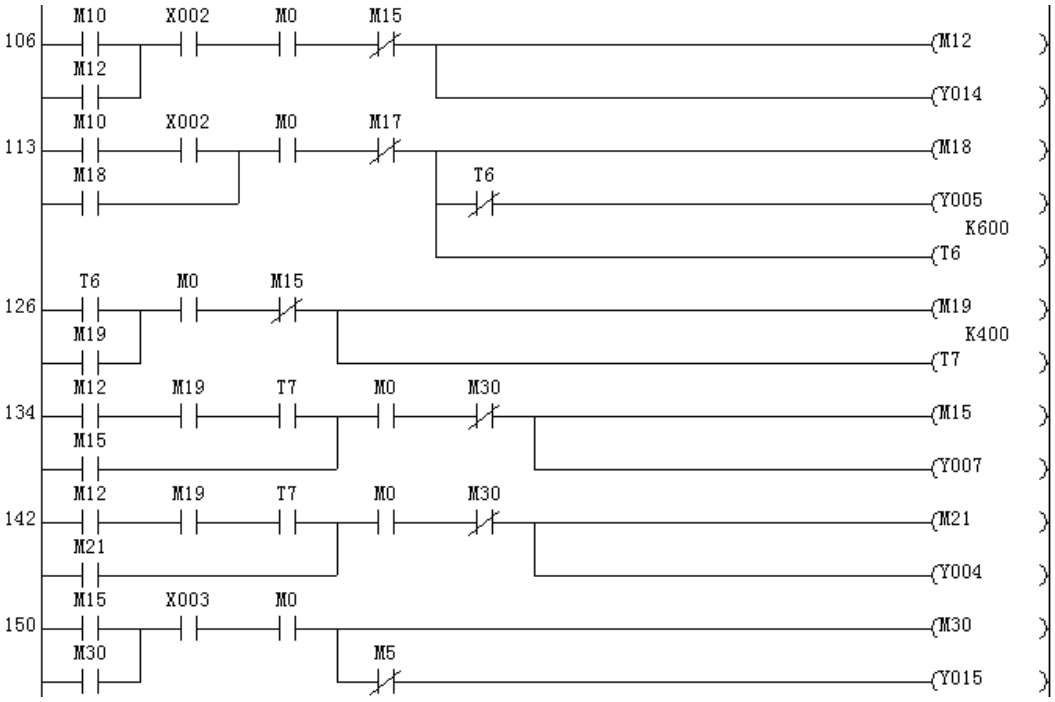

Fig. 12. SBR pool flow ladder diagram

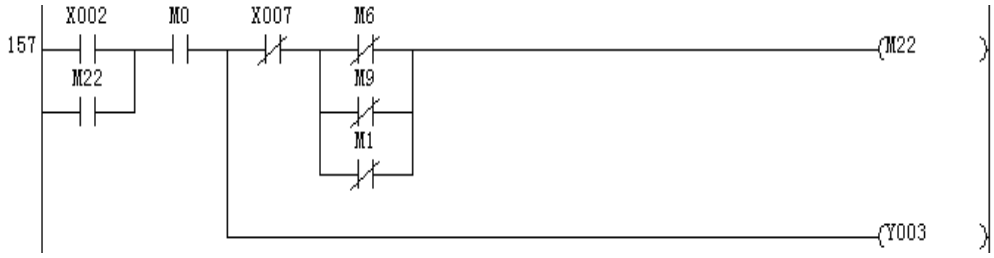

Fig. 13. Ladder diagram of inlet condition for SBR reaction tank 2

5. CONCLUSION

The system designed in this paper combined the widely used SBR sewage treatment technology and designed an automatic control system for a residential sewage treatment. In this system, the staff can understand the process and status of sewage treatment, the change and trend of parameters in real time. So as to optimize and improve the sewage treatment process in time.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Tianlong Xu. Study on treatment of Municipal domestic sewage. Environmental Governance and Development. 2018;48:37-38.
2. Wenjun Wang, Daoming Huang. Research progress of river ecological restoration at home and abroad. Journal of Hydroecology. 2012;33(4):142-146.
3. Jintong Wu. Application of plc Technology in Electric Control system of Boiler. 2017;17:114-115.
4. Jian Chu. The applied research of full-automatic computer food controlling system based on PLC. Advance Journal of Food Science and Technology. 2016; 11(10):661-663.
5. Xinyang Xu, Feng Yu. 2nd ed. Design of sewage treatment works. Beijing: Chemical Industry Press. 2002;99-100.
6. Bin Zhao. Overview of PLC application status and development prospect. Higher Vocational Education. 2012;114(4):193.
7. Shisong Ren, Ming Liang, Weiyu Fan. Investigating the effects of SBR on the properties of gilsonite modified asphalt. Construction and Building Materials. 2018;190:1103–1116.
8. Sebastian De Haro, Nicholas Teh, Jeremy N. Butterfield. Comparing dualities and gauge symmetries. Studies in History and Philosophy of Modern Physics. 2017; 59:68-80.
9. Jian Chu. The applied research of full-automatic computer food controlling system based on PLC. Advance Journal of Food Science and Technology. 2016; 11(10):661-663.
10. Minpeng zhao, Wenli Cahng. Design of automatic control system for sewage based on programmable controller. 2018;26(9):189-192.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/48476