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Applied study on water saving amount based on automation technology

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ABSTRACT

The shortage of water sources and its pollution has become a major threat affecting people's lives and production, while the gradually increasing industrial water consumption and unreasonable irrigation is worsening the situation of China's water resources. Under such circumstance, how to design a self-controllable automatic water-saving system and improve water efficiency is an important issue that needed to be addressed urgently. In this article, the basis technology and processes of the water-saving system is presented. Meanwhile, the advanced control technology is adopted to design the PLC control based water-saving control system specific to the problems existed in china's industrial water consumption and farmland irrigation, so as to realize automatic control of available water resources. The technology can be used in sewage treatment to strengthen system stability, improve water efficiency and reduce labor intensity.

KEYWORDS

Industrial water consumption; Farmland irrigation; Automatic water-saving system.

INTRODUCTION

Water is the source of life, as well as the essential condition of living being and economic development. However, the current situation of water resources in China is not optimistic. The per capita water capacity is one of the indexes to assess a nation's available water resources. Although the total amount of water resources in our country is 280,00 billion cubic meters, China is still one of the thirteen water-short states as its per capita water capacity is only a quarter of the world's average level. Moreover, the total amount of water resources in our country is still decreasing. For example, 20 rivers in upper reaches of the Yangtze River have shrunk 37.1% on average since the 1950s. Even more alarming is the fact that the water quality is also decreasing under the situation of inadequate water resources. The increased sewage discharge and sewage treatment techniques below the world's average level has caused water shortage, bad effects to the whole society and heavy losses to our national economy.

Water shortage has become one of the major factors restricting the sustainable development of our economy and society. The contradictions of water resources are increasingly apparent: one is the contradiction between the sharply increased water supply and limited storage capacity that resulted from rapid industrialization, and another is the contradiction between the rising sewage discharge amount and lower sewage treatment rate. As the contradiction has become the bottleneck which restricted the continued economic development, more and more importance are attached to sewage treatment and reuse of water in reality. And the ultimate goal of sewage treatment changes from compliance of drainage standard to recycled use of water resources. Not only can sewage treatment realize recycled use of waste water, but also generate renewable energy during processing to help production. This process can be repeated to increase economic efficiency and water quality at the same time.

The shortage and pollution of water resources have produced bad effect on people's daily life as well as our national economic construction. The requirements of energy saving and emission reduction and environment protection not only reflect the sewage treatment's necessity and urgency, but also set a higher standard for the process and methods of sewage treatment. The PLC control based sewage treatment system can be used to realize sewage purification. By this means, the goal of environment protection and water conservation can be achieved, while also the treatment costs of industrial sewage and the environment be enhanced, which proves to be of great significance to the rapid development of our economy.

INDUSTRIAL WATER-SAVING

Sewage treatment techniques and water-saving amount

Sewage treatment is widely used in various fields such as construction, industry, energy, environment protection and other fields. It is a process to make the sewage discharge up to the quality of one sort of water or meet the water quality required for recycled use through sewage purification. Sewage treatment in this article mainly refers to the treatment of industrial sewage. According to the action principle, there are four treatment methods for industrial sewage: physical, chemical, physical-chemical and biological processes. Among these four methods, biological process is the mostly used one. However, physical and chemical processes are also added since one process is not sufficient to satisfy the requirement for sewage treatment due to the complexity in treatment techniques. The most commonly used techniques are as below:

(1)Traditional activated sludge process, also named activated sludge process. This method is commonly applied to the biological treatment system of activated sludge sewage. As one traditional process its key components are aeration tank and settling tank. The technique and profit in 2010 is shown in Figure 1. The primary mechanism is microbial metabolism. With small settling tank, the input cost is low and organic contents in sewage are effectively reduced through microorganism metabolism and reproduction. However, this method has its shortcomings that can't be ignored: as too high organic loading in aeration tank is not accepted, higher capital expenditure is resulted from a larger volume of tank which is necessary; the operating effect is determined by the changes in inflow water quality and capacity.

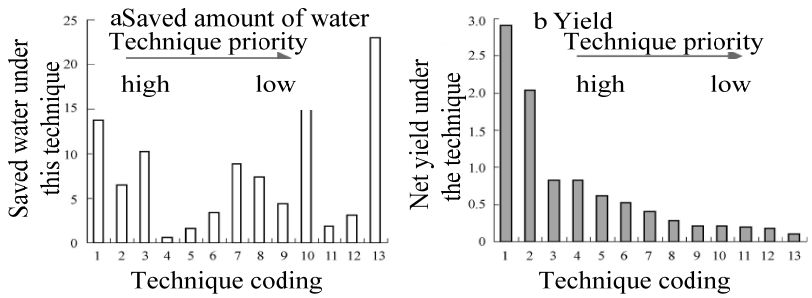

Figure 1 : Comparison of water-saving simulation and yields under thermal power technology (2010)

(2)A/O method, which is also called anaerobic-aerobic process. In which, A refers to anaerobic, while O means aerobic. As a new method developed based on the first process, the process enables the removal of organic matter and nitrogen and phosphorus from sewage. Compared with activated sludge treatment process, this method can significantly

improve the utilization rate of water resources. The situation in 2020 is expected to be as shown in Figure 2. Due to the simple technological process, the internal denitrification and nitrification cycle is generated during the reaction, which can effectively control the usage of water. However, the requirement to manage this system is more demanding.

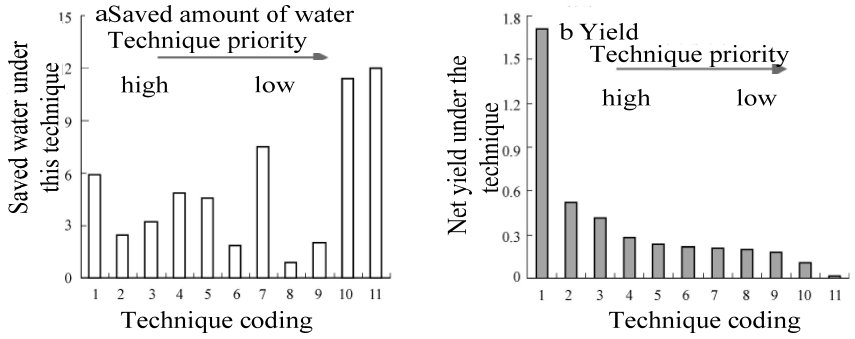

Figure 2 : Comparison of water-saving amount simulation and yields under thermal power technology (2020)

(3) A2 /O method, which is a biological nitrogen and phosphorus removal method. In this aspect, this process is widely used. One of the two A means anaerobic, while another anoxic (hypoxia); O stands for (aerobic). The process is as shown in TABLE 1. A2/O is a type of anaerobic - anoxic- aerobic process used in industrial sewage treatment. With its good effects in removing nitrogen and phosphorus, this process is suitable for industrial sewage treatment where removal of nitrogen and phosphorus is required.

TABLE 1 : The amount of sectional saved water under water demand and zero growth in 2012 and 2020 ($10^8 m^3$)

year	item	high water-consuming industries					
		total quantity	thermal power	steel	paper-making	textile	petrochemical
2002	standard water intake	210.2	47.8	28.4	49.8	65.0	19.3
2010	water-saving target	223.4	47.5	37.8	44.6	87.0	6.5
2020	water-saving target	394.5	80.3	46.3	93.4	145.6	12.7

Note: once-through cooling water not included in thermal power industry

(4) AB method. The process is called absorption bio-degradation. This process has good energy saving efficiency and high applicability in the treatment of high-concentration industrial sewage. But, bioflocculation is the mainly absorption way during periods of high loading, thus generating much more sludge through reaction. Therefore, the reactants during this process has to be processed additionally, so the costs of sewage treatment is increased.

(5) SBR method, which is considered as a granular activated sludge (GAS), or sequencing batch activated sludge process. With basically the same reaction principle as traditional activated sludge methods, the process has different modes of operation.

Analysis of water-consuming industries

The main water-consuming industries analyzed in this article is shown in TABLE 2 below:

TABLE 2 : Realizable saved water of different scenarios ($10^8 m^3$)

year	item	high water-consuming industries					
		total quantity	thermal power	steel	paper-making	textile	petrochemical
2010	by industryy	223.4	47.5	37.8	44.6	87.0	6.5
	industry coupling		44.9	41.6	56.1	74.0	7.1
2020	by industryy	394.5	80.3	46.3	93.4	145.6	12.7
	industry coupling		99.9	56.2	106.2	126.9	5.7

The technological process of the water-saving control system is consisted of two steps: water-filtering and back-washing.

First, open inlet valve and outlet valve and let sewage flow through energized magnetic filter coils. Then impurities will be absorbed onto magnet and purified water flow through outlet valve. The filtering processes of the two units can be conducted simultaneously or individually.

After water filtering starts for a period of time, magnet may have absorbed much impurities. Then such impurities must be washed, which is called back-washing. To start this process, cut off the power to magnet filter and close inlet valve and outlet valve; open blow-down valve and compressed air valve, releasing air to push water into magnet filter to wash off impurities on magnet. Then the sewage generated during this process will flow into sludge pool for secondary treatment. Different from filtering process, only one unit can be operated at the same time. While back-washing process is undergoing at No.1 unit, No.2 unit has to wait till No.1 unit is finished; when both the two units are ready for back-washing, back-washing process will firstly start at the No.1 unit.

Differential pressure gauges are required to be installed on the pipes of units in this system. When differential pressure gauges signal high pressure difference, the system will stop water filtering immediately and start back-washing process automatically, so as to ensure the safe operation of water filtering. Meanwhile, PLC control ports are used to receive connection signals from external parts. In case of any abnormal signal at the control ports, the system will stop immediately for troubleshooting. In this way, system reliability can be improved.

Modes of water-saving control

When the sewage treatment technology is firstly introduced into China, the control system adopted is relay-contactor control. However, due to the increased industrial water use and impurities in sewage with the development of industrial technology, the traditional system control methods can not satisfy the demand on sewage treatment. As a result, the past control systems are gradually phased out. Presently, there are three types of control systems that are mostly used:

Distributed control system, also called DCS system, or total distributed control system in China, is a computer system composed of computer, signal processing, control technology, communication networks and other devices. The on-site control stations, communication system, control stations, cabinets and other equipment can be connected through networking to provide open data interfaces, so as to realize distributed control and centralized operation enabling risk dispersion and safety improvement.

The water-saving control system was developed and promoted by USA in the 1960s. As a programmable logic controller, the system has replaced traditional relay control devices. The PLC system based water-saving control system can satisfy basic requirements while enabling real-time monitoring over treatment through network connection to PLC. The programmable system features simplicity in structure, short cycle in development, easy access to networks and convenient upgrading. Overall speaking, the system enjoys good versatility, simple operation, as well as strong control functions and expansion capability.

The Field Bus Control System is a type of real time network control system based on field bus. The system is capable of realizing mutual connections between filed control devices and intelligent instrument through automation control as per the standard communication protocol, thus enabling data transfer and exchange among equipment, equipment and computers. As it requires less overall cost and installation fees than other control systems, it enjoys high cost performance. Apart from this, it allows the use of abundant resources on the internet, thus realizing real-time transfer and interconnection between different products.

Requirements on functions

The purpose of designing such water-saving system is to produce recycled water through sewage treatment and realize sewage purification. The sewage treatment in China has developed into as new stage along with the gradual progress of water-saving technologies. But the technologies used for treatment are still behind the pace of urban development. Many problems, such as low water-saving control rate, low operating rate of equipment, are still existed. Adding PLC core controller to sewage treatment systems is feasible and convenient, enabling effective re-use of water resources and cost saving.

The PLC based water-saving control system enables simpler design process as well as more functions which includes real-time monitoring over the system. Also, it features a easy interface for operation, allowing users to control PLC system conveniently. The PLC based sewage treatment system can also realize its control over signal input and output.

The control over output signals is expressed in digital output and analog output. The former is used to control a variety of instrument and equipment, mainly contactors of these equipment, including start-up and stop. Analog output is mainly realized by controlling aerator converters, with the final purpose to control oxygen contained in sewage. PLC control is expressed in frequency output to effectively control rotating speed of aerators and finally realize its control over analog output.

Hardware configuration

The first is to choose a PLC controller. To choose a PLC controller, refer to the input/output address distribution list of NO.1 Unit listed below. As the basic principle of the two units is almost the same, the input and output points of the water-saving system can be derived from comparison. Then the controllers and expanded modules higher than such points can be selected. It can be known from the table that, the input and output points are 18 and 16 points, respectively. For this reason, the programmable controller selected is CPU 224 controller of Siemens S7-200 series, with the input and output points of 22

and 18, respectively. For the purpose of normal operation of PLC controller, the corresponding expanded module selected is digital expanded module EM223 of the same Siemens series.

The second is to choose differential pressure gauge. Differential pressure gauge is a necessary part to the sewage treatment system. Without a differential pressure gauge, the water-saving control system is unable to effectively control water filtering process and problems therein can not be discovered and solved quickly. Besides, the instrument may be damaged. This is not difficult to understand. As mentioned above, water filtering process must be stopped immediately when there is a large pressure gap between the inlet and outlet of magnet filter. If differential pressure gauge is not installed, pressure difference can not be displayed. As a result, water filtering process can not be stopped as soon as any problem occurs. A differential pressure gauge is capable of detecting pressure different at the inlet and outlet and effective output of pressure difference signal. Photohelic pressure gauge of American dwyer 3000 IMR series is adopted in this system.

ARMLAND IRRIGATION WATER-SAVING ANALYSIS

The Sequential Function Chart designed in accordance with the above requirements and control tasks is as shown in Figure 3.

A ladder diagram can be derived from the Sequential Function Chart. But attention should be paid to the following aspects:

First, the addresses of other PLC programmable elements is clearly indicated as in Figure 3. Thus there is no listing.

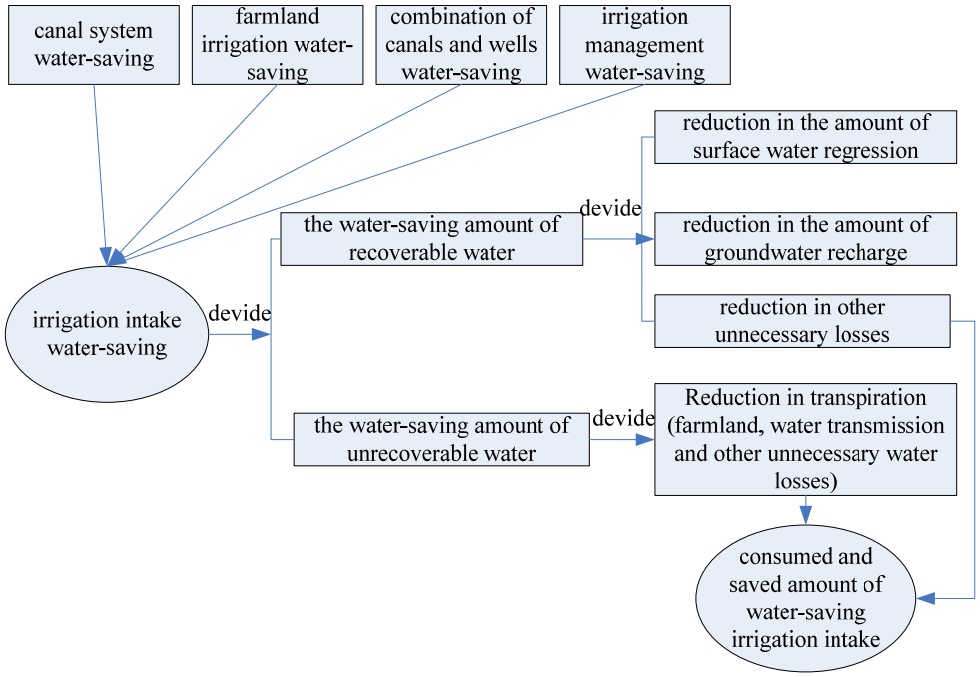

Figure 3 : Components of saved irrigation water

Second, open or close valves and magnet filters in a time-delay sequence way to avoid impacts resulting from process switch. Owing to the pressure difference protection of differential pressure gauge, the water filtering process will stop immediately when pressure difference at the inlet and outlet is higher than rated value. The system will in turn enter back-washing process.

Third, as mentioned above, when both the two units enter back-washing process simultaneously, back-washing process will first start at the No.1 unit because No.2 Unit is delayed by 0.1 second in the sequential function chart. But when one unit is undergoing back-washing process, another unit has to wait because the back-washing process in the two units has interlock function as clearly indicated in the sequential function chart.

Finally, fault diagnosis subroutine requires special attention. In the water-saving control system, faults are more easily occurred to external devices compared with software. Signal output is the main function of external devices. The faults occurred to such devices if not properly handled may cause malfunction, even damages to the system. Therefore, the fault diagnosis subroutine is designed to stop the system and raise alarms in case of faults occurred to external devices. Eight fault diagnosis subroutines were designed in the sewage treatment system with similar fault diagnosis algorithm. Take fault diagnosis subroutine 1 for example. The ladder diagram is as Figure 4. During water filtering, if inlet valve and outlet valves are closed, magnet filter not energized, blow-down valve or compressed air valve are open, the system will be diagnosed with faults followed by alarms. Then the system will stop its operation for repair.

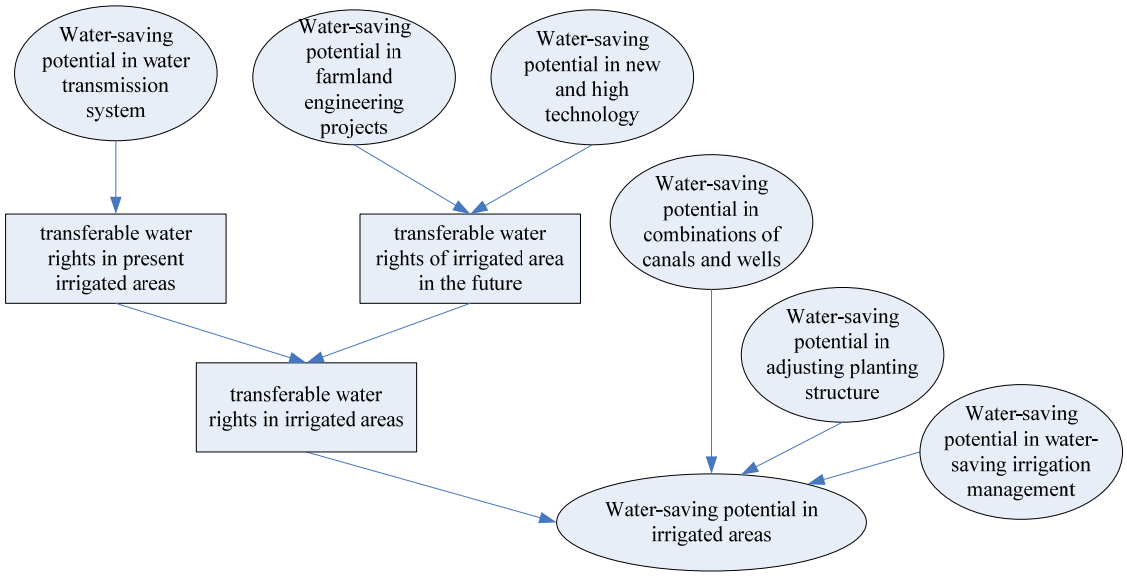

Figure 4 : The relationship between irrigation water-saving potential and transfer of water right

COMMISSIONING AND OPERATION

After design & installation is completed, a systematic commissioning and trial operation is required to check problems and provide solutions.

First hardware commissioning. Proper connection and wiring is required for hardware. Check whether power is supplied stably during commissioning, whether electrical control is in good condition and valves can be opened or closed in a normal way. Also check whether instrument and control system works well. The test results showed hardware functions well.

The commissioning results showed the configurations of hardware were proper to satisfy operation and display PLC control functions. Module procedures under commissioning could also realize control over corresponding functions. The function designs of the water-saving control system is basically realized.

CONCLUSION

In this article, the industrial and agricultural irrigation water-saving systems as well as technological processes, control programs and software and hardware configurations were elaborated. Meanwhile, the automatic control over PLC based water-saving system was realized with differential pressure gauge added in hardware to ensure the normal operation of water filtering process. Structured procedure design methods were adopted in software design with a sequential function chart of the control systems presented.

Featured by its simple operation and easy maintenance, the PLC based controller has good prospect to be promoted. But there is still a long way to go to create an intelligent water-saving and optimal water-saving control system. To achieve this target, profound research on water-saving principles and further study on advanced technologies are required to continually improve water-saving control level and promote water utilization in a reasonable manner.

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