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Fuzzy Control-based Automation Control System Design for Polymer Preparation Station

Tao Yan, Lijun Sun

Yantai vocational college, Shandong 264670, China
taoyan47283@126.com

This paper aims to explore the fuzzy control system design for polymer preparation station. The author takes the process production of certain petroleum plant as a case study, and designs the fuzzy control system. The automatic control system designed in this study can achieve the control rights transfer and the status monitoring through the hot backup module of the sytsem. When a CPU module fails, the control rights transfer can be performed within a short period without affecting the normal operation of the system. The fuzzy control -based automation control system is more reliable, and it can realize the real-time dynamic monitoring of the process in the polymer station.

1. Introduction

With the increasingly tight global energy resources, the importance of petroleum non-renewable resources has become more and more prominent. From original oil development and production applications, oil production is gradually unable to keep up with people's demand. In the aspect of oil mining, production and processing, the polymer flooding effect is more significant, and the oil production is more efficient.
However, the polymer disposing process is rather complicated, and it has relatively highstandard in controlprecision and timeliness. The automatic control goal can only be achieved with the help of computers, thereby increasing the difficulty of manufacturing in the polymer preparation station. Based on this, this paper mainly, taking the Controllogix series system as the research object, explores how to improve the system reliability and security. The design system in this study mainly applies related redundant technology and equipment, and analyzes system monitoring, software programming and system simulation. Figure 1 shows Controllogix data flow diagram

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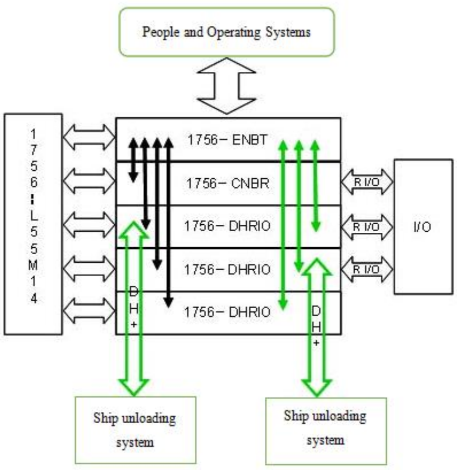

Figure 1: Controllogix data flow diagram

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2. Literature review

As a branch of intelligent control, fuzzy control is the product of the development of control theory to the advanced stage. It is mainly used to solve the control problems of complex systems which are difficult to be solved by traditional methods. Specifically, the research objects have the following characteristics of intelligent control objects: model uncertainty; nonlinearity; and complex task requirements. In these areas, the traditional control methods are basically difficult to achieve better results. Fuzzy control technology is not only a simple fuzzy controller in narrow sense. In reality, it is more general fuzzy control techniques, including regulator, adaptive fuzzy controller and hybrid fuzzy controller and so on. In addition to control, they have generation of process state and set quantity, control switch, and control strategy conversion (Cheng et al., 2017).

In 1975, King and Mamdanils applied the classical fuzzy control theory to control the temperature of the stirred tank of the reactor, and solved the problem of nonlinear time-varying gain of the controlled object. In 1976, Rutherford first used it in the process of industrial production and realized fuzzy control. In the sintering plant, fuzzy control was used to control the temperature of raw materials to achieve effective sintering. Compared with artificial control, the standard deviation was reduced by 40%. In 1977, King and Mamdanils used a fuzzy controller to control the temperature of 80 gallon stirred tanks in a chemical reactor. Fuzzy predictor based on fuzzy model successfully solved the process of large lag and closed loop instability. In 1979, the fuzzy control system of wet cement rotary kiln was developed by Holmblad and Ostergard. 27 fuzzy rules were used to control the stable state. The operation results showed that the control effect was better than the manual operation and the fuel consumption was reduced. This is the first fuzzy control system successfully used in large industrial process (Goharimanesh et al., 2017).

Fuzzy control has become one of the central topics of most electronic magazines in the United States and Europe in recent years. At present, the typical applications of fuzzy control in various fields are as follows:

Fuzzy control is applied in large-scale production process of industrial enterprises. González and so on studied the fuzzy reasoning method deeply, and successfully applied it to the national "eight • five" key new technology development project - "the automatic control management system of alumina clinker firing", and realized the automatic control of the alumina firing process. The problem of automatic control of clinker firing rotary kiln that is not well solved is overcome and it achieves remarkable social and economic benefits (González et al., 2016). Others also applied the fuzzy control to the temperature control of the polypropylene craftsman, the control of the arc steelmaking, and the control of the combustion process of the annealing furnace.

Fuzzy control is applied in typical industrial control objects. Hunt pointed out that fuzzy control is also applied to the typical industrial control objects in the modern control field, such as fuzzy control of AC servo system, fuzzy control in robot control, fuzzy control of vehicle automatic driving, fuzzy control of greenhouse temperature, and so on. It can be said that the fuzzy control can be basically seen in various typical industrial control objects (Hunt et al., 2017).

Fuzzy control technology is applied in intelligent household appliances. Ou and so on stated that the application of fuzzy control in intelligent household appliances is in the forefront of the world. At present, the fuzzy control of the automatic washing machine, the fuzzy control of the electric cooker, the fuzzy control of the air conditioning, the fuzzy control of the refrigerator and the fuzzy control of the microwave oven have come into being. Fuzzy control technology greatly improves the intelligent level and control effect of these appliances. The use of fuzzy control in household appliances has also become a current fashion (Ou et al., 2017).

Fuzzy control is applied to the prediction of complex large objects such as national economy. Large-scale objects such as national economy are very complex. The trend of their changes is influenced by many factors, so it is very difficult to establish an accurate mathematical model for simulation, such as population change trend forecast, the Yellow River Basin rainfall forecast, price rising trend forecast and so on. Vasičkaninová and Bakošová suggested that the fuzzy prediction model can be established through fuzzy control theory and expert system theory, and the change trend of these objects can be obtained (Vasičkaninová and Bakošová, 2017).

Fuzzy control is applied in enterprise management and control. The management of industrial enterprises is also a complex project, and fuzzy control can also play its unique role in this field, such as fuzzy comprehensive evaluation of industrial enterprises, fuzzy cluster analysis of industrial enterprises and fuzzy market prediction and control of industrial enterprises and so on (Ramona et al., 2017).

Fuzzy control is applied in other fields. Truong and Ahn pointed out that fuzzy control can also be applied to other fields, such as economic assistant decision-making, intelligent medical diagnosis system, human behavior and psychology and behavior analysis, socioeconomic model, art and so on (Truong and Ahn, 2017).

To sum up, through the research done by scholars at home and abroad, fuzzy control technology has made great progress. A profound study is made on that the fuzzy control is still the field of intelligent control, but there are few researches on the application of polymer configuration station automation control system design based on fuzzy control. Therefore, based on the above research status, the design of automatic control system for polymer configuration station based on fuzzy control is mainly studied. The basic framework of automatic control system design for polymer configuration station based on fuzzy control is put forward. Some concepts and modeling processes in fuzzy control are discussed in detail, and the fuzzy control method and fuzzy control theory are deeply studied. The simulation verification is carried out by programming, and the advantages and disadvantages of various methods are analyzed. Fuzzy control is applied to the control of polymer configuration in polymer configuration station.

3. Method

3.1 System design

The polymer preparation station is the key link of polymer flooding, andthe control system of the polymer preparation station is the control core of the whole preparation station. Due to equipment dispersion and process complexity, decentralized control techniques must be applied. Three aspects in the process of system hardware selection should take great consideration.First, the system must have a strong communication networking between the various parts of the system to ensure that these parts can quickly and reliably exchange information. Second,the controller must have sufficient memory capacity and high precision fast computing capability to ensure that complex control algorithms can be achieved. Third, the system cost performance is good. In view of the above considerations, this author chooses Rockwell Automation products in this study, whose PLC is the best in the world, whose price is much lower compared with DCS of famous brands, andwhose performance index is sufficient to meet the requirements of the system. ControlLogix system not only possesses advanced communication capability and latest 1/0 technology, but also provides sequence, process, motion and drive control. As the system is of modular structure, users can effectively design, build and change systems, thus saving them significant training and engineering costs. Its features of being easy to achieve distribution and handling make RsLogix ideal for this system. ControlLogix offers two cPu redundancy solutions, namely pure hardware redundancy and software redundancy. Hardware redundancy method indicates inserting two CPU modules into two different racks. In addition to CPU module, there are communication module CNBR, hot backup module SRM and the connecting cable between the two backup modules.

The redundant ContdLogix provides network media redundancy, that is, there are two separate networks. Once a network cannot transmit data, it automatically switches to another network to complete the communication task, which can not be achieved in other PLC products. It also guarantees the security of the network. Its openness is based on Netlinx open network structure including EtherNet/IP, ControlNet and DevieeNet.In this study, ControlNet networking is used in the syestem.As the application develops, the network accesses to the appropriate module, the upper layer can composite EtherNet/IP network, which controls the network through the configuration on Internet, and the lower layer network can also form a DeviceNet network (device network).

On certain data transmission and repeatable data transmission,the ControlLogix system applies the communication technology ofproducer/customer (PRODUCE/CONSUMER). This means that multiple nodes can receive data from the same device at the same time instead of sending the data one by one, which saves the amount of data for communication, and it can not be achieved in other PLCs. They use the communication format of source, destination and data. ControlNet network is a real-time control networktransmitting real-time I/O data and message data at a high-speed including program upload/download, configuration data and peer-to-peer communications, and all of which are transmitted on one medium. The ControlNet network is of highly determination because it can reliably predict when data is sent, which has already been fixed at the time of configuration.

Addressable maximum I/O points (up to 128,000 digital/up to 4000 analog). The controller can control local I/O and can also control remote 1/0via EtherNet I/P, ControlNet, DevieeNet and universal remote I/O networks. Users can place multiple controllers in a Contro1Logix rack. Multiple controllers can read input values from all input interfaces. One controller can communicate through multiple communication modules, andmultiple controllers can also share one communication module, therefore it is very flexible. Not only the network can be redundant, the controller can also be redundant.

The module can be charged and unplugged, which can help minimize losses upon system failure.The producer/customer mode communication, module level fault reporting and on-site diagnostics using time data tagging, optional direct connection or optimized rack connection, all of these features of the I/O module are very convenient in both application and maintenance. As the I/O module itself has a CPU, the module is intelligent. The hot plug function does not affect the production, which is rare in other PLCs. Module-level fault reporting and on-site diagnostics prevent undesirable consequences when the module is misconnected.

3.2 System program

According to the process of the polymer preparation station, the entire control system consists of four parts including water system, disperse system, curing system and output system. The water supply system provides raw material for the disperse device and it is the raw material preparation system for the whole preparation and production. The disperse device is the core of the system. Its output product directly enters the curing system.The polymer solution forms a "mixed liquor" after being processed by the curing system, and thenenters the output supply system (the total exit of the preparation station). These four systems are independent and closely related. Considering these parts are geographically fragmented, separate racks, acquisition modules (remote I/O) are set up in each part, and these parts are connected via the ControlNet network. In order to facilitate centralized management and we take system redundancy into account, the author designs two controllers, selecting L55M12, the most powerful controller module of ControlLogix series controllers. The system applies ControlNet redundant network between the various parts. The upper layer consists of two redundant industrial control computers, and the topology structure of thesystem network is shown in Figure 2. The entire system consists of three parts.

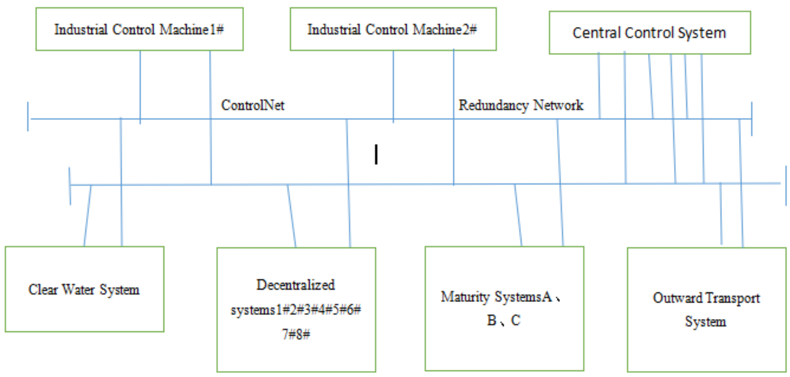

Figure 2: System Topology

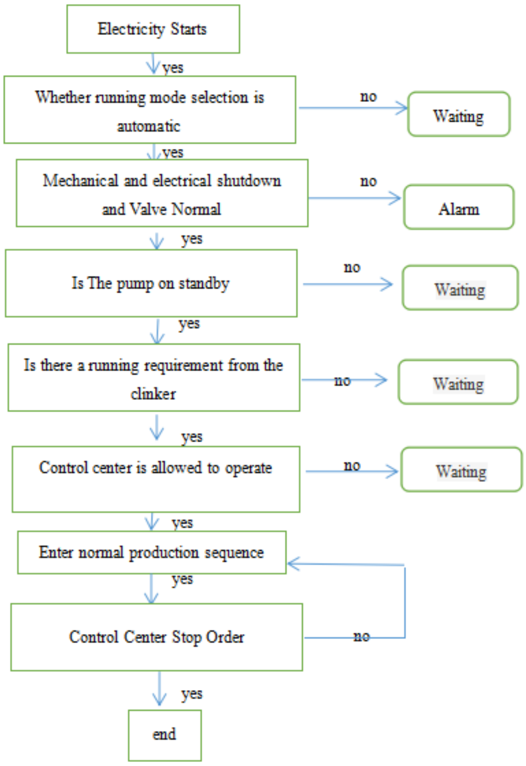

Figure 3: Process of familiarizing part of the system

The author uses RSLogix5000 Enterprise Edition, a RsLogix series of processor programming software and the ladder diagram to programthe controller. Two parts in this system are very important, namely,the disperse part and the curing part. The disperse-curing system in the preparation station is divided into three groups (System A, System Band System C)can operate separately. There is a storage tank in each group. Five curing tank (spare one), three sets of dispersion device. Another two sets of dispersion device are spare for three sets of running devices The system has following two working methods including automatic working mode and semi-automatic working mode.Figure 3 Showsprocess of familiarizing part of the system.

4. Results and analysis

4.1 System software programming

Two CPUs are running at the same time, of which one is in the main control mode and the other is in the hot backup mode. The CPU that has master control possesses output control right, while the hot backup CPU collects data and maintains the communication connection at the same time, but the output is prohibited. These two CPU modules monitor each other's operation status and communication status.Once one of them finds fault of each other's, it will immediately send an alarm to the upper IPC through the ControlNet network and the alarm will be displayed in the the management station. When a fault in the master CPU module appears, the hot backup CPU module will automatically gains master control.
As the hot backup CPU is ready at any time, it will immediately gain the master controland become the master CPU once the main CPU fails. Therefore, the main CPU must pass its own information to the hot backup CPU at any time, while the hot backup CPU must keep track of the changes of the main CPU and keep pace with the main CPU. In this way, these two CPU modules can achieve bumpless switching when the control right transfers. Compared with Contro,the dual- CPU redundancy control software of gix is an economical and effective way, as it can greatly improve the reliability of the system at an effective cost. In addition, when applying the redundant dual-CPU control, it is worth further studying how to use the Map commandand CPU data of main control mode is transmitted to other control devices via ControlNet network.

4.2 System Simulation Analysis

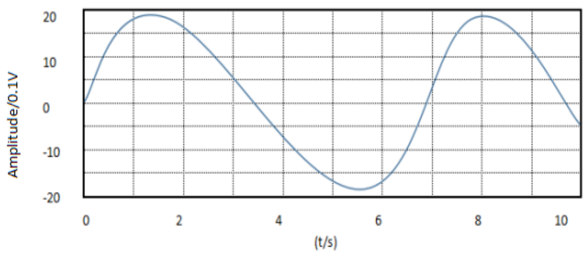

Figure 4: Variation of amplitude of input signal in Fuzzy Automatic Control System

We can see from the above chart thatthe input signal amplitude value of the system is 20.

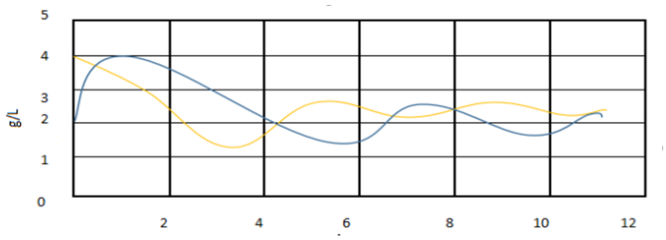

Figure 5: System ATTENUATION OSCILLATION SIGNAL

We can see from Figure 4 and figure 5 that the input signal cycle is short, the output signal oscillation is large, and it needs longer time to achieve stability.
In this study, a petroleum plant was selected as the research object. The annual oil production of the plant reached 1.6 million tons. The test was conducted with ControlLogix system. The oil concentration was tested every four hoursfor four times. The specific test results are as Table 1.

Table 1: Test results of petroleum concentration

The number	The oil concentration(g/L)	Average concentration(g/L)
1	2.12	
2	2.10	2.125
3	2.15	
4	2.13	

4.3 System monitoring interface

When configuring the system, the system is divided into seven configuration interfaces,namely System A, Line B, System C, trend chart, external pump, system setting, and water supply system. In the process, the preparation station will complete up to three ingredients, which requires the preparation station has three independent preparation, curing, storage tanks and outputtingsystem structure. Therefore, when we achieve the configuration, the entire system is divided into A, B, C (there are some equipmentsare multiplexed,meaning that the equipmentscan be subordinate to the system A, the system B, and the system C. These are set in the system setting interface). The interface of System A, System B, System C interface are roughly the same, here we only introduce System A which includes 5 disperse parts, 5 curing parts and 8 pumps. The relevant information configures in this interface.

5. Conclusion

In order to improve the reliability of the control system, the author adopts the dual-CPU network redundancy technology,makes full use of the advantages of AB's products based on the theoretical research of reliability, and builds this system which proved to be a good solution through experiment.

With PLC being a regulating unit, the author uses the inverter to control the speed of pump motor to control the water supply pressure, whichhas the best performance among the current constant pressure programs. Fuzzy control is an ideal control scheme, and in this paper the author makes some improvements to the fuzzy control scheme taking the process characteristics of the system into consideration, making it more suitable for a particular work environment.

This automation systemdescribed in this paper is mainly the control level network, and it is only equipped with the management level network Ethemet interface. The previously mentioned report processing and print managementare also done at the control level. Due to the real-time control and reliability requirements of the control network, this method is not completely satisfactory. With the improvement of communication speed and the realization of network openness, there will be more and better network solutions.

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