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Using PLC Programmable Logic Controller to Realize the Automation Controller of Anaerobic Fermentation of Biogas Engineering

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Abstract: This study regards biogas fermentation system as the research object, summarizing the existing anaerobic fermentation control technology and its research status quo, based on the characteristics of two-phase anaerobic fermentation process to identify the system control parameters and control tasks. Design the automatic control system about anaerobic fermentation process based on PLC and configuration software to realize the automation functions of methane fermentation.

Keywords: *biogas fermentation system, anaerobic fermentation, PLC, automation functions.*

1. Introduction

In recent years, the large-scale biogas project has developed rapidly in China, but many problems still exist, especially the control problem in the production and operation of biogas engineering, mainly in low level and poor precision control. At present, the majority of biogas engineering still uses relay as main control device to build control system, to judge the system control parameters by the people, many problems will arise. For example, the labor intensity, operation errors or time grasp, etc. will influence the fermentation process smoothly, even cause changes in the fermentation type, and finally causes gas rate drop or gas stagnation. Therefore, adopting the process automatic control is particularly important. With the progress of science and technology and the enhancement of industrial automation level, using sensors for detecting fermentation parameters automatically, making use of PLC and computers to build up the automatic control system of anaerobic fermentation process, it is of great importance to improve the control precision, improve volume gas productivity, reduce the intensity of labor, which is a trend of the big biogas engineering technology in the future.

1.1. Study abroad

After years of research and practice, many more advanced automatic control systems of anaerobic fermentation have been applied in foreign countries, and the control systems generally use the feedback control. With the increasing complexity of the process control and control parameters, the modern control methods, e. g. the advanced PLD control, fuzzy neural network control, etc. have been applied to the automatic control system of anaerobic fermentation.

Liu, and others, in order to improve the automatic control of the digesters under the condition of high load capacity, regard organic matter load as controlled variable, select the output gas flow and the difference of set value, and the rate of producing gas, as a parameter to monitor to build two-dimensional fuzzy controller to control the parameters of the fermentation system. The experiments show that fuzzy control theory can control the fermentation process of high load digester. High control precision and the system stability are good[1]. Murnleitner and others, in an anaerobic process with large fluctuations in the substrate concentration, through the fuzzy control system, predict state and make proper control process[2]. Denac and others, in the fermentation system, using PID control method, establish the automatic control system and regulate feed rate to reduce the steady-state errors, and make the system stability better[3]. Peter Holubar and others, through the four continuously- stirred tank reactor under pulse generated by the anaerobic fermentation of organic load test, get the monitoring data of neural network learning, re build modeling which is used to control the anaerobic fermentation methane yield, and the anaerobic fermentation neural fuzzy control method is established[4]. Nadine and others, through the establishment of multiple model estimation observer (OBE), intelligently control fermentation parameters. The observer consists of simple sub-model of describing the typical process and intelligent system, and estimates the process output, according to the analysis of process parameters with p H, and multiple model estimation observers using COD and VFAs fluorescence measurements. It can monitor anaerobic

treatment plants in different areas reliably and effectively[5].

Above all-mentioned, some scholars abroad on the automatic control method of anaerobic fermentation have researched further. In the system the advanced control theory and method are introduced and the advanced control equipment is used in the methane projects. What's more important, they have achieved a good control effect, which is worthy of reference[6].Because the PLC has simple structure, easy to grasp, the price is low, so more suitable for large-scale biogas project.

1.2. The domestic research situation

At present, at home, many small and medium- sized biogas engineering in anaerobic fermentation parameter control have widely used analog meter and relay logic control system, whose shortcomings are: low degree of automation control system, parameter adjustment and line running state, which requires staff performance, low data management level, making it easy to miss important monitoring parameter. The advantages are low cost and relatively simple maintenance, but in large biogas project, this design can bring in large labor intensity, high operation cost, high safety risk factors, etc., which are not acceptable. With the continuous development of PLC technology, the control system of the upper computer and lower computer has been applied in automatic control system of anaerobic fermentation.

In 1992, Shenyang Pharmaceutical University developed the fermentation process using computer control system. The system adopts PID control algorithm, TP801B single-chip microcomputer as the host. And it can control the temperature of fermentation tank and p H two parameters automatically. But the system uses assembly language to write, and has complicated operation and long development cycle [7]. At the end of 2000, the state environmental protection administration departments, a UNDP, and GEF project, and so on, supported the Beijing shunyi seed multiplication farm livestock and poultry with PLC as the core, and set up sewage treatment automatic control system, and completed the acidification tank, anaerobic tank, the temperature parameters of the SBR pool monitoring, and controlled the lower limit of collecting basin, acidification pool, SBR pool , and set up sound and light quotation system. In the actual operation ,it is shown that the system has strong anti-jamming capability, good stability, but can't achieve all functions automatically in operation[8].Wuhan University of Water Conservancy and Hydropower has used computer monitoring and control system for large and medium-sized methane project and with the help of computer, controlled and monitored PH in the process of anaerobic fermentation pool, gas pressure, flow rate and ph fluidized bed in gas pool chlorine content in the parameters[9].

In summary, at home, a lot of research on the computer automatic control system of the anaerobic fermentation process has been done, but in the actual operation of biogas engineering, because the process is complicated and the fermentation equipment is poorly matched, etc., the control system can't be widely applied to.

1.3. Research significance of automatic control of anaerobic fermentation process of large biogas engineering

Biogas anaerobic fermentation is a relatively complex process that involves the material pretreatment, fermentation tank liquid level, PH, REDOX potential, and many other factors. The key how to realize the rapid, efficient and stable biogas production and supply lies in the reasonable setting of various parameters, the use of the current state of the sensors to collect methane fermentation, using computer and software platform for real-time monitoring and control, making all the optimum fermentation parameters satisfy technological requirements. Guarantee that the optimum fermentation parameters satisfy technological requirements and at the same time, according to the environmental changes, repeated tests rewrite the fermentation parameters and increase the gas production of biogas engineering.

The practical significance of the automatic control system of anaerobic fermentation process for large methane project mainly has three points.

1.3.1. Implement two-phase anaerobic biological fermentation phase separation and improve the rate of producing gas

During the two-phase anaerobic fermentation, the acid producing bacteria and methane-producing bacteria, respectively, were placed in two reactors in series, and optimum conditions and process parameters were provided, in order to avoid the mutual interference between creatures of different species and inhibition caused by uneven metabolites and to make acid-producing bacteria and methane-producing bacteria able to live up to their biggest activity, thus greatly improving the processing efficiency and running stability of the system[10,11]. Using the automatic control system of anaerobic fermentation process by means of engineering can make the different fermentation parameters of acidification tank and methane tank controlled precisely, and thus meet the requirement of two phase anaerobic fermentation process, and realize the accurate phase separation--- a substantial increase in the rate of producing gas.

1.3.2. Ensure the biogas engineering is more reliable, safe and efficient operation

The PLC automatic control system in the fermentation process can collect the data on time, and, according to the environmental changes, can control the fermentation parameters, enhancing the stability of the fermentation process. In operation, when a device doesn't go smoothly (such as gas leak) and running parameters is beyond the given value, the system automatically alarms and take emergent measures,

e.g. make the protection device run or stop the system, improving the reliability and security of the running system.

1.3.3. Save operating costs, and improve work efficiency

Automatic control system of anaerobic fermentation process by PLC detects the tank fermentation parameters, using Wincc edit display interface, to make the staff know the whole biogas project running at a glance and precisely control biogas engineering operation. It can reduce the labor intensity, reduce staff, reduce the production cost and improve operational economy of fermentation system.

2. The system hardware meter type selection and design

2.1. End system hardware selection and design

According to the demand of agriculture biogas engineering system, need to monitor feed rate, feed pool fermentation tank liquid level, temperature, pressure, flow rate, gas parameters, such as whether there is leakage, in the whole biogas fermentation engineering, The use of measuring equipment and installation position as shown in figure 4.

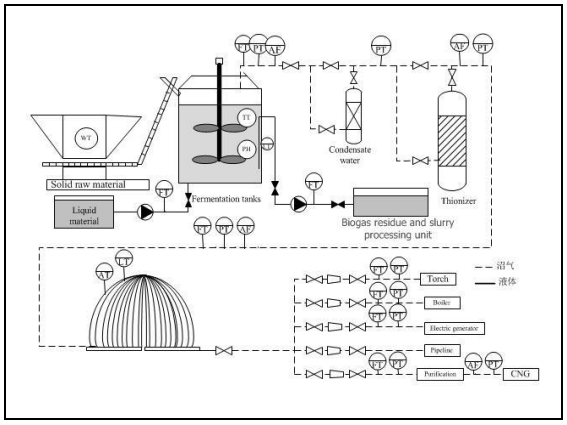

Figure 1: *Biogas engineering online measurement equipment installation figure*

The measuring equipment symbol is as follows: 1. WT-Weight meter, 2. FT-Volumetric flow meter, 3. TT-The thermometer, 4. PT-Pressure gauge, 5. AF-Biogas analyzer, 6. LT-Ultrasonic level meter, 7. AT-Gas leakage alarming device.

Weight meter's main function is to measure the feeding amount in a biogas project each time, and its data will be deposited in the database. Periodic statistics can be carried out. It is usually installed in the feeding pool; The function of volumetric flow meter is measuring the volume of a gas production every step, and can display the instantaneous flow or cumulative flow. It is one of the important indicators to measure methane production; Thermometer is real-time sensor induced by temperature change. In the biogas fermentation process, the amount of gas is mainly determined by the temperature. Therefore, when the temperature is too low or too high, certain measures are taken to ensure the temperature stability in the fermentation tank; The main effect of pressure gauge is to judge whether the pressure of the gas pipeline and gas holder pressure are normal, such as gas holder pressure requires lighting the torch in order to reduce pressure automatically[12]. Design drawings with the Chinese ministry of agriculture, it is suitable for other biogas engineering.

All measuring equipment can be set up according to the need to upload data cycle, achieve the goal of remote monitoring, and can have a remote control according to the data of the corresponding index.

2.2. Design of biogas anaerobic fermentation front-end system based on PLC

End system is subdivided into the sensor data acquisition module, backup upload module, adaptive event processing module, local monitoring module, early warning alert reporting module, chain automatic control module.

Data acquisition module is mainly through PLC to tank liquid level, pretreatment pool level, tank parameters such as temperature, concentration of fermented liquid, PH value for data acquisition and install overload alarm device; In methane gas composition, gas distribution unit acquisition parameters such as flow rate, reservoir volume and pressure and install gas leakage and overload alarm device; In sewage treatment unit installation COD, BOD, total P and total N monitoring devices such as environmental protection index; In the marsh fertilizer production units installed N, P, K and trace elements testing instrument; At the scene of the gas station acquisition environment conditions, such as temperature, humidity and wind speed[13]. Backup upload data module: through the sensors to collect data, using the PLC to the whole engineering production data summary, at the same time depending on the acquisition parameters respectively set the period of collecting data, it can be accurate to seconds. Uploaded to the management system statistics to classify data report form cycle, management system by data from the backend system for real-time monitoring, ensure the normal operation of biogas engineering safety.

2.2.1. The sensory information monitoring network module

The function of this part is based on the fermentation container internal environment perception, the sensor data are transmitted, according to the network which involves the scope of this section ,it will be divided into three parts: the inside of a fermentation tank from perception between sensor nodes, fermentation tank and the greenhouse environment monitoring network, the control of greenhouse monitoring center and the cloud monitoring center communication network[14].

1) Fermentation tank control network of the internal perception between nodes

The network portion of the main function is to control the sensor data acquisition through self-organization network terminal connection of different sensor devices, set time periods to implement the sensor data to automatically, and realize the data collection in the PLC; Then the PLC to perform the controller devices are installed on the self-organized network terminal interaction between the sensor and controller, when the internal temperature of the tank is too high, the temperature sensor using PLC programming has good self-organizing network data , which can be sent to the greenhouse, shutter machine controller to control the shutter machine switch. When the internal temperature of the fermentation tank is lower than a certain value, the PLC starts heating boiler as a fermentation tank for heating[15].

2) Warnings that report module

Biogas engineering intelligent warning system can be divided into:

A mechanical failure occurs in the tank to remind the warning. If the tank mixing slurry appears to stop the work, the first time the local alarm, and the alarm to the pipe system. The control room of the management system and the management staff of the mobile phone end of the app application will receive alarm reminder. The monitoring center of the monitoring system.

Operation parameters warning: when the tank temperature is higher than a certain value, PH value beyond a certain range end early warning system will report to the superior operation parameters.

Operation violation warning: such as feed to the pretreatment system in the pool of capacity limit alarm to remind stop feeding, capacity of sand basin has been to the ceiling was banned feeding pool feed irregularities.

3) Chain automatic control module

Setting the chain control values makes each work link chain control effectively. The current working link state determines whether the next work link will work, for example, set the fermentation tank liquid level value, when it achieves the value, the feed pump stop feeding.

The disaster weather warning: extreme disaster weather warning is put forward to the management system.

3. Biogas anaerobic fermentation management system design based on PLC

Management system main function is divided into two parts, The first part is regarded as a backend system, central control room to monitor the whole process of biogas production and processing, which may process all kinds of alarm system at any time, schedule any department and coordinate the whole biogas project running. Second part for the data upload function, central control room to the end system to the various data to carry on the summary, report form data upload to the server.

PLC main function is in the case of outside load change to maintain the charged stable quantity, thus ensuring smooth production process, safety and economic operation. It includes the following aspects:

3.1. Pretreatment system

From raw material into the feed pool, began to monitor the incoming pool, ratio of grit chamber and grit chamber of liquid level, to monitor the running status of the pool, receiving the early warning alert at any time and making corresponding processing. At the same time it can set up the system of chain mechanism to handle end system: the restrictions, such as grit chamber stopping feeding shelf at a certain level. By the same token, the ratio of grit chamber and grit chamber can also set up a chain mechanism. Control interface design as shown in figure 2.

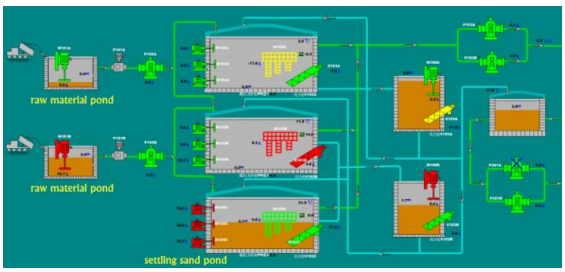

Figure 2: *pretreatment system operation interface*

3.2. Biogas fermentation system

It can monitor the running state in the fermentation tank on time, can monitor the internal liquid level, temperature, PH, parameters such as gas production rate. Liquid level sensor, SOKYO_PS1300 sensor is chosen, which has antiseptic function, suitable for biogas fermentation device. Temperature sensor detects the temperatures of the three points in the tank respectively, and respectively adopts the platinum thermal resistance PT100 temperature sensor. PH sensor with the function of ORP thermal resistance sensors can measure the PH and REDOX potential can be measured. Using chain system, according to the tank liquid level, whether controlling fermentation tank is fed, at the same time it can be on the end of the system to monitor the operation of the early warning calculated. As shown in figure 3.

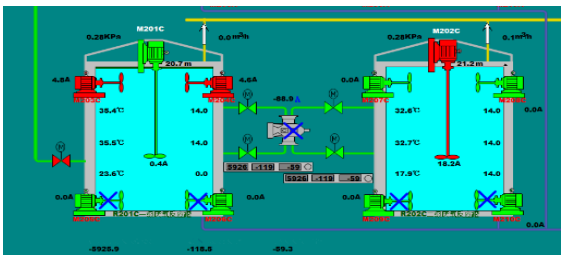

Figure 3: *fermentation tanks parameters monitoring interface*

To control the fermentation parameters fermentation tank can produce gas stable anaerobic environment, accelerate the methanogens degradation of organic matter, improve the rate of producing gas. Fermentation tank needs to be installed within the sensor types and specific indicators as shown in table 1.

Table 1: *Methane-producing tank configuration*

Control content	quantity	I/O	range
Liquid level	1	AI	0-25m
PH	1	AI	0-14
ORP	1	AI	-2000～2000mv
Material temperature	3	AI	0～150℃
Pump start-stop control	3	DO	
Manual/automatic indicator	3	DI	
Running indicator	2	DI	
Malfunction	4	DI	

3.3. Combustion system

The end system to monitor the pressure of the gas holder, making use of chain system automatically lighting the torch to analyse the gas holder pressure, can be manually set the torch burning out.

3.4. Real-time/history curve function

It can be viewed in setting methane pressure within a certain time period, the instantaneous output/cumulative production history curve, the temperature, various parameters, etc.

3.5. Alarm query

To keep a record of the related information of all the alarm system (alarm time, cause, whether having been solved) and can query by using the keyword index.

3.6. Chain system

To achieve automatic control of the whole biogas project, through the relationship between different equipment to set up mutual restriction conditions, so as to realize automation control. For example, feeding pool level is set high, when liquid level reaches this value, the feed pump stops working, and high level can be set manually.

3.7. Report uploaded

Upload related data from the management system (such as flow rate, PH value, alarm information, etc.) to server system and the time cycle can be set according to the requirement.

4. Conclusion

To sum-up: The automatic control system of anaerobic fermentation process has been installed and debugged, and has set up a formal release. The running results show that the system runs stably and reliably and is easy to operate. It meets the requirement of control process and ensures the two phase anaerobic fermentation environment, making each stage of activity of the strains obviously improved and realizing the rapid, efficient and stable gas, which have the desired effect.

PLC and Wincc configuration software in the automatic control system of the anaerobic fermentation process can realize functions as follows:

- Biogas fermentation engineering status of each sensor data collection. Collect the fermentation parameters in the biogas fermentation tank, e.g. liquid level, temperature, ph, process and control automatically.
- Upload automatically front-end data statistics, as a whole reserves in a regional and even national state of biogas fermentation engineering data.
- Automatically the PLC can realize logic control. End systems are implemented by PLC design, realizing the induction function, realizing biogas engineering chain between the coordination of all equipment and equipment features, and fully realizing the automation of biogas fermentation.
- Management system in the biogas fermentation process monitors and manages on time. It can display real-time data in the biogas fermentation and monitor real-time production state in the biogas fermentation process and can set and modify fermentation parameters, guarantee the methane project works well.
- Report query, print, and fault alarm. The database can obtain historical data at any time, generate reports and print. When the fermentation parameters are beyond the preset upper and lower limit, the system will automatically alarm and prompt operators will eliminate trouble.

5. Acknowledgements

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