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Design of Control System for Profile Control and Drive of Unmanned Offshore Platform based on PLC

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Abstract

Profile control and oil displacement technology is one of the important means to enhance oil recovery, which is widely used. Aiming at the problems of high safety risk, low operation efficiency and high cost of human resources in the traditional offshore profile control operation, which relies on manual operation, an offshore unmanned platform profile control system based on PLC is designed, which can realize the remote automatic control of profile control operation. The working principle and hardware composition of the control system are introduced in detail.A remote automatic control system based on Siemens S7-200 smart PLC and Forcecontrol configuration software is designed. The practice proves that the system is easy to operate, can improve the operation efficiency and safety, and has good economic benefits.

Keywords

Offshore Production Platform; PLC; Unmanned Platform; Profile Control and Displacement; Remote Control.

1. Introduction

With the increasing global demand for energy and the limitation of resources, the efficient development of offshore oilfields has become an important research field. As one of the key technologies to improve oilfield production and recovery, profile control and oil displacement technology[1] can effectively improve the recovery of crude oil and reduce the cost of oilfield development[2-3]. However, due to the special working environment of offshore platform, higher requirements are put forward for the efficiency and safety of the control system. Li Xiaoyong and others discussed the use of big data and artificial intelligence technology to optimize the strategy of displacement control and realize the intelligent operation process of displacement control[4]. Qiu Yadong and others realized the automatic adjustment and continuous monitoring of the injection volume in the chemical flooding process by cooperating with the surface control system, which significantly reduced the time of single well measurement and adjustment[5]. Liu Chunyue analyzed the possibility of reducing production and operation costs through unmanned transformation, and also reduced the possible environmental risks caused by human operation[6]. Wang Zhijian and others studied the realization of intelligent control system based on PLC in the application of layered water injection, and realized precise water injection control through optimized PID control strategy[7]. These studies show that the application of automation and intelligent technology can effectively improve the efficiency and safety of profile control operations and reduce production costs.

As a development mode of offshore oilfields, the number of unmanned platforms has been increasing in recent years. As a typical offshore oilfield, CNOOC Kenli 6-1 Oilfield has several unmanned platforms, and the oilfield has entered the rising period of water cut, so it is necessary to take measures to stabilize oil production and control water cut. The offshore platform displacement operation relies on manual operation, which has the problems of high safety risk, low operation efficiency and high cost of human resources, so it is necessary to introduce automation and intelligent technology to

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improve operation efficiency and safety[8]. According to the specific requirements of the oilfield, a PLC-based remote control automatic fluid preparation and injection system for the unmanned offshore platform is designed and developed in this study. The system makes use of the advantages of PLC in automatic control system, such as high reliability, flexibility of configuration and convenience of programming.By accurately controlling the injection process of profile control and oil displacement agent, it aims to optimize the percolation characteristics of the reservoir, and then realize the improvement of oil recovery. The system can not only achieve more accurate and efficient operation, but also run stably in extreme environments, which significantly improves the efficiency and safety of the operation.

2. System Introduction

In order to meet the process and control requirements of profile control and oil displacement automation operation, combined with the process characteristics of offshore unmanned production platform, the control system is mainly composed of hardware layer, software layer and communication network, which has four functions of remote control, remote monitoring, data analysis and alarm, and can realize two operation modes of single well online profile control and multi-well online profile control. The hardware layer includes programmable logic controllers (PLC), sensors (pressure, liquid level, flow, etc.), actuators (pumps, valves, etc.), industrial computers and displays. The software layer includes operation and management system, control algorithm, data analysis module and alarm system. The communication network uses submarine optical cable to realize high-speed data transmission between the central platform and the unmanned platform. The system structure diagram is shown in Fig. 1.

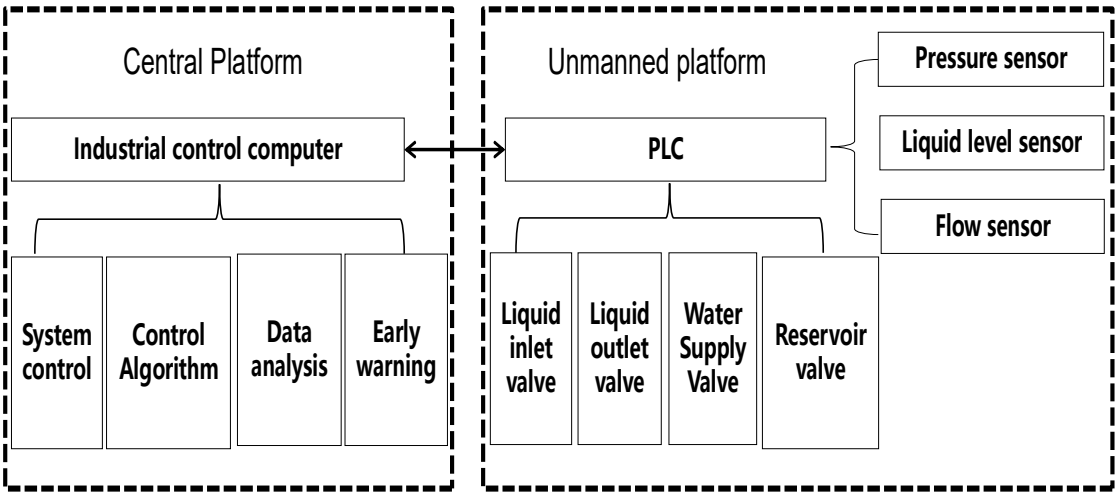

Fig. 1 Schematic diagram of system structure

3. Hardware Design

This design uses Siemens S7-200 SMART series PLC as the control core, which has the advantages of high reliability, simple programming and strong expansibility, and can meet the complex control requirements of the offshore unmanned platform control system.

The hardware layer also includes a variety of sensors and actuators. In terms of sensors, the pressure sensor is used to monitor the pressure changes in the pipeline in real time to ensure that the injection pressure is within a safe range; the liquid level sensor is installed on the liquid storage tank and other equipment to accurately measure the liquid level of the profile control and flooding agent so as to supplement the agent in time; the flow sensor is responsible for monitoring the injection flow of the profile control and flooding agent to provide data support for accurate control of the injection volume. In the actuator, the pump is used to deliver the profile control and displacement agent from the liquid storage tank to the injection well, and the valve controls the flow direction and flow rate of the profile

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control and displacement agent. The selected pumps and valves have good sealing and corrosion resistance, and can adapt to the harsh working environment at sea.

In addition, the hardware layer is also equipped with an industrial computer and a display. The industrial control computer is used as the host computer, and the Forcecontrol configuration software is used to monitor and manage the whole system. The display displays the running status, real-time data and alarm information of the system intuitively, which is convenient for the operator to understand the system situation and carry out the corresponding operation.

4. Software Design

4.1 Logic Control

The PLC analyzes and processes the data collected by the sensor according to the preset control logic, and controls the action of the actuator. Under the mode of single well online profile control, PLC controls the injection rate, pressure and time of profile control agent according to the profile control plan. When profile control is needed, the PLC controls the metering pump to inject the profile control agent into the well according to the set concentration, and monitors the injection pressure in real time through the pressure sensor. If the pressure exceeds the preset range or fluctuates abnormally, the system will automatically realize early warning.

In the operation mode of multi-well online profile control, PLC can realize the coordinated control of multiple wells. According to the production situation and profile control plan of different wells, it can perform profile control operation on multiple wells at different time or at the same time. For the wells with low injection pressure, the injection volume and injection rate of profile control and displacement agent can be increased appropriately, while for the wells with high injection pressure, the injection rate can be reduced to avoid excessive pressure on the formation. Through logical judgment and algorithm operation, PLC allocates resources reasonably and realizes efficient operation of the whole platform.

4.2 Data Processing and Analysis

PLC needs to fuse and analyze a large number of real-time data collected during its operation. Taking the calculation of injection volume of profile control and oil displacement agent as an example, PLC calculates the cumulative value of injection volume of profile control and oil displacement agent in real time according to the flow data collected by the flow sensor and combined with time information. At the same time, through the differential operation of continuous pressure data, the change trend of injection pressure is analyzed, and the information of pressure change rate and pressure fluctuation range is obtained. These data processed by PLC can provide the basis for the subsequent adjustment of injection parameters of profile control and flooding agent.

In the aspect of flow control, the system uses high-precision metering pump with servo control, which can realize the adjustment of small opening under the control of PLC. Through the introduction and use of high-precision metering pump, the high-precision control of injection flow rate of profile control agent from 10% to 100%, injection pressure of 25 MPa and control accuracy of ± 1% has been realized.

In the aspect of concentration control, various profile control and oil displacement agents can be accurately mixed according to a predetermined proportion under the control of PLC. According to the feedback signal of the flow sensor, the PLC adjusts the addition amount of each profile control and displacement agent in real time, ensures that the concentration error of the profile control and displacement agent is controlled within a very small range, stabilizes the concentration of the polymer solution near a set value, and ensures the profile control and flooding effect.

4.3 Real-time Monitoring and Early Warning

The system is equipped with comprehensive and accurate sensors to monitor the whole process of profile control and oil displacement in real time and in all directions. These sensors include, but are not limited to, temperature sensors, pressure sensors, flow sensors, flooding agent concentration

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sensors, and the like. Based on the real-time monitoring data, the PLC realizes the feedback control function. When the monitored parameters exceed the set threshold range, the PLC immediately starts the corresponding control strategy. For example, if the injection pressure exceeds the preset upper limit value, the PLC can automatically reduce the rotation speed of the injection pump to reduce the injection volume of the profile control and flooding agent, thereby reducing the pressure; if the concentration sensor detects that the concentration of the profile control and flooding agent deviates from the normal range, the PLC will adjust the concentration allocation device to restore the concentration to normal.

At the same time, the system also has the function of fault warning. When the data of a sensor fluctuates abnormally or deviates from the normal range for a long time, the PLC judges that there may be a fault. For example, if a pressure sensor continuously outputs an abnormally high or low pressure value, the PLC will send a fault alarm signal to inform the remote monitoring center that there may be problems such as sensor failure or pipe blockage. In addition, for some key parameters that may affect the effect of profile control and drive and the safety of the system, such as the abnormal increase of injection pressure, PLC will take emergency measures to stop the profile control and drive operation while alarming, waiting for further inspection and treatment to ensure the safe and stable operation of the system.

In addition, the software layer also includes an operation and management system, which provides a friendly human-computer interface for operators to facilitate parameter setting, operation mode selection, system start and stop, etc. The data analysis module is responsible for storing, analyzing and counting historical data, generating reports and curves, and helping technicians to evaluate the effect of profile control and optimize the profile control scheme; The alarm system gives an alarm in time for various abnormal conditions during the operation of the system, and records the alarm information for subsequent query and analysis.

5. Communication Design

In the automatic control system of unmanned platform profile control operation, the communication design between the operation end (unmanned platform) and the remote control end (central platform) is very important, which is directly related to the real-time, accuracy and reliability of the whole system, and then affects the efficiency and safety of profile control operation.

At present, the communication between the central platform and the unmanned platform is mainly realized by means of submarine optical cable. As a long-distance, large-capacity and strong anti-jamming communication transmission medium, submarine optical cable provides a solid foundation for the stable exchange of data, ensures the integrity and stability of communication signals in the long-distance transmission process, and provides a reliable communication line for the remote monitoring and control of unmanned platform.

One data acquisition server is deployed on the central platform, and Modbus TCP communication protocol is used to realize the acquisition of all new data points on the unattended platform. Through the Modbus TCP protocol, the data acquisition server can identify, analyze and collect new data point information generated by various sensors, equipment and control systems on the unmanned platform, covering process parameter data such as pressure, temperature, flow and liquid level, as well as key data such as equipment operation status and alarm information[9].

34 new acquisition points are added to an unattended platform, and the data packaging and return strategy is adopted after the PLC acquires the data. Because the TCP header usually occupies 20 bytes, the IP header usually occupies 20 bytes, and the data of 34 acquisition points occupies 76 bytes in total, the data is updated once every 100ms. Considering the factors such as two-way communication, protocol overhead and margin, the required bandwidth is about 26Kbps, which will not bring communication burden.

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6. Effect Analysis

6.1 Operation Efficiency Improvement

In the traditional offshore profile control operation, manual operation involves many steps, such as field monitoring, parameter adjustment, equipment start and stop, etc., which are cumbersome and time-consuming. The PLC-based unmanned platform profile control system realizes the remote automatic control, and the operator only needs to operate on the central platform through the upper computer software to complete the precise control of all the profile control equipment on the unmanned platform, which greatly reduces the labor intensity of the construction personnel and improves the operation efficiency.

Under the operation mode of multi-well online profile control and oil displacement, PLC can intelligently allocate the injection volume and injection time of profile control and oil displacement agent according to the real-time production data and profile control plan of each well, so as to realize the collaborative work among multiple wells. This optimized resource allocation method avoids the mutual interference between wells and improves the efficiency of profile control and oil displacement of the whole platform.

6.2 Security Enhancements

The environment of offshore platform is complex and harsh, and there are many potential safety hazards, such as bad weather, oil and gas leakage, etc. Through the remote monitoring function, operators do not need to work in a dangerous field environment to reduce the risk of personal injury. At the same time, the system monitors the equipment operation status and process parameters in real time. Once abnormal occurs, it can send an alarm signal in time to inform the remote monitoring center to take appropriate measures to avoid accidents.

The fault early warning function of the system can detect potential problems such as sensor failure and pipeline blockage in time and send out early warning. At the same time of alarm, PLC can automatically take emergency measures, such as stopping the operation of profile control, closing the relevant valves, etc., to prevent the further expansion of the fault and ensure the safe and stable operation of the system.

7. Conclusion

Aiming at the problem that the profile control operation of offshore unmanned platform relies on manual operation, this study successfully designed and developed the profile control system of offshore unmanned platform based on PLC. The system integrates hardware layer, software layer and communication network to realize the functions of remote control, monitoring, data analysis and alarm, and has two operation modes of single-well online profile control and multi-well online profile control.

By using Siemens S7-200 SMART series PLC as the control core, combined with a variety of high-precision sensors and actuators, as well as the application of force control configuration software, the reliability, accuracy and flexibility of the system are ensured. With the help of submarine optical cable and Modbus TCP protocol, the communication design realizes the stable and efficient data transmission between the central platform and the unmanned platform without causing communication burden.

The actual application results show that the system significantly improves the operation efficiency, enhances the safety and optimizes the effect of profile control and oil displacement, and has good economic benefits and application prospects. In the future development of offshore oilfields, similar automatic control systems are expected to be more widely used, which provides strong support for improving the oil recovery and production management level of offshore oilfields, and also provides valuable reference for other similar engineering applications.

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References

[1] Tian Jinjie, Wang Chengsheng, Chen Weiyu, et al. Design of intelligent decision system for profile control and oil displacement in offshore oilfield. Proceedings of China Oil and Gas Artificial Intelligence Science and Technology Conference, 2023: 231-236.

[2] Jin Baoguang, Jin Baoguang. Enhanced response mechanism of polymer flooding and optimal control of injection concentration [J]. Science, Technology and Engineering, 2018, 18 (17): 44-48.

[3] Zou Wanqin, Xie Xiangen, Liu Min, et al. Design and application of automatic control system for polymer injection in offshore oilfield. China Offshore Oil & Gas, 2010, 22 (05): 323-325,351.

[4] Li Xiaoyong, Li Jingwei, Fu Yarong, et al. Current situation and development trend of intelligent water plugging and profile control technology for oil and water wells [J]. Petroleum Drilling and Production Technology, 2021, (04): 545-551,558.

[5] Qiu Yadong, Xu Xiaoyu, Li Haicheng, et al. Continuous monitoring and automatic measurement and adjustment technology for chemical flooding [J]. Petroleum Drilling and Production Technology, 2022, 44 (05): 660-664.

[6] Liu Chunyue, Liu Chunyue. Analysis of unmanned reconstruction of wellhead platform in Bohai Oilfield [J]. Chemical Engineering Design Communication, 2022, 48 (10): 20-22.

[7] Wang Zhijian, Cui Zhihao, Huang Xueqin, et al. Key technology of intelligent control of water injection rate at wellhead of surface stratified water injection [J]. Mechanical Design and Manufacturing, 2024, (09): 320-324,330.

[8] LIU Jianzhong, XU Wenjiang, JIang Weidong, et al. Progress and prospect of offshore oil production engineering technology of CNOOC [J]. China Offshore Oil & Gas, 2024, 36 (05): 128-136.

[9] Chen Qiliang, Chen Qiliang. Application of automatic industrial control system in oilfield production process. Chemical Management, 2019, (35): 226-227.