Development and Application of Petroleum Development Equipment Integrity Management System Based on Wireless Sensor

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Abstract. This paper designs and implements a large-scale instrument and equipment monitoring system from the perspective of the current management of large-scale instruments and equipment for petroleum development. The system is interoperable with the current petroleum extraction equipment management system and the large life cycle management system of large-scale instruments and equipment, combined with wireless sensor network technology, real-time monitoring of large-scale equipment. The system facilitates the management of large instruments and equipment by large instrument and equipment management departments and improves the efficiency of petroleum development equipment management.

1. Introduction
The modern management and safe production of oil extraction are important matters for the petroleum industry. At present, most oil fields are located in swamps, deserts and basins, shallow seas and other areas. Due to the sparse population of cities far away from cities, transportation and communication facilities are relatively backward. In addition, the distribution of oil wells in oil fields ranges from tens to hundreds of square kilometres, and the distribution is relatively scattered. At present, most of them use manual patrol wells, which regularly check the operation of equipment and record oil production data. This method will inevitably increase the labour intensity of workers, increase the development cost, and affect the real-time and even accuracy of equipment monitoring and oil recovery data. And when the pumping unit and electric pump fail, they cannot be found in time, and effective monitoring, prevention and control cannot be obtained.

The wireless sensor network is a self-organizing network, which has the characteristics of flexible deployment, low networking cost, and safe and reliable data transmission. The wireless sensor network technology integrates sensor technology, embedded computing technology, distributed data processing technology and communication technology, and collects data from monitoring points through the sensing terminal. These data are sent wirelessly and transmitted in a self-organizing multi-hop network to the business application platform. Therefore, the use of wireless sensor network technology for real-time monitoring of liquefied petroleum gas cylinders can make up for the deficiencies of traditional...
manual detection. In view of the fact that large instruments and equipment for oil mining are relatively expensive, they are generally managed by dedicated personnel. It is easy to damage without strengthening management and it is impossible to find the operator who is damaged. How to ensure the normal operation of these large-scale equipment, to find the person who mishandled when a fault occurs, and to improve the efficiency of the use of these large-scale instruments and equipment is a problem in front of the managers of large-scale oil extraction equipment. This paper uses wireless sensor network combined with RFID technology to achieve real-time monitoring of large instruments to solve the above problems [1].

2. The overall design of the system

2.1. Demand analysis
The remote monitoring system based on wireless sensor network designed in this paper is applied to unmanned environments such as oil fields and oil wells. Therefore, it must have a sampling node for environmental parameters. At the same time, in order to process the captured data, a central service node must process and analyse the data. More importantly, the on-site data needs to be displayed on the remote monitoring display for the staff to view and deal with the problems found in a timely manner. Therefore, the main control room in the system is essential. In this way, the nodes of each part of the system designed according to functional requirements can be combined together to obtain satisfactory performance and results in practice.

2.2. Overall structure
The large-scale oil mining equipment management system based on wireless sensor network is mainly composed of three parts. Figure 1 shows the structure diagram of its large-scale oil mining equipment management system.

![Figure 1. Oil exploitation large equipment management system](image)

Firstly, the sampling node. Collect parameters and identify status, and use sensors to collect environmental parameters, such as temperature, humidity, and gas density. Status recognition mainly
includes the status of the field equipment, so as to judge whether the equipment is operating. If the equipment fails during the operation, it must react to the main control room and use the processing countermeasures in a timely manner. Secondly, the monitoring centre. Real-time monitoring of the operation of the drilling rig equipment. Oil drilling personnel use the display of the main control room to realize real-time detection of the working conditions of the drilling rig and other equipment. If operating failures are found, strategies should be used to deal with them in time. Thirdly, the central service node. To process and transmit data, the original data of the sampling node is used to make it easier to understand the data, so the node is required to have the function of data processing. In addition, data transmission enables the original or processed data to be wirelessly transmitted to the main control room and stored [2].

2.3. Main functions of the system

2.3.1. Basic information management. The main function is to maintain the basic equipment model, obtain basic equipment information, and manage user information and monitoring device information. The basic equipment information is obtained from the instrument equipment management system through the Web interface. Equipment basic model maintenance includes sub-modules such as equipment type maintenance, equipment storage location maintenance, equipment voltage level maintenance and equipment storage unit maintenance. User information management includes user authority information settings, user organization settings and user detailed information settings. The monitoring device management includes functions such as device detailed information setting and device and device association information setting.

2.3.2. Equipment operation information. Mainly record equipment usage records, equipment maintenance records, equipment attribute change records and equipment use approval records. Some of the information comes from the device management system. This module records most of the data during the operation of the device. After the system goes online, the data will continue to increase. Each time the user opens the instrument device by swiping, the user's login will be automatically recorded Information and exit information.

2.3.3. Monitoring and control of monitoring devices. This module is mainly some auxiliary functions related to the monitoring device, such as setting the authority of the monitoring device, ensuring safe communication, and recording the information of the monitoring device connected to the system.

3. Hardware management

3.1. Network topology
The hierarchical wireless sensor network topology control algorithms mainly include LEACH algorithm, GAF algorithm, GAF improved algorithm and so on. According to the need to build a clustered chain network at the drilling site, the design of the topology control mechanism in this paper refers to the LEACH algorithm. In this algorithm, the cluster heads are first generated by random election, and then the end node selects the adjacent cluster heads to join to form a cluster. During communication, the cluster head sends the data of the nodes in the cluster to the coordinator. But the LEACH algorithm always thinks that the cluster head node in the network can directly communicate with the gateway. The hierarchical wireless sensor network designed in this paper is a chain structure. The gateway can only communicate with the cluster head node closest to it. Therefore, a new topology generation control mechanism is designed based on the LEACH protocol. In this mechanism, all cluster head nodes (including gateways) are fixed, that is, the gateway and cluster head nodes are manually configured, and then each end node selects different cluster head nodes according to the designed algorithm Join, as their parent node [3].
The gateway and each cluster head constitute the trunk of the network, and each end node is equivalent to a branch. When a router in the network is connected to a new device (end device or another router), it forms a parent-child relationship with the newly added device, the new device becomes a child device, and the original device becomes a parent device. For a router, its sub-devices and sub-devices at all levels belong to its branches. Assuming that a router address is \( A \), if the destination device with address \( D \) is to become a branch device with router address \( A \).

\[
A < D < A + C_{\text{skip}}
\]  

(1)

In the formula, \( C_{\text{skip}} \) is the maximum number of devices that the router is allowed to join. The end node does not have the ability to receive other devices to join, so there is no branch device. After a router receives a data packet, if the destination address is a branch device of the device, it sends the data packet to its next-level router for processing; otherwise, it is sent to its parent device, and the data packet will be transmitted to the next level along the trunk. Destination equipment. According to this routing method, when a certain end node wants to send data to the gateway, the data packet is first transmitted to the cluster head of this cluster, and then sent to the gateway node step by step through the previous cluster head, as shown in Figure 2.

As can be seen from Figure 2, in order to ensure the reliability of data transmission, it is only necessary to ensure reliable wireless communication within a single hop range, so that the node's wireless transceiver can work at a lower power level. In addition, this routing mechanism does not need to perform route discovery, establishment and maintenance, which further saves energy expenditure and greatly reduces the transmission delay of data packets, which is very conducive to energy saving of the network and timely transmission of monitoring information [4].
3.2. Wireless sensor node module design

The system uses TI's CC2430 as the main control chip of the sensor node module. CC2430 is a system-on-chip (SoC) that supports ZigBee / 802.15.4 protocol launched by TI. The chip integrates an RF transceiver, enhanced 8051 MCU, 128KB High-performance modules such as programmable flash memory and 8KB RAM. Various sensors convert the collected analogy signals to digital signals through A / D and pass them to the microprocessor module. The microprocessor module is responsible for controlling the data processing operations, routing protocols, power consumption management, and task management of the entire node. The RF radio frequency module is responsible for wireless communication with other nodes, exchanging control messages, and sending and receiving data [6]. For the RF module, the size, price and performance of the antenna are all parameters that need to be considered. A PCB antenna is used to connect the whip antenna to ensure transmission distance and reliable communication. It uses 2 AA batteries for power supply.

4. System software design

The sensor is equipped with a wireless transmission module. The system is mainly connected to the PC and the RTU by wireless or wired network. The RTU uses the wireless transmission module to send and receive data. The dynamometer belongs to the gateway of the sensor group. The sensor value, and also realize the receiving and storage of temperature, pressure sensor and electric quantity, and then send the RTU through processing.

When the computer sends instructions to the sensor, the PTU's workflow is: the two are connected to each other using a network cable, and a communication link is created through TCP. RTU uses the monitoring of the TCP port of the PC to obtain the data packet sent from the PC, and then implements the analysis of the data packet. If the data packet is an alarm response, then send it directly to the sensor. If the data packet is a data collection command, then reorganize the command frame and then send it to the sensor. If the transmission fails, the PC will resend until it is successfully sent. Then RTU will continue to listen to TCP. Figure 3 shows the PC sending corresponding instructions to the sensor [5].

![Figure 3. PC sends corresponding instructions to the sensor](image-url)
5. System implementation

Wireless sensor nodes, relays and gateways use the ZigBee protocol stack, which can realize ad hoc networks. The wireless sensor node is installed on the liquefied petroleum gas cylinder, and the relay or gateway node is installed on the community building, cylinder filling station and transportation trunk road. When the steel cylinder is used, filled, and transported by the user at home, the wireless sensor node, relay, and gateway node form a sensor network. In this way, on the one hand, the gateway can send the data of the wireless sensor node to the data centre using GPRS; on the other hand, the gateway node will also set the overvoltage to be lower than the dielectric strength of the protected electrical equipment. "High potential introduction", the lightning current can be automatically led to the ground through the lightning arrester. After the atmospheric overvoltage introduced by the line is over, the lightning arrester quickly restores the non-conducting state to the ground, so that the current of the power line will not leak to the ground through the arrester the earth. In this way, it can effectively avoid the damage to electrical equipment and personal caused by high potential. It can be seen that the lightning arrester is a protection device used to protect electrical equipment from overvoltage hazards caused by lightning and limit the amplitude and duration of freewheeling.

An important factor that determines the reliability of data transmission in sensor networks is the communication capability of two adjacent nodes, namely the single-hop wireless transmission distance. The system test is divided into two situations, barrier-free and barrier-free, starting with a linear distance of 5m and increasing by 5m in sequence. Each time 100 frames of data are sent to 30m. It can be seen from Table 1 that when there is no barrier between nodes, there is no packet loss when the single-hop distance is less than 15m; when the distance reaches 20m, there is a 2% packet loss rate; when the distance continues to increase, the communication quality drops sharply. When there is an obstacle between nodes, such as a wall barrier, the transmission reliability is good when the distance is less than 10m. In practical application, it is necessary to consider the actual situation of the monitoring environment and reasonably lay out the sensor nodes to ensure the communication quality of the wireless sensor network [6].

| Table 1. Single-hop transmission distance test results between nodes |
|---------------------------------------------------------------|
| Distance / m | 5 | 10 | 15 | 20 | 25 | 30 |
|----------------|---|----|----|----|----|----|
| Number of frames received without barriers | 100 | 100 | 100 | 98 | 86 | 52 |
| Number of frames received with obstacles | 100 | 96 | 80 | 30 | 10 | 0  |

Tests show that the system has the characteristics of simple architecture, convenient implementation, and high reliability, and provides a complete set of feasible solutions for intelligent environmental monitoring and alarm. The system can be improved from the following aspects in the future: one is to increase the integration of hardware and reduce the volume of nodes; the second is to optimize the hardware and software structure to further reduce the system power consumption; the third is to study sustainable power supply solutions; Expand the functions of the control centre, such as remote control of security equipment [7].

6. Summary of papers

The thesis designs a hierarchical wireless sensor network for monitoring oil drilling field equipment. The network is composed of several interconnected clusters, and each cluster includes a cluster head node and several end nodes. Laboratory simulation tests show that the network can realize the monitoring of wellsite drilling equipment, which lays a good foundation for improving the safety monitoring level of drilling production site. The current laboratory research needs to further test the network structure optimization and network stability. After these tasks are completed, it can be extended to field trials.
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