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Well head multi parameter data monitoring system based on LoRa

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Abstract: Oilfield wellhead data is an important indicator to reflect the normal operation of oil well equipment. This paper monitors the data of standpipe pressure, hanging weight, torque and other parameters, which is helpful to improve the safety and production efficiency of the entire oilfield. Therefore, this paper proposes a set of multi parameter monitoring system based on LoRa to further explore and study in order to reduce oilfield accidents.

Keywords: LoRa; Multi parameter monitoring.

1. Introduction

With the development of intelligent drilling, real-time and accurate monitoring of drilling parameters is a difficult point in the drilling process. Torque, hanging weight and riser pressure are very important parameters in the drilling process. Through the research of multi parameter real-time monitoring system, and through wireless transmission to the cloud, real-time wellhead multi parameter real-time monitoring. In addition, due to the remote area, the well pad far from the main oil area cannot realize network communication. Due to the particularity of transmission medium and oilfield terrain, wired instrument has high maintenance cost and transmission distance is limited more. With the development of network technology and communication technology, wireless communication technology is widely used in monitoring [1]. Through the research on the existing communication technology, a data transmission mode with long transmission distance, stable transmission effect, large coverage and low operating cost is selected, and LoRa transmission mode is selected. LoRa technology is applied to the field of oil fields to provide real-time and reliable field data for the oil field data acquisition system [2], which will improve the intelligence of oil field data acquisition to a certain extent and promote the process of intelligent oil fields.

2. Monitoring system architecture

The hardware of the whole multi-parameter monitoring system is composed of sensor acquisition module, wireless communication equipment, cloud display platform and power supply, etc. After output standard signals of pressure sensor, torque sensor and suspension sensor, they are collected by A/D module and transmitted to the cloud through loRa wireless, realizing multi-parameter monitoring and providing power for the whole system with regulated voltage power supply.

Acquisition layer: The acquisition module is at the front end of the whole mobile intelligent front-end system, consisting of pressure sensor, suspension sensor and torque sensor nodes. Each sensor node is placed at each position point, and the required data is collected by the sensor, and then transferred to the application layer through the data transmission layer.

Transport layer: Provides transparent data transmission between end users and reliable data transmission services for the application layer. The data transmission service is reflected by the protocol. The method of uploading data to the Internet: the simplest HTTP protocol is used to upload the data to the server in plain text, and the server receives and stores the data to the database, so as to realize the accurate transmission of the message between the two terminal systems. In this paper, the data from the data acquisition layer is transmitted wirelessly to the application layer through the LoRa device.

Application layer: Server module. Its function is to receive the data sent by the lower module, and complete the data storage by the database server, the statistical data analysis by the application server and the data processing server, etc., to provide the cloud database server, the application server and the data processing server for the whole system.

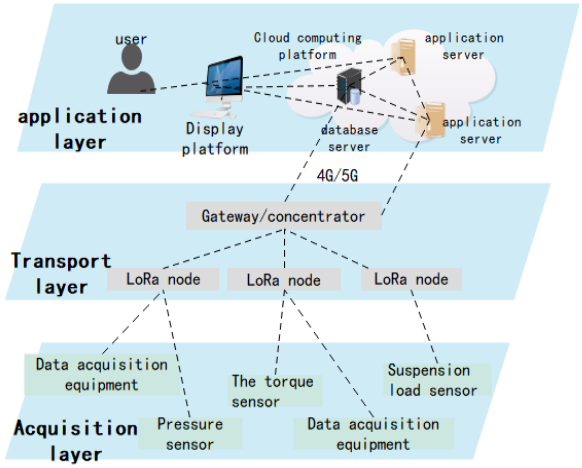


Fig.1 Overall Monitoring System

3. Design key modules

3.1. Acquisition layer

Many different sensors are installed in the oil drilling field environment. The pressure sensor, suspension sensor and torque sensor and signal acquisition module adopt RS485 standard Modbus-RTU universal protocol, which is easy to integrate into third-party application systems [3]. The sensor signal can also be processed by the AD sampling chip, and

then converted into the corresponding value to communicate with the upper computer in RS485 or wireless mode.

3.1.1. Sensor

According to different sensor principles, requirements to be measured and application occasions, select the appropriate sensor, the principle of different output gas, light, electricity and other physical quantities, in order to facilitate the required measurement parameters conversion, acquisition, transmission and display operations. A sensor is a device or device that can feel a specified measured signal and convert it into a usable output signal according to a certain law. An input is something that is measured, which may be a physical quantity, a chemical quantity, a biomass, etc. Output is system hardware module deletion [Lenovo]: a physical quantity that is convenient for transmission, conversion, processing, display, etc. This quantity can be gas, optical, electrical physical quantity, but mainly electrical physical quantity; There is a correspondence between output and input, and there should be a certain degree of accuracy. Sensors are also known by other names, such as transducer, transducer, detector, etc.

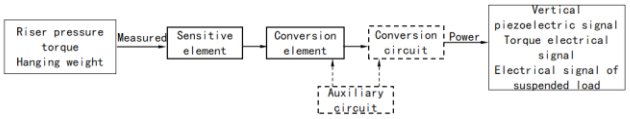


Fig.2 Sensor composition

Sensitive element Sensitive element refers to the sensor can sensitively directly feel or respond to the measured (non-electric quantity, such as displacement, strain) device or element.

Conversion element conversion element, also known as sensing element, refers to the sensor can be sensitive element feeling or response to be measured (non-electric quantity) into suitable for transmission or measurement of electric quantity (electrical signal) devices or components. It is usually not directly felt to be measured.

The conversion circuit will convert the output of the component for processing, such as signal amplification, operational modulation, so that the output becomes easy to display, record, control and processing useful electrical signals or electricity, such as voltage, current or frequency.

In order to meet the monitoring requirements, the sensor with high measurement accuracy, good sensitivity, small size and easy installation is selected.

3.1.2. Acquisition Module

In order to realize the conversion and acquisition of multi-channel analog signals such as pressure, torque and suspension of the opposable tube, A/D acquisition module supports multi-channel analog input, multi-channel digital output to RS485, instrument data is converted into digital signals and transmitted to the cloud monitoring center through RS485, and standard Modbus RTU communication protocol is supported. See Figure 3 below.

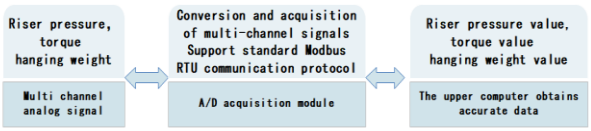


Fig.3 Data acquisition technology

It adopts eight-channel analog acquisition module, supports current or voltage acquisition, and is equipped with jumper device to switch the range, supports multi-specification acquisition range, supports various configuration software docking, supports multi-channel DO signal output, has 12-bit resolution, 0.1% precision ADC, high performance and low power consumption 32-bit ARM embedded CPU, supports Modbus RTU slave station protocol.RS485 communication port with lightning protection and electrostatic protection, industrial temperature range, to cope with harsh site. As shown in Figure 4 below.



Fig. 4 Eight-channel analog acquisition module

The technical parameters of the acquisition module are shown in Table 1 below.

Table 1. Technical parameters

technical characteristics	performance parameter	technical characteristics	Performance parameter
AI	Eight way single end	DO	Eight way single end
AIresolving power	12bit	Output signal type	NPN
AIrange	0-10V, 0-20mA	output voltage	Vou t=VCC
Acquisition speed	1KHz	communication interface	RS485
data format	N, E, O.8.1	Baud rate	1200-115200bps
accuracy	0.1%	Communication protocol	Modbus RTU
Power supply	DC5-35V	Operating temperature and humidity	-40°C~85°C 0%RH~95% RH

When collecting the data output of pressure, torque and suspension, the device communication protocol follows Modbus-RTU to communicate according to the device address, function code, start address, register address and CRC check, and realizes the data connection at the next layer through different address commands [4].After the acquisition module is powered on normally, the initialization is complete, and the module is connected to the computer through the USB serial port for parameter configuration. At the same time, RS485 is used to connect to the LoRa node for data transmission. A/D analog acquisition starts timing, when more than two seconds after A/D acquisition operation mark position, and then A/D acquisition, collected data stored in A register, finally data analysis, because 0-5V analog acquisition is through A/D conversion circuit, the voltage signal is collected through RS485 transmission to the next module LoRa node for transmission.

3.2. Transport layer

In the process of data transmission, due to remote areas, well sites far away from the main oil area cannot realize network communication. It is necessary to study and compare existing communication technologies, such as optical cable, wireless bridge, 4G, Lora, etc., and select a way with long transmission distance, stable transmission effect, large coverage and low operating cost. Therefore, using a communication technology with long transmission distance, low power consumption, low cost and high reliability applied to wireless instrument can improve the production efficiency better.

Table 2. Scheme comparison optimization

Transmission mode / Transmission characteristics	Lora	NB-IoT	Sigfox
Frequency band	Unlicensed frequency band below1GHz, no extra charge	Working in the authorized frequency band, you need to pay	Unlicensed frequency band, no extra charge
Suitable Scenarios	Low cost, large number of connections, and infrequent communication	Frequent communication, short delay or large data volume	Scenario of transmitting data in a fixed period
Network application	Ad hoc network	Based on LTEFDD or GSM	Sigfox base station and cloud platform
gateway	Gateway needs to be deployed	No gateway needs to be deployed, but it can be directly deployed in GSM or LTE networks	unwanted
Coverage	Long distance：<11km	Long distance: 1~2km in city, 20km in suburb	Long distance（50Km)
power waste	low	low	low

Table 3. Technical Parameters of LoRa node and Gateway

LoRa node（USR-LG206-L-C）		LoRa Gateway（USR-LG220-L）			
technical parameter					
Wireless parameters	Operating frequency band	398~525MHz	Wired network port	Wired WAN port	wAN* 1
	Transmitting power	10dBm~20dBm	WIFI	WIFI Wireless LAN	Support 802.11b/g/n
	Receiving sensitivity	-138.5dBm@0.268Kbps	Key	Reload	One touch factory reset
	transmission distance	2500m (test condition: sunny, open, maximum power	4 LoRa channels One management channel and three data channels	agreement	USR private protocol, simple, safe and reliable
				Frequency band	398MHz~525MHz, 128 channels in tota
				passageway	Channel 1 is the management channel, and channel 2, 3 and 4 are the data channels
				Transmitting power	Maximum transmitting power 20dBm
Hardware parameters	data interface	UART : RS232/485	4G	Support scope	-42 (China Mobile/China Unicom 2/3/4G Telecom 4G
		Baud rate:1200bps-115200bps		SIM/USIM card	Standard 6-pin SIM card interface, 3V/1.8V SIM card

At present, low-power wide-area network is the main wireless transmission technology used in oil drilling sites. Low-power wide-area network transmission technology represented by Lora, Sigfox and NB-IoT will gradually become the mainstream of transport layer connection technology and be more widely used in well sites.

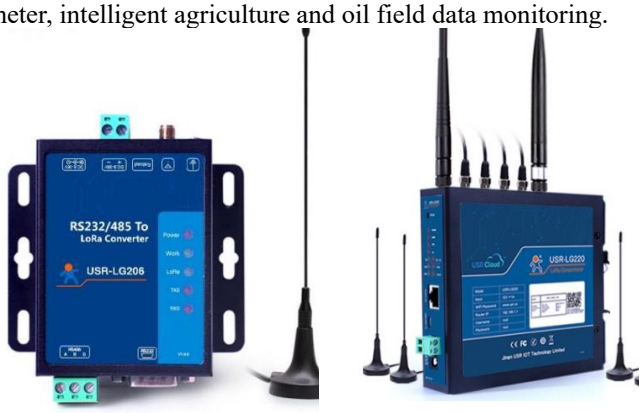
According to the transmission requirements of oil drilling site, transmission distance and communication mode, as shown in Table 2 above; Select Lora wireless transmission mode. Realize terminal data processing optimization, provide conditions for data security, and effectively reduce the pressure of platform server. Realize the programming, diagnosis, debugging of the field equipment, improve the service response speed; Fault alarm improves the device online rate in remote areas. The intelligent gateway is used in conjunction with the cloud management system of Wucom, which greatly improves the management efficiency.

The LoRa network consists of terminals (with built-in LoRa modules), gateways (or base stations), network services, and application services. Application data can be transmitted both ways.

In order to realize the terminal equipment of riser pressure, torque and suspension data acquisition at the wellhead of oil field drilling through wireless transmission to the cloud, diversified interfaces such as equipment and sensors are provided, which are connected with the field drilling equipment and sensors, so as to collect data information and store it locally, and implement data preprocessing. Through investigation and product comparison, USR-LG206-L-C and gateway USR-LG220-L, LoRa data transmission terminal

and gateway with personal-link products, are selected, as shown in Figure 5.

USR-LG206-L-C operates in the frequency band of 398~525MHz. Serial port is used to send and receive data, which lowers the threshold of wireless applications and enables user devices to communicate with concentrator through LoRa technology. LoRa has the advantages of concentrated power density and strong anti-interference ability. The communication distance can reach 2500m (open visual range, antenna gain 3dBi, height greater than 2m, 0.268Kbps air rate).USR-LG220-L supports one wired WAN port, one WIFI wireless LAN, and 4G network interface. With rich networking functions, it is convenient for users to lay their own network, and can ensure the multi-directional data network transmission without loss. LoRa proprietary protocol makes communication more simple, secure and reliable. Users do not need to care about the protocol. The supporting concentrator and LoRa terminal module can communicate through simple configuration, Table 3 lists the technical parameters of the two. USR-LG206-L-C can realize data acquisition and control of client terminal equipment and signal quality monitoring of its own LoRa nodes. Usr-lg220-l is an Internet of Things base station concentrator based on low power WAN LoRa private protocol, through USR private protocol to realize the concentrator and terminal module free networking, concentrator and server communication. It provides a non-tariff, high performance, low power consumption, intelligent AD hoc network, remote wireless data transmission communication mode. Man, Man's LoRa products have the characteristics of long distance, low power consumption, multi-node and low cost. Currently, they have played an important role in many scenarios such as intelligent meter, intelligent agriculture and oil field data monitoring.



LoRa node（USR-LG206-L-C） LoRa gateway（USR-LG220-L）

Fig.5 Transmission equipment

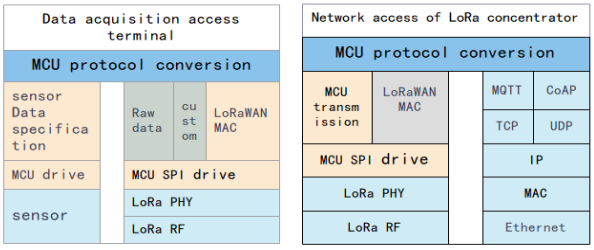


Fig.6 Protocol of each node in LoRa system

LoRa is a kind of LPWAN communication technology. It is an ultra-long-distance wireless transmission scheme based on spread spectrum technology. It mainly operates in 433, 868MHz and other global free frequency bands. LoRa gateway is a remote data transmission gateway using LoRa wireless modulation technology. Microcontroller MCU is mainly responsible for completing the initial configuration and low-power processing of each module, and cooperating with each module to complete data reading, storage, simple analysis and processing and reporting, as well as the delivery and execution confirmation of control instructions. RF layer: the lowest RF RF layer (Regional ISM, regional free frequency band); L1 layer: LoRa Modulation (mode debugging and coding) to achieve wireless coding modulation of digital signals. Including spread spectrum coded modulation and frequency shift keying coded modulation FSK; L2 layer: LoRaMAC (MAC layer): Implements wireless link management of LoRa terminals, including the three working modes described in the following section.At the same time, the packet encapsulation format of MAC layer is defined [5].

The data at the application layer and the MAC commands needed to establish a connection between the terminal device and the gateway are transmitted as the MAC payload. Implements network management between the server (i.e., gateway) and terminal devices.

In the data monitoring architecture, data information such as drilling parameters pressure, torque and suspension in the drilling process is collected by sensors, and the convergence of LoRa terminal is provided through LoRa wireless technology, and the data is transmitted to LoRa gateway. Connect to LoRa WAN WAN server and cloud platform via Ethernet LAN or 2G/4G/5G public mobile communication network. You can manage multiple LoRa terminals.

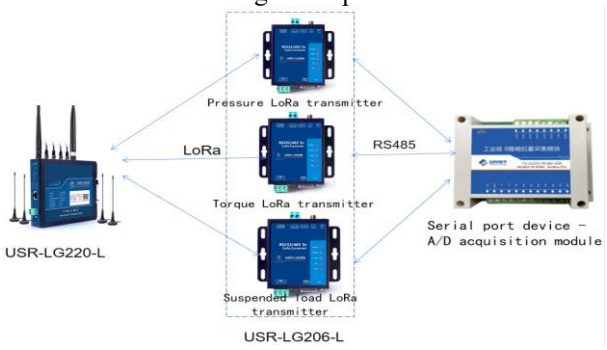


Fig.7 LoRa node to concentrator communication topology

Located at the heart of the LoRa star network, the LoRa Gateway is the information bridge between the terminal and the server and is a multi-channel receiver. The pressure, suspension and torque of the data acquisition module can communicate with the central point simultaneously through three Lora terminal nodes, from which data can be reported randomly. The node can automatically adopt frequency hopping and rate adaptive technology according to the external environment and channel blocking. Logically, the gateway/can receive signal combinations of different rates and different frequency points. The physical gateway can receive data from 8, 16, 32, or more channels at the same time, which reduces the probability of conflicts between a large number of nodes and facilitates accurate data transmission.

3.3. Application layer

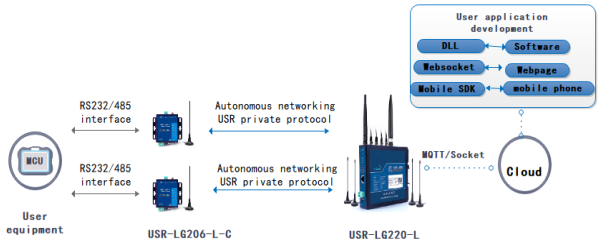


Fig. 8 LoRa networking application

Located at the upper end of the whole platform, the cloud server subsystem is mainly responsible for user login management of the whole platform, receiving data transmitted from the lower end, completing usage, storing data in the data base, and analyzing, processing and applying the data. The transmission layer transmits data to the server in the cloud through Ethernet, 5G, 4G, 3G, WIFI and other protocols such as MQTT and HTTP to complete data monitoring[6], fault alarm and other functions. It is also widely used in oil field to realize remote transmission of drilling parameters. MQTT and socket server login and connection, provide MQTT/Socket protocol and support cloud development, support MQTT protocol transmission, provide human cloud services, and provide a variety of secondary development SDK, convenient for users to directly develop front-end pages, the parameter page is displayed as shown in Figure 9.

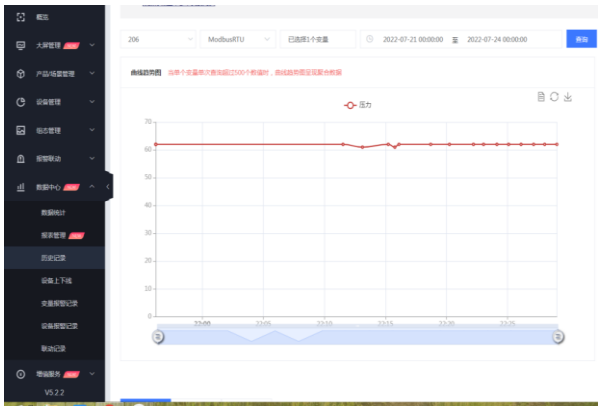


Fig. 9 Parameter page display

Through wellhead parameters such as pipe pressure, temperature, suspension and torque, data monitoring, data management and forwarding, the cloud server system provides the service to manage data received and stored in the database. At the same time, the system supports data exchange between devices at the terminal layer and the acquisition layer, and provides data forwarding service. Data reception and storage: The cloud service interacts with the lower terminal layer to receive sensor data sent by the terminal layer and stores the sensor data in the database for other applications or services. The cloud service also receives service requests from the terminal layer and responds to them. Combined with relevant technologies, it can provide more technical basis for the judgment of the working state of the oil well, and realize a series of decisions such as remote diagnosis, operation and prediction by comparing relevant data in the simulation field, so as to reduce the occurrence of oil well accidents, reduce unnecessary losses, improve oil production efficiency, enrich the function of the smart oil field, and further promote the development process of the smart oil field.

4. Conclusion

In this paper, the data monitoring of pipe pressure, temperature, suspension weight, torque and other parameters is carried out. The low power WAN technology is applied to the data transmission of oilfield wellhead instrument, and the communication between user terminal and oilfield wellhead instrument is realized through LoRa wireless network and public network, so that the user terminal can monitor the data and operation status of each instrument remotely. This paper analyzes the network structure, hardware and software design of the system. The system has long communication distance, low power consumption and low cost, which can greatly meet the needs of data monitoring system and has a very wide application prospect.

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