The Monitoring System Design of Oil Well Dynamic Fluid Level

Caili Song, Xin Guan
School of Computer Science, Xi’an Shiyou University, Xi’an 710065, China
1290103647@qq.com

Abstract. Dynamic fluid level is the most important indicator in the process of oil field development. By monitoring the dynamic fluid level of oil well, the working mode of pumping can be adjusted in time to maximize the utilization of resources. In this paper, a set of oil well dynamic liquid level monitoring system is introduced. The device collects sound wave data periodically and transmits data with the upper computer via WIFI and 4G to realize real-time monitoring of oil well dynamic liquid level. The monitoring software system of the upper computer is deployed on LAN and Aliyun server to realize remote users access to dynamic liquid level data in the oil field.

1. Introduction
The dynamic fluid level is a liquid level in the annular space of tubing and casing in the normal production of a pumping well. During oilfield production, the dynamic fluid level directly affects the production efficiency of oil well[1]. In the process of oil well exploitation, the maximization of output and comprehensive efficiency is the ultimate goal, and the liquid supply capacity of the formation is the fundamental factor to restricting the realization of this goal, which is reflected by an important index- the dynamic liquid level of the oil well, so it is very necessary to measure the liquid level of the oil well[2].

This system is composed of data acquisition device and upper computer monitoring software system. Using ARM chip STM32F407 as the main processor of the device to collect, store and transmit dynamic liquid level data. The software system includes data management and the data acquisition device control. In order to adapt to the oil wells in different environments, the software system is deployed on the local server in oil field LAN and on Aliyun server.

For the oil wells massed in oil field, the device transmits data to the local server in the oil field LAN via WIFI. For the remote ones that cannot be connected to the oil field LAN, the device transmits data to Aliyun server via 4G. Meanwhile, Aliyun server can meet the demand of remote users outside the oil field to access the dynamic liquid level data. In order to keep the data on the local server consistent with on Aliyun server, synchronization software is used to synchronize data manually or periodically.

2. Architecture
This system is divided into two parts: data acquisition device and upper computer monitoring software system. Data acquisition is the basis of the software system. The device communicates with the server in different ways according to different environments and as a data source for data visualization.

The software system consists of a management and monitoring software, a control software and a synchronization software, mainly realizes a two-way transmission with the device, and collects, stores
data and controls device. Also, it provides users with the website for data access. The system architecture is shown in Fig. 1.

![System architecture](image1)

As the system hardware and software connection shown in Fig. 2, in the well site with massed oil wells in LAN, the device transmits data to the local data acquisition server within the LAN through the wireless router via WIFI, yet the independent oil wells outside the LAN transmit data to Aliyun server via 4G. The database server, IIS server, data acquisition server, device configuration, these four modules are deployed on local server and on Aliyun server respectively. And the data synchronization software in LAN is used to keep the consistency of two regional databases.

![Connection between hardware and software](image2)

3. Key technologies of the system

3.1. Relevant technology of data acquisition device

Using embedded development technology, the main processor of the device is STM32F407 chip, system initialization program is programmed in assembly language, and the acquisition program with C language. Data are transmitted via WIFI and 4G respectively, and the control signal is transmitted with RS-232 protocol. And the device is equipped with SD card to storage data and LCD to show the current parameters.
3.2. Relevant technologies of data transmission

WIFI is a short-range wireless transmission technology that enables Internet access to radio signals over hundreds of feet. And the most obvious advantage of WIFI is the higher transmission speed, in the case of weak signal or interference, the bandwidth can be adjusted to ensure the stability and reliability of the network effectively[3].

4G is the popular name for the fourth generation of mobile communication whose official name of ITU is "IMT-Advanced"[4]. And it has the characteristics of fast communication speed, high storage capacity and high compatibility.

The two communication modes of WIFI and 4G in the device adopt TCP/IP protocol, and data acquisition program is programmed in C# language based on C/S (Client/Server) architecture.

MODBUS is a serial communication protocol, which was published by Modicon in 1979 for the use of programmable logic controller (PLC)[5]. It has two modes of communication, ASCII and RTU.

RS-232 and RS-485 are both serial communication standards. The difference is that RS-232 can realize point-to-point communication but does not support networking function, while RS-485 solves the networking problem.

The device adopts RS-485 standard, and turns the serial port into an interface that uses MODBUS RTU mode. RS-232 serial port is used to communicate directly with the device in the field without network.

3.3. Data storage and calculation

Using SQLServer 2008 R2 database as the local database server, and SQLServer 2012 R2 database as Aliyun database server. Aliyun ECS (Elastic Compute Service) server is used as the remote server to realize remote monitoring of devices and data by remote users. The mutual synchronization between the local database and Aliyun database is transmitted via 4G by synchronization software.

As for data calculation and management, data visualization access to web page is programmed in C# language based on B/S (Browser/Server) structure and ASP.Net technology, and deploy it on the IIS server. The browser is used for data editing and display, and the acoustic data and analysis results are displayed in images.

4. The software design of data acquisition device

The ARM chip of STM32F407 of ST company is the main CPU of the device, and the initialization is programmed in assembly language and the functions of data collection, storage, transmission and local display is C language. Receiving configuration data and restart command of upper computer with interrupt function to realize remote control. The main program and interrupt program flow of the device is shown in Fig.3.

Initializing the basic parameters of the chip and setting the default working parameters first, and then entering the process of acquisition, storage, transmission and display. The working mode, acquisition interval and algorithm selection of the device shall be set according to the parameters transmitted by the upper computer.
4.1. Initialization
The device default parameters include device index, device type (includes Low-pressure, Medium-pressure and High-pressure type), acquisition time interval, dynamic liquid level algorithm (Coupling method and Sound velocity method) and pump hanging position.

4.2. Data storage
The data is encapsulated into frames before storage and transmission. The frame contains two parts: header and data. The header contains device index, acquisition time interval and other information. The data section is acoustic data that contains 9000 points in 2-bit hexadecimal format. In order to ensure the continuity of data in case of network disconnection, the data is stored in the SD card in the form of a file, and the file name consists of device index and current time.

4.3. Data transmission
The data transmission consists of WIFI transmission and 4G transmission, and the dual-channel transmission mode is used to transmit the data to the local server and Aliyun server respectively to ensure the data reliability.

4.4. Status display
In order to facilitate the debugging of the device and observe the current status, the LCD screen is equipped on the device to display the working parameters of the device in real time.

5. Upper computer software system
The upper computer monitoring software system consists of three modules. The management and monitoring software realizes the maintenance of the basic dynamic liquid level data and the visualization of the acquisition data. The control software realizes data acquisition, device control and its parameter management. The synchronization software realizes the synchronization of LAN data and Aliyun data to ensure the consistency of data.

5.1. The management and monitoring software
The management and monitoring software is based on B/S architecture, whose architecture is shown in Fig.4, including database, IIS server, management and monitoring software. Database is the basis for the upper management and monitoring, among which the main data tables include device configuration table, data table, event table and some basic data tables. IIS server is used to deploy the upper management and monitoring software as a client browser server. The client mainly provides the
basic data maintenance and the visualization of dynamic liquid level data, so as to display the real-time data according to the selected conditions. The functional module diagram is shown in Fig.5.

![Fig.4 The management and monitoring software architecture](image)

5.2. The control software system

All software in the control software system are based on C/S architecture, and its architecture is shown in Fig.6, including database, data acquisition, device configuration and MODBUS interface. It has many functions such as data collection, basic device configuration, remote parameter modification and device control, and parameter interface provided by MODBUS protocol. The functional module diagram is shown in Fig.7.

![Fig.6 The control software architecture](image)

5.2.1. Data acquisition software

Data acquisition software uses TCP/IP protocol to communicate with the device, and can receive and process the data sent by device in real time. Processed data will be stored in the local database and visualized, which will be displayed on the interface in the form of image. At the same time, casing pressure, fluid level and other important indicators in the well are calculated and displayed, so that users can observe the changes in the well in real time. Users can monitor all working wells simultaneously on the acquisition software, as well as a single well. The functional module diagram of data acquisition software is shown in Fig.8.

![Fig.7 Functional modules](image)
5.2.2. Software of configuring device by serial port and that by network
For the program of configuring device by serial port, using RS-232 serial port to configure acquisition device parameters, or directly start a certain device to measuring liquid level. The program of configuring device by network adopts UDP protocol and the configuration data is sent to device in the way of broadcast. Device determines whether to conduct parameter configuration while receive the data. If the configuration is successful, the device returns the received configuration data to the software, which receives a response that updates the database based on user options. The functional module diagram of software of configuring device by serial port and network is shown in Fig.9.

5.2.3. MODBUS protocol interface software
MODBUS protocol interface software works with the acquisition device in the MODBUS RTU mode as the dynamic liquid level data interface to avoid repeated measurements, save time and manpower, and provide data for data analysis. The functional module diagram is shown in Fig.10.

5.3. The data synchronization software
Using the data synchronization software to achieve the connection with the local database and Aliyun database with ADO technology. And choosing the certain data table to synchronize manually or periodically. The functional module diagram is shown in Fig.11.
Fig. 11 The functional module diagram of the data synchronization software

6. Conclusion
This whole system can not only conduct data monitoring in LAN, but also conduct data maintenance and control in the case of no network environment using the 4G card. In the later stage, it is considered to develop mobile terminal APP so as to achieve the purpose of real-time monitoring oil well fluid level with mobile phones, which shall be based on WeChat applet and can run on various mobile system, convenient to browsing the acquisition data and device parameters remotely.

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