A Short Distance Oil Pipeline Leakage Monitoring System Based on Wireless Communication

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Abstract. This paper illustrates a short distance oil pipeline leakage and blocking monitoring system, which utilizes wireless communication technology to achieve the transmission and control of the temperature and pressure data of the pipeline in WSN mode, the control center achieves remote monitoring and management, as well as automatic detection and alarm function of pipeline leakage and blockage. The result shows that the system has wide coverage, accurate data transmission and strong real-time performance, and it is of great significance in reducing resource waste, decreasing economic loss and avoiding environmental pollution.

1. Introduction
With the development of petroleum industry, the production of oil has been increased. The utilization of oil pipeline has been improved, and pipeline transport has become one of the main means of transportation of petroleum products[1]. At the same time, the aging oil pipeline and corrosion perforation have become increasingly prominent; there are also some lawbreakers who damaged the pipeline. Thus these factors caused pipeline leakage accidents and serious waste of resources. Besides, the leakage of crude oil can cause environmental pollution and threaten people's lives and property. To nip it in the bud, the monitoring and treatment of pipeline leakage should be taken into consideration in advance, and it needs to establish an effective pipeline leak monitoring system, so that the leak spot and its location can be detected in time when the leak occurs, and the production manager can immediately adopt the maintenance measures to reduce the damage caused by the leakage.

The leakage of the pipeline between the oil well and the measuring house belongs to a category about short distance oil pipeline wireless monitoring, which is different from the joint station to the joint station, the pipeline between station and station is a long-distance and crude oil pipeline. In the past, there was no doubt that it was absolutely correct to monitor the pipeline leakage of long distance pipeline. However, for the pipeline from the oil well to the metering, few people have studied the pipeline leakage when the pipe diameter is smaller, so the pressure inside the pipe is small, and the transmission distance is short. If the existing long-distance pipeline leakage monitoring method is used to monitor the short distance oil pipeline, the cost and precision are not suitable. Therefore, for leakage monitoring of oil pipeline with short distance, narrow pipe diameter and small pressure, we need to use modern detection technology, information processing technology and wireless sensor network technology in order to develop new method. It is very meaningful to study the intelligent monitoring system of short distance oil pipeline with low cost, automatic detection and alarm function.
2. **The research status**

The hardware implementation method of pipeline leak detection includes pipeline internal detection technology. However, there are too many restrictions on the application of this technology, mainly because many oil pipelines in China still use the early-day old oil pipeline, and do not have the conditions for intelligent detection in the pipeline. It is necessary to carry out equipment modification to oil pipeline, pipe fittings and field station in advance. These conditions restrict the promotion and application of in-pipe testing. In addition, there are also detection methods such as cable detection, optical fiber detection and infrared ray detection. The application of leakage detection cable is mainly used in the leakage detection of liquid hydrocarbon fuel. The cable is laid parallel to the pipe. The hydrocarbons that leak out of the pipe leak into the cable, it will change the characteristics of the cable. The principle of leak detection by optical fiber is that the leakage of the heat material from the pipeline causes the temperature change of the surrounding environment. The temperature along the pipeline is measured with distributed optical fiber temperature sensor changed beyond a certain range, we can judge the occurrence of pipeline leakage. Infrared detect leakage is the use of precision infrared camera to record the thermal radiation effects around the pipeline and the spectrum of air above the pipeline, detect leakage and location according to spectrum analysis. Because the distance from the oil well to the measurement is not far, it belongs to the short distance oil pipeline. These hardware implementation methods are too expensive in terms of construction, operation and maintenance costs.

A pipeline leakage detection and positioning technique is based on the negative pressure wave method, which is a very widely used leak detection method, this method need to identify whether negative pressure wave is due to the pipeline leakage or working condition adjustment. It can be used for real-time monitoring of sudden leakage of pipeline. However, this method has a disadvantage. When the pipe has a small leak, the pressure change does not meet the sensitivity index of the detection system, the system will miss the leak. In addition, during the diagnosis of the pipeline leak, the pressure signal often contains a large number of noise signals and it should be de-noised before working condition identification, otherwise, there will be a false alarm, and the noise reduction requires complex algorithm to support.

In recent years, there are many new algorithms have been proposed, some people put forward the method of using image processing to deal with the signal, convert the pipe pressure signal into the corresponding image form, using morphological theory to remove noise. According to the connectivity of the signal image, to judge the signal is normal or leaking. This method has a high requirement for the accuracy of the upstream and downstream pressure signal acquisition in the pipeline. Once the signal capture error is large, it will directly affect the result of image processing and lead to errors in judgment of working state.

3. **The main contents of this paper**

This paper mainly aims at the short-range oil pipeline in oil field, the oil wells were scattered in the fields, after crude oil is extracted, the pipeline sends crude oil to the nearby metering room, as the farmland has irrigation canals, therefore there are many pipelines for passing through the canal. The leakage of this part of the canal will directly contaminate the water body, downstream pollution of large areas of water, the destruction of the environment brought huge economic loss. Because of these issues, this paper presents a leakage and blockage monitoring system based on wireless sensor network.

3.1 **General design idea**

The system applies the wireless sensor network to achieve the leakage and blockage monitoring function, the system achieves data transmission and control in WSN mode, as well as using intelligent detection technology to achieve automatic detection of pipeline leakage point and blockage point. After the terminal device has been set up, the parameters of the electric current and voltage of the oil well, the pressure and temperature of the oil pipeline can be collected and send wirelessly to the control center in time. These data are monitored and managed remotely in the control center, when the
data is sent back to the upper computer, the upper computer can detect the leakage and blockage by analyzing the system and send the alarm information.

In environment sensitive area, the monitoring system of oil pipeline leakage is mainly composed of three parts, the first part is the control center part of the system, it is placed in the oil production team's duty room, using the industrial control machine as the physical carrier, Delphi and SQL server are used to complete the design; the control center of the system is connected with two other parts via the interface card, the connection mode is wired RS485 and wireless RS485 respectively. The second part is the pressure sensing part, which is installed in the metering room of the oil production team, corresponds to each line passing through the sensitive area of the environment. This part is based on Mega128 microprocessor, the pressure transmitter of diffused silicon was used to measure the pressure change of pipeline. The last part is the temperature sensing part, it was placed on the banks of the canal, bound to the oil pipeline and buried underground. This part uses a large number of single-bus temperature sensor DS18B20 to measure the variation of soil temperature in the region. The temperature data is transmitted to the control center by wireless module. The way to power supply is solar and wind complementary power supply. The schematic diagram of the system is shown in figure 1.

Fig1. Schematic diagram of the system

3.1.1 Temperature sensing part. In an environmentally sensitive area, the temperature sensor is distributed along the pipeline every three meters. Because there is usually more than one pipeline crossing the canal, we assign addresses for each temperature sensor. The temperature sensor in the region forms an array, the location of the leak can be located. The temperature sensor uses DS18B20 single bus digital temperature sensor, the sensor sensing temperature ranges from 55 °C to + 125 °C, the minimum accuracy of 0.0625 °C, the performance indicators can satisfy the actual demand of engineering. The control module adopts Mega128 as the core, and the standard Modbus-RTU protocol is implemented, wireless communication with RS485 communication. The communication module adopts the NRF24L01P radio frequency chip and RFX2401C amplifier chip produced by Nordic production. This module works in ISM frequency band, power reaches 100mW, transmission distance is over 2000 meters, RS485 transmission.

Since the temperature sensing part requires the power supply of dc 12v, so the solar and wind complementary power supply system uses 50W/18V single crystal solar panels, 100W/12V wind turbines, 100AH/12V lead acid storage battery, 100AH/12V buried box, 200W/12V wind-solar hybrid controller, 8m high light pole. The wireless communication module shall be installed on the lamp post after Installation rainproof and lightning protection facilities.

3.1.2 Pressure sensing part. In the oil production team, a dozen oil Wells are scattered across vast farmlands, the crude oil pipeline is collected into the metering room by different routes. For different pipelines, the metering room is equipped with control valves, instruments, safety protection devices. The pressure sensing part will be installed on the pipeline through the canal, according to safety
production requirement, the pressure sensing device is installed in the explosion-proof housing. The pressure measurement adopts the diffusion silicon pressure transmitter, range 0-4MPa, DC12V power supply, RS485 output, data format: 9600bps, standard Modbus-RTU protocol. If there are multiple pressure sensing lines in the metering room, all pressure sensors are mounted on a RS485 bus and wired to the control center in the duty room.

3.1.3 Control center part. In the environment sensitive area, the control center of the oil pipeline leakage monitoring system takes the industrial control machine as the carrier, the control center runs the monitoring system software, equipped with UPS, and installed in the duty room. The two interface cards of the industrial control machine, one connecting the RS485 bus from the metering, and the other one connecting the RS485 interface of the wireless communication module, it is used to send and receive the instructions and data of the sensing part.

3.2 Algorithm implementation

3.2.1 Processing of pressure signals. The data collected through the pressure sensing device will be an important basis for judging the leakage state of the pipeline. However, the original data contains more noise components, special algorithms are needed for processing. Analysis of a piece of raw pressure data collected, as shown in figure 2, pipeline pressure fluctuations are still relatively severe, the normal pressure value of the pipeline should be between 0.9MPa-1.1MPa, when the pressure value exceeds 1.2MPa, the warning should be issued and measures should be taken to prevent the pipeline from being blocked. The red circle is used to draw the point that the pressure data exceeds 1.2MPa in the 250s range, and there are four such points in the 250s. We can see from figure 2, the Pressure fluctuations sometimes exceed 1.2MPa, but these are short periods of time, it does not mean that the pressure variation of the monotone rising of the pipeline blocking is more than 1.2mpa, therefore, these data are interference elements for the system.

\[
\sum_{n=0}^{N-1} x(n)x(n+m) \quad 0 \leq m \leq N - 1
\]

\[
P_N(\omega) = \sum_{m=-(N-1)}^{N-1} r_N(m)e^{-j\omega m}
\]

According to formula (1) (2), we do autocorrelation and power spectrum analysis of signals, as shown in figure 3, we found that there is an important frequency component at the frequency point of 0.08Hz, the amplitude is around -5dB, the other frequency values are in the normal range below -10dB. In figure 3, the location of the point is drawn in the red circle, it should be an interference signal, the period is about 12.5s, this time is approximately equal to the one reciprocating time spent on the donkey head of the drilling machine. Therefore, the fluctuation of pipeline pressure is affected by the
reciprocating action of the drilling machine, this should be filtered out, it is realized by using FIR band pass filtering.

![Fig3. Power spectrum of pressure signal](image1)

In addition to filtering the noise interference of fixed frequency point, and given the stability of the system itself, it is necessary to eliminate the noise caused by the system itself to data reading, conversion and transmission, for this purpose, another median filtering is performed. Here, the window length is n, the output of median filter is:

\[ y(k) = \text{med}\{x(k-n+1), x(k-n+2), \ldots, x(k)\} \]

(3)

In this article, the window length is n=5. After two filtering, the signal has no interference except the initial stage. The waveform of pressure signal after filtering is shown in figure 4. The pressure data in the figure is below 1.2MPa, this indicates that not only the initial time system pressure adjustment, but also the other time system enters the normal monitoring state without disturbance.

![Fig4. Waveform of pressure signal after filtering](image2)

3.2.2. Implementation of the system program. The system starts with a period of initialization. Then the Modbus protocol command is sent to read the data of the pressure sensing part of the pipeline. The median filtering algorithm is used to eliminate the error data that may be generated in the acquisition, conversion and communication of the system itself. The reading instruction is performed on the temperature sensing part, and the median filtering is performed. Then a band-pass filter is applied to the pressure sensing data to remove the interference of the fixed frequency.

The next step is to determine the threshold value, the first part is about pipeline blockage. First, determine whether the pressure value is greater than 1.2MPa, if it is not satisfied, then the program is executed, on the contrary if satisfied, the sign of the blockage is added 1. The second part of the
threshold judgment is about pipeline leakage. First, determine whether the pressure value is less than 0.3MPa, if it is not satisfied, then the program is executed; if satisfied, the program also needs to determine whether temperature is more than 40 °C, if it is not satisfied, then the program is executed, if satisfied, the sign of the leakage is added 1. The second half of the program should also determine whether the leak indicator is greater than 3, if it is not satisfied, then the pipeline has pressure fluctuation or temperature fluctuation, operators don't have to deal with it, if satisfied, it means that pipeline pressure continues to drop, soil temperature in sensitive areas rapidly increased, this situation indicates that the oil pipeline with hot water is leaking and sends alarm.

4. Conclusion
The system can effectively achieve the intelligence of leakage monitoring of the pipeline from the oil well to the metering, it can monitor the temperature and pressure parameters of the pipeline. The system not only saves labor cost but also solves the problem of centralized data processing; furthermore it has the advantages of wide coverage and fast data transmission as well as high communication quality. WSN network is used for data transmission and control of the system, especially for signal interference problem. The system with a fast response speed, strong real time and without distance limit, which can detect and locate the pipeline leakage and blockage due to aging, corrosion and stealing. With the help of modern detection technology and means, the system uses data analysis and processing theory to monitor and locate the pipeline leakage and blocking points of the pipeline from the oil well to the metering, it has great economic and social values in reducing waste of resources, decreasing economic loss and avoiding environmental pollution.

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