Research on remote oil and gas pipeline leakage detection system

Zhang He[1*], Y Q Tang[1], P Ren

[1] *Mechatronic engineering College, University of Southwest Petroleum, Xindu Str. 8, CHIN-610500 Sichuan, China*

Received 23 November 2014, www.cmnt.lv

Abstract

The pipeline transport is the main mode of transportation of oil and gas which is the most important source of energy in modern society. However, leakage has become the major failure of oil and gas pipeline operation, especially the leakage accidents caused by pipeline corrosion and perforation occur frequently, which seriously interferes with the normal production, and causes huge economic loss and environmental pollution. In this paper, the remote oil and gas pipeline leakage detecting system based on the technology of Internet and ZigBee was studied. Through the wireless Internet and ZigBee network, this system realizes the remote detection of oil and gas pipeline leakage with CC2430 communication chip at the core. Experimental results show that this detecting system is capable of judging and positioning pipeline leakage in time and accurately.

Keywords: Internet; ZigBee; CC2430; Coordinator node; Sensor nodes

1 Introduction

With the constant discovery of oil and gas fields in China and the use of the West-East Gas Pipeline Project, the popularizing rate of oil and gas use has raised greatly, and brought great convenience to people's lives. Using pipelines to transport natural gas is the most secure and efficient way for transportation, but deformation and leakage of pipelines would occur due to pipelines' wear, corrosion, aging and man-made destruction caused by the long time operation and long distance transmission, etc. The leakage brings a serious security hidden danger to pipeline's operation and the unpredictable threat to the safety of human life and property. Therefore, accurate leakage detection of oil and gas pipelines has an important significance in minimizing the loss and pollution of the environment, and ensuring the safe operation of oil and gas pipeline network. At present most of the oil and gas pipeline leakage detecting systems are visible, their scope of application and operating conditions have significant limitations, and those systems can't be applied to underground pipelines, submarine pipelines, environment extremely hostile, or environment where is unable to wiring or be covered by GPRS. As a result, to design a remote oil and gas pipeline leakage detecting system which has a wide coverage, and is not affected by environmental restrictions has a great significance [1,2,3].

2 System structure

The remote oil and gas pipeline leakage detecting system based on the technology of Internet and ZigBee uses three-tier structure that is "testing center – coordinator node – sensor detecting node". Through the Internet, software of the detecting system in testing center is connected with the coordinator node which links the sensor node by the ZigBee[4]. The architecture of remote oil and gas pipeline leakage detecting system is shown in Figure 1.

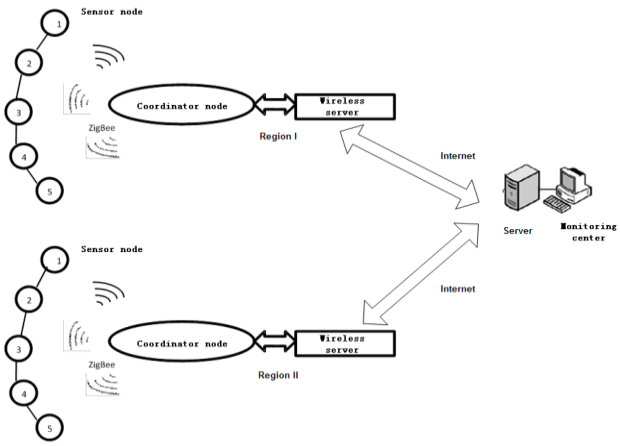


FIGURE 1 The architecture of remote oil and gas pipeline leakage detecting system

Through the wireless ZigBee technology, the sensor nodes of each area in Figure 1 transmits pressure values measured by each sensor to coordinator node which is connected with external Internet through the ZigBee wireless communication network server, and links to remote monitoring center by the Internet. Based on pressure values analysis processing in the testing center, the system can judge whether there is a leakage or not, and position the location of pipeline leaks. The ZigBee wireless communication network server is a protocol conversion interface of ZigBee nodes and Ethernet, it is responsible for wireless sensor network's establishment, management

* ***Corresponding author's*** e-mail: zhanghe@swpu.edu.cn

and Internet connection, so as to realize the remote detection. Coordinator node is an interface of ZigBee network and external network, it can control the whole wireless network and the patterns of its connection with the external network[5].

3 The wireless terminal design

3.1 ZIGBEE COMMUNICATION MODULE

ZigBee communication module uses the radio frequency communication chip CC2430 produced by TI company. CC2430 SCM specializes in IEEE802.15.4 and ZigBee protocol communication, and it can control the connection of ZigBee network with other existing networks. Its RF kernel is based on CC2420 which is the industry's leading radio frequency communication chip. CPU, memory, common peripherals and RF radio unit are integrated on a single chip. Its basic frequency is 32MHZ, programmable FLASH is 128KB and SRAM is 8KB. It has an 8-bit CPU (8051), CPU, memory, common peripherals and RF radio unit are integrated on a single chip. It has a 8-bit CPU (8051), basic frequency 32 MHZ, 128 KB programmable FLASH and eight KB SRAM, a 8 to 14-bit programmable ADC converter with 5 channels, 4 timers (including a MAC timer), 2 USARTs, a DMA controller, a AES128 coprocessor, a WDT, an internal voltage regulator, and 21 programmable I/O pins that can be configured as general purpose I/O, or pins dedicated to peripherals. In receiving and transmitting mode, its current loss is less than 27 mA and 25 mA, which is particularly suitable for conditions where requires long-term supply for battery applications [4,6]. Only a few external components are needed in the applications of CC2430, and the typical application circuit is shown in Figure 2.

In order to extend ZigBee communication's distance, IC such as power amplifier, low noise amplifier, RF transceiver switch are increased based on the RF module integrated in CC2430. The communication distance can reach 600 m, which is completely meet the requirements of communication in the region.

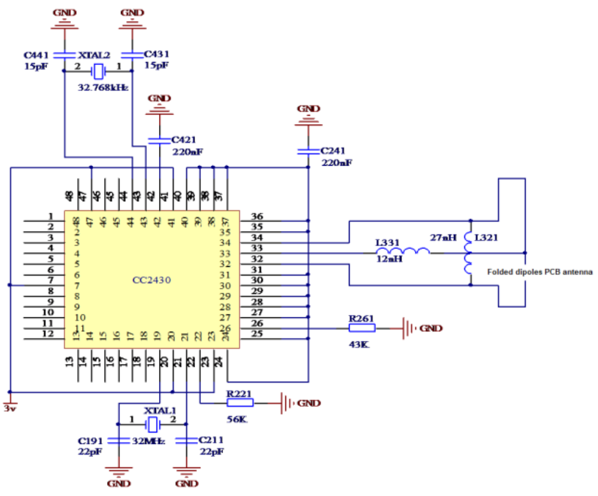


FIGURE 2 The typical application circuit of CC2430

3.2 SOFTWARE DESIGN OF ZIGBEE WIRELESS SIGNAL TRANSCEIVER MODULE

The software design of ZigBee wireless signal transceiver module includes software design of coordinator node and software design of sensor node [5,6,7]. When the system is running, sensor node must transmit its own network address to coordinator after it applied to join the network, coordinator then establishes an address table and stores those data, in order to distinguish the position of the sensor nodes. The program flow diagrams of Coordinator nodes and sensor nodes are shown in Figure 3 and Figure 4 below.

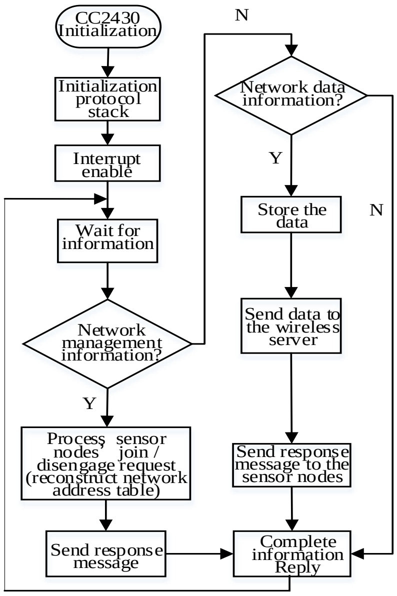


FIGURE 3 The program flow diagram of coordinator nodes

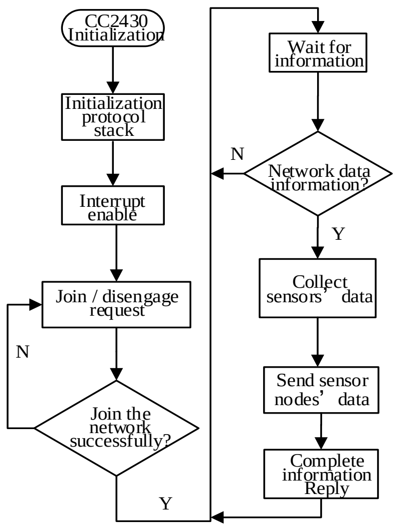


FIGURE 4 The program flow diagram of sensor nodes

3.3 SENSOR NODE MODULE

The sensor node module combines ZigBee communication module with sensors to implement the acquisition of measuring objects. The pressure gradient method is used in this study to test leakages, and the oil and gas pipe pressure values at both ends of the pipelines are collected by pressure sensors[8], the frame of pressure sensor nodes module is shown in Figure 5. As figure 1 shows, each region of the pipeline can be divided into four sections, the pressure gradient method is used for each section during the measurement process. Pressure distribution presents a "fold line" change due to leakages under the conditions of a steady flow of fluid. Therefore, if the pressure value at both ends of each section can be measured by pressure sensors of each section, we can calculate the actual position of the leak [9].

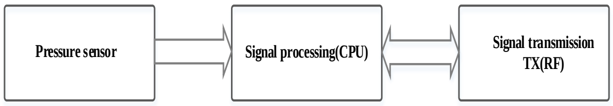


FIGURE 5 The frame of pressure sensor nodes module

3.4 JUDGMENT AND POSITIONING OF PIPELINE LEAKAGE

According to the data transmitted from the sensor nodes, remote monitoring center can judge whether the pipeline leaks or not by using the sequential probability ratio test method. As random signals are required to meet the Gaussian distribution while the sequential probability ratio test method is used to judgment leakages, in practice, we must preprocess the collected pressure signals first, to make the those signals meet the Gaussian distribution, and then the sequential probability ratio test method can be used for pipeline leakage detection. Based on research and practice, the Kalman filter's recursive form is suitable for online applications, as a result, the Kalman filter is recommended in the testing center to achieve the data similar to the Gaussian distribution[10,11].

In this research, positioning pipelines leaks is based on by the sequential probability ratio test method. Assume that the time the pressure wave produced by the leakages spends travelling to the entrance is t_i, the estimated time of occurrence then is t'_i. Similarly, if it takes the pressure wave t_0 to travel to the exit, then, in this situation, the estimated time of occurrence is t'_0. In the case of other conditions are the same, the time difference can be obtained as

$$\Delta t = t_i - t_0 = t'_i - t'_0 = (m_i - m_0)T , \quad (1)$$

Where, m_i and m_0 are the number of points collected when leakage occurs in the inlet and outlet; T is sampling period, s. The positioning formula is

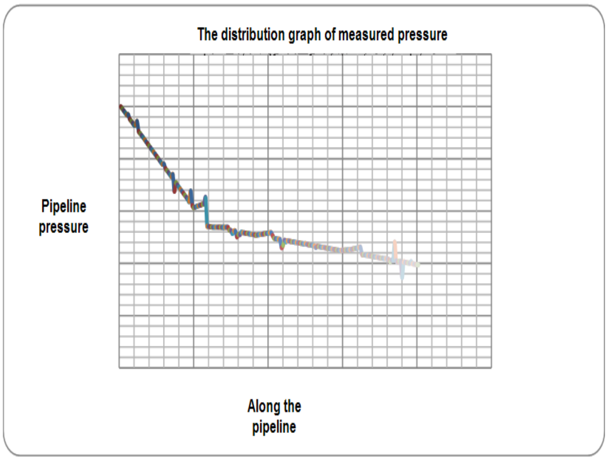
$$X = \frac{L + a(m_i - m_0)T}{2}, \quad (2)$$

X - is the distance between leak point to the measuring point in entrance, m;

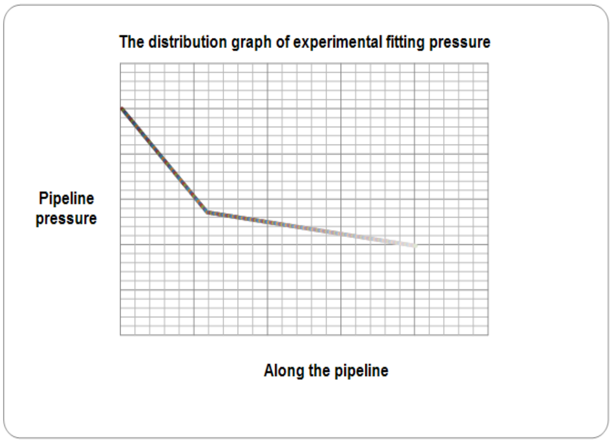
a - is the speed of the pressure wave in pipeline, m/s.

4 Conclusion

Leakage is the main potential safety hazard of safe operating of pipelines, how to prevent accidents to ensure the safe and stable operation of pipelines is a compre-hensive subject. In this paper, the remote oil and gas pipeline leakage detecting system based on the technology of Internet and ZigBee was studied. A short section of water pipe (25 m) was adopted in the experimental tests (experimental results are shown in Figure 6). The data collected by sensors are sent through the ZigBee wireless networks and the Internet to the detecting center which is designed by VB programming environment for display and analysis. The experimental analysis shows that in the case of low-leakage, the sensitivity of sensors and vibration strength of the pipelines have a direct influence on the results and accuracy of the test. Experiments show that using the sequential probability ratio test method can not only detect leakages, but also accurately positioning. Overall, this system is low cost, widely applied, and can realize the remote oil and gas pipeline leakage detection economically and applicably.



a)



b)

FIGURE 6 The results of the tests:
a) The distribution graph of measured pressure,
b) The distribution graph of experimental fitting pressure

Acknowledgments

This work was supported by Foundation of Sichuan Educational Committee (Research on pattern recognition, No. 112B020).The authors would like to thank the Si-chuan Educational Committee and Southwest Petroleum University for supporting the present work.

References

[1] Liang H.W, Gao B.K and Wang X.F J 2011 Chemical industry automation and instrument 6（38）.653-655Kroto H W, Fischer J E, Cox D E 1993 *The Fullerenes* Pergamon:Oxford
[2] Huang C.G J 2010 Theoretical studies of science and technology communication,19,71-72
[3] Aimé L E, Amerigo T, Giuseppe Vendramin1 2009 FFT- Based Spectral Response for Smaller Pipeline Leak Detection. International Instrumentation and MeasurementTechnology Conference: pp 328 – 331
[4] Mahmoud M, Mohamed A G, Mohamed A M, and Marwan A Aasi 2010 A New Concept for an Effective Leak Detection in Multiphase Fluid Pipelines. First International Conference on Sensor Device Technologies and Applications: pp206-210
[5] Zhang X.T and Wang Y.X J 2012 Application of Single-chip microcomputer and embedded system 1.56-58
[6] Yang F.G and Yang Q.J J 2012 MEMS and application 31(2),80-82-86;
[7] Wu Q.S Liang H and Shi Z J 2012 Coal mine machinery 33(2),223-226;
[8] Chen B and Zhu H J 2009 Computer and network 32,229;
[9] Lu X.Y, Li Y.H Yang X.C J 2006 Measurement and control technology 25(1),77-78
[10] Cui Q, Jin S.J, and Wang L.K J 2005 Petroleum journal 26(4),123-126
[11] Zhang S.Q, Gao T.Y, Xu H, Hao G.P 2009 International Conference on Measuring Technology and Mechatronics Automation Study on new nethods of improving the accuracy of leak detection and location ofnatural gas pipeline Vol 1 PP: 360 - 363

Authors

Zhang He, 1973, Nanchong, Sichuan, China

Current position, grades: Associate Professor in school of Mechatronic engineering College, Southwest Petroleum University.
University studies: Bachelor degree in 1995, Detection Technology and Instrumentation
Scientific interest: Automation instrument and device, Oil and gas intelligent measurement and control system
Publications: More than 15 research articles - Materials and Design; Mathematical Problems in Engineering; Information Technology Journal; Journal of Convergence Information Technology; International Journal of Digital Content Technology and its Applications
Experience: electronic information and down-hole testing.

Tang Yongqiang, 1990.07.26, Zigong, Sichuan, China

Current position, grades: Postgraduate
University studies: Measuring Technology And Instrument
Scientific interest: Instrumentation Engineering
Publications: Chemical Engineering and Technology
Experience: Graduated from Southwest Petroleum University, Chengdu, Sichuan, and now is in graduate school.