Research on Building Gas Pipe Leakage Detection Based on LabVIEW and Multisim

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Abstract. According to the micro energy vibration signal which is generated by the internal gas injection when the building gas pipe leaks, a set of building gas pipe leakage detection and analysis system is designed. The final analysis results of the system can provide the basic analysis data for the timely detection of building gas pipe leakage and the quantitative and qualitative change results caused by leakage. The system selects 801S vibration sensor to extract the vibration signal generated by pipeline leakage, and then amplifies the weak voltage signal converted by vibration signal through signal conditioning circuit. The signal conditioning circuit completes the simulation through Multisim platform and verifies that the expected results meet the requirements. Finally, the signal processing program and detection program based on HHT algorithm are designed and constructed by LabVIEW platform to decompose the data of the conditioned signal and determine whether there is leakage. The results show that the dynamic and static characteristics of the system are fine, and the accuracy is high, especially the effect of the low-frequency and low-pressure (200Hz and below 5V) signal detection is very well.

1. Introduction

With the rapid growth of the number of urban gas pipeline construction, pipeline leakage diagnosis methods are also developing rapidly. At present, there are a variety of pipeline leakage diagnosis and identification methods at home and abroad, mainly including BP network, fuzzy neural network, support vector machine, process neural network, D-S evidence theory, back-propagation neural network, etc[1].

Natural gas pipelines are laid in cities or urban areas with relatively concentrated population. Due to the influence of pipeline joints, pressure bearing, installation technology, electrochemical corrosion, ground construction and other factors, natural gas pipeline leakage is often caused, resulting in explosion or fire, causing heavy losses to national and people's lives and property[2].

In recent years, with the development of leakage monitoring technology, there are many application methods, such as negative pressure wave method, acoustic wave method, optical fiber temperature measurement method and so on. First of all, due to the characteristics of pipeline transmission medium, the gas has compressibility, so the application effect of mature application method in oil pipeline is not obvious; secondly, optical fiber monitoring must have optical fiber with good laying quality and good operation and maintenance. At the same time, due to the high sensitivity of optical fiber, there are many external interferences in temperature measurement methods, such as
weather, farming and watering, etc., which have great effect on the monitoring effect interference. In particular, infrasound, whose frequency is very low, has a long wavelength when it is below 20Hz. At the same time, air absorbs it very little, and its propagation distance is longer than that of ordinary sound wave, light wave and radio wave[3].

The object of this paper is the construction gas pipe. Compared with the underground gas pipe buried in public places in the city, the diversified detection of the building gas pipe is different (the characteristics of the existing detection methods are divided into four methods: acoustic, ultrasonic, thermal infrared and pressure[6]). At present, there is no specific detection method and mature detection model. The vibration acoustic signal of building gas pipe is generated by natural gas shooting. With the increase of propagation distance, the high-frequency signal attenuates greatly, while the low-frequency signal itself has a low frequency (especially below 200Hz), and the attenuation change is small. Therefore, the low-frequency signal of leakage signal can propagate along the pipeline for a long distance[4]. In this paper, the low-frequency signal of the leakage signal is analyzed and studied, and a set of building gas pipe leakage detection and analysis system is designed to detect and analyze the low-frequency and low-pressure vibration signal generated by pipeline leakage. In this paper, the vibration signal generated by infrasound wave is taken as the detection object, and the EMD method of HHT is used to locate, qualitatively and quantitatively analyze the acoustic signal of pipeline leakage.

2. Design of leak signal detection system

2.1. Overall design of the system
In this design, the pressure is about 0.5MPa and the length of the pipeline is about 5m. Three nodes are set as the detection points, and the vibration signals are collected from the three nodes of leakage, air outlet and air outlet. Under normal conditions, the three sensors on the pipeline are equal within a certain tolerance range, and under abnormal conditions, the sensor close to the leakage port will be smaller. Therefore, leakage is detected by comparing the values of sensors in the group, and the approximate position is determined according to the comparison times[5]. When the pipeline leaks, the vibration signal collected by the vibration sensor is converted into electrical signal, and then the electrical signal is transmitted to the signal conditioning circuit, converted and amplified into voltage signal. The signal is transmitted to the integrated master station server of virtual instrument through acquisition card pci-6251[7]. The integrated master station realizes data processing and HHT algorithm analysis and acquisition of vibration signal based on LabVIEW, extracts vibration signal information, and realizes positioning qualitative analysis. The overall design block diagram is shown in Figure 1.

2.2. Design of signal acquisition module
Detectors are the five senses of intelligent buildings. There are many kinds of conventional sensors applied in intelligent buildings, and the sensing technology is quite mature[8]. In this design, the vibration signal is collected at three nodes of leakage, air outlet and air outlet by using vibration sensor 801S.

The physical figure of the vibration sensor 801S is shown in Fig. 2.
The circuit design of signal acquisition module is shown in Figure 3.

![Figure 3. Simulating circuit diagram of signal acquisition module](image)

2.3. Design of signal conditioning circuit

In order to make the output signal meet the requirements of analysis and detection, the simulation vibration signal generation circuit and signal conditioning circuit are designed by Multisim software. The vibration signal generating circuit is responsible for generating the vibration wave signal and transmitting it to the signal conditioning circuit for operation and amplification[9].

In the design of signal conditioning circuit, the operational amplifier produced by ad company is selected. In the first stage, filter the DC signal and amplify the signal three times. In the second stage, the reference compensation is realized. The upper signal is biased to 1.65v. The third stage realizes voltage following. After the design is completed, the Software Multisim produced by Ni company is used for simulation. The simulation diagram is shown in Fig. 4, and Fig. 5 is the simulation result. It can be seen from the figure that the output signal has the reverse amplification result compared with the input signal, and the predetermined target has been achieved. The simulation results show that the

![Figure 4. Signal conditioning circuit diagram](image)

![Figure 5. Waveform](image)
2.4. Signal analysis and diagnosis program design
A large number of experiments have proved that the low-frequency signal of natural gas pipeline leakage signal is non-linear and non-stationary. Analysis shows that the signal frequency is about 100Hz, and the residual threshold value is below 0.5, which is normal state, otherwise it is fault state or abnormal state.

Hilbert Huang Transformation (HHT) is a new nonlinear non-stationary signal processing algorithm. HHT realizes intrinsic mode function (IMF) through empirical mode decomposition (EMD) of signal. Each IMF sequence generates a three-dimensional discrete-time spectrum including time, frequency and amplitude. The time spectrum can provide accurate time-frequency characteristics of each IMF component. Therefore, HHT algorithm analysis can describe the classification of nonlinear and non-stationary pipeline leakage vibration signals, which has objectivity and adaptability.

When the signal is input, the envelope is obtained by cubic spline difference, and then it is judged whether the mean value of the upper and lower envelopes is zero. If the upper and lower envelopes are symmetrical with zero axis, they are "filtered", that is, the signal is processed by empirical mode decomposition, and the standard deviation is 0.25 as the threshold value. The appropriate signal is selected and Hilbert transform is performed. If the number is already a monotone function, then stop filtering.

In this paper, a complete signal acquisition and analysis system is designed on the virtual instrument platform. Firstly, the vibration signal is collected by the vibration sensor 801S. After the signal conditioning circuit, the vibration signal is input into the host computer by the data acquisition card pci-6251 through the synchronous whole cycle data acquisition circuit. In LabVIEW platform, the components screened by EMD enter the fast Hilbert transform to get the analytic signal, and then get the instantaneous frequency through the steps of phase derivation, and finally get the Hilbert transform waveform. The program diagram is shown in Fig. 6.

3. Results and analysis
IMF component and residual component are shown in FIG. 7. It can be seen from Fig. 7 (a) that the amplitude of the waveform is the largest, which means that the frequency of the first IMF component is the highest; from Fig. 7 (b), its amplitude is smaller than that of FIG. 7 (a), that is to say, the frequency of the second IMF is lower; and the amplitude of waveform in FIG. 7 (c) is the smallest.
Figure 7. IMF component waveform diagram

Table 1. Experimental verification results

| original signal | Fitting equation | Residual size | amplitude | frequency | conclusion       |
|-----------------|------------------|---------------|-----------|-----------|------------------|
| IMF C(1)        | 6*sin(4*pi(1)*50*t) | 0.048         | 6V        | 100HZ     | Vent             |
| IMF C(2)        | 4*sin(3*pi(2)*30*t) | 0.049         | 4V        | 141HZ     | Air outlet       |
| IMF C(3)        | 3*sin(3*pi(3)*5*t) | 0.068         | 3V        | 74HZ      | Leakage port     |

From the above research, the signal analysis system designed in this paper can completely decompose the vibration signal of building pipeline leakage, and can be applied to the analysis and processing of the actual signal of building pipeline leakage. According to the analysis in Table 1, the gas outlet node component 1 detection data is normal, which is normal; if the residual error of the outlet detection data meets the requirements, but the frequency exceeds more, it is judged as an abnormal state, which is caused by the air pressure problem caused by the existence of the leakage; the residual error of the leakage detection data exceeds the standard, and the frequency is too small, it is judged as the fault state, and the pipeline may be out of service here There is a leakage problem.

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