Development of water leakage detection and localization system

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Abstract: Detection and localization of pipeline leakage is one of the important means to save water resources. A set of leakage detection was set up and experiments were carried out. The system contains flowmeter, pressure gauges and vibration sensor. The signal was continuous collected to constantly detect and alert water leaks. The leakage location is based on GCC-PHAT algorithm. a leakage detection and location system based on GCC-PHAT algorithm is proposed. Experiments have verified that our system works well.

1. Introduction

With the continuous improvement of China urbanization level, the water supply network system is improved. It is understood that the length of water supply pipeline in China presents a trend of accelerating growth every year. Since 2008, the construction speed of water supply pipeline in China has increased at an average annual rate of 30,000 kilometers, with an average annual growth about 6.5%. However, there are some issues about pipe maintenance due to the rapid development of urban water supply network. Water leakage is one of the main issues.

Traditional leak detection methods include acoustic principle detection[1], Thermography[2], radar detection[3], current method and potential gradient method utilized based on metal properties of metal pipe. However, these methods cost a lot of labour and equipment, with low detection accuracy. Therefore, many experts and scholars have done further research on the principles, instruments and data processing of water leakage location.

Laucelli et al. [4]proposed an optimal DMA design in a real WDN(Water Distribution Networks) to reduce leakage. They refer to a two-step strategy for changing the hydraulic paths to reduce pressure and leakages through the WDN. Anuj Purwar et al. [5]used the Internet of things approach to design automated water management systems. Ismall et al.[6]employs an accelerometer sensor MPU6050 to

measure the vibrations of the water pipeline of Acrylonitrille Butadience Styrene (ABS) pipe from three different axes, which are x-, y- and z-axis. An Arduino controller board was used to process the vibration data from the accelerometer sensor and the data was transmit over wireless ZigBee networks every ten milliseconds. M. JayaLakshmi et al. [7]proposed an enhanced underground pipeline water leakage monitoring and detection system using wireless sensor network.They use small Printed Circuit Boards (PCB) and different types sensors (acoustic, pressure, temperature, flow rate, etc.) to locate the leakage, the proposed system shown in Figure.1. Flow sensor is used to measure the flow of the water between two points. Transmitter and receiver module constructed using AT Mega 8 Microcontroller. Communication between the two modules is done by ZigBee wireless communication. The transmitter has the flow sensor which monitors the flow rate. The flow rate values are shown in LCD. If there is a change in the flow rate value, then it sends an alarm signal.

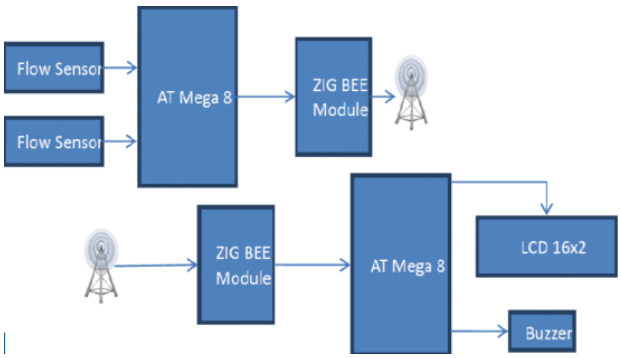

Figure 1. M. JayaLakshmi et al. proposed system [7]

2. Water leakage detection and localization system

2.1 GCC-PHAT algorithm

GCC is a generalized cross-correlation algorithm, which can process multiple signals and reduce or eliminate the influence of noise on the accuracy of estimation of time delay[8-9]. The schematic is shown in Figure 2. Firstly, the sensor signal is obtained by sensors 1 and 2, and then sampled by A/ D converter to get the original signal. Then by using a movable finite length window to frame and analyse signal with Fourier transform, we could get cross-power spectrum of the frame. After the cross-power spectrum is weighted in frequency domain according to a certain weight, the cross-correlation function of this frame is obtained by inverse Fourier transform. According to the principle of cross-correlation function, the time corresponding to the peak of the function is the delay time between two sensors. The weighting of the signal in the power spectrum is beneficial to highlight the relevant parts of the signal and suppress the disturbed parts by the noise. In this way, the peak value of the correlation function delay is more prominent. By comparing the quality of CC(Cross Correlation), Roth, SCOT(Smoothed Coherence Transform), improved SCOT, PHAT(Phase Transformation) and other weighting functions, we selected PHAT function as the weighting function in GCC algorithm. Figure 2 shows the schematic flow diagram of the GCC-PHAT algorithm[10].

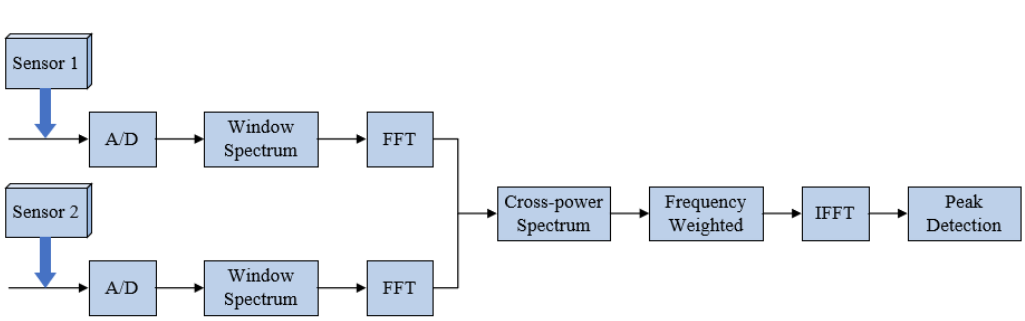

Figure 2. T*he schematic flow diagram of GCC-PHAT algorithm*

2.2 Water leakage detection and localization system

This paper proposes a kind of system which can detect and locate the leaking point in real time The system use three different instruments: pressure gauges, flowmeters, vibrating sensors to get several environmental parameters. By adjusting the relevant parameters, analysing the data of the vibration sensor and calculating the leakage point, the position of the leakage point is finally located, and the positioning error is within 1 metre. Figure 3 shows the flow chart of the whole system. Two ends of the experiment pipeline are respectively equipped with pressure gauges, flowmeters and vibration sensors. The acquired signal is connected to PLC by RS485 communication line, and the data is transmitted to PC by network.

The PLC module is mainly used for data acquisition, preliminary judgment of pipeline leakage and preliminary processing of vibration signal。The specific process is as follows:

(1) PLC uses MODBUS-RTU protocol to collect the real-time data of six instruments from site and send them to PC.
(2) PC saves the data to SQL database.
(3) Computers make corresponding response, after the data processed and judged.
(4) Users could read the specific data in website.

In the data processing algorithm, we use the GCC-PHAT algorithm. The algorithm weights the power signal. In this way, the related signal is highlighted and the noise interference is suppressed. The peak value of the correlation function at the time delay is more prominent. The higher the GCC-PHAT function value is, the more reliable the sound source signal will be received.

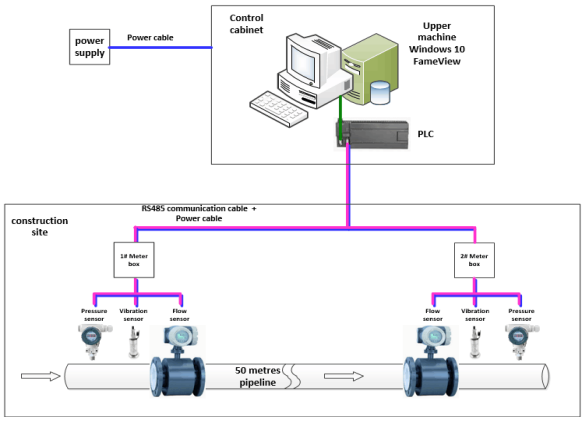

Figure 3. Flow chart of the water leakage detection and localization system

3. Experiment and results

Water leakage detection and localization experiment is based on the water saving project of Wuhan Changjiang Water Resource Commission Of the Ministry Of Water resource. We installed the aboved system on the 50 metres experimental road section, and observed and collected data for 15 days. During the experiment, a leakage valve was installed in a certain part of the pipeline. By adjusting the valve, the situation of whether the pipeline has leakage was simulated. The flowmeters at both ends of the pipeline change as shown in Figure 4. It shows that the indication of flowmeter is changed according to the amount of water leaked out. Figure 5 shows the change of corresponding pressure gauge value. As shown in Figure 6, the collected signals was calculated using GCC-PHAT algorithm. From the Figure 6, we could find that the results of the location of water leakage fluctuates to some extent, but the fluctuation range is not too much, which means it can locate the leakage point well.

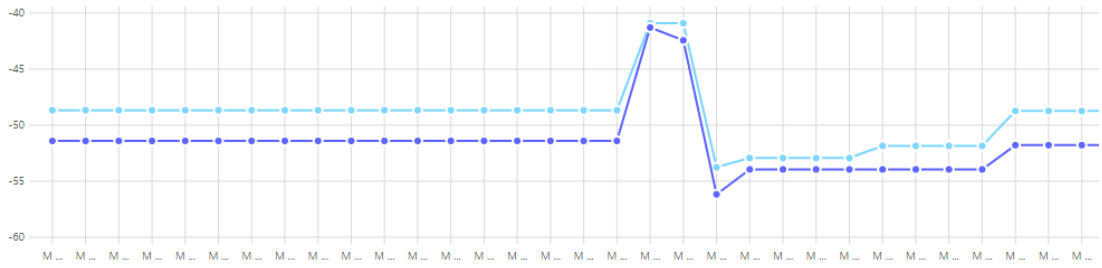

Figure 4. The changes of flowmeters

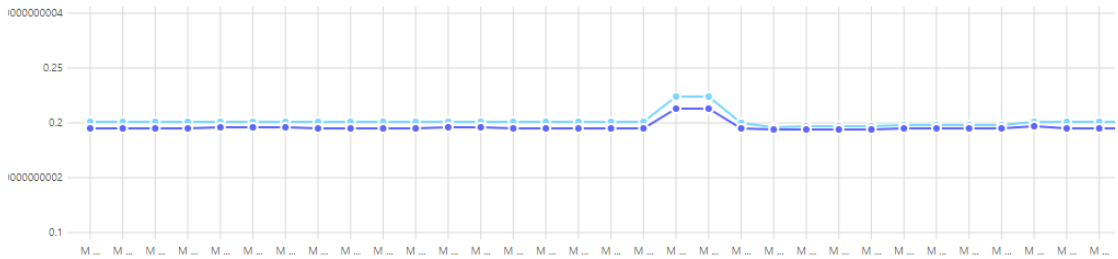

Figure 5. The changes of corresponding pressure gauge value

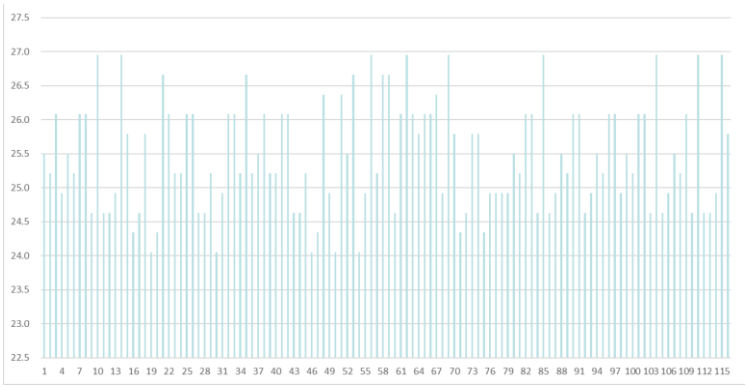

Figure 6. Results of water leakage location

4. Conclusion

Pipeline leakage detection and localization technology is one of the important means to save water resources. In this paper, a water leakage detection and location system was built and experiments were carried out. Experimental results have verified the effectiveness and the localization accuracy. Furthermore, the method is robust against the low frequency structural vibration introduced by other external forces. Meanwhile, we test the system by water saving project and get expected experimental result.

However, our system still needs improvement to adapt to large scale deployment, for examples: miniaturize equipments, which use current microcontrollers and wireless transmission to collect and control the sensor data, and algorithm optimization; and adopt better algorithms in data processing for more accurate positioning results.

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