Study on a GIS-based Real-time Leakage Detection Monitoring System

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Keywords: Leakage Sensing Pipe; Leakage Sensing Monitoring System; RTD-1000

Abstract

In modern modern society, the social demand for continuous water supply and stable water quality is rising. Existing leakage detection methods are numerous but are difficult in finding the exact location. Proposed monitoring system can be applied to waterworks pipe network administration in underground facilities. For this system, leakage sensing pipe, RTD-1000(Remote TDR Device : Embedded TDR System) and GIS-based warning system is developed. Consists of leakage sensing pipe and monitoring system which has two-level construction architecture. One level is underground facilities, sensing pipe, pipe connection network and control box. The other level is monitoring devices and center assisted by RTD-1000 and dedicated pipe network database. To apply this system, water leakage point of waterworks pipe can be detected exactly using GIS and water leakage detection program activated from RTD-1000. In this paper, the architecture of RTD-1000 is introduced and dedicated software for warning system is proposed. For the prove of efficiency of this monitoring system, simulation is performed using GIS data, Arcview, Access database.

Introduction

Waterworks pipe network is an important component of water supply plant. Currently, it is difficult to detect effectively the abnormal status of a pipe due to the superannuation of a pipe network or an accident, since pipe networks are laid under the ground. Existing leakage detection methods are numerous but are difficult in finding the exact location of the leakage and not real-time. They require a lot of human resources and cost and there are many realistic limitations. However, due to lack of understanding of water and its containment and management facilities, water deficiencies are becoming a fact. Therefore, it was necessary to effective maintenance and management of these underground facilities.

In order to construct of underground facilities monitoring system, it was essential to construct database of underground facilities data. But, database construction includes not only adjustment of design and land register but also correct wrong and missing data. So, it was prerequisite of constructs underground facilities database and composed underground facilities administration system that investigate underground facilities exactly. For the implementation of this system, leakage sensing pipe and embedded TDR(RTD-1000) is developed. In this paper, for the prove of efficiency of this monitoring system, test area simulation is performed. Using MapObjects and GIS data.(Smith Lawrence et al., 2000).
Related Technology

GIS (Geographic Information System)

GIS is an integrated system of computer hardware, software, geographical data and human resources designed to efficiently collect, store, update, analyze and express information in all forms that can be geographically referred to. In the field of waterworks and sewers, GIS can be used for integrated monitoring and management with underground facilities. This is a very important element to increase support and maintenance efficiency, prevent underground facility related accidents and secure responsive countermeasures in case of accidents. (Bong-Mun Choi., 1999) In addition, it can quickly analyze various geographical information for establishing space-related plans and determining policies, thus increasing efficiencies. (Philippe Rigaux et al., 2001) It is being used in current construction history, managing facilities, civil affairs, and water purification. However, its use in leakage detection methods is poor. (In-Sik Hong., 1999)

Existing Leakage Detection Methods

Current leakage detection methods may produce inaccurate results due to wrong inputs of distances or changes in the pipe material. They cannot guarantee the exact locations and may produce costly yet unsatisfactory results. Overall monitoring is difficult to impose because leakage detection only covers one block at a time.

Leakage Sensing Pipe

This paper proposes a leakage sensing pipe for efficient leakage detection. Currently, the tentative product has been completed. The leakage sensing pipe has 2 wires wrapped parallel in a spiral in Figure 2.1 shows section of coating layer in leakage sensing pipe. It is made to identify the wire state at the time of leakage. Each wire's pitch distance has no effect on cross-wiring. And for a wide range of detection, it is set normally at 5~10cm distance.

![Figure 2.1 Structure of Leakage Sensing Pipe](image-url)
Leakage Detection Monitoring System

Constructing Leakage Detection System Using Leakage Sensing pipe. Geographic information on the GIS is classified into layers according to its properties. For example, in case of roads that divide geographic elements, all information related to the road can be expressed as a single layer or multiple layers depending on the purpose (ETRI, 2001). Investigating and calculating all objects included in all the layers on the GIS will decrease the system’s performance. To resolve this in this paper, investigation is done only on active layer objects to improve the efficiencies. The monitoring system increments the counter every time it adds a new layer. At this time, the top-most layer becomes the active layer. The layer extraction module extracts only the modules in the active layer and stores it in the record set. Figure 3.1 displays GIS map for water leakage detection, and Figure 3.2 displays water leakage detection layer (ESRI, 1998).

![GIS map for leakage detection](image1)

**Figure 3.1** GIS map for leakage detection

![Leakage detection layer](image2)

**Figure 3.2** Leakage detection layer
**Database construction**

When construction leakage sensing pipe, inspector construct database through TDR measurement merge using TDR. Leakage sensing pipe network database constructs in following order.

- Connect water leakage sensing pipe and sensing wire for water leakage detection.
- After connect the leakage sensing pipe network, achieve TDR measuring and construct database.
- Construct sensing pipe database information through TDR measurement laying under the ground leakage sensing pipes continually.
- Constructed information transmits by monitoring center.
- Above process constructs database repeatedly.

Figure 3.3 expresses process that construct leakage sensing pipe database.

![Figure 3.3 Sensing pipe database construction process](image)

**Implementation of Monitoring System**

Consist of monitoring system which has two-level construction architecture. One level is underground facilities, sensing pipe, pipe network and control box. The other level is monitoring devices and center assisted by RTD-1000 and dedicated pipe network database. As in Figure 3.4, the monitoring system is composed of layer extraction, leakage distance calculation, display, TDR control interface, CDMA(Modem Control module) and DBMS(DB module). And Figure 3.5 is installed RTD-1000 system in construction area. Monitoring system contains communication module in main frame as digitalized TDR module, because establishing on outside, it is system that can receive control of monitoring center.
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RTD-1000 (Remote TDR Device -1000) Structure

The monitoring system must always be connected to the RTD-1000. RTD-1000 can find leakage location using pipe and display on GIS. In order to find out the exact leakage location, the wire length within the pipe must be accurately measured.

In this paper, the protocol in Figure 3.6 is defined to connect the TDR and the monitoring system. The Identify field shows the TDR's unique identifier and the Path field shows the path that the TDR can search. In order to find out the exact location of the leakage, the wire length within the sensing pipe must be accurately measured. This is related to the velocity of propagation. Since the VOP changes with the permittivity of the...
cable, the TDR sends the VOP values of the measured values as well. The Pulse field shows the pulse width that is output when the wire length is measured by the TDR. Pulse width is useful in determining the validity of the measured values. The Wavedata field contains the wave form of the TDR's measured length. During manual inspection, when leakage is suspected, the wave form can be checked to confirm leakage. (Riser-Bond)

![Figure 3.6 TDR Communication Protocol](image)

**Leakage Sensing Algorithm**

Monitoring system are available manual search and automatic search. Automatic search can set search period. Search cycle is possible setting search time (For every hour, during time in per minute setting possibility). In the case of automatic search, in appointed time each path (Default 4 channel path) measurement repeatedly search result and warning message display on monitoring screen. Order of automatic search is as following.

1. Compare base distance data and measurement distance data. When usual transmission cycle and event cycle (Detect leakage), measurement data send server and saved log file.
2. Otherwise, system save measurer data and log file to RTD-1000. Transmission mode by event cycle can reduce impression of communication measurer data by frequent transmission repeat. Figure 3.7 is show automatic search algorithm.

![Figure 3.7 Automatic search algorithm](image)
Simulation

In this chapter, operation experiments on scenarios are done to prove the efficiency, practicality, and site adaptability of the proposed leakage detection warning system. Monitoring system will convert the wire length to the leakage location and display. Monitoring system detects leakage either manually or automatically. For developed RTD-1000's harmonious operation, do an in-depth study development of pipe connect equipments that one body with joint, development of connect accessory like pump and collect data of study, and simulate it connect with system. To test the leakage detection on the GIS, in Figure 4.1, a leakage sensing pipe layer is made in a city and show monitoring process. (Mitchell Andy et al., 1999) (Bruce A. Ralston et al., 2002) As in Figure 4.2 and Figure 4.3, show the monitoring system structure and monitoring computes the leakage location and displays it on the GIS. This system provides information on the leakage sensing pipe to be used in recovery. And analyze TDR waveform information log file about water leakage information. In addition, the proposed system was proved to be more efficient than existing leakage detection systems since its detection is real-time.

Figure 37.1 Monitoring Process

Figure 4.2 Structure of Monitoring System
A point that the user does not know is leakage. As in Figure 4.4, the monitoring system computes the leakage location and displays it on the GIS. This system provides information on the leakage sensing pipe to be used in recovery. And analyze TDR waveform information log file about water leakage information. Figure 7 is show the TDR pulse log data.

Conclusions

In this paper, we proposed a monitoring system and simulated that accurately can find the leakage location by applying leakage detection techniques using RTD-1000. Leakage location was displayed to the administrator visually on the GIS through the monitoring system. In operation tests, it showed more efficient and accurate detection capabilities than existing leakage detection methods. Performance was improved by computing only the active layers from the GIS files, in the algorithm structure. With this system and its capability for accurate leakage detection, the convenience of the residents will be enhanced with stable water supply through the reduction of leakage incidents, along with the reduction of personal expenses and number of unnecessary constructions. In addition, new technology, new construction methods, and technical manpower can be obtained.
with the development of the RTD-1000. The suggested RTD-1000 can be applied not only to waterworks but also to underground drain pipes. The system can be applied to almost all systems such as oil pipelines, sewer pipe that use database. Moreover, wide wireless Internet connection, 3D GIS modeling and development and improvement of constructing RTD-1000 are thought to be required.

Acknowledgement

This research was supported by a grant (4-2-2) form Sustainable Water Resources Research Center of 21st Century Frontier Research Program.

References

Smith Lawrence, Fields Keith, Chen, "Options for Leak and Break Detection and Repair of Drinking Water Systems", Battelle, 2000
Bong-Mun Choi, "City Information and GIS", 1999
In-Sik Hong, "Development of Wireless Inspection Examination Automated Response System for Remote Control", 1999
ESRI, "ESRI Shapefile Technical Description to GIS", 1998
Riser-Bond, "Metallic Time Domain Reflectometer manual"