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UNDERGROUND VALVE STATION SAFETY MANAGEMENT USING UBIQUITOUS SENSOR

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ABSTRACT

For effective safety management of city gas facilities, system development through the introduction of advanced equipment has been made up to these days. The safety management system by information and communication technology has contributed to enhancement of pipeline life. Various kinds of remote monitoring system for safety management exist, but monitoring system for underground valve station is not established due to economic aspect.

The compact devices, low power consumption design, convergence of current technology, specific sensor technology, and technical standard for field installation are required in order to introduce ubiquitous sensing concept into underground valve station monitoring.

About 9,000 underground valve stations are under the control of Seoul City Gas, which are installed on the important points and each branch of distribution pipelines of 4,000km. When the emergency occurs, they shut down the gas supply. There is a terminal box to measure the cathodic protection current of the pipeline in each underground valve station, which is used to this development of monitoring system by realizing one of the ubiquitous sensing concept.

We developed ubiquitous sensor which has the capabilities of gas leak detection and water level detection from heavy rainfall as well as cathodic protection current measurement. We can easily supervise our facilities in our Central Command Center through wireless CDMA(Code Division Multiple Access) network. This system enables bi-directional communications by using 800MHz cellular network.

Underground valve station is exposed to severe vibrations, external loads by vehicles and heavy rainfall in summer. Therefore, we designed this ubiquitous sensor to endure vibration, humidity, water and to be suitable for explosion proof. It was impossible to provide AC(Alternating Current) supply to the ubiquitous sensor because of the site environment. So we used lithium ion battery, designing the ubiquitous sensor to minimize current consumption.

First, we installed ubiquitous sensors at 10 valve stations of downtown area in Seoul. The field data gathered from the sensor includes cathodic protection current, gas leak, and status of water level. By measuring and analyzing cathodic protection current, the status of cathodic protection in each pipeline can be diagnosed in real time. This information is used to decide the necessary impressed current in rectifier. In the event of alarm, the signal is transmitted to Central Command Center. After instant analyzing, the field staff goes to the site and investigate.

Including these contributions, the advantages of the system are effectiveness of safety management and ease of installation by its compact size, gaurantee of wireless communication capability from underground, scalability, and compatibility. In the near future, we will develop this ubiquitous sensor furthermore to enhance control function and extend our underground valve station monitoring system to the real time pipeline damage prevention against excavation.

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1. INTRODUCTION

'Underground valve station safety management using ubiquitous sensor' collects information of CP current, water level due to rainfall, gas leak from all valve station. This system reduces the measurement recording time. there is no need to check the condition of valve station. Measurements are analyzed automatically and alarms are generated if values exceed defined alarm limits. Alarms can be seen in alarm views and can be automatically forwarded to maintenance personnel's emails or mobile phones. Condition of valve station can be identified immediately and repair actions can be started before accident occurs.

The system shares the collected information in graphical trend and table data format for any authorized participant. Graphical interfaces can be seen with a normal web browser from any existing PC in the company's intranet. Users in different offices and workplaces can browse the latest and historical measurements and alarm information on their PCs. Shared information increases important knowledge in the company. Data can be used for analyzing, reporting and supervising the condition of valve station. From the system, users can see alarms from abnormal conditions and measurements in history trend lines. Measurements and alarms are stored in the server's database.

Optionally, the server can send alarms also to operator's mobile phones. Authorized users can see views using a normal web browser anywhere within the company's network. Abnormal conditions are detected immediately and preventive repair actions can started before accident occurs. The system also shows historical measurements in trends. This data can be used to supervise and tune the system to optimal performance.

2. SYSTEM DESIGN

2.1 Development by each step

- Communication environment investigation in valve station: CDMA/ZigBee/Wibro/Bluetooth
- Deciding on the specifications for the first development of the valve station gas leak remote monitoring system.
- Production of the trial product and field operation, monitoring
- Deciding on the upgrades, revises, and supplementations for the second trial product development.
- Deciding on detailed specifications of second product of the valve station gas leak remote monitoring system. (CDMA communication method: TCP/IP / SERVER & CLIENT method)
- Selecting and developing of explosion-proof and waterproof case
- Developing and producing of the second product of the valve station gas leak remote monitoring system
- Operating and monitoring of trial product in site
- Upgrade operation program of first step: switch operating program using web method
- Deciding on the detailed specification for third product of the valve station remote monitoring system
- Waterproof and explosion-proof performance supplementations of sensor box
- Production and site installation of third step trial product
- Site operation and monitoring of trial product

2.2 First step

For the construction of 'Underground valve station safety management using ubiquitous sensor', at first step, we focused on the tests and analysis of context-aware information and transmittable communication technology at the gas facilities inside the valve station. We reviewed and tested the applicable communication method and designed RTU for the data collection based on the tested contents. (RTU : Remote Terminal Unit : have the function of data collecting and transmitting to server)

2.2.1 Communication technology analysis

Considering the property of site condition based on the result of the analyzing condition factors and characteristics of the city gas facility, we've carried out the analysis of property by communication method and environment analysis and tests for selecting applicable communication method. Of the various communication methods, there are two methods that can be applied to city gas facility; which are short-distance and long-distance. For short-distance methods, we've reviewed the mothod of RF as well as IEEE Bluetooth based on 802.15 (802.15.1), UWB(802.15.3), Zigbee(802.15.4), and for the

mid-long distance method, we've reviewed Wibro, WiMax, CDMA(code division multiple access) methods in comparison by items.

	CDMA	Wi-Fi	WLAN	BlueTooth	ZigBee	WiBro	WiMax
standard(IEEE)	802.11b	802.11b	802.11g	802.15.1	802.15.4	802.16/20	802.16
frequency	800MHz	2.4GHz	2.4GHz	2.4GHz	868M/915M/2.4GHz	2.3GHz	10~66GHz
transmission speed	2Mbps	11Mbps	54Mbps	1Mbps	20/40/250Kbps	50Mbps	32~134Mbps
arival distance	1Km	100m	1Km	10m	30m	1km	1~5km
connection method	QPSK	CCK	OFDM/ DSSS	Freq. Hopping	CSMA-CA	OFDM	OFDM/x-QAM
CDMA : Code Division Multiple Access WI-Fi : Wireless- Fidelity WLAN : Wireless- LAN WiBro : Wireless Broadband WiMax : Worldwide Interoperrability for Microwave Access							

Table 1 Comparison at each communication method

2.2.2 Field communication environment research

When you compare the site properties of the valve chest to apply all the reviewed methods to the city gas facility, the gas facility is closed shut and the constant power supply and radio signal transmission is almost impossible due to such factors as concrete/metal lid. Thus it was judged that the suitable method was mid-long distance method. We choose 10 valve stations of Seoul City Gas as the testing place for mid-long distance communication methods. The applicable CDMA and Wibro were used in the testing.

There are two kinds of cover structures of the valve station: with only one layer cover or two. Thus, the rates of successful communication were categorized into when the cover is full open, when only one layer cover is closed, and both layer covers are closed, and we analyzed them. First, to test if mid-long distance communication is possible from inside of valve station to the outside, we used CDMA method and installed the transmitter inside the valve station. We used spectrum analyzer to test electric field strength.(Fig. 1)

Fig. 1 Communication test for surveillance

The equipments used for the test was transmitter program developed for valve station monitoring environmental test, CDMA modem and Wibro terminal. Two wireless modems were connected to separate laptops for each for the control of data transmission and reception. One set was put inside the valve station and the other was put in the car. The communication success rate was checked by sending and receiving data from and to each other. Wibro was tested by the same way. Because water level sensor is usually installed on the floor, it was tested each on the low-level, mid-level, and high-level of the valve station.

CDMA communication method showed excellent communication result from all 10 sites (V1~V10), and Wibro communication method showed excellent result of the communication network only in two sites in downtown area of Seoul(V6, V9) where the population density is very high. It was confirmed that according to the nature of underground valve station, CDMA communication method is most suitable.

CDMA communication test					
equipment : notebook computer, CDMA, Wibro Modem, transmission program					
site NO	location	depth(m)	electric field strength (dBm)	Test result	
				CDMA	Wibro
V1	Goyang	1.8	-67	success	fail
V2	Goyang	2.0	-70	success	fail
V3	Goyang	1.9	-61	success	fail
V4	Goyang	1.8	-68	success	fail
V5	Goyang	2.2	-64	success	fail
V6	Seoul	2.0	-71	success	success
V7	Seoul	1.8	-50	success	fail
V8	Seoul	2.1	-69	success	fail
V9	Seoul	2.2	-73	success	success
V10	Seoul	1.9	-63	success	fail

Table 2 Result of CDMA/ Wibro communication test at site

Using CDMA's minimum electric field strength of -130dBm as the standard, Fully opened showed -55, one layer cover closed showed -67, and two layer covered showed -77. This theoretically shows that wireless communication is possible from the valve station to outside. Considering that the depth of the valve station's location is 2m underground, it can be safe to say that the availability of communication shouldn't be a problem.

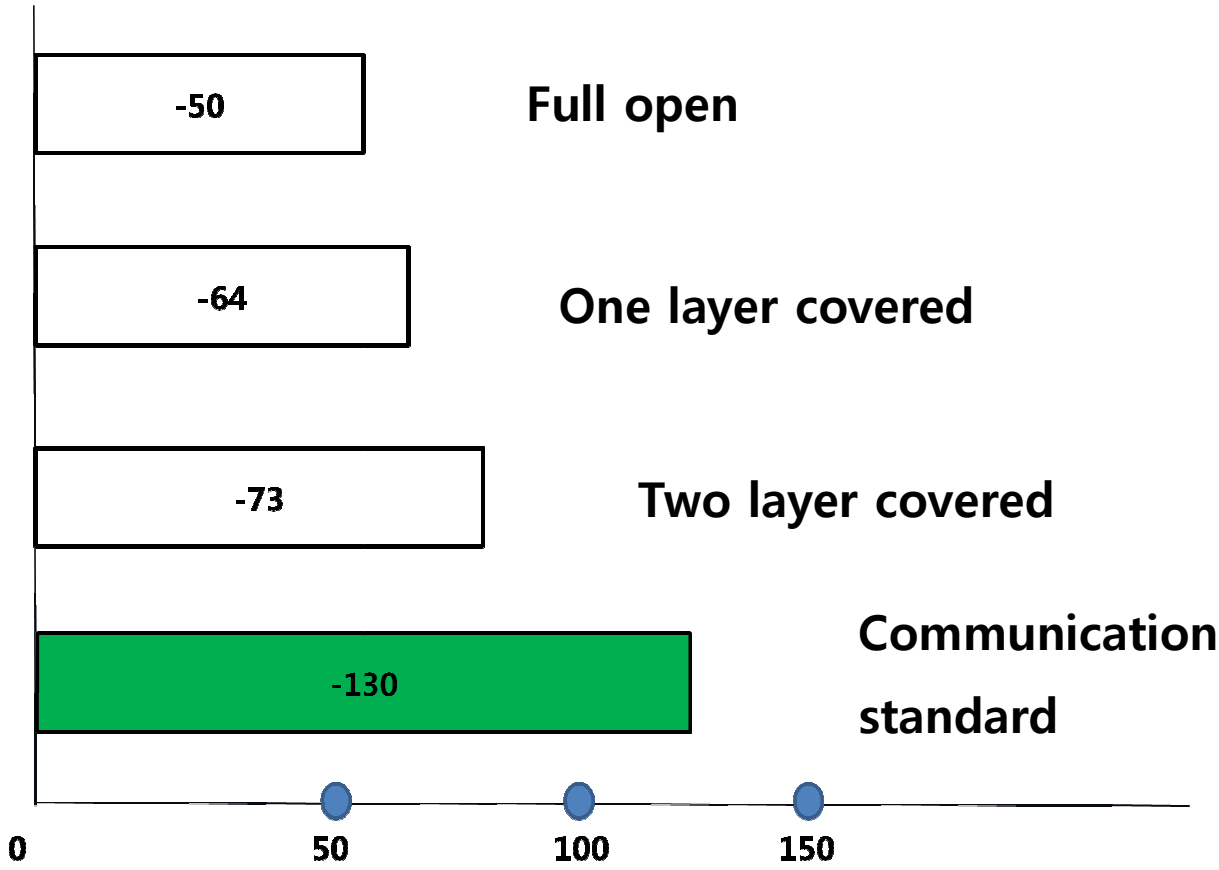

Fig. 2 CDMA electric field strength (dBm)

2.2.3 RTU design

1) main function

- Valve ID No. and server IP storage function
- Data saving and event data saving functions by each sensor
- battery's low voltage monitoring function (check when RF TX/under 3.0V)
- Real time function
- communication function: CDMA Wibro, Wifi control function
- measurement function: detect gas leak, current in valve station, water-level
- control means and communication means are unified by international standard units.

2) RTU detail function

gas leak	- contents : percentage - measurement method : Diffusion combustion
CP current	- measurement contents : measure CP current - measurement range : -40A ~ +40A(DC current) - measurement method : measure the value of SHUNT voltage, value of current - value of SHUNT voltage : -400mV(at -40A) ~ +400mV (at +40A) - measurement precision :±0.5%
water level detection	- measurement contents : water level of valve station - measurement range : 0.0m ~20m(height : 1.4m ~ 2.1m) - measurement method : measure resistance value of Lever SS Sensor Model, height of water(cm) - output value of sensor : method of resistance value output (require none of power supply from outside) - measurement precision : ±10%

Table. 3 RTU detail function

2.3 Second step

In the second step, based on the results of the first step's study. We established context-aware information transmission method from valve station to outside and focused on prototype development considering the characteristics of each facilities and optimization for the effective system. For CDMA communication system is applied underground, the the radio wave should not be disturbed by surrounding environment and it should be able to be sent from the ground to the base station.

We separated the status, sleep mode, status information measurement mode, status information transmission mode, while the device is wating. It is designed to attach anywhere in valve station. When we need to acquire the status information like gas leak, It’s possible to attach to ceiling of valve station. The RTU installed in Valve station measure the information in valve station and communicate to the server using CDMA communication method.

Measurement Cycle and time are available to be changed as well as the communication cycle. By default, the measurement cycle operates two times a day while the communication cycle operates once a weak. Fig. 3 shows developed device and case. The sensor box for measuring gas leak, water level, CP current was produced separately and installed left of the terminal case.

Fig. 3 Device and case

Since the RTU case is installed inside the underground valve station, when considering temperature, relative humidity, types of gases, leak etc, it is separated to Zone 2(division 2, case 1) so that it can be designed ‘increased safety Exe’, but to increase safety, it was designed to ‘flame proof structure Exd’. In addition, Gas detection sensor has to detect gas leak without the inflow of moisture or water. So we added membrane vent to design the case to protect electronic circuit.

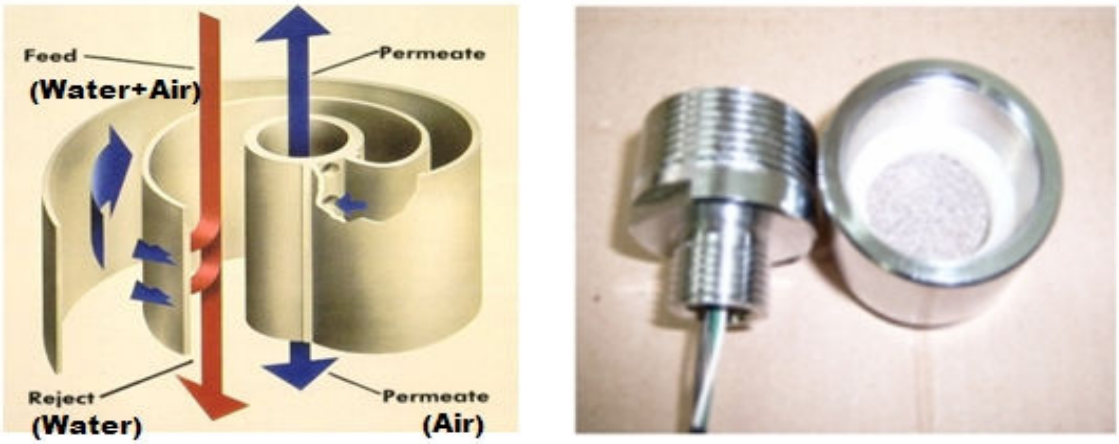

Fig. 4 Membrane vent of gas leak detector

2.4. Third step

We focused on developing and optimizing prototype considering characteristics of each sensor to establish method of efficient context-aware information transfering. In addition, for intelligent services, context-aware model Data Warehouse, application services and middleware platforms were designed. For the development and stabilization and for the next stage, we completed the test focused on the field application of each facility. After reviewing the improvement of the field application facilities according to the on-site analysis, it is induced to improve reliability and safety of the entire system.

In order to upgrade for the improvement of each sensor ‘s accuracy and water-resistant to moisture, the sensor box was molded inside, external antenna is used, not only terminal case but also sensor box and connection cable was produced as explosion-proof and those are installed on site in 10 sets.

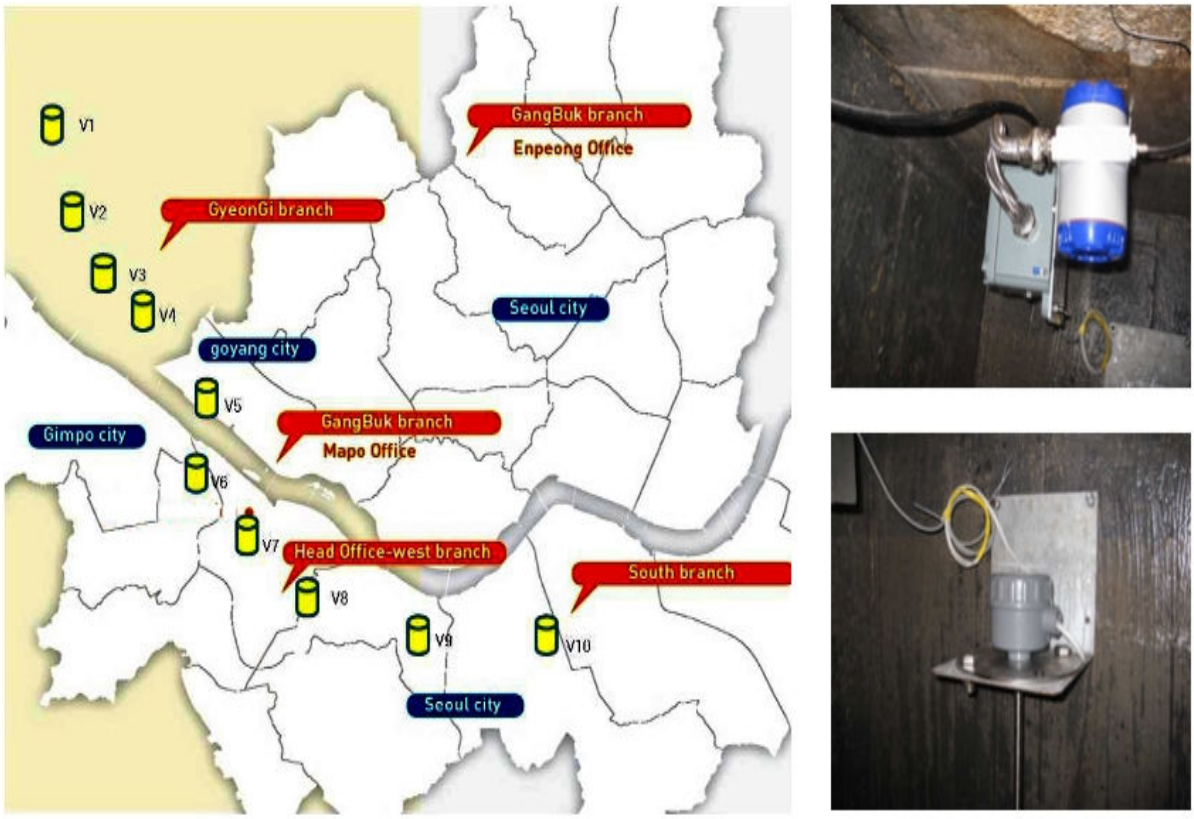

Fig. 5 Installation site, RTU in valve station

3. SYSTEM OPERATION

'Underground valve station safety management using ubiquitous sensor’ is composed of the client / server unit of the Central Command Center and on-site installation RTU, CDMA communication networks.

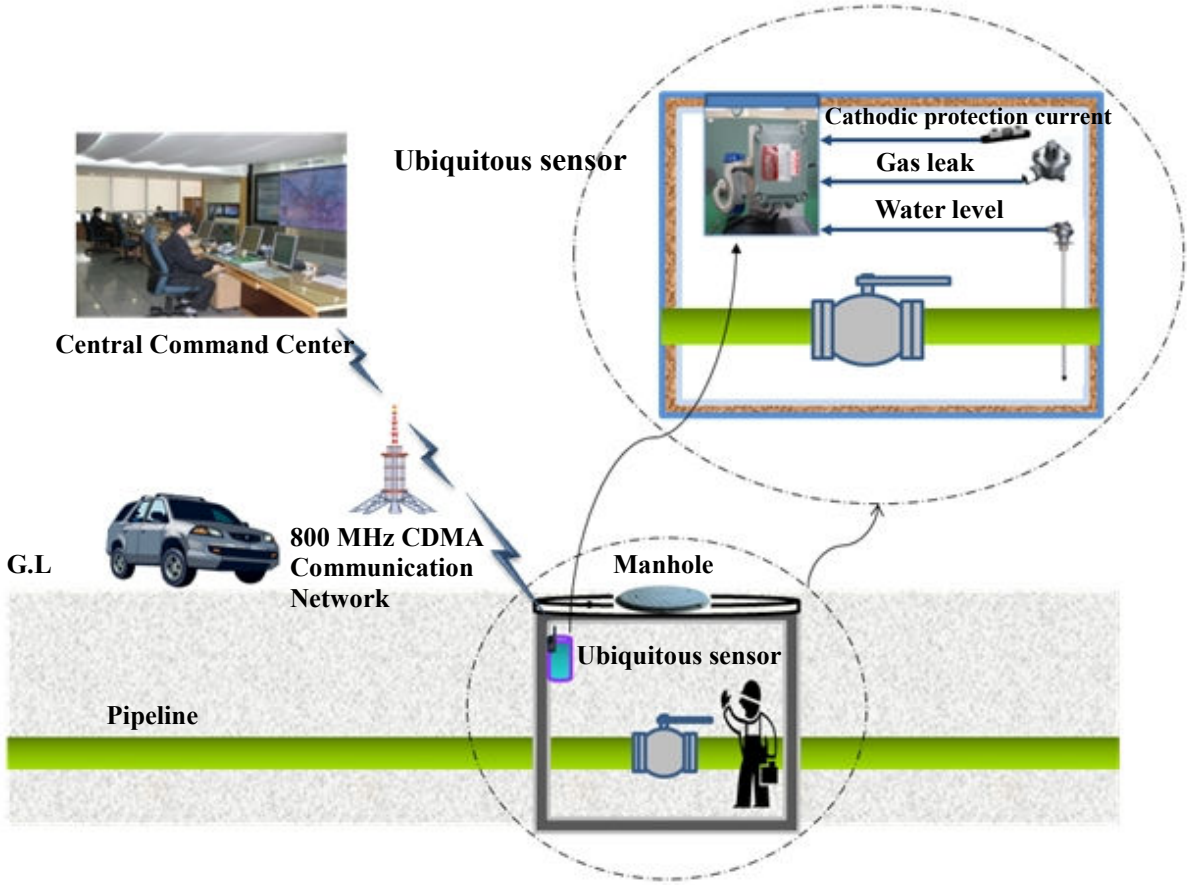

Fig. 6 Underground valve station safety management using ubiquitous sensor

The composition of client / server database of Central Command Center has implemented using oracle based on Window XP. Without any special considerations about computer hardware, it can be used and installed universally. Consisted of a web based operation, it can be used anywhere. The client's screen is composed of the detail information of each valve station and an event alarms, data views, data search, including the historical information and so on in order to promote the availability of the user.

Fig.7 shows the client's run screen based on this system. The user can obtain all the data required for safety management of the facilities through this window. In the integrated display window, the received data of each valve station and the measured time and the status values are displayed in text form. The graphical display which could easily grasp the trend of the value of the sensor is provided. Operators can search the desired type of data separated step by step. This type of information is provided in real time according to the transmission circle of wireless RTU.

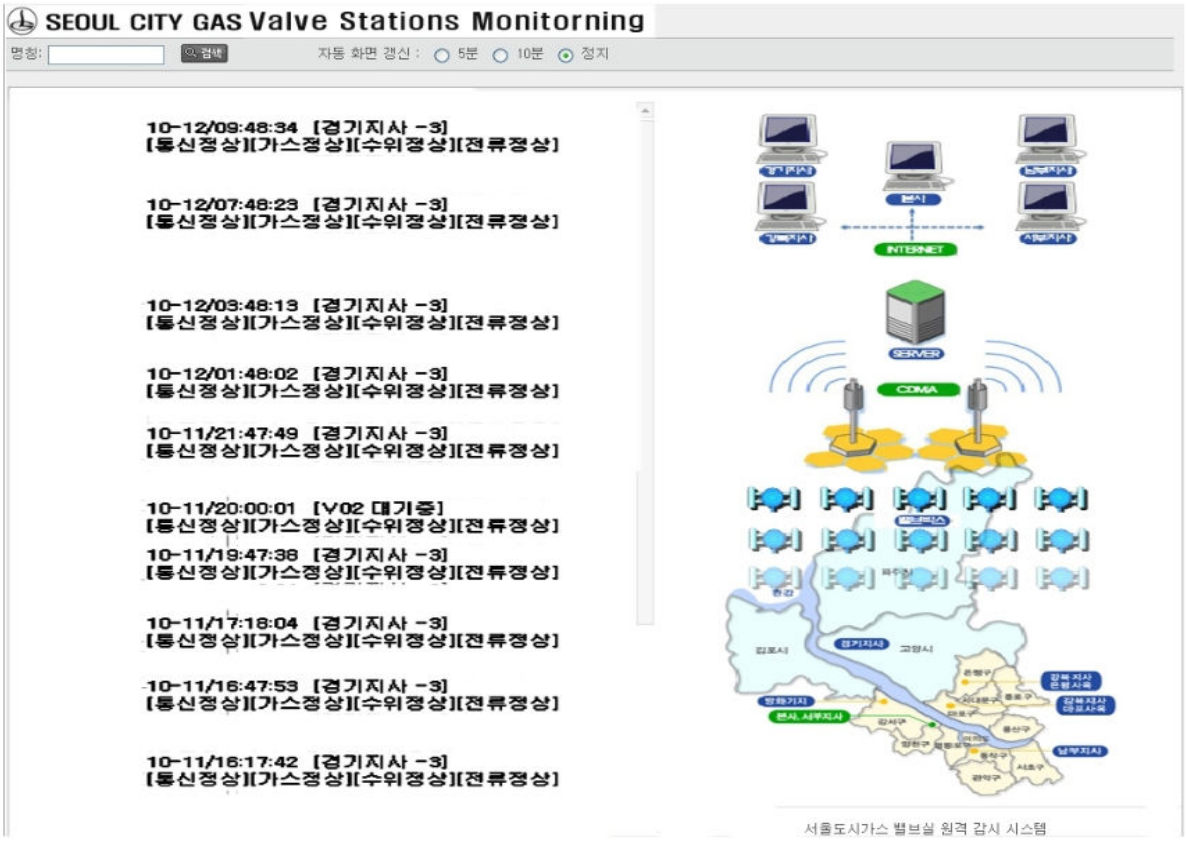

Fig. 7 Monitorning program

3.1 Handling the situation

Monitoring System is designed to prevent accidents by early detection of the operating conditions of valve station. When an abnormal situation arises in the valve station, the event is occurred immediately and transmitted to server through the wireless net. Then the alarm occurs on the operator's screen. The operator looks at the screen and notify the closest patrol on-site to move to the site. This progress is transmitted simultaneously to operator by text-message of mobile phone in relation to the GPS monitoring system.

3.2 System connection

'Underground valve station safety management using ubiquitous sensor' will be connected with 'The exposed pipeline stress monitoring system' and 'Underground CP surveillance monitoring system'. They will be intergrated to 'Ubiquitous-based intelligent intergrated safety management system'

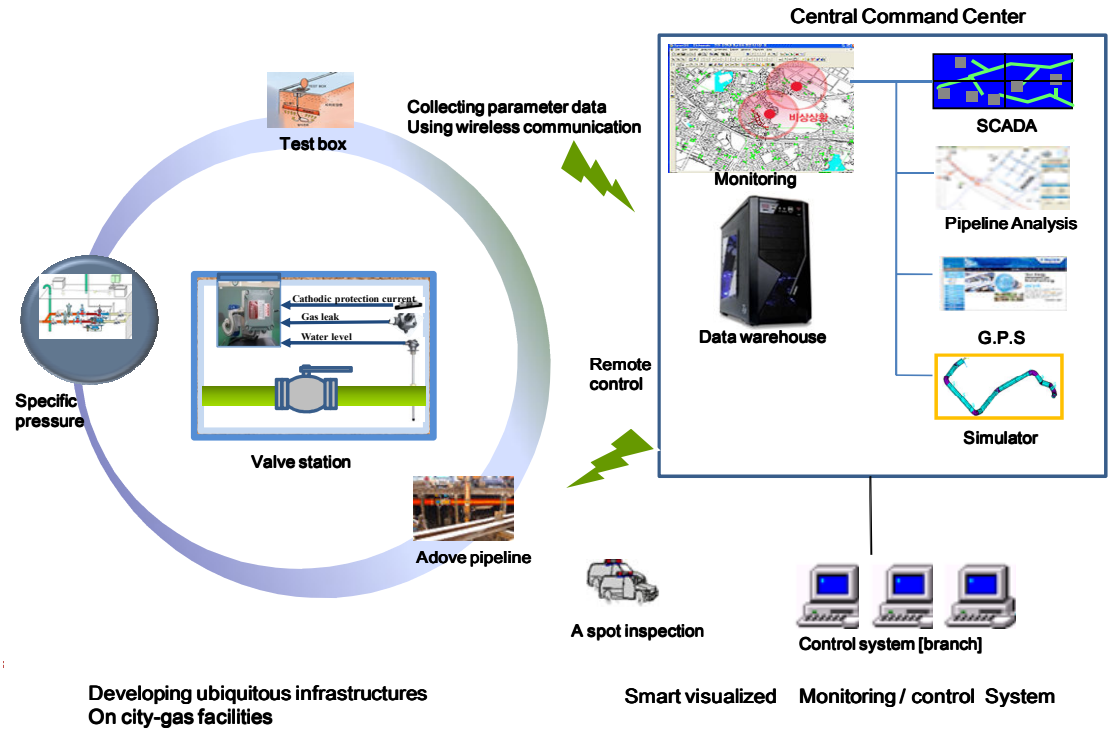

Fig. 8 Ubiquitous-based intelligent intergrated safety management System

4. CONCLUSION

'Underground valve station safety management using ubiquitous sensor' is developed with applying the sensor network technology about underground valve station located on the road, with RTU of low power, low cost and locating in a narrow space, with a remote monitoring system. It's installed on sight, and its usefulness has been confirmed. By attaching USN(Ubiquitous sensor network) to city gas facilities which needs the ubiquitous technology, we could build web based monitoring system of collecting data through communication network.

This system has exceptional capability in the ease of installation and management by its compact size, reasonable price, scalability and compatibility. It is planned to continue applying the Ubiquitous sensor technology in infrastructure facilities such as communications, electricity, water supplies etc. We will develop this ubiquitous sensor more and extend 'Underground valve station safety management using ubiquitous sensor' to pipeline damage prevention against excavaton.

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