Smart Water Management Technology with Intelligent Sensing and ICT for the Integrated Water Systems

KUMURA Takahiro, SUZUKI Naofumi, TAKAHASHI Masatake, TOMINAGA Shin, MORIOKA Sumio, Ivan Stoianov

Abstract

The increasing demand for water arising from global population growth and urbanization in recent years is stressing the water supply to its limits. On the other hand, water infrastructure such as pipes has been deteriorating due to aging. Under these conditions, new technologies in the water infrastructure have been required to enable the distribution of high quality water to users in a safe and cost-effective manner, from the perspective of efficiently using our world's precious water resources. The NEC Group is collaborating with Imperial College London to develop a Smart Water Management System based on ICT to operate the water infrastructure more efficiently. This article introduces our efforts.

Keywords

sensor, big-data, data acquisition, analysis, virtual modeling, control, water, infrastructure, deterioration, water demand

1. Introduction

The available water on the surface of the earth is a rare resource, which is only 0.01% of the water that exists on the earth. It is expected that the supply-demand balance of water will become tight due to worldwide population growth from now on.

Water infrastructure is a large scale system which consists of a lot of processes such as intake from water sources, purification, distribution to users, sewerage disposal, and so on (**Fig. 1**). Operation of the infrastructure needs a lot of engineers with expertise and enough experience and it takes long time to bring up such skillful engineers. So, the shortage of the experts who will respond to expansion of water project to meet increasing water demand in worldwide would be concerned.

A trigger of the research of smart water management was the customer's demands to manage operation of water infrastructure more efficiently. Water demand increase and population concentration to urban area will increase loads on water infrastructure, which deteriorate the infrastructure. As a result, the cost to maintain or renew the infrastructure will increase (**Fig. 2**). On the other hand, there is customer's demand to high quality water that should be supplied with low price.

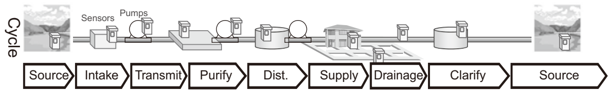
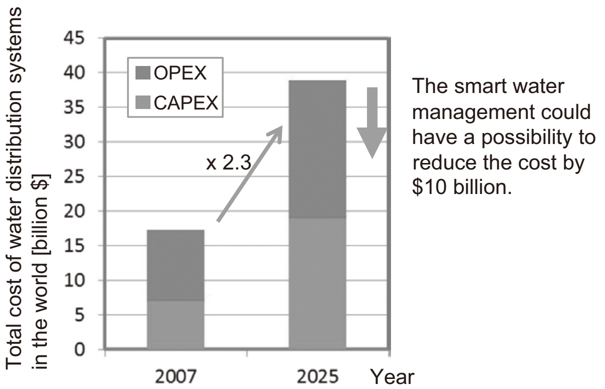


Fig. 1 Processes in water infrastructure.



Source: Global water market, and cost estimated by Ministry of Economy, Trade, and Industry of Japan.

Fig. 2 Provisional calculations of maintenance cost of water infrastructure (W/W).

We start the research because we thought that ICT (information and communication technology) would be useful to solve these issues. That is, the efficient water operation management would be realized by modeling the water infrastructure and its optimal operation with electronic control. It will enable to suppress the increase of the cost to maintain or renew the infrastructure and the same quality of service under the challenging conditions, demand increase and aging assets will be achieved without increasing the price of water.

2. Joint Research of Smart Water Management with Imperial College London

We have started a joint research project with Imperial College London (ICL) to advance the development and implementation of a novel concept of adaptive water distribution networks with dynamically reconfigurable topology for optimized pressure control, leakage management and improved system resilience. This research joins together ICT, cloud and big data technology, sensing technology of NEC and the ICL pioneering academic research in hydraulic modeling and sensing, model predictive control and optimization for large scale water supply networks (**Fig. 3**).

UK water utilities currently operate one of the oldest water supply infrastructure (e.g. around 50% of the pipes in London are over 100 years old and 30% or less are over 150 years old). This presents unique challenges to meet increasing population demand while at the same time keeping the cost to the customer unchanged. Many cities in the world are gradually facing the same problems and applying successfully the technologies and analytics of this joint project to ageing network infrastructures in the UK would lead to a worldwide transfer and application. In the UK, the implementation of District Meter Areas (DMAs) has greatly assisted water utilities in reducing leakage (**Fig. 4**). DMAs segregate water networks into small areas, the flow in and out of each area is monitored and thresholds are derived from the minimum night flow to trigger the leak localization. A major drawback of the DMA approach is the reduced redundancy in network connectivity which has a severe impact on network resilience, incident management and water quality deterioration.

In our joint research program, the concept of adaptively reconfigurable networks integrates the benefits of DMAs for managing leakage with the advantages of large-scale looped networks for increased redundancy in connectivity, reliability and resilience. Self-powered multi-function network controllers are designed and integrated with novel telemetry tools for high-speed time-synchronized monitoring of the dynamic hydraulic conditions. Computationally efficient and robust

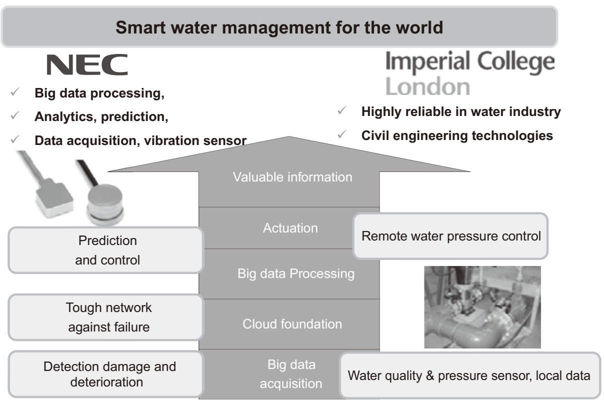


Fig. 3 Joint Research with Imperial College London.

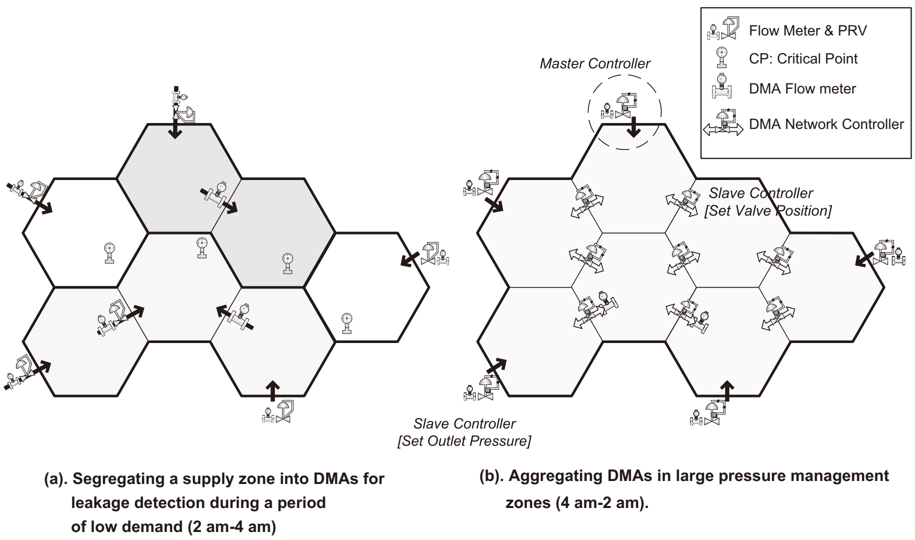
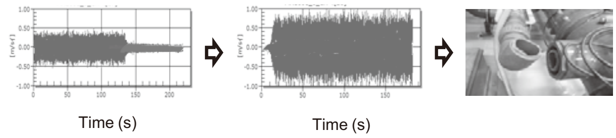


Fig. 4 Adaptive sectorisation of water distribution networks with dynamically reconfigurable topology.

Photo Sensor unit for monitoring of water infrastructure.



(a) Mechanical vibration increases before bursting. (b) Burst pipe.

Fig. 5 Vibration signal change before burst.

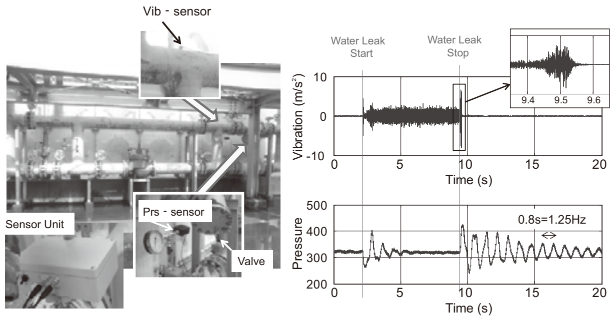


Fig. 6 Rapid change of water pressure and mechanical vibration of pipes caused by sudden opening or closing of valves.

optimization methods are being developed and applied for the dynamic topology reconfiguration and pressure control of water distribution networks. A field demonstrator which is part of an operational network in a dense urban setting has been built and used to evaluate the developed sensing, data, analytical and control technologies and assess the operational benefits.

2.1 Visualization of Health Condition of Water Infrastructure and Hydraulic Conditions

To operate water infrastructure efficiently, we have to understand the health condition of water infrastructure and the hydraulic conditions (pressure and flow) with high spatial and temporal resolution at first. It is currently impossible to capture and analyze the dynamic hydraulic conditions and also impossible to know the condition of the infrastructure in real time by visual observation. So, we have been developing a new sensing technology including sensing units that consist of water pressure sensors to measure the hydraulic conditions and vibration sensors to understand health condition of the infrastructure (**Photo**). The advantage of this technology is that we can collect detail data with high sensitivity, high temporal resolution and wide frequency range. It enables to get water pressure data with rapid change in real time, which we have not been able to get so far.

2.2 Capturing a Pre-failure Signs of Water Pipe Burst with Vibration Sensor

We did experiment to capture a pre-failure signs of water pipe burst with vibration sensor. Preliminary work included an extensive experimental program which was carried out in the Hydrodynamics Lab of Imperial College London (Pipe Rig which simulates the operation of water supply networks). As we increased water pressure in the pipe gradually, we captured signatures in the vibro-acoustic signals which were indicative of the pending pipe burst and finally the pipe burst. Advanced signal processing algorithms were developed to utilize these vibro-acoustic signals in order to detect pre-failure warning signals, which means we can predict the burst of a pipe and change it before burst by observing the vibro-acoustic signals (**Fig. 5**).

2.3 Understanding of Water Pressure and Pipe Vibration Changes Caused by Valve Operation

We did experiment to collect data of water pressure and vibration of pipes when water valves are opened or closed suddenly by using newly developed sensor units (**Fig. 6**). We observed vibration signal corresponds to water pressure signal. It indicates that rapid change of water pressure puts a large mechanical load on pipes, which accelerates deterioration of pipes. We think we can control pumps and valves optimally to take good care of deteriorated pipes by understanding the pipe condition with sensors.

2.4 Smart Operation of Water Infrastructure with Virtual Modeling

We can simulate in real time the complex hydraulic conditions in large scale networks using data that are collected with sensors with big-data technique. This is an approach to describe the water infrastructure and hydraulic conditions in real world with mathematical model. We regard the water network as a communication network and try to operate water infrastructure by remote and electronic control of pumps and valves. It enables efficient operation of water infrastructure which prevents water loss by suppressing burst of deteriorated pipes and sup-

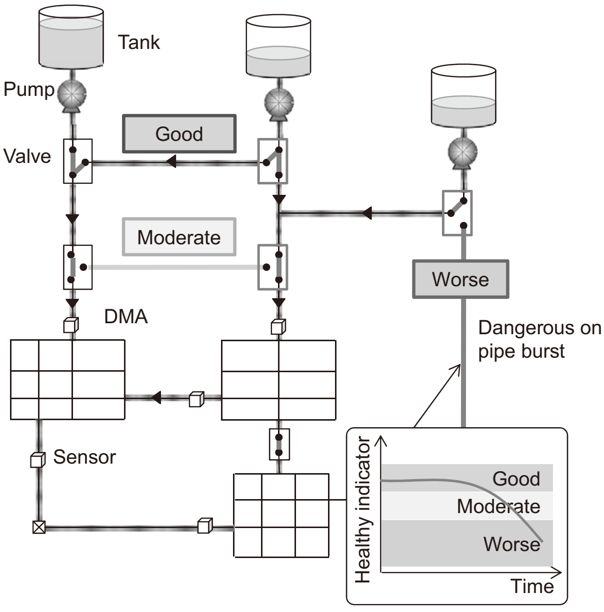


Fig. 7 Prevention of burst by modeling of water infrastructure and change of distribution path.

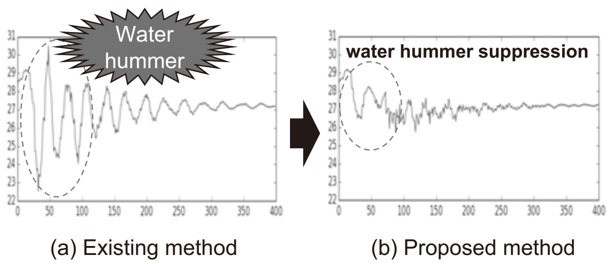


Fig. 8 Suppression of water hummer by precise control of valves.

plies necessary and sufficient amount water to users (**Fig. 7**).

Moreover, by supplying enough water to bulk users individually by changing water distribution path with electronic control of water valves, we can prevent excess water production and suppress facility investment.

Next, we introduce our research to create algorithm to pumps and valves from simulation by using virtual modeling of water infrastructure. The model that we have been developing is so precise that it can describe dynamic change and transition of water pressure, which enable higher level control of water networks than so far. As an example, we will show a case that impulse of water pressure was input to a model that consists of pumps, pipes and valves. By inputting control signals to valves that control then precisely with high temporal resolution, we can make impulse waves to interfere and suppress the total amplitude of water pressure (**Fig. 8**).

Furthermore, the NEC group has also been conducting research to make optimal operation plan of water infrastructure by predicting water demand from data such as weather, events, time, and seasons by using big data technology.

3. Conclusion

We have introduced our research to realize effective use of water resource by utilizing ICT. Recently, sensors with high sensibility and low price are on the market. With the growth of the Internet, we can send and receive data everywhere in the world. Moreover, the virtualization of computer and storage, and development of software defined networks facilitate effective utilization of ICT for infrastructure in many fields. In near future, technologies and concepts in different fields such as civil engineering and ICT will be integrated. Moreover, social infrastructures in the real world will be virtualized by ICT. Then, smart society will be realized where we can operate the infrastructures by precise data analysis and control.

We will continue research and development to solve social issues by ICT with group companies and partner companies.

Authors' Profiles

KUMURA Takahiro
Assistant Manager
Green Platform Research Laboratories

SUZUKI Naofumi
Principal Researcher
Green Platform Research Laboratories

TAKAHASHI Masatake
Principal Researcher
Green Platform Research Laboratories

TOMINAGA Shin
Assistant Manager
Green Platform Research Laboratories

MORIOKA Sumio
Manager
NEC Europe Ltd.

Ivan Stoianov
Lecturer
Department of Civil and Environmental Engineering
Imperial College London

The details about this paper can be seen at the following.

Related URL:

NEC Conducts Smart Water Systems Research with Imperial College London
http://www.nec.com/en/press/201210/global_20121023_03.html

Development of Ultrahigh-Sensitivity Vibration Sensor Technology for Minute Vibration Detection, Its Applications
http://www.nec.com/en/global/techrep/journal/g12/n02/pdf/120215.pdf

InfraSense Labs (Imperial College London)
www.infrasense.net

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese | English

Vol.9 No.1 Special Issue on Solutions for Society - Creating a Safer and More Secure Society

Vol.9 No.1

January, 2015

Special Issue TOP

NEC Information