UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A TECHNIQUE FOR REAL-TIME LEAKAGE DETECTION AND LOCATION IN WATER DISTRIBUTION NETWORKS

SALAH MUAMER ABURAWE

DEVELOPMENT OF A TECHNIQUE FOR REAL-TIME LEAKAGE DETECTION AND LOCATION IN WATER DISTRIBUTION NETWORKS

By

SALAH MUAMER ABURAWE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2014

DEDICATION

To

My Mother and My Wife

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF A TECHNIQUE FOR REAL-TIME LEAKAGE DETECTION AND LOCATION IN WATER DISTRIBUTION NETWORKS

By

SALAH MUAMER ABURAWE

March 2014

Chairman: Associate Professor Abdul Rashid Bin Mohamed Shariff, PhD
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Most water utilities worldwide suffer from the problem of water loss which effects the financial, social and environmental concerns. Leakage in water distribution networks is a significant issue that costs a lot, which is further complicated by the problem that the location of the leakage is usually hidden underground. The aim of this research was to develop a technique for real-time leakage detection and location in water distribution networks with acceptable accuracy, able to identify its location in the field quickly, and with reasonable cost thus encouraging its wider application. Currently acoustic methods are commonly deployed, which requires long time to perform, in addition to the high-cost resulting from the expensive devices and expenses of the field survey itself. There are also some analytical methods that rely on hydraulic analysis concept to detect the leakage. However they are unable to determine the location of leakage accurately, as they just identify a group of hot spots that are likely to be the location of leakage, and require to return to the field to find the location of the leakage. The analytical methods that rely mainly on the hydraulic modeling of the network have contributed to reducing the time needed to locate the leakage thus reducing some fraction of the cost. A combination of hydraulic analysis methods with geospatial technology should provide additional advantages. This research was conducted to develop an analytical technique to locate the leakage without the need to conduct a detailed field survey. It was done through a set of hydraulic analysis scenarios using pressure and flow field data at specific points in the network obtained in real-time using SCADA system. The development was conducted through three main stages. The proposed technique was evaluated theoretically before conducting any costly practical activity. The practical stage was accomplished in two phases, the first phase was a laboratory study to identify the hydraulic behaviour of the network before, during and after the leakage. The second phase was a field work conducted using a real water network as a case study located in Shah Alam, Selangor, Malaysia. A group of fabricated leaks were placed at specific locations in the network, and the associated pressure changes at certain observation points were monitored. A study of the results obtained from the practical stage using a calibrated model was done in the application and validation stage. A series of hydraulic analysis scenarios were applied on the hydraulic model in order to locate the leaks which had been fabricated in the field. It was found that the results were affected by the level of model calibration, where six leak locations were detected out of nine leak locations fabricated in the field. This result shows the possibility of using the developed technique to locate the leak In the case of the availability of sufficient field data to build a high calibrated hydraulic model.

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Abstrak tesis yang dikemukakan kepada Senat universiti Putra Malaysia
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PEMBANGUNAN TEKNIK PENGESANAN KEBOCORAN DAN LOKASI DALAM MASA NYATA UNTUK RANGKAIAN PENGAGIHAN AIR

Oleh

SALAH MUAMER ABURAWE

Mac 2014

Pengerusi: Professor Madya Abdul Rashid Bim Mohamed Shariff, PhD
Fakulti: Kejuruteraan

Banyak syarikat bekalan air dunia menghadapi masalah kehilangan air yang menyebabkan kerugian kewangan, masalah social dan persekitaran. Kebocoran air di dalam sistem pengagihan adalah isu serius yang dari segi kos dan lebih merumitkan keadaan apabila kebanyakan kebocoran terlindung di bawah tanah. Objektif penyelidikan ini adalah untuk membangunkan pendekatan secara geospatial bagi mengesan kebocoran dan lokasi di lapangan secara masa nyata di dalam sistem pengagihan air dengan ketepatan yang boleh diterima pakai dan kos yang murah untuk menggalakkan aplikasi sistem secara menyeluruh. Pada masa sekarang kaedah akustik digunakan yang memerlukan masa yang lama untuk dilaksanakan disamping kos yang tinggi ekoran dari penggunaan peralatan yang mahal dan perbelanjaan untuk kerja-kerja pengukuran di lapangan. Terdapat juga kaedah analitik yang bergantung kepada konsep analisis hidraulik untuk mengesan kebocoran paip. Walau bagaimanapun ianya tidak berupaya untuk mengesan dengan tepat lokasi kebocoran di mana ianya hanya boleh mengesan kawasan panas keberangkalian berlaku kebocoran dan memerlukan pemeriksaan di lapangan untuk mengesan kebocoran dengan tepat. Kaedah analitik telah menyumbang kepada pengurangan masa untuk menentukan lokasi kebocoran yang sedikit sebanyak dapat menjimatkan kos. Kombinasi di antara kaedah analisis hidraulik dan teknologi geospatial boleh memberikan kelebihan. Penyelidikan ini adalah untuk membangunkan pendekatan secara analisis geospatial untuk mengesan lokasi kebocoran tanpa memerlukan kerja-kerja pengukuran tapak yang terperinci. Ianya dilaksanakan dengan senario analisis hidraulik menggunakan maklumat tekanan dan aliran sebenar pada lokasi yang spesifik di dalam sistem pengagihan yang boleh didapati secara masa nyata menggunakan sistem SCADA. Pembangunan telah dilaksanakan melalui tiga peringkat

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I certify that an Examination Committee has met on **25 March 2014** to conduct the final examination of **Salah Muamer Aburawe** on his **Doctor of Philosophy** thesis entitled, "**Development of A technique for Real-Time Leakage Detection and Location in Water Distribution Networks**", in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy degree.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AC	Asbestos Concrete
AWWA	American Water Works Association
CAD	Computer Aided Design
CIS	Customer Information System
DMA	District Metered Area
DXF	Drawing Exchange File
EPA	Environmental Protection Agency
GIS	Geospatial Information System
GPS	Global Positioning System
HGL	Hydraulic Grade Line
ITA	Inverse Transient Analysis
IWA	International Water Association
MNF	Minimum Night Flow
NRW	Non Revenue Water
NTPF	Network Pressure Footprint
NDPF	Node Pressure Footprint
PRV	Pressure Reducing Valve
RTU	Remote Telemetry Unit
SCADA	Supervisory Control And Data Acquisition
UNICEF	United Nations International Children's Emergency Fund
WaterGEMS	Water Geospatial Engineering Modelling System
WDS	Water Distribution System
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Most water utilities worldwide suffer from the problem of water loss causing significant effects not only on operational processes of the water system but also on the financial, social and environmental aspects.

Water losses can be classified to **direct losses**, which is the physical losses in the water system due to the loss in the amount of treated water because of the leaks in pipes, as well as the damage that may affect the facilities of water system directly, and **indirect losses**, which appear as economic or commercial losses (Farley et al., 2008; Pilcher et al., 2008).

Figure 1.1 Examples of water leakage

There is clearly evident that the problem of water loss is a very complex issue and has impact on water systems. In this regard, it is reported that more than 32 billion cubic meters of water are lost annually worldwide from the distribution networks because of the problem of leakage, while more than 16 billion cubic meters of water are consumed by users, either unmetered or not correctly metered because of theft and robbery (Kingdom *et al.*, 2006).

Therefore, reducing water loss will not only increase the amount of water needed for consumption but also preserve the availability of water and protection from leakage and theft.

Water means money, it is even more valuable than that; it means life itself. So, before searching for new water resources, we should think about preserving what is available right now. Therefore, leakage in water supply networks is the most important threat facing water resources of any country, especially in countries that are already lacking water resources.

The problem of leakage in water distribution networks is a significant issue that costs a lot per year, which further complicates the problem that the location of the leakage is usually hidden underground (Gallet *et al.*, 2012). In order to address this problem, effective techniques must be developed to detect and locate leakages in real-time so as to prevent exacerbation of the problem. Developing a method to detect leakages is no longer the main obstacle now as there are many methods and techniques currently available and used to perform the task. The question that arises now is “How effective are these methods in solving such problem radically?”.

1.2 Problem Statement

The most important characteristics of leakage detection techniques in water systems are ease of application, cost of implementation, as well as accuracy and speed of getting results through them. Some leakage detection techniques rely on hardware and equipment to detect leaks in limited pipes, and this is usually preceded with the use of these techniques with other theoretical and analytical methods to identify some hot spots which are expected to be leakage points (Hunaidi, 2010).

Hence, researchers are still trying to find an analytical method which can be used to detect the exact location of leakage in water distribution networks. What has been reached so far is an estimation of the leakage location with error rate that is possibly related to tens of meters which are sometimes through hot spots (Bentley, 2006). The problem is exacerbated when there are leaks in more than one location in the network at the same time, as well the lack of reliability in demand data as a result of illegal consumption of water (EPA, 2010). Traditional methods of leakage detection in water distribution networks, which mostly rely on acoustic techniques are both time consuming and costly. In addition, their weakness that affects the efficiency in the use of non-metallic pipes has encouraged researchers around the world to develop analytical methods based on the high analytical capabilities of the computer to solve this problem (Puusta *et al.*, 2010).

Based on the above argument, it is concluded that the efficiency of any method is determined by three key factors, which are, accuracy, cost and time. These factors can show the efficiency of the method and its effectiveness in carrying out the task. Therefore, the problem of leakage detection not only lies in finding a method to do that particular task, but an ideal method is characterized by better accuracy to reduce the field work required for repairing as well as reduce the current application cost due to the expenses of field devices, and get a quick alert for the presence of leakage through real-time monitoring.

Since location is the main issue, a combination of hydraulic modeling technology with geospatial techniques help to improve the accuracy and reduce the cost. Adding the SCADA system to the combination allows access to field data in real-time, which contributes to reduce the leakage detection time. Figure 1.2 shows the cycle of targeted leakage detection phases, starting from field data collection phase until maintenance phase.

Figure 1.2 The Technique for Real-time Leakage Location

In this research, an attempt was done to find an analytical technique for leakage detection in water distribution networks, to be systematically developed and validated. Furthermore there are needs to take into consideration the three key factors to ensure access to a perfect solution for aforementioned this problem.

1.3 Research Goal and Objectives

The major goal of this study was to develop and evaluate an analytical technique for real-time leakage detection in water distribution networks for more accurate results and cost saving.

Hence, the specific objectives to achieve the stated goal are as follows:

i. To develop the analytical technique for leakage detection in water distribution networks.
ii. To design the conceptual model of an integrated system that can be used to perform the task of leakage detection.
iii. To validate the developed technique by establishing real field leakage scenarios and comparing between field and simulated pressure values.

1.4 Scope of the Study

The scope of this study is limited to develop an analytical technique to detect leaks in water distribution networks. The research covers conducting laboratory experiment and establishing real field leakage scenarios to verify the designed technique. The research also demonstrates the outlines the integrated geospatial system that can be used for leakage detection based on the designed technique.

1.5 Significance of the Study

The significance of the study is that it will produce an improved technique to detect leaks in water distribution networks, which may contribute to resolve this issue in an effective manner by improving the accuracy, reducing the cost and saving the time required for locating the leakage.

The proposed technique provides the three key factors required for an effective leakage monitoring and detection, while the methods and techniques used at the present time do not meet the three key factors at once, demonstrating failure in their performance, and thus inability to provide an ideal solution to the problem.

1.6 Thesis Organization

The thesis is organized in the following manner. Chapter Two presents a literature review of the five important topics related to the research, namely, non-revenue water, leakage detection and location, hydraulic modelling, SCADA systems for monitoring and controlling and integration of geospatial technology with other related systems.

Chapter Three presents the research methodology and the stages involved in the research work, starting with the development of the target technique for leakage detection and location, proposing an integrated system to perform this technique, and conducting a laboratory experiment and field works to verify and validate the developed technique. This has been done through three main stages: theoretical stage, practical stage, leakage detection and technique validation stage.

Chapter Four discusses the results obtained in the three stages of the research work, together with their comparison and discussion.

Chapter Five is devoted to the conclusions based on the discussion of the results, as well as the recommendations for future research.

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