CMN 2017

Congress on Numerical Methods in Engineering

July 3 - 5, Valencia, Spain

Edited by: Irene Arias, Jesús María Blanco, Stephane Clain, Paulo Flores,
Paulo Lourenço, Juan José Ródenas and Manuel Tur

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Congreso de Métodos Numéricos en Ingeniería
3-5 julio 2017, Valencia, España

FROM METERING TO WATER BALANCE

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Keywords: water metering, water balance, software, smarter metering

Abstract *Metering is an essential activity in Water Distribution Systems. Not only the utility revenue clearly is proportional to the metered values, but also the evaluation of the performance of the network relies on it. Both the input volume in the network and the metered consumption are normally not measured simultaneously. As a consequence, to calculate the water balance, approximations should be done regarding the metered consumption. The time needed for reading all water meters will influence the required approximations and, consequently, determine the inaccuracies in the water balance calculation. In the experience of these authors, this time can be about 10 days or go up even to three months depending on the characteristic of the system and how the meter reading is performed. Reading all meters simultaneously is materially impossible in most systems since household meters are not equipped with telemetry and in the cities that do have telemetry systems implemented, not all the customers are covered with this technology. In this work, we estimate the influence over the final water balance result of not collecting measurements from all the water meters simultaneously. Additionally, a tool is presented for automating water balance calculations, including the detection of anomalous readings due to reading failures or other causes. Finally, some considerations on the use of automatic meter reading are raised taking into account possible advantages and disadvantages from the points of view of both the consumer and the utility.*

1. INTRODUCTION

Water distribution systems are critical infrastructures for the economic and social development of cities. Global trends such us urbanization, population growth and climate change have been making stronger the position of water as a key resource for sustainable urban development. In today's context, with a growing level of water demand, rather than increasing supply, the sector has to improve the way it uses its available resources [1]. A solid framework for improving water network operation and reducing non-revenue water is required. It is contrasting that cities with big difficulties to satisfy demand do also have high indexes of non-revenue water.
For a quite long time, water network models have been used for assessing the operation of distribution systems with the aim of improving it [2, 3]. In most of the cases the results of these models strongly depend on the estimation of the water demand that is or should be satisfied. Water demand plays an important role on those models, even more when trying to consider event detection and energy optimization based on hydraulic models. Large and inefficient systems based on poor measurements and alchemy-based operations are water biggest enemy [2]. In today's context, most of the utilities are compelled to protect water as a resource and to have an efficient operation in order to preserve its financial viability.

2. WATER METERING INFRAESTRUCTURE

The installation of water meters, in the experience of these authors, can be rejected by the end user because of their billing association. Even from the utilities perspective it is, in many cases, reduced to supply information regarding consumption just for billing purposes. In Germany, for example, it is normal to find cities where water meters are read just once a year. It is hard to use a one year measurement for much more than billing purposes. The purpose of metering water cannot be restricted to feed the billing system but to make it part of a wider process leading to a more efficient operation of the networks. However, it should be taken into consideration the costs of reading and processing water use with certain frequency.

Traditionally many utilities have been using manual reading of water meters. Time and personal costs make it prohibitive to increase significantly the frequency of measurements. Several technologies have been entering the market as a way to simplify and empower the metering process. These technologies can be divided in the following categories:

- Walk-by technologies, mainly using wireless m-bus and requiring personal to get relative close to water meters in order to take the reading directly from them.
- Concentrator based technologies where measurements are sent by cable or radiofrequency to information concentrators. From the concentrators, the information is sent to internet servers using mobile networks or other connections to internet.
- Technologies based on the internet of things where one antenna and its corresponding gateway can receive information of devices located in a radius of about 5 km.

Without any doubt, using these new technologies can help to improve the way a water network is operating. Nevertheless, the investment cost of hardware is not the only limitation. Specialists are required to find the best technological offer for the company and to exploit it correctly once it is installed. The biggest companies have normally informatic departments and economical resources to better achieve the introduction of these new technologies. For smaller companies, it is more difficult to make a jump to a better metering infrastructure. In Spain, the introduction of new water metering technologies is still under development. Table 1 shows some of the public data regarding this topic.

Table 1. New metering technologies in Spain

Location (Company)	**Connection points**	**Connections using new metering technologies**	**Details**
Valencia (Aguas de Valencia)	417868[i]	260000[ii]	At the end of 2014 there were 490000 intelligent water meters but only 260000 were systematically sending reading through a fix communication channel. At the end of 2015 the total of all connected clients was 417868.
Zaragoza (Aguas de Zaragoza)	340000[iii]	34000[iii]	Zaragoza has more than 34000 intelligent water meters (with walk-by function)
Santander (Aqualia)	92239[iv]	1229[v]	These meters were installed as part of the project Smart Water
Bilbao, Etxebarri (Consorcio Aguas Bilbao Bizkaia	5750[vi]	2300[vi]	40% of clients already have water meters with tele-reading

[i] http://elpais.com/diario/2006/03/25/cvalenciana/1143317879_850215.html
[ii] http://www.aguasdevalencia.es/Page/255
[iii] http://www.elperiodicodearagon.com/noticias/la-cronica-zgz-casablanca/zaragoza-supera-34-000-contadores-agua-inteligentes_1016975.html
[iv] http://www.medioambientecantabria.es/documentos_contenidos/18812_5.1.pdf (Visited 2017.05.18)
[v] http://santander.es/contenido/noticia/finaliza%20la%20segunda%20fase%20del%20despliegue%20de%20la%20gesti%C3%B3n%20inteligente%20del%20agua%2C%20de%20la%20que%20se%20benefician%20cerca%20de%208.000%20santanderinos
[vi] http://consorciodeaguas.com/Web/OficinaPrensa/noticias_detalle.aspx?id=309 Visited 2017.05.18, published 2015.03.10

Málaga (EMASA)	210000[vii]	115000[vii]	115 000 electric water meters, From them 102 000 have Walk-by functionality and 11 000 are remotely read by radio frequency
Vigo (Aqualia)	140000[viii]	4600[viii]	Standard water meters are read once every two months

3. INFORMATION PROCESSING

It is clear that new metering technologies can bring much more information of what is happening in the network but it come at some cost. The next question is what can be done with that information in the praxis and which value it brings to the utility. As important as the hardware solution adopted the software accompanying it is also important for processing metering information. The development of this paper has included the implementation of a software app for automating the process of metering information. The software has been included under the platform named Xirka. An abstract view of the parts integrating the system is presented in the Figure 1:

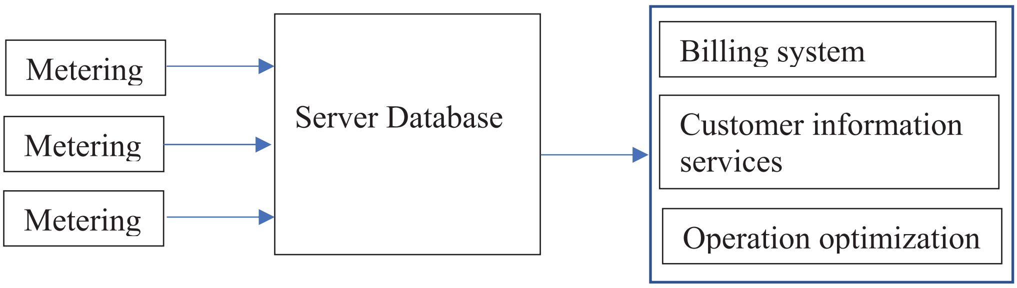

Figure 1. Abstract view of software functionalities

More than just metering, the solution presented is aimed to monitor devices and integrates the motorization with other systems for supporting decision making, billing systems, notifications and information retrieval. The consumption of water can be monitored by users directly from their mobile phones or using any browser connected to internet. Values are integrated with a system automating the generation and retrieval of invoices for billing purposes; this automation can be used not only from the side of utilities but also from the side of companies dedicated to the administration of buildings where consumption is shared among apartments. Historical values and the correlation among measurements are used to train predictive analytic

[vii] http://www.malagahoy.es/malaga/Emasa-instala-contadores-electronicos-consumo_0_664134119.html
[viii] http://www.atlantico.net/articulo/vigo/aqualia-extiende-telelectura-contadores-agua/20160904004552547633.html Visited 2017.05.18, published 2016.09.04

models that will be able to identify abnormal consumptions and rare events to forecast potential problems or future behavior of consumptions. Hydraulic models for decision making support will be updated with the corresponding measurements of water demand.

All metered information, independently of the technology used and its data transmission should reach the same database server. Note that this server provides several interfaces for receiving and interpreting data in different formats. It basically offers a WebAPI that returns any requested information in the well-known JSON format. This WebAPI can be extended if required for interpreting new input formats to introduce information into the system. This way, any utility would be supported during the roll out of a new metering or data transmission technology, precisely because the software system can incorporate measurements from different sources and different formats. These capabilities have been possible thanks to the cloud architecture adopted in Xirka. Basically, it has a web role for dealing with user interaction, a worker role to perform all data processing and a database server for persistency. The results are available in https://xirka.de.

One of the advantages of the software ideas developed during this research is the plausibility tests performed after every measurement. This help to identify any potential problem either during the measurement or during the transmission of that measurement to the system. If any discrepancy is shown, the decision was to inform directly both the utility and the end user about the problem. Additionally, in the cases of plausibility, users are able to access their consumption at any time. The system will notify proactively those users demanding significantly more water than the rest of “similar” users in the community. The idea considered was to make the user aware of his/her water consumption in order to influence him/her on saving water. Reducing consumption can extend the operational life of the water infrastructure and reduce the overall cost of infrastructure projects.

Calculating key performance indicators depending on metering data will require additional information from the network. One important function developed during this work is the automatic detection of the existing District Metered Areas (DMAs). Indicators and water balance will then be calculated considering each DMA separately and also the water network as a whole. The identification of existing DMAs has been achieved by using a modified graph decomposition algorithm. Graph decomposition can basically help to identify trees in water networks and also the largest set of components (blocks) connected to the rest of the network by one single link (bridge) [5]. Nevertheless, the algorithm used considers not only the search of graph components but also the position of water meters and valves potentially positioned between two existing DMAs [6]. Figure 2 represents a simple network; on the left, the result of a plain graph decomposition algorithm is observed, while the identification of DMAs with our algorithm is given on the right.

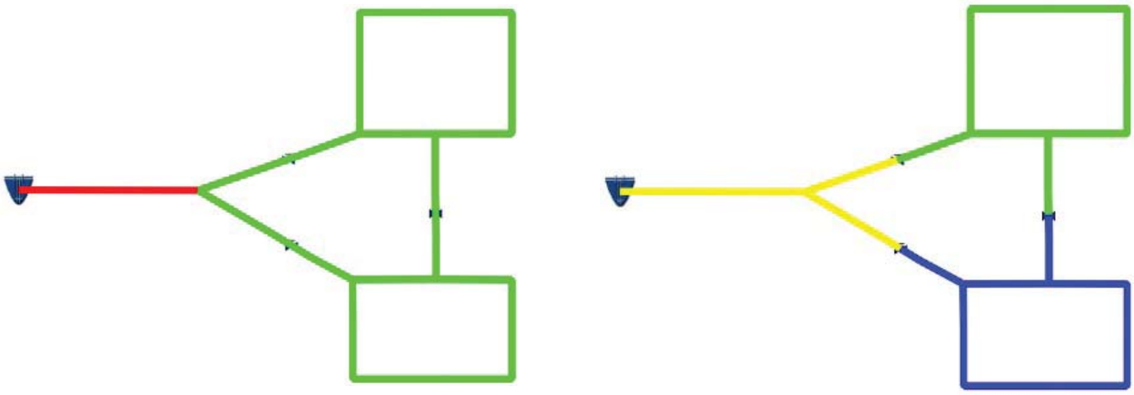

Figure 2. Network graph decomposition

Note that in the previous figure the plain graph decomposition algorithm is unable to identify as DMAs the loop at the top and the loop at the bottom. It is because no consideration is done regarding the presence of valves. In the case of the extended algorithm that is taking valves into account, the mentioned loops are identified in different DMAs. The results of running DMA identification can help on deciding where to put sector water meters. For each of the DMAs the software developed will calculate the water balance automatically. It is considered a basic first step to further analyze and improve the way networks are operating.

4. USE CASE

Despite the ideas resulting from this research are intended to help any utility, special efforts have been invested to make them also reachable to small utilities. Big water utilities have been investing in new technologies for automating the metering of consumption. Smaller utilities do not normally have enough resources for exploring new technologies. Precisely as a pilot utility it has been taken a small water distribution system with about 1550 connections and 83 km of pipes. The utility managing this network located in Xátiva, Valencia, is named Aguas Bixquert S.L. Annually it registers about 435.000 m³ delivered to the end consumers. Regarding measurements, the network currently has 3 pressure sensors and 3 flow sensors taking information every 20 minutes.

A solution for automatically reading water consumptions at costumer and district levels will help to make reliable water balances and as consequence it will help to improve the operation and management of the distribution network. Event detection algorithms can be used to recognize the occurrence of potential leaks. Additionally, these algorithms will help to gain in transparency with the consumption invoiced to customers. They can detect errors in measuring devices or potential leaks or abnormalities at the costumer side that make the consumption out of normal ranges.

Increasing the frequency of measurements is a great advantage for improving the management of the distribution system. However, the question is if such a technology can be successfully installed and used at an affordable price for small utilities. Manual measurement is not an option because it is prohibitive when the reading frequency is increase too much. Using wireless m-bus combined with walk-by reading is a better option but still relays on the personal taking measurements. It is possible to combine water meters with wireless m-bus senders and collectors; this will bring more automation to the reading processes but at a higher cost. Another alternative is the use of the internet of things technology. This way the cost of the antennas and communications will be lower than the cost of the other alternatives when measurements are taken at least once a week. Offers from different companies were received for assessing cost and running comparisons among alternatives.

5. CONCLUSIONS

The situation in many water utilities regarding measurements is not as good as desired/needed for improving the operation process substantially. Even for those companies with several sensors installed in the field and implementing a quasi-real time modelling strategy to monitor their network, there are many limitations regarding the estimation of the water demands used in models and decision algorithms. The amount of water used by customer is most of the time metered because the incomes of a water company depend on it. Nevertheless, these measurements are taken once or twice a year and cannot say much about the demand patterns in the network that are normally used for modelling water distribution system.

Going from monitoring to action in a water network implies quasi-real time knowledge of what should be happening in the network and a quasi-real time decision making process indicating the action to be taken next. Both the knowledge of what should be happening and the decision processes are normally based in a model of the system. This model in ancient time or in places without resources can be living in the years of experience of a very small group of operators. Modern systems normally use mathematical models running on computers for representing the reality of the network or at least an approximation good enough of it. A common limitation is the estimation of water demands at model nodes. Users make a stochastic use of water that certainly follows some pattern when they are grouped in numbers and in a time interval, but they are not easy to predict in real time for a reduced number of users. The software approach presented in this work is a good step on integrating meter readings directly into hydraulic models.

Moving to new metering technologies making it possible to increase the information regarding consumption includes several challenges. Despite it is a true advantage for utilities, it can also be a danger for the information privacy of connected clients. Treating information anonymously and increasing measurement transparence and enhanced customer services are key factors to succeed on the use of smarter metering solutions. It is time now to improve the way water is metered and to use the resulting information on improving network operation and providing a better service experience to the users.

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