SMART WATER GRIDS AND NETWORK VULNERABILITY

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ABSTRACT

Smart things have a broad appeal and Smart Water Grids are becoming increasingly popular. What is a Smart Water Grid and what is so innovative compared to traditional water metering? A review of the benefits of Smart Water Grids is presented in the context of water conservation and efficient management of scarce water resources. The pros and cons of a Smart Water Grid are discussed at face value in the context of aging infrastructure. Smart Water Grids cannot substitute for basic water infrastructure. Added benefits may also be available through incentives and stimulus legislation. Setbacks resulting from negative public opinion and a lack of community involvement are also possible.

The need for a clear understanding of the sources of water in terms of quantity and quality is also emphasized. The interface of Smart Water Grids with natural systems such as rivers, lakes, and reservoirs is also a key component of a smart approach to the use of water resources. These natural components are subjected to climate variability and single events can disrupt daily operations. Some anthropogenic activities as well as extreme climatic conditions can have devastating consequences. Robust systems may have alternative supply sources when facing scarcity of resources or changes in water quality/contamination. Deep understanding of the network vulnerability and preparedness for disaster prevention may also contribute to the “smart” reputation of water distribution systems.

WATER INFRASTRUCTURE EFFICIENCY

As the world population continues to grow, the demand for water and energy increases. According to UN-Water (2012), there is an increase of freshwater demand of 64 million cubic meters per year in addition to the irrigation demand. In addition to the increase in water demand, climate change adds more stress to the total water availability. The current water infrastructure of many countries is aging and continues to deteriorate. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) put together a World Water Assessment Program (WWAP), which contains multiple facts on their website. According to UNESCO (2009), some distribution systems have leakage rates of 50%. Some of the big challenges related to maintenance include awareness, problem location, and funding. Since water distribution networks are so vast, it is hard to know where the leaks are located. Finding leaks is very important. However, the pipes are buried under streets and sidewalks making them hard to access.

According to the USGS, water systems in the US experience 240,000 water main breaks annually, which results in 1.7 trillion gallons of water loss every year (Symmonds, 2012). Table 1 presents a water balance prepared by the American Water Works Association (AWWA). It shows that a lot of water is not accounted for by the utility companies, which means there is no revenue for that volume of water produced. Besides water losses, utility companies experience data losses associated with production, treatment, and distribution of water.

Table 1. Water Balance Table (AWWA, 2012)

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Un-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non Revenue Water</td></tr>
<tr><td>Unbilled Un-metered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="3">Apparent Losses (Commercial Losses)</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses (Physical Losses)</td><td>Leakage in Transmission and Distribution Mains</td></tr>
<tr><td>Storage Leaks and Overflow from Water Storage Tanks</td></tr>
<tr><td>Service Connections Leaks up to the Meter</td></tr>
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Revenue loss can also be associated with errors in the billings systems and with meter degradation over time. Some examples of billing systems errors are incorrect programming, meter size, consumer class, and ancillary attribution. Just like any infrastructure, however, meters degrade over time, whether it is a component failure, wear and tear, calibration shifts, corrosion, water quality, etc.

WHAT IS A SMART WATER GRID

A smart water grid is an innovative way to monitor water distribution networks. As sketched in Figure 1, it consists of a two-way real time network with field sensors, measurement and control devices that remotely and continuously monitor and diagnose problems in the water system. Smart water meters can monitor some key parameters such as flow, pressure, temperature, quality, consumption, and energy usage.

Some of the advantages of smart water grids are better understanding and analysis of the water networks, leak detection, water conservation, water quality monitoring, and a lower cost to the consumers. Implementing smart water grid technology will allow the utility companies to build a complete meter database. Having a detailed meter grid should help to pinpoint the locations of water leaks. The utility companies may discover missing and/or illegal connections. In addition, companies would know the quantity of water being used and lost in the system. The improved monitoring of the metering system and faster response to impending failures. Hinchman et al. (2012) further explain that utility companies would be able to receive this data from meters several times a day compared to several times a year. This pool of data will yield a better mass balance of the system, which will allow for a more detailed analysis and a better understanding of the water distribution network (Schlenger, 2013).

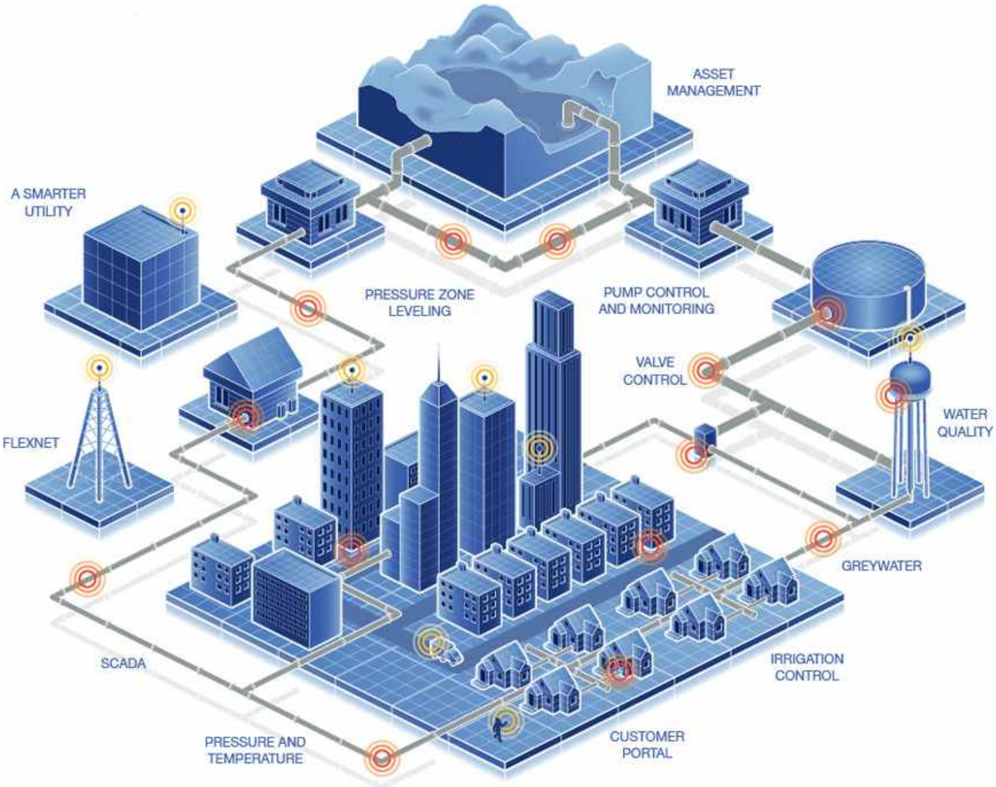

Figure 1. Smart Water Grid Diagram (from AquaSense, Sensus 2012)

COSTS AND INCENTIVES

Hinchman et al. (2012) discuss how smart grids can lower energy costs and conserve water. The energy costs for water utilities make up 60 to 70 percent of operating expenses. This energy goes towards treating and moving water. Knowing the quantity of water needed, and accounting for any losses, the utilities can produce less water. This will be reflected in lower energy costs as well as in water conservation.

Sufficient funding is needed to upgrade existing infrastructure and to implement smart water grid technology. The total cost of replacing aging water infrastructure in industrial countries may be as high as 200 million US dollars per year, as was estimated by the World Business Council for Sustainable Development (UNESCO, 2009). In addition, dams, dikes, waterways, and other water structures require maintenance. UNESCO (2009) lists sources of funding for water utilities. In industrial countries, the three main sources of funding are user tarifs, public expenditure, and external aid. In developing countries, the funding comes from taxation, service charges, and occasionally from donor assistance.

It would probably cost more than one trillion US dollars to bring US water supply and sewage infrastructure up to the state-of-the-art standards. The US Environmental Protection Agency (EPA) conducted a survey of the current drinking water infrastructure (Berst 2013). The survey showed the need for $384 billion dollars to improve the current drinking water infrastructure through 2030. The improvements are needed in distribution and transmission, treatment, storage, and source systems. In their survey, EPA does not mention upgrading old meters to smart meters. If the smart water grid technology is implemented, it may save money in the long run. If smart water grids are implemented, utility companies may have large annual savings of about 12 billion dollars (Sensus, 2013).

In sluggish economic times, funding for water infrastructure can be even more limited. Hinchman et al. (2012) discuss monetary incentives in the US and report that companies producing advanced water technology do not get any incentives from the federal government to enter and invest in this market. Symmonds (2012) also reported that the federal government does not provide a large enough economic stimulus for water infrastructure projects due to other competing demands. In reality, the federal government gave 3.4 billion US dollars through the Smart Grid Investment Grant Program (USDOE 2010). If smart water grid gains more popularity and insight, the federal government might provide similar funding or incentives for smart water grid companies. Some of the incentives can be provided in the form of grants and loans, and may eventually be part of a stimulus package on infrastructure.

AWARENESS, DISADVANTAGES and SETBACKS

There are several setbacks associated with implementing smart water grids. Besides the lack of funding and incentives provided by the federal government to implement this technology, the cost to update current infrastructure and implement this technology is fairly high. It is also important to consider that a smart water grid cannot replace the basic infrastructure. The infrastructure must be functioning very well in order to obtain full benefits of this smart water grid technology. This technology requires more research to maximize the capacity of the system.

The water "crisis" has been partly attributed to a crisis of governance (Hinchman et al. 2012, and UNESCO 2009). Water professionals, politicians, and the public are not well aware of the existing water crisis and new ways to manage water distribution systems. Both water professionals and politicians could learn more about the new technology and benefits of smart water grids. It would also be beneficial to educate the public on water distribution, availability, conservation, and technology available to make the system more efficient. Community involvement can be stimulated by providing citizens with more information regarding water conservation and smart water grids. Information can be provided on the internet and by mail. Community events can also inform citizens.

Another setback associated with the public is a potentially negative opinion towards this technology. This negative opinion can be traced back to a feeling of government's invasion and control. Some citizens might not want meters to be installed on their property to record their water usage. As much as the public needs to be open-minded and learn about the advantages and disadvantages of this technology. Manual reading of flow meters can cause problems with access of individuals on private property. Wireless transmission of data is usually safe, but may be subject to claims that the devices cause health problems and physical ailments that may be more psychological than real. Nevertheless, this can lead to fierce opposition and verbal advocacy at public presentations.

WATER QUALITY AND NETWORK VULNERABILITY

While smart water grids emphasize water quantity aspects, one important forgotten aspect of water distribution systems deals with water quality. The quality of the water can be impacted by changes in water quality and quantity at the sources, and also by possible accidental water plant releases of "below standard" water treatment batches. The water quality at the source is somewhat at the mercy of natural cycles in floods and droughts. Low flows and warm temperatures may favor algae growth, low dissolved oxygen, salinity problems, fish kill, odors, etc. Floods may on the other hand bring large concentrations of sediments, accidental industrial releases, etc.

Ideally, smart water grids may be well equipped with ways to purge water inside the network system that does not meet certain quality standards. These water losses can be better monitored and controlled with smart water grids than without.

In terms of water quality at the source, smart water grids should be prepared for the worst possible scenario of water quantity/quality at the source. For instance, the water quality of reservoirs is normally very stable and dependable. To blindly rely on this source of water could yield to consequences damaging the “smart” reputation of water grids. If the systems shuts down because of unexpected circumstances, the public opinion may turn against the proponents of smart systems.

As an example of this, it is possible to experience unusually high sediment concentrations during major storms and typhoons in South Korea. For instance, An (2012) studied the impact of typhoons on the distribution and propagation of interflows carrying large concentration of clay particles in Imha Dam. In the past decade, reservoir waters became heavily silted and highly turbid for several months after typhoons Maemi and Ewiniar. The high turbidity problems shown in Figure 2 lingered for several weeks and could be attributed to thermal stratification during the summer months and very large floods from typhoons.

Figure 2. Discharge of highly turbid water during Typhoon Ewiniar downstream of Soyang Reservoir in 2006 (from An 2012)

In the context of smart water grids, it is important to consider alternative sources of water during some potentially critical times of the year. Robust systems may have alternative supply sources when facing scarcity of resources or changes in water quality/contamination. For instance, semi-arid areas impacted by forest fires can see the water quality at the source deteriorate greatly for several years. It is important to develop strategic relationships in such cases. Perhaps the water sources can be exchanged with groundwater users for a certain period of time. Other users may not mind using water with a different water quality. After all, thorough understanding of the network vulnerability can lead to “smarter” distribution systems. The ability to prepare scenarios for disaster prevention may also positively contribute to the “smart” reputation of water distribution systems.

CASE STUDIES

Several projects worldwide have implemented this technology and have seen promising results. One of the projects was located in the Mediterranean island nation of Malta. Malta gets their energy from imported fossil fuels, which is used to provide water. The desalination plants provide more than half of Malta's water supply. IBM worked with Maltese national power and utilities to produce world's first national smart utility grid. This project involved replacing hundreds of thousands of analog electric meters with smarter meters, which could monitor electricity usage, water leaks and energy losses, set variable rates, and even rewards customers who would consume less power (Amrosio, et al., 2012).

Mumbai is India's largest city with a population of 13 million people. Itron meters were installed in the system that supplied tap water to half of the city's residents. By implementing these smart meters, there was a 50 percent decrease in water losses (Itron Inc, 2013). The city was able to identify leak locations as well as promote water conservation. This project exceeded the target's goals and provided a higher quality water network. Other case studies done by this company can be found on the Itron, Inc website.

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