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DEVELOPMENT OF A MICRO WATER GRID (MWG) PILOT PLATFORM FOR GREEN BUILDINGS

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The objectives of this Micro Water Grid (MWG) pilot platform project are to i) address the need for reliable municipal water supplies, ii) identify and strengthen vulnerable water system elements, and iii) design an optimal micro water grid pilot platform for *green buildings*. This paper describes the overall context of the MWG and considers appropriate analytical methods for water demand, hydraulic analysis and decision models for optimal MWG pilot platforms. This is an on-going research project and various MWG design scenarios, along with numerical results, will be presented as the research progresses.

INTRODUCTION

The U.S. National Academy of Engineering (2008) announced 14 major challenges that must be addressed in the 21st century, many of which are related to the sustainability of water resources. The Leadership in Energy and Environmental Design (LEED) program also encourages the sustainable use of water (UGBC 2006). How we use water resources will be key elements of many engineering approaches in the future. In most developed countries, centralized grid systems constitute the major water infrastructure. When these infrastructure elements were first installed, water resources were not expensive and nobody envisioned that these resources would become unsustainable.

There are growing concerns in many countries related to issues such as water scarcity, promoting water efficiency, improving water quality, reducing water related energy use, and renovating deteriorating water infrastructure. A Smart Water Grid (SWG) is a high-efficiency water management system that integrates information and communication technologies and can make a major contribution towards sustainable water resources management. It is designed to utilize various water sources including rainwater, reclaimed and desalinated water, and groundwater; as well as treat, distribute, manage, and supply water efficiently to balance water resources on a real-time basis using advanced sensor networks.

SWG technologies include smart water meters (AMI – Automatic Metering Infrastructure), sensors (for monitoring and managing parameters such as water pressure, temperature, quality, tank levels, consumption and related energy use), advanced modeling, GIS-based (Geographic Information System) water mapping, smart irrigation, automatic robots, leak detection, customer information systems, and asset management systems, all of which combine to create a data-driven platform for the intelligent management of water resources. The data collected also helps consumers and utilities make informed decisions; intelligent water information networks facilitate efforts to balance spatial and temporal water resources use by measuring real-time water demand and supply via a two-way water resources information network (Brzozowski, 2011).

It is expected that these will greatly improve our understanding of how the nation's water distribution systems operate on a real-time basis, which will be key for efforts to implement sustainable water resource management through IT applications. In this project, a *MWG (Micro Water Grid) is defined as 'SWG implemented at the individual building scale'*. Customers within a building will have access to their real-time basis total water use and thus be able to make informed decisions related to their water use. At the same time, central water operators will receive real-time water demand information that will make future forecasting more accurate. In areas experiencing serious water shortages that need to implement stringent water restrictions, operators will be able to transfer water between MWG enabled buildings.

The goals of this project are to design an optimal MWG pilot platform for use in green buildings. This will i) address the need for reliable municipal water supplies, ii) identify and strengthen vulnerable water system elements, and iii) enhance the use of various water resources including recycled water, harvested rainwater, groundwater, desalinated water and treated water. The specific objectives are to i) design a MWG systems layout within a building (i.e. a smart water grid embedded within the building's water distribution systems) as well as considering water transfer among MWGs, ii) analyze water demand and develop more accurate forecasting models, and iii) develop decision support systems to optimize the design of MWGs.

METHODS

Water Demand Analysis

Water conflicts and shortages arising from increasing population pressure, competing users, environmental concerns, and climate change impacts will all continue to put pressure on global water resources. Facing rising costs, urban areas around the world are taking significant steps towards setting water conservation goals. To analyze and forecast water demand in a proposed green building, we plan to collect data from existing buildings that are similar to the proposed MWG in scale. To achieve this, the following data will be required (Tanverakul and Lee, 2013):

- Daily (or monthly) water consumption data at the individual building level
- Weather data (average daily or monthly temperature, evapotranspiration, rainfall)
- Socio economic data (residents' median income, the median value of area properties)
- Lot size, age of building, total number of fixtures (e.g. bathrooms, kitchens, faucets, etc.), and average number of occupants

For this, multi-linear regression will be performed for the green building's water distribution systems to analyze the influence of explanatory variables spatially and seasonally over time. Multi-linear regression models can simultaneously estimate the impact of each individual explanatory variable on residential water demand, resulting in a valuable forecasting tool. Independent variables or predictors (X_i) can then be singled out to examine their precise impact on the dependent water demand variable (Y). Residential water demand is assumed to be a function of weather, conservation program interventions, housing values, income levels, household size, and lot size (Tanverakul and Lee, 2013). The data will be in the form of panel data, which focuses effects through time series and across different spaces. Regression parameters will be estimated utilizing techniques such as instrumental variables. With these, water demand will be modeled/forecast for the proposed green building.

Hydraulic Analysis of MWG

A water system with its myriad components, including pumps, valves and tanks, is highly susceptible to hydraulic transients that create a series of alternately high and low pressure waves passing through the water network. This type of transient flow phenomenon is introduced in pipe network systems by suddenly changing the flow (Lee et al, 2012). Just as a major water system is susceptible to hydraulic transients, water hammer within a green building's water distribution system can also induce transient pressure propagation. Water hammer is the term used to describe the destructive forces that manifest as pounding noises and vibration that develop in a piping system.

When water hammer occurs, a high intensity pressure wave travels back through the pipe system, gradually diminishing in intensity until all the energy has been dissipated. This very destructive force may result in a number of undesirable outcomes, including ruptured piping, leaking connections, weakened connections, pipe vibration and noise, damaged valves, damaged check valves, damaged water meters, damaged pressure regulators and gauges, damaged recording apparatus, loosened pipe hangers and supports, ruptured tanks and water heaters, and the premature failure of other equipment and devices (Lee et al, 2012). While it is known that hydraulic transients are common inside a high-rise building system, *the range of pressures experienced within the system requires further investigation.* In this section of the project, a numerical model that replicates the range of pressures typically encountered in green building systems will be designed and analyzed.

Application of AHP toward Optimal MWG Design

The objective of this section is to arrive at the best MWG design by considering various criteria: i) feasibility, ii) sustainability, iii) reliability, iv) the availability of water resources, v) life cycle costs (including water and energy costs) and vi) functionality. Given sufficient information about the attributes of each of these MWG design alternatives, experts can decide on the alternative that will provide the best performance for a particular building based on the preference tradeoffs among the various MWG design attributes. Preference elicitation tools can be applied to MWG design decisions to assess the experts' opinions and, more importantly, their valuation of different attributes.

The authors will adopt AHP (Analytic Hierarchy Process) to optimize the decision-making process. AHP is a multi-attribute preference elicitation method that allows for the examination of tradeoffs among attributes for a given level of utility. The procedure follows Lee et al (2009, 2013). The AHP determines the preference for an item via the pair-wise comparison of attributes. Assessing pair-wise preferences will enable decision maker or experts to focus their attention on a pair of elements with respect to a single property without the need to also take into account other properties or elements (Saaty, 1990). This model will therefore help optimize the design of MWG pilot platforms.

CONCLUSIONS

This paper has provided a detailed description of the goals and context of the MWG pilot platform project. Three methods have been covered: i) demand analysis/ forecasting within an individual green building, ii) hydraulic transient analysis for high-rise buildings and iii) the use of a decision support system for optimal MWG pilot platform design. This is an on-going research project and candidate designs will be presented, along with numerical results obtained as the research progresses.

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