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Review of Smart Home Energy Management Systems

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Abstract

Recently smart home energy management systems (SHEMS) have been developed very fast. The relevant techniques enable SHEMS to support network controlling via demand responses, maybe including peak shaving and load shifting, as well as some ancillary services. This paper reviews the concept of SHEMS and looks into its background. It highlights SHEMS' major components, and comparatively analyzes various technological approaches. It also discusses some of the concerns and challenges, and suggests a framework for future systems.

Keywords: SHEMS; smart grids; demand response; ICT.

1. Introduction

SHEMS has been in existence in the energy sector for several decades. The key functions of such systems are to monitor, control, and optimize the flow and use of energy [1]. In general, SHEMS has formidable applications in the generation, transmission and distribution systems of the electrical network. Significant among the applications include supervisory control and data acquisition with energy management system functionalities. SHEMS is important development of recent for residential customers. Demand response, demand side management, peak shaving and load shifting which are considered to offer solutions to the network operator have further boosted the drive for more robust and intelligent SHEMS [2].

This paper focuses on the evolution and trend of SHEMS. Organization of this paper is as follows. The second section details the components of SHEMS. The third section outlines energy management

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evolutions. Some leading state-of-the-art technologies of SHEMS are summarized in the fourth section. Finally, the future development of SHEMS are discussed and summarized.

2. Components of SHEMS

Technically, SHEMS consists of five parts.

The first part is measuring device. Measuring devices are vital to SHEMS. Most often, what can be measured can be controlled. Gas, water and electricity meters are the main measuring devices for households [3]. The advent of Advanced Metering Infrastructure [4] enables measurement of detailed, time-based information and frequent collection and transmittal of data to desired destinations.

The second part is sensing device. Household sensors that are relevant for SHEMS application is for detection of current, voltage, temperature, motion, light and occupancy [5]. Other sensors are specially designed for health, safety and security reasons such as smoke, and epilepsy sensors. They sense the desired parameters at different locations and send the signals to a centralized system. Using these parameters, smart appliances can be monitored [6], controlled or scheduled to operate at desired periods.

The third part is enabling ICT [7]. ICT is the linking pin connecting the sensor, meters and devices to the monitoring or control unit. Both wireless and wired communication technologies are developed for the integration of various domestic devices. Wi-Fi, networking, Home-Plug and Z-wave are some of the leading technologies facilitating home area networks [8]. In an overview of the leading communication standards for home area networks is presented with no distinct winner.

The fourth part is smart appliance. Smart appliances provide residential customers with insight into their energy use, the behaviour of enabling energy-efficient and eco-friendly. They are domestic appliances with integrated intelligence and communication systems which enable the devices to be monitored and controlled remotely. Washing machines, refrigerators and dishwashers are some of the domestic appliances that have been made smart [9]. If manufacturing and adoption of smart appliances become widespread, we may see residential consumers reduce demand on a large scale without being unduly inconvenienced.

The fifth part is energy management system. There is at the moment no fit-for-all solution as various developers focus on different aspects. Energy management principles, software platforms and embedded intelligence in SHEMS are different from each manufacturer. In general home energy management offers either of the following functionalities:

First, informative overview about the various graphic forms of energy usage data.

Second, advanced functions include information, automation and control either locally or from third parties.

Third, integrated systems with all the features of the advanced functions but also includes the possibility for forecasting and scheduling of loads and local generations at household levels.

Finally, automated operations provide customer selection to determine priorities and will of the home equipment and the local generation of the operation.

3. Evolutions of SHEMS

SHEMS is derived from energy management system (EMS). EMS also has age-long application in the residential sector. The use of workable night thermostat as a form of automated energy control dates back to the early 1900’s. However, energy management became a real concern especially with the multiple energy crises, increasing cost and with the idea of energy conservation in the 1970's. Honeywell developed a unique solar energy management system in the last 1970s based on microprocessor systems as a significant contribution to solving energy crisis. The technological evolutions in the 1980s further changed the energy management system, particularly with the advent of personal computers. Early developments of energy management system, from manufacturers such as General Electric, Hitachi, Siemens and Toshiba, were based on proprietary hardware and operating systems. Software system such as UNIX, LINUX [11] and Windows-based systems added many possibilities to the solutions of energy management system in the early 2000s.

Developing a functionally and customer-friendly energy management system at residential level requires a relatively different approach from the existing energy management system in the distribution and transmission networks. Recent developments in embedded systems technological have further enhanced energy management system functionalities. Many of the bulky, space-consuming solid state technologies have given way to more compact, small and efficient embedded or chip-based systems. Like any other energy management system, SHEMS has the end-goals as to conserve energy, reduce cost and improve comfort. Basically, SHEMS offers five key services defined in being monitoring, logging, control, management and alarms.

4. SHEMS in Different Regions

SHEMS is evolving in both complexity and capability, the rise in technologies of SHEMS is a clear indication of how much attention this sector has received. The implementation of low-power wireless sensors networks enhances the smart grid concept in homes enabling energy management systems capabilities, and so also are the uncertainties on customers' needs and how they are to be met [13]. SHEMS therefore balances energy efficiency and savings with comfort levels of the inhabitants through automated actions. Geographically, the level of development and drivers of SHEMS differ from region to region. The following is the main technical state of the region.

4.1 Asia and Africa

There is no well-defined direction for the implementation of SHEMS in Asia and Africa. Large disparities exist among the various countries. In general SHEMS is mostly deployed as an integrated system with local generations for standalone or emergency systems. In Japan, Toshiba is actively involved in the development of commercial systems to optimally control energy use in homes, buildings and factories [14]. Panasonic collaborate with government of Singapore for pilot project on SHEMS.

4.2 USA and Australia

The US leads in the deployment of SHEMS. It is mainly driven by concerns over the aging power infrastructure. Additionally, benefits from better demand or supply management and enabling of demand response applications furthers account for the quantum jump in SHEMS solutions. Australia and New Zealand [15] are far ahead of other regions of the world, especially Europe, in terms of large-scale smart meter deployment. SHEMS in these regions are mostly utility-led and also motivated by customer retention possibilities.

5. The Future of SHEMS

In this section, a framework for future SHEMS is briefly described. They indicate what should be taken into account in building sustainable SHEMS and how they interrelate. An integrated framework for developing future SHEMS, it takes into account the building itself such as the type of building, year it was built and the orientation. Also important are the kind of residence in that house such as elderly, large family, students or singles. Secondly, the connection of the SHEMS to the utility is very important for its integration and sustainability. It enables residential demand response applications. In the third place is the local installation at the customers' site. Are there smart meters, sensors and appliances and how are they integrated? Are there distribution generators at the customer site and how can that be coupled with the system? Fourth is the energy management principle to be implemented. The ICT, software platform and the algorithms must support different appliances and technologies from other vendors [16]. Regulatory, social-economic and environmental concerns which are often overlooked during the design stages are worth considering if the SHEMS solution will be sustainable. Finally, it is important to outline the key stakeholders in the SHEMS. This may differ from region to region and from country to country. At the heart of it all sits the customer, who makes the choice [17]. The unpredictable behaviour of residential is an important factor to be taken into account.

6. Conclusion

The short-term opportunity of implementing an energy management system is not with individual consumers. However, with the aggregation and integration of several consumers there is a high potential. Utilities and SHEMS manufacturers need to interface to integrate components and ensure smooth utility-household interaction [18]. Systematic top-down integration is recommended [19]. This means a move from centralized systems to micro grids or virtual power plants, to aggregation of buildings and finally to individual buildings. SHEMS is more than transferring of data [20], and also more than switching on and off devices. Overall goals for the implementation of SHEMS must be clearly defined and sub-defined for the various interest groups such as researchers, government, manufacturers, and consumers.

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