Chapter 13

Optimum Power Control of Household Appliances Using IoT in Smart Buildings

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ABSTRACT

This chapter presents a model that is developed to distribute the electrical power among the home appliances efficiently with a given capacity. This chapter works only on the consumer side demand management by designing admission control of the appliances. The authors have proposed an algorithm to schedule different appliances by considering three different cases. The simulation is carried out in MATLAB/Simulink. The results show that the appliances efficiently utilize the provided power by reducing the wastage in power consumption in all cases. Finally, consumers can control the operations of the appliances according to their requirements and the available capacity using IoT.

INTRODUCTION

Residential and commercial buildings consume the most electricity worldwide. It is about 60% of the global electricity according to the United Nations Environment Programme (UNEP, 2015). Hence, it is important to develop algorithm to reduce the power consumption in building sector in an efficient manner. It will also make the grid system more stable.

According to International Energy Outlook 2016 (IEO, 2016) Reference case, the energy consumption in buildings increases on an average of 1.5/year worldwide from 2012 to 2040. As the urbanization has increased, around 80% of people in the world have electricity access. For instance, the typical

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household power consumption is approximately 11,700 kWh each year in the U.S, where in France it is 6,400 kWh. In the UK and China, it is 4,600 kWh and 1,300 kWh, respectively. The global average was roughly 3,500 kWh in 2010 (Crystal, 2015). Countries of the population with less than 5% living below the poverty level have four times higher energy consumption. North America consumes 26% of the world's energy where Europe consumes 33%. According to the Lawrence Livermore National Laboratory (LLNL) (Fischer, 2013), the efficiency of energy usage is 39%, that means more than half of energy is wasted because of inefficiencies.

Bangladesh is a developing country, whose agriculture and industrial power consumptions was 45%, the residential consumption was around 47% of power usage in the past few decades (Masuduzzaman, 2012). However, this power is not utilized in a proper way for which a considerable amount of power is wasted in residential and commercial sectors. This wastage can be minimized by using Internet of Things (IoT) which utilizes the building consumption efficiently.

Peak power reduction is shown as an efficient way to manage energy consumption in smart buildings in different studies (Adika & Wang, 2014; Costanzo, Zhu, Anjos & Savard, 2012; Pipattanasomporn, Kuzlu & Rahman, 2012; Yao, Costanzo, Zhu & Wen, 2014). A significant research has been performed during the last decade for energy management in buildings. A mixed integer programming approach was proposed in Agnetis, Pascale, Detti and Vicino (2013) to schedule the household appliances. In Chavali, Yang and Nehorai (2013), a greedy approach was developed to find the optimal start time of the appliances to reduce the consumption. Another greedy approach was proposed in O'Brien and Rajagopal (2015) to reduce the peak consumption considering known and unknown load demands. Home appliances are scheduled in Setlhaoloa, Xia and Zhang (2014) by considering a nonlinear model to reduce the electricity costs by shifting the load consumptions. Two different scheduling algorithms are proposed in Sadid, Abobakr and Zhu (2017) to reduce the peak power consumption.

Reducing power consumption and improving the effective and efficient use of energy in building motivate the development of smart grid. Demand Side Management (DSM) is one of the fundamental concepts of smart grid. It is the *planning, implementation and monitoring of those electric utility activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility's load shape (Gellings, 1985)*. It helps the customer to reduce their electricity demand and allows shifting their load consumption pattern during peak period so that the grid is not overloaded by consumer demands. A layered architecture for DSM is proposed in Costanzo et al. (2012) consisting of three layers: Admission Controller (AC), Load Balancer (LB), Demand Response Manager (DRM). The AC is the bottom layer which interacts with the appliances and accepts or rejects their requests based on their priority and the available capacity. If the request is accepted, then the corresponding appliance starts its operation. The DRM is the upper layer which represents an interface with the grid. The LB is the middle layer which makes cooperation with the AC and the DRM using optimal load scheduling considering the capacity constraints.

Present work is motivated by the fact the operation of thermal appliances which will be controlled in a practical environment that optimizes the power consumption and ensures the comfort level of the temperature. Hence, it is required to build such a system which encapsulates the appliances functionality, ensures cooperation between them, provides easy maintenance and allows upgrading the system with the fast-moving world.

The main contribution of this research is two-fold: (i) an algorithm is adopted by considering the concept of progressive filling to efficiently distribute the power among the home appliances, specifically