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APPLICATIONS OF DEMAND SIDE MANAGEMENT STRATEGIES IN THE RESIDENTIAL SMART GRID

E.F. Bijl*, B. Asare-Bediako* and W.L. Kling*

*Eindhoven University of technology, Department of Electrical Engineering, Electrical Energy Systems,

P. O. Box 513, 5600 MB, Eindhoven, The Netherlands

E-mail: e.f.bijl@student.tue.nl; b.asare.bediako@tue.nl; w.l.kling@tue.nl

Abstract. The electricity grid in existing residential areas is aging, yet it must be able to cope with changing characteristics of generation and consumption to maintain a satisfying quality of service. Demand side management applications are expected to provide some solutions to the challenges. However, the success of demand side management strategies in the residential smart grid depends on how the opportunities and drivers of distribution network operators, consumers, manufacturers of smart appliances and energy retailers are addressed. This paper qualitatively analyses three DSM applications in the residential environment: Energy@Home, PowerMatcher and Mirabel. The Energy@Home project uses time of use prices to reduce peak loads. The one-way communication reduces privacy concerns but can't respond in real-time. The PowerMatcher technology is a multi-agent approach in which the devices participate in the energy market. This gives consumers incentive to operate devices on the most profitable moments. In the Mirabel project, devices trade flexibility in energy use and these flexibilities are scheduled centrally. This leads to low peak loads at the cost of high centralized control effort and raised privacy issues.

Keywords: Demand side management, demand response, distribution network, smart grid

INTRODUCTION

Electric power generation is evolving from centralized to decentralized operations and also from controllable and reliable sources to less controllable and intermittent sources based on renewables. About 30% of the electricity consumption in Europe in 2010 was residential and is growing steadily [1]. Higher peak loads reduce the lifetime of components of the power network and increase congestion risks, which increases both operational costs, and costs of necessary additional investments for capacity and reserves. Fundamental changes in the grid are imperative for a future sustainable power supply. The solution is to optimally control distributed flexible loads to match generation and alleviate network constraints. In this paper three applications of demand side management (DSM) in the residential smart grid are described and qualitative comparisons are made.

STAKEHOLDER ANALYSIS

Distribution network operators (DNO) have the responsibility to maintain the quality, reliability, safety and the efficiency of the local power network [2]. Peak loadings should be avoided and operational reserves must be sufficiently large. Energy retailers provide competitive tariffs to acquire and bind customers. Device manufacturers are driven mainly by market share, profit and sometimes sustainability. Customers (consumers as well as prosumers) are requested to alter their consumption in DSM programs. Aspects for encouraging participation are trust, privacy, comfort and energy awareness. Trust in the application, relieving privacy concerns, ensuring high quality are necessary requirements for accepting the application. Energy awareness increases the effectiveness.

DEMAND SIDE MANAGEMENT APPLICATIONS

Energy@Home

Energy@Home technology is an application in which time of use prices are used. The E@H technology has two main functions. Firstly, visualise the consumer's energy use on a smart appliance, computer or smart phone. Secondly, manage the appliances to operate at less expensive times of the day while still maintaining a proper execution of programs. Smart devices communicate services and expected load profiles and are controlled by a central unit in the homes. The network of devices consists of a HAN network using Zigbee and a LAN network using Wi-Fi [3].

PowerMatcher

The PowerMatcher technology is a distributed agent-based energy broker system. Device agents, concentrator agents and a single auctioneer agent are present in a PowerMatcher environment. The system could operate as a virtual power plant if an objective agent that combines business logic to the system is present. Devices participate in the market by formulating bids for consumption and production. The auctioneer sets the market equilibrium price. Concentrators combine bids and communicate the set-price to the device agents [4]. The flexibility of demand depends on how devices formulate bids.

Mirabel

The Mirabel project's concept uses flex-offers with certain energy consumption and potential time shifts to achieve stability and affordable energy prices. This results in a distributed, decentralised and scalable infrastructure. Flex-offers are generated by smart appliances and communicated to nodes. These flex-offers are aggregated to higher level nodes and scheduled using an evolutionary algorithm. A negotiation component sets the prices of flex-offers based on flexibility in time and energy. Production and consumption for stochastic devices such as PV-cells and wind turbines are predicted using forecasting models [5].

COMPARISON OF DEMAND SIDE MANAGEMENT APPLICATIONS

In table 1, an overview is given for the comparison of the three DSM applications. The PowerMatcher is effective and takes little computational effort as its communication only contains bids and prices. However, this can result into a large change of energy use within a time limit, which could result in a peak-load at later times. This peak is called the payback effect [6]. Energy@Home focusses more on the customers for energy awareness and relieving privacy concerns with user interfaces and one-way communication. However, it has also the risk of the payback effect due to time of use prices that are sent a day ahead [6]. Mirabel can prevent the payback period because of the assignment of flex-offers; it does however depend on whether sufficient flex-offers are accepted. The Mirabel solution takes more computational effort than the PowerMatcher and Energy@Home applications.

Table 1. Overview of challenges for stakeholders and the ability of each solution to participate in DSM

Stakeholder	Challenge	PowerMatcher	E@H	Mirabel
DNO	Peak loads	++	+	+++
	Protection	0	0	0
	Power quality	0	0	0
	Ancillary services	+	0	0
	Payback effect prevention	+	0	+++
	Control effort	+	0	+++
Retailers	Energy tariffs	Retailers become of no importance.	Retailers have to provide TOU prices	More business models possible
	Forecasting	Burdon to customers/ devices	Burdon to retailers	Burdon to all participants
Manufacturers	Standardizing	For all solutions similar amounts of standardizing is required.		
	Cost of smart appliances	Costs for smart appliances are slightly higher than regular for all solutions.		
	Computational effort	+++	+	++
Customers	Energy awareness	0	+++	+
	Privacy issues	++	0	+++
	Trust	Impossible to estimate trust at this stage.		
	Comfort	All solutions respect the comfort constraints before flexibility of loads.		

CONCLUSIONS

The Energy@Home, PowerMatcher and Mirabel applications are examples of demand response functions under development that can effectively reduce peak loads. However, two aspects are not covered in a satisfying manner in discussed implementations. First is preventing the payback effect without high centralized control effort and minimizing the impact on privacy. Secondly both the PowerMatcher and Mirabel solution did not put much effort in developing user interfaces. It is vital for the success of any solution to give feedback to the user to show the benefits and other feedbacks.

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