EVALUATING THE CUSTOMERS' BENEFITS OF HOURLY PRICING BASED ON DAY-AHEAD SPOT MARKET

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ABSTRACT

From October 2012, electricity customers in Sweden have the possibility to pay their electricity consumption based on the hourly spot prices on the day-ahead electricity market, Nordpool spot. Customers will know the electricity prices 12-36 hours in advance and will have the possibility to schedule their electricity usage in order to reduce their cost of electricity. This paper investigates the potential cost savings that could be achieved for different customers by adapting to the hourly pricing scheme. The savings could be attributed to different electrical appliances such as electric heaters, dishwashers and laundry machines. A case study on a number of selected residential customers has been carried out. The study results show that the economic incentives to reschedule loads based on the hourly tariff will be limited for customers without electric heating. Even for customers with electric heating, the economic incentives may be too small to adapt to this hourly tariff.

INTRODUCTION

As the share of intermittent renewable energy generation is increasing, the need for flexible electricity generation and/or flexible demand would increase to account for the intermittent nature of renewable energy. In the Nordic countries the flexible generation is mainly provided by hydro power. However, in most other countries, flexible electricity generation is provided by fossil based generation units but with the cost of reduced efficiency of the power plant [1]. To reduce the need for flexible generation, demand side management (DSM) can be used to increase the flexibility of the customers [1]. Most commonly used DSM programs are, e.g., real-time pricing (RTP), time-of-use tariffs, critical peak pricing and power tariffs [2]. The main benefits of most DSM techniques are to reduce peak demand in the system, to avoid extra investments in transmission and distribution systems as well as the peaking generation capacity [2].

RTP is a DSM technique that aims to reduce the peak demand by giving the customers incentives to reduce their demand when the overall demand is high or when there is a shortage of generation. The RTP reflects the actual situation in the power system and include both the demand and the available generation when setting the price of electricity. With a large share of renewable generation in the power system, the available generation may exceed the demand for certain periods (e.g., high wind condition), and thus part of the electricity generation must be curtailed if there is not enough flexible generation/demand. With a RTP scheme, the price of electricity would be low during these periods, thus, offering customers incentives to shift their consumption to these hours. This would reduce the need to curtail energy and would help the integration of renewables in the power system.

According to a reformulation in the Swedish electricity act [3], electricity customers in Sweden can chose to pay their electricity usage on an hourly basis, without having to pay anything extra for the hourly metering. This lead to development of new tariffs based on the hourly prices available on the day-ahead spot market. These tariffs can be seen as RTP tariffs and the idea is to create incentives for customers to become more active on the electricity market [3]. However, there is a risk that the peak power increases if a large share of the customers in an area schedules their loads [4-5]. This paper investigates the possible savings that could be obtained by different customers by changing the daily consumption pattern of their different electrical loads according to the hourly price signals from the market. The aim is to see whether the economic incentives of these new tariffs are large enough to enable customers to shift their consumption pattern.

The organization of the paper is as follows: Section 2 describes the proposed approach and presents the data used in the case study, Section 3 presents the main results from the optimization, and finally the conclusions are made in Section 4.

THE PROPOSED APPROACH AND CASE STUDY

The approach proposed in this study is presented in Figure 1. The first step is to gather all data needed. The second step is to compute the load profile for the reference scenario and then calculate the electricity cost for the reference scenario, i.e. without any load management. The final step is to reschedule the flexible loads to minimize the electrical cost for the customer. The optimization model is based on the work presented in [5] and is implemented in the optimization software GAMS, General Algebraic Modeling System [6] with the objective function being minimization of the electricity cost for the customers by scheduling their flexible loads.

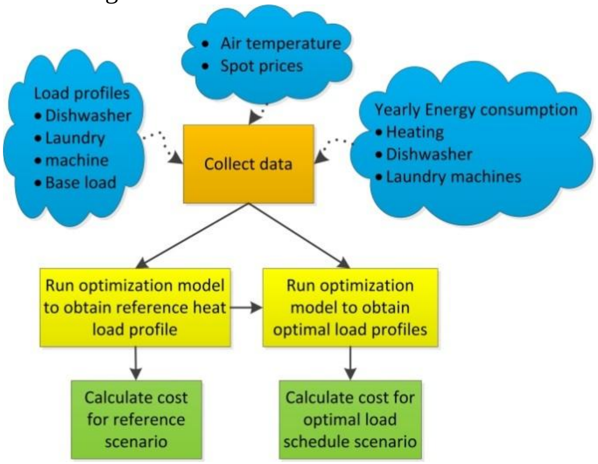

Figure 1 The proposed approach

The optimization model considers the thermal properties of the house as a lumped capacity model and is further described in [5]. In this study, the model has been extended and consider, in addition to heating of houses, other household loads, e.g. laundry machines and dishwashers, to be flexible. All other loads are assumed to be time critical and are collectively referred to as the base load. The results from the optimal load scheduling are compared with a reference scenario without any load management.

Energy usage and load profiles

In this study, three houses with different energy consumption are investigated. The data on energy consumption by the different loads, as shown in Figure 2, has been extracted from a study conducted by The Royal Swedish Academy of Engineering Sciences (IVA) [7] and a measurement project conducted by the Swedish Energy Agency [8].

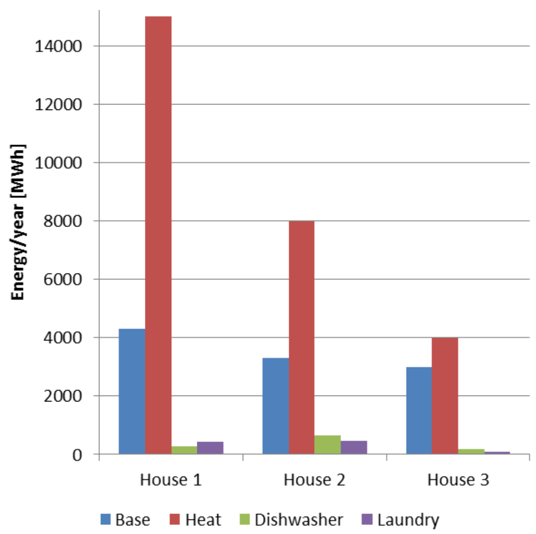

Figure 2 Energy usage for the period September 2005 – August 2006 for the studied houses

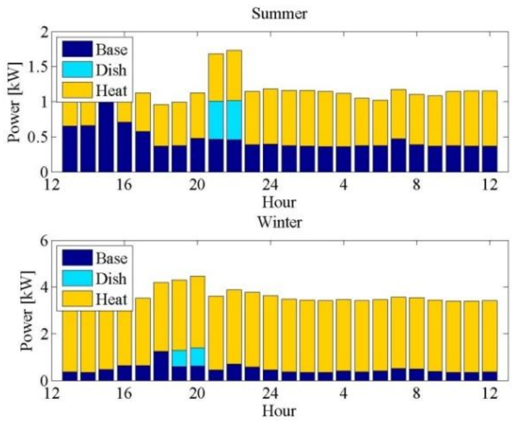

Figure 3 Load profile for "House 1" in the reference scenario

The load profiles for the dishwashers and laundry machines are extracted from the measurement project and are used to simulate the reference scenario, i.e. no load management. Although electrical heating loads have been measured within the measurement project [8] the measured load profiles have not been used in this study. The reason is due to unavailable information on the geographical location of the measured houses and the corresponding outdoor air temperature. Instead, the yearly energy consumption for three typical houses in Sweden and air temperature data for the city of Gothenburg has been used to estimate the load profile for the electrical heat loads during the simulated period.

Figure 3 presents the load profile for a 24-hours period during the summer and during the winter for "House 1" in the reference scenario. As shown in the figure, the energy consumption varies to a large extent between the seasons. The share of flexible load can be below 20% of the total load during a summer day and above 90% during a winter day.

In the optimal load scheduling scenario, the heat loads are limited by the temperature variations inside the house and a temperature deviation of ±1.5 ºC from 21 ºC is allowed. Additionally, the average energy consumption during one day must be equal to the energy consumption in the reference scenario. The installed heat capacity is limited to 10% higher than the peak demand in the reference scenario.

For the optimal load scheduling, the load profile for a complete program of the different machines and the annual energy consumption is assumed to be equal to the reference scenario, hence the number of runs is also equal. However, each machine conducts, at most, one run every day. Additionally, for the laundry/drying machines, only one machine can start during the night (between 22 and 07) and during the day (between 8 and 17). The reason for this constrain is that it is assumed that no one will move the clothes between the machines since most people are sleeping during the night and working during the day.

Spot price of electricity

Historically, the electricity usage in Sweden has either been paid based on the monthly average spot price at Nordpool or based on yearly price contracts. Since the electricity price is based on historical average prices, the customers are not aware of the electricity price at the time of delivery (i.e., when the consumption occurs). The customers, in this case, have had limited possibilities to affect their electricity cost in ways other than by reducing their consumption of electricity.

Today, most electricity retailers are offering the customers to buy their electricity at an hourly tariff based on the day-ahead spot market. In addition to the spot market price, the customers pay a provision to the electricity retailer, energy tax, green certificate, value added tax (VAT) and a network tariff. The actual numbers varies depending on the location of the customer and the retailer whom the customer has the contract with. The green certificates also varies during the year but has been assumed fixed in this study. In Table I, the numbers used in the case study are presented.

Table I Components in electricity cost

Tariff	Cost
Energy	Prevailing spot market price
Retailer provision	0.014 SEK/kWh*
Energy tax	0.29 SEK/kWh*
Green certificate	0.03 SEK/kWh*
VAT	25 %
Network tariff	0.14 SEK/kWh*

**1SEK = 0.12€ at 2012.01.14*

Historical spot market prices for electricity have been used for the time period simulated in the case study, to calculate the electricity cost for the customer, both for the reference scenario and for the optimal load scheduling scenario. Figure 4 presents the historical spot market price at Nordpool for September 2005 – August 2006 [9].

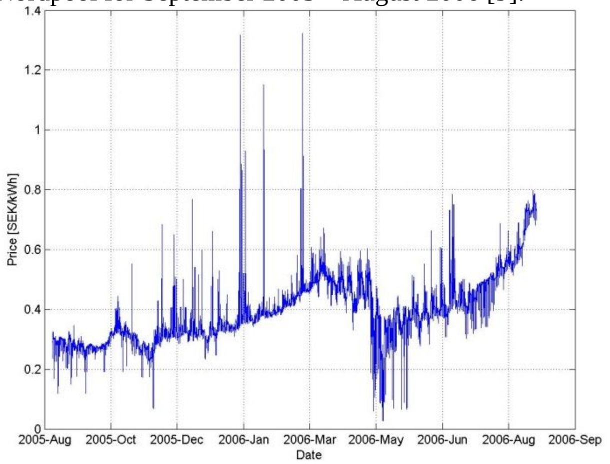

Figure 4 The Nordpool spot market price of electricity September 2005 – August 2006

If a large share of the customers would adapt to hourly tariffs and reschedule their loads, the spot price of electricity would change and likely become more evenly distributed. On the other hand, if the amount of intermittent renewable generation increases, the difference in the spot price within a day may instead increase due to the intermittent nature of the renewable sources. However, possible changes in the spot prices have not been considered in the present study.

RESULT AND DISCUSSION

This section presents the main results from the study.

Cost reduction

The cost reduction achieved by the optimal load scheduling is presented in Figure 5 as compared to the reference scenario. As can be seen in the figure, the major cost savings are achieved by shifting the electric heating loads. Compared to the reference scenario, the electricity cost could be reduced by about 1.7%, if all loads were to be shifted. For all houses, the savings achieved by scheduling the dishwashers or laundry machines were relatively small. For customers without electric heating, the rescheduling of the dishwashers and laundry machines would lead to a cost reduction of about 0.5-1.2% of the total electricity cost.

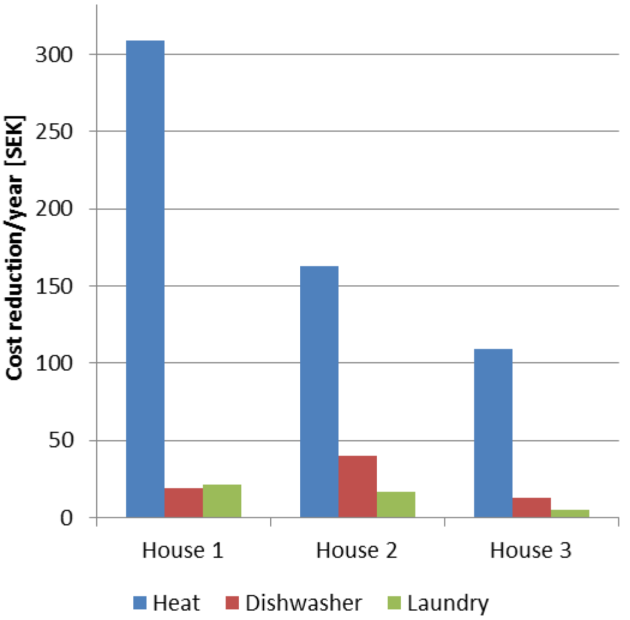

Figure 5 Cost reduction for the houses in the case study for the simulated period

Load profile

The load profile achieved by the optimal load scheduling is presented in Figure 6 for a 24-hours period during the summer and during the winter.

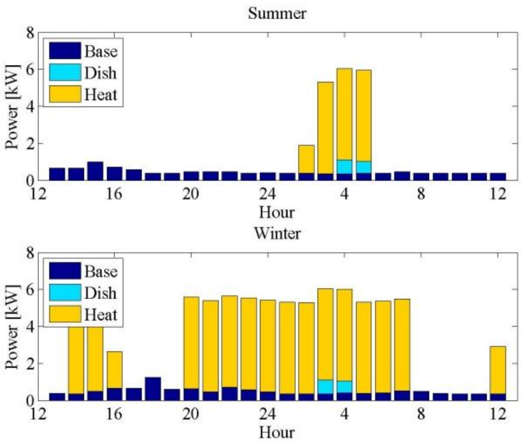

Figure 6 Load profile for the optimal load scheduling

As can be seen in the figure, the peak demand has increased both during the summer and during the winter, although it has been shifted in time. For all three houses in this study, the peak demand has increased substantially compared to the reference scenario, especially during the summer. The reason is due to the fact that the heating system is operating at its maximum power for a short period and that the dishwashers and laundry machines would start simultaneously.

Discussion

This study shows that, as the tariffs are designed today, with the customer knowing the price in advance, in combination with an energy-based network tariff, might result in an increased peak demand in the short-term. It is important to note that the changes in the load profile may lead to "feed-back" changes in the spot market price in a longer term, which in turn will lead to a change in the consumption pattern again before an equilibrium point is reached. Additionally, it is difficult to predict how an increased amount of renewable will affect the volatility of the electricity price.

The savings that could be gained in by shifting the electricity consumption seems rather low for the simulated period. One reason for that is that the installed capacity of the heat system was assumed to be small. A higher installed capacity would increase the saving but also increase the peak demand. With a high installed heat capacity, the peak demand could be limited by the main fuse in the building. Most houses in Sweden have a three-phase connection with a main fuse of, at least, 16A which will limit the peak power to about 11 kVA.

The thermal model is a simplified model of a house and does not consider the heat transfer between the walls and the indoor air. However, in Sweden it is common with hydroic systems where water is heated and circulated in radiators. Hence, the heating power is not heating the indoor air directly, and the fast increase in air temperature that could occur for other system, is avoided.

It is assumed that to increase the incentives for customers the hourly tariffs may be combined with some other tariff, such as power tariffs. Additionally, a power tariff would likely reduce the peak power demand.

CONCLUSIONS

The results from this study indicate that the savings that could be gained by customer (re)scheduling their laundry and dishwasher loads are rather small. It is assumed that the inconvenience this might cause the customer may be higher than what they are actually gaining in monetary terms to encourage the customers to participate. Customers that are using electricity for heating could gain somewhat larger reduction on their electricity bill by adopting the hourly spot price scheme, especially customers with a high heating power installed. Additionally, the results indicate that there is a risk that the electricity demand might increase during low price periods, which in turn could require reinforcements in the electrical distribution systems if the hourly tariff gets widely spread.

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