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ScienceDirect

Energy Procedia 116 (2017) 470–480

Energy Procedia

www.elsevier.com/locate/procedia

The 15th International Symposium on District Heating and Cooling

Heat source shifting in buildings supplied by district heating and exhaust air heat pump

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Abstract

The heat supply for Swedish multi-family residential buildings is becoming more complex, and today it is fairly common to combine district heating with a second heat source. The most common heat source to combine with district heating in Sweden is an exhaust air heat pump. On average, the exhaust air heat pump covers 31% of the yearly heat load and is given full load priority. There is a missed potential in cost and CO_2 savings when one heat source is given full load priority, since marginal production costs and CO_2 emissions constantly vary in both the electrical grid and the district heating system. The aim of this study is to evaluate how buildings with several heat sources should be operated using hourly energy prices. Hourly heat and electricity prices for Gothenburg have been established for two years based on the marginal costs of heat and electricity generation. These prices have been used to evaluate the most common combinations of heat sources. Results show that the most common combination with an exhaust air heat pump with full load priority does not lower costs compared to the reference case with only district heating. However, having a control system that allows heat source shifting and gives load priority to the heat source with the lowest cost each hour can greatly reduce the heating cost, and systems with larger heat pumps show even greater potential for heat source shifting.

Peer-review under responsibility of the Scientific Committee of The 15th International Symposium on District Heating and Cooling.

Keywords: Heat source shifting; Exhaust air heat pump; District heating; Hourly pricing

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1876-6102
Peer-review under responsibility of the Scientific Committee of The 15th International Symposium on District Heating and Cooling.
10.1016/j.egypro.2017.05.094

1. Introduction

The total energy usage in Sweden for the year 2012 was divided among buildings (38%), industry (36%), transportation (24%), and other (2%) [1]. This makes buildings the largest energy-using sector in Sweden, which is also true for the world as a whole. Energy in buildings is primarily used for heating, ventilation, and air-conditioning (HVAC) and secondarily for electrical appliances [2]. The main heat sources for HVAC purposes vary greatly between different countries. In Sweden, district heating (DH) has a market share of 60% [3], and every town with more than 10,000 inhabitants has a DH system [4].

The marginal cost of heat generation (the extra cost per MW associated with increasing the generation) can vary significantly within a single day, and a factor of 2–3 in cost difference is not uncommon in DH systems. All Swedish DH providers have an heat tariff where the price of heat is constant during all hours in one month [5]. Some companies have a tariff that is constant for the whole year, while some provide seasonal pricing. The most common pricing model for electricity in Sweden today is also to have fixed prices over one month or longer periods of time. Costumer prices are set by the electricity traders based on their estimates of the average price for electricity on NORDPOOL, the deregulated electricity spot market for northern Europe. How long the prices are fixed is up to the customer, but the longer the prices are fixed, the larger the risk is for the trader that charges a premium on top of its price for taking the risk. What is true for both DH systems and the electrical system is that having constant prices and large variations in generation costs can lead to suboptimal solutions, since the customer has no incentive to regard his or her heat usage from a system perspective.

Since the need for space heating in buildings can be fulfilled by either DH or electrical heating, primarily with a heat pump (HP), it is also of interest to consider optimizing the two together from a system perspective. Buildings with DH and HP today most often have fixed prices for heat and electricity and utilize the HP for base load and DH for peak load. This is a suboptimal solution, since the marginal production cost of the two systems varies during each day; hence, the system that is best for providing the base load also shifts.

Today it is possible for any customer of the Swedish electrical grid to receive a tariff with hourly prices based on the NORDPOOL day-ahead electricity spot market. This opportunity is seldom seized except by large industries and a few enthusiasts. Hourly prices make it possible for electricity customers to optimize their local systems within a larger system perspective. Load can be shifted to low-price hours to save money, and such actions help to balance the electrical grid. It has been shown in previous studies that shifting heat loads over time is possible by utilizing buildings for thermal energy storage [6-8]. Even greater possibilities can emerge if customers with DH and HP make the choice to switch to hourly electricity pricing and are also provided with hourly heat pricing. This makes it beneficial not only to shift heat loads over time but also to shift loads between DH and the electrical grid. It is these possibilities that are studied in this paper. Adding flexibility in heat sources on the consumer side might increase the interaction between the DH system and the electrical grid, enhancing the possibility of the two systems balancing each other. This can be very beneficial if there is no strong correlation between the marginal cost of heat and electrical generation.

The aim of this project is to study the effects of implementing a heat tariff with hourly pricing for buildings with both DH and HP for space heating. The correlation between NORDPOL day-ahead spot prices and the marginal costs of heat generation in Gothenburg is studied for the years 2013 and 2014. A case study is carried out for a building with both DH and HP and hourly energy prices for both. To decide what type of HP should be used in the case study, a survey of a national building database is carried out. The case study shows how economically beneficial it is to shift load between the two systems and whether they can supplement each other. It is assumed here that the customer pays heat and electricity prices based on the marginal production costs for each; hence, the economic benefit is allocated to the customer. However, the reduced cost for the customer should reflect the reduced cost of heat and electricity generation for the energy suppliers. It should be possible to implement the same control of the heating system with another business model without hourly prices.

DH systems can have very different mixes of heat sources. This study is limited to the DH system in Gothenburg, Sweden, which has a very wide mix of heat sources. A total of 28 heat sources can be grouped into these categories: