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Heat load patterns in district heating substations

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HIGHLIGHTS

- ▶ Heat load patterns vary with applied control strategy, season and customer category.
- ▶ Time clock operation of ventilation is the most important factor of daily variations.
- ▶ It is possible to identify outliers by only using two descriptive parameters.
- ▶ A resolution of 1 h in heat meter value analysis is enough.

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ABSTRACT

Future smart energy grids will require more information exchange between interfaces in the energy system. One interface where dearth of information exists is in district heating substations, being the interfaces between the distribution network and the customer building heating systems. Previously, manual meter readings were collected once or a few times a year. Today, automatic meter readings are available resulting in low cost hourly meter reading data. In a district heating system, errors and deviations in customer substations propagates through the network to the heat supply plants. In order to reduce future customer and heat supplier costs, a demand appears for smart functions identifying errors and deviations in the substations. Hereby, also a research demand appears for defining normal and abnormal heat load patterns in customer substations. The main purpose with this article is to perform an introductory analysis of several high resolution measurements in order to provide valuable information about substations for creating future applications in smart heat grids. One year of hourly heat meter readings from 141 substations in two district heating networks were analysed. The connected customer buildings were classified into five different customer categories and four typical heat load patterns were identified. Two descriptive parameters, annual relative daily variation and annual relative seasonal variation, were defined from each 1 year sequence for identifying normal and abnormal heat load patterns. The three major conclusions are associated both with the method used and the objects analysed. First, normal heat load patterns vary with applied control strategy, season, and customer category. Second, it is possible to identify obvious outliers compared to normal heat loads with the two descriptive parameters used in this initial analysis. Third, the developed method can probably be enhanced by redefining the customer categories by their indoor activities.

1. Introduction

Future smart energy grids will require more information about the energy flows in various interfaces in the energy system according to [1]. This information is not always available today for most interfaces. One interface where dearth of information exists is substations in district heating systems. These substations constitute the interface between the distribution network and the customer building heating systems. This existing dearth of information can be explained by the previous lack of measurements, since large amount of data required to perform these analysis have not, by reasonable cost, been possible to collect. Previously, manual meter readings were collected once or a few times a year. However, automatic meter reading systems are now being installed which makes hourly meter readings available at low cost.

The main purpose with this article is to perform an introductory analysis of high resolution measurements in order to provide valuable information about district heating substations for creating future applications in smart heat grids. This is a novel area of research with a very low availability of articles in international scientific energy journals.

In the past, efforts have been performed to optimise the operation of heat supply plants and district heating networks and

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to discover and eliminate corresponding errors and deviations. Heat load patterns from customer substations have often been taken for granted, both in design and in operation.

However, the heat load in a district heating system is the aggregated heat load from all customer substations connected to the network and the heat losses from the network. Errors and deviations in customer substations and internal heating systems in buildings will propagate through the district heating network to the heat supply plants. In order to reduce future customer and heat supplier costs, a demand has appeared for more intelligent functions identifying errors and deviations in customer substations and heat supply systems in connected buildings. Hereby, a research demand appears for defining normal and abnormal heat load patterns in customer substations.

The operation of the heating and ventilation systems in a building is shifting depending on the activity in the building. In schools, where no or few people are present during nights and at weekends, no or little ventilation is necessary at these times. During school holidays, the indoor temperature can be reduced. But multi-dwelling buildings need to be heated and ventilated 24 h a day, 7 days a week, all year round. Hence, the heat load pattern is different from building to building depending on what kind of activity that takes place in the building.

The best would of course be to make sure that the customers' facilities are working well, but with hundreds or thousands of customer substations, it has until now been economically impossible to monitor all customer substations. Today, with automatic meter reading systems installed in most district heating systems in Sweden, new opportunities arise to systematically identify errors in the heat supply or control settings at the customers. If an error in a customer substation can be identified and eliminated, it may of course lead to less heat being sold, but the risk is that if it is not eliminated, the company may lose the total heat sales to the customer depending on the fact that other heating alternatives can be more competitive.

Very few studies have been performed concerning horizontal analyses of the heat load pattern in a large number of substations. The reason is that before the large amount of data required to perform these analysis have not, by reasonable cost, been possible to collect. Automatic meter reading systems now installed makes hour meter readings available at low cost.

One work where heat load patterns have been analysed for 50 buildings is [2], where the main aim was to estimate heat load capacities for billing purposes. In order to increase energy efficiency in multi-dwelling buildings, heat loads has been monitored and evaluated in [3]. There are works about indoor comfort like [4] were thermal inertia in a building is evaluated, which indirect is about heat load patterns. Characteristic for [2–4] is that expensive specific equipment had to be installed in the substations in order to collect hourly measurements.

A method of error detection in district heating substations by using information from billing systems is presented in [5].

There are studies performed in order to optimise the substation, often with the goal to decrease the primary return temperature as in [6–9]. There is also a study to identify faults in substations where a method to identify temperature sensor fault is described [10]. In that study, there is also a method described for separating hot water use from space heating, which from a heat load pattern point of view is very interesting. By using multi-agent systems, where the substations and the heat plant can communicate with one another, a possibility to control each part of the system, including the substations, and optimise the whole system would be possible [11,12].

This introduction forms a background to answer three research questions in a field of research which in many ways is a white spot on the district heating knowledge map:

- How do heat load patterns vary in substations?
- Can heat load patterns be simplified to identify outliers by using heat meter readings?
- In what plausible directions can this early research on substation heat load be enhanced?

2. Method

Heat load patterns are not the same in all buildings. It depends on the building properties, but also of the type of activity that takes place in the buildings. To be able to evaluate if a heat load in a building is normal or not, it is necessary to know what heat load pattern is to be expected. From the customer records at two district heating systems, 141 buildings have been selected to be analysed. In the company customer records, seven customer categories are available of which five are used in this study. Two descriptive parameters and four heat load patterns are identified for each data set and plotted in diagrams presented in the results section.

2.1. Gathered data

The collected data sets are meter readings from 141 buildings connected to the district heating systems in Helsingborg and Ängelholm in the south-west of Sweden. In total, there are about 13,000 buildings connected to the two district heating systems from which about 10,000 are one- and two-dwelling buildings. The data sets are hourly measured 1-year series from 1st of January to 31st of December, i.e. 8760 values annually for each building. All data sets are from the year 2010.

The metering data sets come from databases in the automatic meter reading systems. In a few cases, single unreasonable 1-h-values appear in the data sets. They have been corrected by interpolation from the surrounding values. The unit of the values from the meter reading system is kWh/h. The values are often called heat powers, but it is actually delivered heat during 1 h. They could also be referred to as hourly average heat loads.

2.2. Customer categories

In the company customer records, the customer buildings are split into different types of customer categories depending on the activity in the buildings. The subdivision is made due to governmental demands to report statistical data that is collected each year. The national categories for customer categories in the national district heating statistics are: Manufacturing industries, one- and two-dwelling buildings, multi-dwelling buildings, ground heating, public administration, and others.

In this study one- and two-dwelling buildings and ground heating have been excluded. The reason for excluding one- and two-dwelling buildings is that they use less heat per building. It takes the same effort to eliminate a fault in a small building as in a large building, but there is probably less to gain. Ground heating deliveries differ from other usage of district heating since it is the heat in the return pipe that is used in the application and only less than 0.5% of the district heating deliveries in Sweden are supplied for ground heating purposes [13].

In the company customer records for the used heat meter data, the subdivision in different categories has in some cases a higher resolution.

The main part of the buildings in the group "Others" in the national statistics is in the company customer records sorted under the category Commercial buildings. Public administration from the national statistics is split into Public administration and Health and Social Services. In this study, the analysis is split into the following five different customer categories: