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Energy storage and integrated energy approach for district heating systems

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Abstract

This paper deals with the potential of using the thermal storage capacities within local district heating systems to balance the low and medium voltage grids by the use of heat pumps (HP) and combined heat and power (CHP) plants. The state-of-the-art of district heating systems as well as the coupling of the heat and power grid is discussed. The research work of the project NATAR (local heating grids with lowered temperature as provider of balancing power) and the local heating grid of Dollnstein, which serves as an use case, are further described. A first analysis of measured data of the district heating system indicates an optimisation potential regarding to the control strategy of the combined heat and power plant as well as the usage of the available thermal storage capacities.

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Keywords: district heating system, variable temperatures, low-exergy, heat pumps, coupled energy systems, balancing power

1. Introduction

District heating systems include three different parts: Heat production, distribution and consumption. The structure of the producers as well as of the consumers may be highly different. The temperature level of heat distribution varies depending on the requirements, e.g. low-temperature heat or steam. Local district heating systems are able to integrate renewable energies and combined heat and power to the heat supply of rural communities. This is particularly advantageous where refurbishment and installation of solar equipment is limited, e.g. due to the historic character of the buildings. In the southern part of Germany, many district heating systems utilize biomass for the generation of heat, either wood chips or biogas. A further dissemination of these systems is limited by two facts: On the one hand, the heat losses of the grid must be minimized in order to be economical. Therefore, the density of consumers per length of the grid must not fall below a certain limit. On the other hand, the local biomass potential is limited and long distance imports are neither ecologic nor economic [1,2]. In order to reduce the heat losses in an existing heating network, reducing the temperature and therefore the heat losses to ambient is a promising approach to optimise such a system. Low-exergy district heating grids are operated since 1990s. Under certain conditions, these belong to the

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most ecological and economical supply structures [3,4]. The structures of consumers contain typical buildings with modern energy-efficient building standards. Therefore, it is feasible to operate heating grids throughout the year on a basic temperature level. At consumer level, heat pumps (HPs) use that low-temperature level to provide the heat according to the consumers needs. The successful implementation of a central, high temperature heat pump has been demonstrated once [5]. However, this district heating grid does not have the opportunity to reduce the temperature in summer. New concepts are suggesting variable grid temperatures. This approach is quite promising, but still subject of ongoing scientific research projects. Reducing the heat losses and providing a basis for integrating low-temperature heat sources are the main reasons to install local district heating systems with variable temperature levels.

2. Background

Due to the turnaround in the energy policy, the grid has to integrate more and more decentralized and fluctuating power producers as photovoltaics or wind power plants. This leads to higher stress within the power grid. Storage devices are therefore needed to reduce the phases of high stress within the power grid. Beside of, storing electrical energy, the store of sensible or latent heat is an alternative. Local district heating systems have large storage capacities, due to the grid itself and installed storages. If both, coupled electrical producer and coupled electrical consumer exist within the system, there is the potential of multiple coupling between the heat and power grids. The capacity of the heating system may be used to balance the electric demand and supply [6]. Heat pumps, which use electric power to produce heat, may provide negative balancing energy and use them more efficient as electrical heaters. Combined heat and power (CHP) plants can provide heat and positive balancing energy. Both opportunities depend on the installed storage capacities and the status of the system. The integrated operation mode of multiple producers of heat and power leads to a high system complexity. To achieve reliable, efficient and effective control strategies, prior investigation and optimisation is necessary.

There have been some investigations and projects about CHP plants providing positive balancing energy within local district heating systems integrating heat storages [7,8]. The TU Dresden investigated the integration of both, heat pumps and CHP units, using a fictive district heating grid. Mainly the project included computational calculations to optimise the operation modes of the CHP units and of the heat pumps within the district heating system. The research proved that the three actions,

- increasing the temperature of the buildings,
- storing the heat inside the heat grid
- and controlled charging of the water storage,

could relief the power grid. The project results also included that the common operation of CHP plants and heat pumps is a promising economical approach [9]. These theoretical calculations have to be verified by real measurements.

3. Case study: Installation Dollnstein

Dollnstein is a small village in southern Germany. In 2015 the local heating system with approximately 40 connected consumers has been completed. Dollnstein has implemented one of the first local district heating systems with variable temperatures. Three main hydraulic circuits (School, Thorgasse (TG), Papst-Viktor-Str. (PV)) connect private consumers as well as public buildings with the energy central. Since the supply area in Dollnstein has a diverse structure, including historical buildings, there is a large heat demand on a high temperature level, at least in winter. It is economical not reasonable using power from the grid by the decentralised heat pumps to meet the high heat demand in winter. Nevertheless, to improve the technical efficiency and economic viability, lowering the temperature of the grid during the summer is an attractive opportunity. Figure 1 displays the installed hydraulic system. On the right side, the three circuits connecting the consumers with the energy central are shown. Each consumers heat transfer station contains a heat pump and a heat storage. The energy central contains all other heat producers and storages. The high-temperature storage (HT storage) feeds the heat grid. High temperature storage means within this paper the storage with the higher temperature level up to 80 °C. The solar thermal system, the heat pump, the CHP unit