Christoph Meier, Carsten Wemhöner, IET - Institute of Energy Technology,
OST – Eastern Switzerland University of Applied Sciences

P&D Renosource – Multi-source heat pump system for the heat generator replacement with ground probes for peak load coverage

Abstract

The project investigates a boiler replacement in two multi-family dwellings, where the oil boilers are replaced by indoor installed propane heat pumps with the two heat sources air and a peak load coverage by borehole heat exchangers. By designing the ground source for peak coverage, existing space and drilling depth constraints are overcome and the heat pump is operated without fossil fuel peak coverage. This is also supported by the high possible flow temperatures of 70 °C of the propane heat pumps. The monitoring of the heat pumps over three heating periods therefore serves not only for operational evaluation and optimization, but also for the verification of simulation models, which are used to develop advanced design and planning recommendations for these multi-source systems. Furthermore, an evaluation of indoor propane heat pumps with regard to efficiency and economy will be performed. The goal is to document a best practice system for multi-source applications and indoor installed propane heat pumps.

Zusammenfassung

Das Projekt untersucht einen Wärmeerzeugerersatz in zwei Mehrfamilienhäusern, bei dem die Ölkessel durch zwei innenaufgestellten Propan-Wärmepumpen ersetzt werden, und die als Wärmequellen Luft und eine Spitzenlastdeckung über Erdwärmesonden nutzen. Durch die Auslegung der Erdreichquelle auf Spitzendeckung werden bestehende Platz- und Bohrtiefeneinschränkungen überwunden und die Wärmepumpe wird ohne fossile Spitzendeckung betrieben. Dies wird auch durch die hohen möglichen Vorlauftemperaturen der Propan-Wärmepumpe von 70 °C unterstützt. Das Monitoring der Wärmepumpen über drei Heizperioden dient daher neben der Betriebsauswertung und –optimierung auch zur Verifizierung von Simulationsmodellen, mit denen erweiterte Auslegungs- und Planungsempfehlung für Mehrquellensysteme entwickelt werden. Weiterhin wird eine Bewertung der innenaufgestellten Propan-Wärmepumpen in Hinblick auf die Effizienz und Wirtschaftlichkeit vorgenommen. Ziel ist die Dokumentation eines Best Practice Systems für den Mehrquelleneinsatz und den Wärmeerzeugerersatz mit innenaufgestellte Propan-Wärmepumpen.

Motivation

When replacing boilers with heat pumps, there may be restrictions on heat sources, which can limit or prevent the use of heat pumps, especially with higher capacities in larger existing buildings. The restrictions can be mitigated or completely avoided by using multiple sources, thus enabling the monovalent use of heat pumps.

Results of the SFOE-Project HP-Source

In the SFOE project HP-Source [1], two strategies for multi-source integration for the most frequently used heat sources in Switzerland, air and ground probes, were investigated using simulations.
On the one hand, peak load coverage with ground probes and air as base load was evaluated. Both sources can thus be designed for a reduced source capacity, whereby restrictions can be minimized for both the air and the ground probe source. For the design of the ground probes, it was also determined that the size of the ground probes decreases disproportionately, as shown in Figure 1. With a design for 50% heating capacity, for instance, the ground probe field can be reduced to 20% of its size. The reduction is higher for compact ground probe fields, which reduces the space required, especially in difficult spatial conditions.

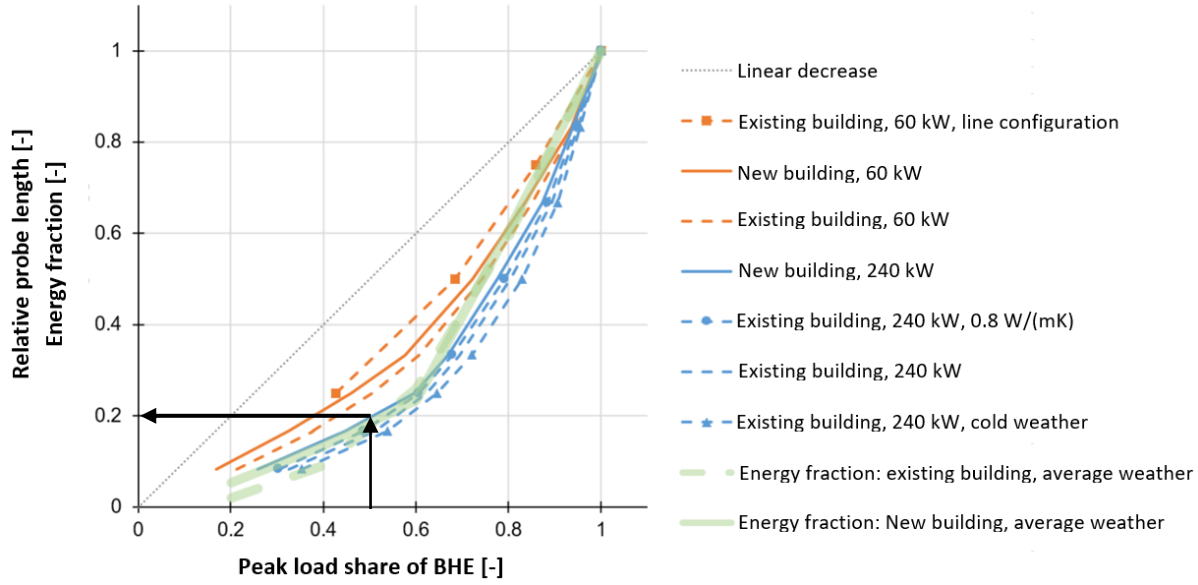

Figure 1: Parameter variations for the Strategy "Peak load coverage" [1]

The second strategy considered was the regeneration of a primary ground source with the secondary regeneration source of air or solar collectors, which can also cover the domestic hot water demand in summer operation. Regeneration can thereby save space by a possible closer probe distance and higher heat extraction. The multi-source setting can also increase the efficiency, too, by using the best temperature levels. A cost-optimized degree of regeneration was evaluated between 60%-80%.
For larger capacities, the two strategies “peak load coverage” and “regeneration” can also be combined.

P&D Project Renosource

Background

The building company “Lägern Wohnen” owns two apartment buildings in Baden, each with 28 apartments and a total of 4,190 m^2 of living space. Most of the apartment buildings in Figure 2, built in 1972, are mainly in their original condition and were only slightly renovated in the 1990s. The joint heat generation using oil-fired boilers with a total capacity of 200 kW is installed as central heating system in the basement of one of the apartment buildings. The other apartment building uses a pipe connection to the heating central. The analyzed heating oil consumption over the last 14 years resulted in an average annual consumption of 60,000 l heating oil or 600 MWh/yr.

One heat pump per building with a shared ground probe field has been planned to replace the fuel boilers. Due to space restrictions for the ground probes to the parking lot between the buildings due to the steep surroundings, see Figure 2 on the right, additional regeneration using an air heat exchanger was planned.

Figure 2: Investigated multi-family houses in the P&D project Renosource (source left: Lägern Wohnen. source right, Google Earth)

However, the drilling of the first two boreholes at the planned depth of 300 m had to be stopped at a depth of 130 m due to artesian water. Therefore, in addition to the space limitations, the cantonal authorities restricted the drilling depths to 130 m. The project was therefore subject to precisely the same restrictions that were investigated in the HP Source project using simulations. A peak load operation of the ground probes with the base load source of outside air was therefore selected as the new concept. The outside air heat exchanger was enlarged and simulations showed that the length of the probes could be reduced to 16 probes of 105 m each if only the peak load is covered by the probes. On the other hand, the increase in the size of the air heat exchanger can be limited due to the source combination. The air heat exchanger also serves to regenerate the ground in summer. The sources are integrated by an intermediate brine cycle, which has the advantage that both sources are available for both heat pumps, so that there is no limitation of the two sources due to the heat pump capacity.

Two indoor brine-to-water heat pumps with the natural refrigerant propane were used as heat pumps. This has advantages for the existing buildings, as flow temperatures of up to 70 °C can be reached.

Objectives of the P&D Project

The P&D project combines the two investigated concepts of "peak load coverage" and "regeneration" and thus offers ideal conditions for verifying the simulation results of the "HP-Source" project [1] with real measurements. Operating experience can be gained with the real plant operation of the multi-source system as well as design and control strategies for operation can be derived and tested. The project objectives therefore include the following points in detail:

- Verification of the concept of the peak load probe over the complete project phases "planning - commissioning - monitoring – optimization"
- Review of the planning principles and hydraulic integration
- Evaluation of 3 years of operation (optionally also longer measurements of the multi-source system)
- Model validation with operating data and system optimization
- Optimization of source management (e.g. by means of setpoint shifting: dynamic balance point, combination with summer regeneration, etc.)
- System comparison abstracted from the real boundary conditions in order to verify whether multi-source systems can also offer advantages without space or depth restrictions
- Evaluation of the operating behaviour of large-capacity propane heat pumps installed in-doors

Measurement concept

The measurement concept includes heat meters for the individual heat sources of the ground probes and the air as well as for the heat emission side and electricity meters for the heat pump and the auxiliaries. In addition, the operating states such as the compressor speed and pump status as well as the valve positions are recorded. The measured variables can be used to evaluate the seasonal performance factors, the source shares, the defrosting operation of the air heat exchanger and the degree of regeneration for the ground probes, and respective optimizations can be made.

Project state and perspectives

The project was planned in combination with simulations in the first half of 2023. The Ground probes were drilled in fall 2023 and commissioning took place in the first quarter of 2024. The measurement data of the first winter period is currently being recorded and evaluated.

References

[1] C. Wemhoener, Ch. Meier, S. Buesser, M. Baetschmann, HP Source – Integrationsmöglichkeiten von Wärmequellen, Final report SFOE, Rapperswil, Nov. 2023 (in German)