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Energy and Efficiency Analysis of Heat Pump Systems in Non-residential Buildings by means of Long-Term Measurements

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This paper presents a cross-comparison of 17 ground-coupled heat pump systems installed in different non-residential buildings. Based on high-quality measurement data collected with high temporal resolution over several years of operation, this study includes energetic and economic analyses, presents typical weak points of heat pump-based systems and develops requirements for their installation and operation. The heat pumps have thermal powers ranging from 20 to 300 kW_{therm}, eight of them are reversible. They are integrated into various hydraulic concepts including different ways of direct cooling and waste heat recovery.

Sophisticated monitoring-systems have been recording detailed performance data of the heat pump systems of each building: system temperatures, volume flows, supplied heating and cooling energy, electrical consumption of the heat pump, auxiliary energy demand of the pumps, operating times and operation modes of the heat pumps have been monitored with a typical time resolution of 60 seconds.

From this dataset, the energetic performances, the control and operation algorithms and the usage of thermal storages were thoroughly analyzed and evaluated; whereby weak points were detected and optimization measures are indicated. Furthermore, the electrical load profiles of the heat pump systems are put in relation to the load profiles of the public grid. As the monitoring systems have already recorded data over several years of operation, various effects occurring during real operation, - including user intervention and system malfunctions - are reflected in the dataset. This results in a realistic range of seasonal and annual performance factors and allows conclusions on the most sensible factors for an efficient working system.

The heat pump systems of the analyzed buildings reach seasonal performance factors (heat pump with compressor and primary pump) between 3 and 5.6 kWh_{therm}/kWh_{el} in heating mode, 4.8 to 5.8 kWh_{therm}/kWh_{el} in active cooling mode and 12 to 16 kWh_{therm}/kWh_{el} when using direct cooling. Crucial design factors are the auxiliary energy demand of the primary pump as well as the supply temperature for the distribution systems. Good efficiencies can be reached when using heat pumps systems which include direct cooling, waste-heat-recovery and distribution systems which permit supply temperatures near room temperature (16 to 20 °C in cooling mode, 28 to 33 °C in heating mode). Only if each single component is dimensioned correctly and only if they are well matched together into one coherent HVAC system with well-developed control strategies, is it possible to truly benefit from the high efficiencies that are possible when using environmental energy. Moreover, if the storage tanks have a sufficient size and/or the distribution systems provide thermal storage, a heat pump system can easily react to the current demands and fluctuations of the public electricity system and thus become an important part of the Smart Grid of the future.