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Techno-Economic Assessment of Distributed Heat Pumps Integration within a Swedish Neighborhood: A Cosimulation Approach

Authors : Monica Arnaudo, Monika Topel, Bjorn Laumert

Abstract : Within the Swedish context, the current trend of relatively low electricity prices promotes the electrification of the energy infrastructure. The residential heating sector takes part in this transition by proposing a switch from a centralized district heating system towards a distributed heat pumps-based setting. When it comes to urban environments, two issues arise. The first, seen from an electricity-sector perspective, is related to the fact that existing networks are limited with regards to their installed capacities. Additional electric loads, such as heat pumps, can cause severe overloads on crucial network elements. The second, seen from a heating-sector perspective, has to do with the fact that the indoor comfort conditions can become difficult to handle when the operation of the heat pumps is limited by a risk of overloading on the distribution grid. Furthermore, the uncertainty of the electricity market prices in the future introduces an additional variable. This study aims at assessing the extent to which distributed heat pumps can penetrate an existing heat energy network while respecting the technical limitations of the electricity grid and the thermal comfort levels in the buildings. In order to account for the multi-disciplinary nature of this research question, a cosimulation modeling approach was adopted. In this way, each energy technology is modeled in its customized simulation environment. As part of the cosimulation methodology: a steady-state power flow analysis in pandapower was used for modeling the electrical distribution grid, a thermal balance model of a reference building was implemented in EnergyPlus to account for space heating and a fluid-cycle model of a heat pump was implemented in JModelica to account for the actual heating technology. With the models set in place, different scenarios based on forecasted electricity market prices were developed both for present and future conditions of Hammarby Sjöstad, a neighborhood located in the south-east of Stockholm (Sweden). For each scenario, the technical and the comfort conditions were assessed. Additionally, the average cost of heat generation was estimated in terms of levelized cost of heat. This indicator enables a techno-economic comparison study among the different scenarios. In order to evaluate the levelized cost of heat, a yearly performance simulation of the energy infrastructure was implemented. The scenarios related to the current electricity prices show that distributed heat pumps can replace the district heating system by covering up to 30% of the heating demand. By lowering of 2°C, the minimum accepted indoor temperature of the apartments, this level of penetration can increase up to 40%. Within the future scenarios, if the electricity prices will increase, as most likely expected within the next decade, the penetration of distributed heat pumps can be limited to 15%. In terms of levelized cost of heat, a residential heat pump technology becomes competitive only within a scenario of decreasing electricity prices. In this case, a district heating system is characterized by an average cost of heat generation 7% higher compared to a distributed heat pumps option.

Keywords : cosimulation, distributed heat pumps, district heating, electrical distribution grid, integrated energy systems
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