To the Media

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Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

Location: Meitnerstr. 1,
70563 Stuttgart
Germany

Algorithms for More Efficient, Grid-Friendly Heat Pumps

New method reduces peak loads in power distribution networks

Heat pumps, with their ability to provide ecofriendly heating and hot water, are crucial to the transition to climate-neutral buildings. However, these sustainable heating systems could overburden electric power distribution networks as their numbers rise. The Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) in Germany recently developed algorithms to reduce peak loads. Its researchers tested their new method in Sweden, where heat pumps see widespread use and winters are particularly frosty. The algorithms proved their merits: They help run heat pumps in an efficient, grid-friendly way that trims the load on the distribution network's transformers by ten percent.

The share of heat pumps in the German heating mix is expected to rise sharply in the years ahead. Without adjustments to accommodate these pumps, they could overburden low-voltage distribution networks in residential areas. The problem is that when it gets cold outdoors, heat pumps have to deliver a great deal of heat at the same time, especially in the morning and at night. Demand for electricity in the distribution network spikes at these times. Peak loads in the networks and transformers that convert the upstream medium-voltage grid's voltage to the distribution network's voltage then surge – perhaps even high enough to cause overloads.

This new method is one of many that the ZSW has developed for grid operators, manufacturers and users. The idea is to operate heat pumps, e-charging stations and other devices that consume a lot of power in legacy grids in an intelligent way that does not appreciably inhibit their performance.

Heat pumps – not necessarily a burden on distribution networks

To this end, ZSW researchers developed algorithms to reduce concurrent operation of heat pump loads in a given grid area. "The challenge is to keep everyone's house warm in the early morning and evening hours without all heat pumps starting up at once – even on days when the outdoor temperature drops to minus ten degrees Celsius. "We developed a predictive method of operating heat pumps that draws on heat demand forecasts to accomplish this," says the ZSW's Dr. Jann Binder.

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When the forecast predicts a rising grid load, the heat pump switches on earlier and runs longer, but with lower output. The house, with its capacity to retain heat, serves as a storage medium to lighten the load on the grid. Researchers apply this method judiciously to keep heat loss in check and the temperature close to the set point.

The researchers had two options, one being a centralized approach with a hub that uses virtual energy prices to incentivize household heat pumps to operate in a distributed way. The other option is a decentralized approach with no connections to a central hub. In this case, heat pumps respond only to locally detected temperature fluctuations and grid voltage reductions. The centralized approach lightens the grid load by the targeted ten percent. It also requires three percent less added heating energy than the decentralized approach because it provides a more precise way of precluding the need for preheating and concurrent heat pump operation. However, it does require a lot of calculation to determine the individual schedules and more communication among all heat pumps and the hub.

Ten percent lower peak loads for transformers

The indoor temperature range did not change much – only from 20 to 22 degrees to 19.2 to 22.2 degrees Celsius – as a result of the ten percent peak-time reduction in transformer loads achieved by the simpler decentralized approach. Adding in a forecast for the outdoor temperature trend raises the lowest temperature to 19.4 degrees. The lowest indoor temperature drops to 17 degrees when the same reduction in transformer load is accomplished with a linear reduction in the heat pump's output. In other words, the temperature drops by as much as 3 degrees rather than merely by 0.6 degrees.

The ZSW was determined to keep it simple when it developed the decentralized approach. "This algorithm does not need an outside communication link to remotely control heat pumps," says Binder. "Information is sourced from the locally metered grid voltage." The voltage dropping below a certain threshold indicates the grid load is too high. The algorithm then kicks in to modulate the heat pump's output. This decentralized algorithm can exploit a house's capacity to store heat precisely and specifically to the extent necessary – without the complicated bidirectional communication needed for central heat pump management. The temperature does not drop nearly as much as it would if a central hub switches the heat pumps off in the event of a bottleneck.

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Field tests in Sweden

Sweden provides excellent conditions for studying heat pumps' impact on the power grid's load and for trying out grid-friendly ways of operating these pumps. This Scandinavian country levies a high carbon tax, so heat pumps have been adopted on a wide scale.

ZSW researchers chose Ramsjö, a village near Stockholm, for trial runs. With houses heated mainly by heat pumps and cold winter days that place a very heavy load on transformers, it provided the perfect proving grounds.

Why heat pumps are so climate-friendly

Heat pumps are trending. Around 53 percent of new buildings erected in Germany last year were equipped with this technology. The share is lower for retrofits in legacy buildings, but the figure is sure to rise sharply as these pumps replace heating systems in renovating residential buildings. The reason for this rise is that the heating sector has no choice but to say goodbye to natural gas and oil as the world moves towards climate neutrality.

Heat pumps will ease this transition. They source most of their energy from their immediate environment, the air or the ground. Heat drawn from the environment is renewable and available in practically unlimited quantities. Heat pumps need electricity to raise the temperature to the required level. This power is increasingly being drawn from wind and solar power plants, so the technology is getting more climate-friendly by the year. One kilowatt-hour of electricity can generate an average of three to five kilowatt-hours of heat per year, depending on the operating conditions and the type of technology in the heat pumps.

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About ZSW

The Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Centre for Solar Energy and Hydrogen Research Baden-Württemberg, ZSW) is one of the leading institutes for applied research in the areas of photovoltaics, renewable fuels, battery technology, fuel cells and energy system analysis. There are currently around 300 scientists, engineers and technicians employed at ZSW's three locations in Stuttgart, Ulm and Widderstall. In addition, there are 100 research and student assistants.

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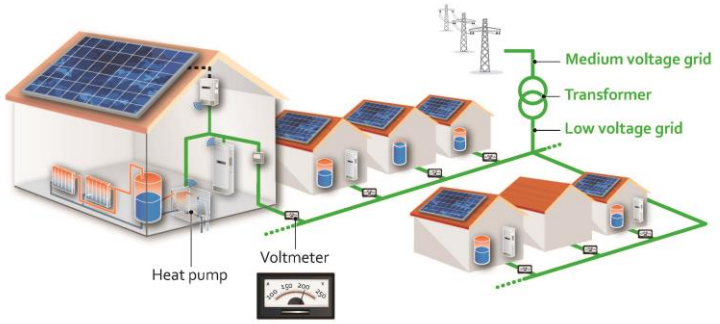

Grid-friendly operation of heat pumps in the low-voltage network
Artwork: ZSW

Images are available from Solar Consulting or at https://energie.themendesk.net/zsw/.