

Coordination could spare billions in grid upgrade costs and accelerate electrification

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From left, Stanford University researchers Ram Rajagopal, Thomas Navidi and Abbas El Gamal. Credit: Abbas El Gamal

The electric grids of the future will need to handle much bigger loads due to electrification of transportation and other sectors. This could mean expensive infrastructure upgrades to ensure their reliable operation, but a new study from Stanford University says most of those upgrades may be unnecessary.

Better [grid](#) reliability could be achieved instead by installing software in homes and businesses that coordinates various consumer demands and resources. Such [coordination](#) not only improves reliability of the electric grid, but also helps reduce its peak load, for example, during extreme weather conditions. The researchers say that coordination, if implemented widely, would save utility companies and their customers billions of dollars in grid infrastructure upgrades.

The study shows that, under status quo local control of demands and resources, four-in-five existing transformers will fail by 2050. Those transformers will need to be replaced, as could other infrastructure such as voltage regulators and possibly even electricity distribution lines.

"Under centralized control of the demands and resources across the grid, the number of transformer failures declines to just one in four," said Ram Rajagopal, a professor of civil and environmental and electrical engineering at Stanford and co-senior author of the study appearing in the journal *Joule*. "Such dramatic reductions in future distribution grid upgrades can accelerate the rate of electrification adoption."

Reliability matters

Electricity demand is projected to balloon over the next several decades in part because electricity is widely considered more climate-friendly than [fossil fuels](#) and because more people around the world will gain access to—or transition to—electrified heating of homes and water, air conditioning, and cooking.

Meanwhile, distributed [energy resources](#) like rooftop [solar panels](#) and residential and commercial batteries will certainly increase. So will [smart appliances](#) like electric vehicle chargers, electric space and water heaters, and air conditioners, whose power usage can be controlled to reduce consumer costs and total power system demand. That is, when connected through the Internet of Things, the operations of millions of these next-generation devices can be coordinated.

"The team decided to look at how much coordination of distributed energy resources and smart appliances can help grid reliability," said Abbas El Gamal, a co-senior author of the study who is a professor of electrical engineering and senior fellow of the Precourt Institute. "We found that the benefits of coordination can be very significant using nothing but software. No new infrastructure. No replacements of distribution lines. It can all be done using existing computer clouds."

Today, appliances and energy resources within each home or business are operated more or less independently. Each consumer makes choices about their heating and cooling, storage of excess solar generation, as well as charging electrical vehicles based mostly on personal need. That is to say, today there is not much coordination of such resources across different consumers.

Present day approaches prioritize lowering consumer's electricity costs over grid reliability, but there is a trade-off. Declining reliability can increase the cost of electricity, too, as failing transformers and other infrastructure must be upgraded.

Pleasant surprises

No one to date has gone to the lengths of this study to understand and quantify that trade-off, because it's not easy to do. The team used models of distribution networks of varying sizes, mixes of homes and

businesses, and from a range of climates across the United States. They then applied recent projections of increases in electrification and distributed energy resources and their adoption scenarios up to the year 2050.

"We developed our methodology over several years. We were conservative in our assumptions and our estimates," said Thomas Navidi, lead student author of the paper, who will soon finish his Ph.D. in [electrical engineering](#). Navidi spent much of the last two years on the nuts and bolts of the simulations and experiments.

"One key finding that caught our attention was how valuable coordinating thermal loads is to our findings. It was very significant, even more so than battery storage and flexible scheduling of EV charging," Navidi said, explaining that these loads include everything that uses electricity to raise or lower temperatures, from cooling or heating a home to making aluminum. "We are also making our software publicly available so anyone can calculate the potential benefits of coordination to their grids with their own assumptions."

In addition to improved reliability, the team also found that coordination can reduce peak load on the distribution grid by some 17%, which has the added benefit of reducing electricity costs during extreme climate conditions.

Next steps include developing a coordination scheme that would work across large numbers of homes and businesses, rolling out a pilot, and then—if the pilot works—developing a broader rollout that would include incentives to consumers to install the necessary software to achieve critical mass of adoption that could reap considerable rewards.

"In light of these savings and benefits, we think our software-only coordination approach deserves attention," said El Gamal. "It could save

billions."

More information: Thomas Navidi, Coordinating Distributed Energy Resources for Reliability can Significantly Reduce Future Distribution Grid Upgrades and Peak Load, *Joule* (2023). [DOI: 10.1016/j.joule.2023.06.015](https://doi.org/10.1016/j.joule.2023.06.015).
[www.cell.com/joule/fulltext/S2542-4351\(23\)00265-9](https://www.cell.com/joule/fulltext/S2542-4351(23)00265-9)

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