In the wake of the great winter storm, how can Texas create a more resilient power grid?

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As temperatures plummeted below freezing for 10 straight days and snow and ice blanketed Texas, all eyes turned to the state's power grid to understand how 4.5 million Texan customers could lose electricity at once.

Frigid temperatures wreaked havoc on Texas' natural gas, nuclear and coal plants, as well as wind turbines that struggled to operate during the storm. Many have blamed the Electric Reliability Council of Texas (ERCOT), the energy grid operator for 90% of the state, for its failure to upgrade and winterize equipment to better withstand subfreezing temperatures.

Texas Gov. Greg Abbott said that what happened during February's ice storm was "completely unacceptable," and Dallas Democratic state Rep. Rafael Anchía called the catastrophe a "massive failure" and a clear signal that Texas needs a more resilient power system that "can respond to ever-increasing extreme weather."

During the past year, a team of researchers at The University of Texas at Austin has been working on a project that could help with that, using advanced modeling to predict when certain electrical substations—which convert high-voltage electricity from power plants and other big generators to a lower voltage for distribution to homes—will be thrown offline during an extreme weather event. The goal is to help design a better, more resilient system by assisting energy companies, policymakers and state agencies in planning infrastructure investments during the next decade.

The team has been focused on flooding from major hurricanes —something more common in Texas.

But now, they are considering how the model could be tweaked to improve the state's power grid in the face of a winter storm—something that could become more common as a result of climate change, says project lead Erhan Kutanoglu, an associate professor of operations research and industrial engineering.

The model—designed for flooding emergencies—works like this:

Researchers collect meteorological data about an impending hurricane—its expected path, wind speed and precipitation totals (based on a number of potential scenarios). That information is used to create a hydrological model that looks at where water is expected to flow, including inland and storm surge flooding. The hydrological model is tied into elevation maps that show the topography of the region and pinpoint those areas most at flood risk. Researchers then overlay the highly advanced flood maps with the locations of certain infrastructure, like electrical substations, to see what parts of the system are most vulnerable during the storm.

All of these variables are fed into a decision-making model—also known as a stochastic optimization model—that takes into account all the data to show the probability of one outcome happening versus another. The model then spits out recommendations about the best short- and midterm interventions to employ in the face of the storm.

Short-term interventions would include more immediate and less costly solutions, like where to position temporary water dams around substations so they don't flood or where to pre-position mobile substations in case a particular substation goes down. These decisions would be made ahead of an impending hurricane, based on where it's predicted to cause flooding.

Midterm interventions include higher-price investments energy companies could make over a 10-year period to harden infrastructure, like raising substations off the ground or installing nearby battery storage for areas that are expected to flood often.

Life-and-death decisions

The idea is to make the most informed investment decisions, because preparation for and recovery from disasters are both dangerous and costly.

"You have to make choices," says Operations Research and Industrial Engineering Professor John Hasenbein, who works on the project's stochastic optimization model. "No one has an infinite amount of money, so you have to decide what certain mitigations are worth based on the loss of power that occurs during storms. That's the tradeoff everyone has to make. Power companies and consumers: How much are they willing to pay?"

Researchers have used hurricanes Harvey and Imelda as case studies. They do not have the exact locations of substations across Texas—that information is private. However, using Google Maps and data from the Homeland Infrastructure Foundation Level Data (HIFLD) Open Data set, which includes foundation-level geospatial data, the team was able to map out a representation of the full Texas power grid. Power companies will be able to input their own data into the model once it's complete. The UT team is already sharing its findings with CenterPoint Energy and Entergy.

Of course, the decisions power companies make affect millions of homes, businesses and critical infrastructure tied to the grid—as seen during the most recent winter storm. The UT model does take into account how many people will be affected when substations go offline.

"The grid, as we all now know, is highly interconnected. What happens in one place affects what happens everywhere else. It's not as simple as a road going down that doesn't affect another road," says Hasenbein. "A substation or generation station goes down, and the provider has to rebalance all the power. So, when you want to make decisions about resilience, you have to think about the correlations. A lot of times those correlations aren't taken into consideration."

Adapting the model

Kutanoglu and Hasenbein say it would be harder to create model for a winter storm because it is harder to predict in the long term how often such storms will occur. An ice storm also doesn't follow a clear path from the Atlantic Ocean up the coast like a hurricane. But the basic structure of the model works for any kind of disaster-related question that needs a solution, Kutanoglu says. The genesis of this latest model stemmed from a project Kutanoglu and Hasenbein worked on as a part of Planet Texas 2050, a university-wide grand challenge initiative that seeks to improve the state's response to extreme weather resulting from climate change. That project looks at how to stage ambulance assets and evacuate hospital patients during hurricanes. In that case, researchers overlayed the same flood risk maps with hospital location information, rather than electrical infrastructure.

"Essentially, this same model could be used when making any kind of critical weather-related decisions," Kutanoglu says.

Kutanoglu says that although a winter storm like Texas just saw is unprecedented—and in that sense, highly unpredictable—ERCOT did know that frigid temperatures, freezing rain and snow were in the forecast, which should have given them an idea, in the short term, of how to communicate to utilities, power generators and the public to prepare. The difference between the winter storm and recent hurricanes, however, is that it also affected the supply side—power plants that actually generate electricity—not just distribution assets such as power poles and substations.

"When the whole natural gas power plant is offline, it affects millions of people, not just one neighborhood," Kutanoglu says. "In that sense, I think there is a difference between hurricanes and winter storms on how they impact the infrastructure. This winter storm basically crippled our entire generation capacity."

Kutanoglu says this could be factored into a future model. Because so many industries have something at stake—coal, natural gas, fossil fuels, green energy—it would be especially beneficial to have an objective way of deciding where to make investments.

"As scientists, we can step back and look at these issues in quite a quantitative way and say, 'This is it. This is your problem,' " Kutanoglu explains. "We are now developing a case study using the winter storm and associated power plant vulnerabilities in the already-modeled Texas grid, just as we used Harvey and Imelda as case studies for hurricanes."

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