Researcher is working to predict electric power blackouts before they happen

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High-voltage transmission lines.

The largest power outage in United States history, the 2003 Northeast blackout, began with one power line in Ohio going offline and ended with more than 50 million people without power throughout the Northeast and the Canadian province of Ontario.

Despite the apparent failure of the electric grid during such cascading events, blackouts aren't necessarily grid failures. Blackouts are often the result of automated protection measures that ensure power surges or downed power lines don't damage trees, people, appliances or other parts of the grid.

In the past, utility engineers have used static models of local electric grids to aim for single-contingency, worst-case scenario protection strategies rather than dynamic, real-time solutions to a unique grid disturbance.

Through advanced modeling and computer simulation, Travis Smith and fellow R&D staff members in the Department of Energy's Oak Ridge National Laboratory Power and Energy Systems Group are developing tools to improve grid protection operation analysis and prediction under different scenarios. These new grid protection tools are not only for familiar events like equipment failures, energy shortages or extreme weather, but they can also protect against influxes of renewable energy sources and "smart" grid components, such as communication devices and sensors, which both pose new protection challenges.

"We're integrating existing tools to do an even better job at what they already do," Smith said. "We eventually want to feed real measurements from the grid into the model, which for utilities means a faster response time because they can plan for individual scenarios."

For decades, utility planning engineers have used the Power System Simulator for Engineering (PSSE) or comparable software to plan utility infrastructure and power distribution. PSSE executes dynamic simulations of power transmission so engineers can analyze and optimize the grid's performance.

Once planning engineers plan the grid, protection engineers must design protection strategies based on that plan.

"Protection engineers ask, 'If something goes wrong, if there's a fault, can we isolate one part of the system?' " said Smith, who worked as a protection engineer and consultant for more than 15 years before coming to ORNL.

To simulate faults, or changes in electric current that typically indicate something has gone wrong on the grid, protection engineers use Computer Aided Protection Engineering (CAPE) software. However, predicting the protection strategy needed for any number of events—from a tree felling a power line during a storm to an abrupt rise or fall in consumer demand—is a much heavier computational burden than planning for the system to work under normal conditions.

"When protection engineers look at the grid, they are studying it under static conditions," Smith said. "So they simulate a fault to see what happens, but that simulation is not taking into account real-time dynamics on the grid."

In the end, grid protection relies on a string of automated protective relays, devices placed on transmission lines and substations. If a relay registers a disturbance, such as a drop in voltage, it will trip a switch and shut off local power. More often than not, protective relays are older electromagnetic devices that cannot transmit data to the utility company.

"Technicians often have to physically go to the substation and pull out a data file to understand what happened," Smith said.

When the first hours of a blackout are spent investigating what caused the outage, it can be difficult to prevent adjacent relays from tripping and creating further problems.

For real-time solutions, Smith is developing a detailed protection program for ORNL's consolidated PSSE/CAPE software that analyzes changes in parameters such as current, voltage, frequency and impedance to coordinate protective relays into a low-impact protection strategy as an event is occurring.

He is refining the program and investigating the impact of renewable energy on grid protection using models of the Eastern Interconnection (EI), one of the nation's major grids, for the years 2008–21. The models are provided by the Eastern Interconnection Reliability Assessment Group, which analyzes and forecasts EI transmission conditions.

"The program script is automated so it can quickly analyze all the contingencies and provide a guidebook for a range of circumstances," Smith said.

One of the biggest R&D challenges is related to the size of the computational problem, which slows simulation times. For models that simulate the grid five to 10 years from now, an infusion of wind energy, small-system energy storage devices and communicating sensors makes the amount of computation even more daunting, and simulation time steps shrink from milliseconds to microseconds to detect viruses or cyber-attacks.

"Once you have a faster, smarter grid, you need protection for a faster, smarter grid," Smith said. "I'm working with computer scientists at ORNL to see if we can push the model to run faster than real-time speeds so we can predict what will happen before it happens."

While Smith says he currently may be "the only person in the world using this kind of program right now," he predicts utility companies worldwide will adopt real-time protection analysis in the next few years.

It will happen "soon, if we see a large blackout," Smith said. "We'll zoom into the model using EMT (Electro Magnetic Transients), see what is happening among protective relays, and run higher resolution time step simulations to solve the problem before it gets out of hand."

Provided by Oak Ridge National Laboratory

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