LANL physicists discuss electrical grid in journal article

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Electrical grids are the largest engineered systems ever built. Expected to reliably deliver power whenever and wherever consumers demand it, the systems affect almost every aspect of our day-to-day lives. Today's grids already exhibit complex nonlinear dynamics that are not well understood and will become more complex as renewable energy sources are incorporated and consumer appliances become more intelligent and autonomous. Scott Backhaus of Condensed Matter and Magnet Science (MPA-CMMS) and Michael Chertkov of Physics of Condensed Matter and Complex Systems (T-4) are authors of an article for _Physics Today_ that outlines the physics of several phenomena associated with power grid behavior and describes technologies that should prove influential in the workings of the future grid.

Significance of the research

Today's grids have evolved to be resilient only against simple perturbations like the sudden loss of a generator. Tomorrow's will have to integrate the intermittent

power from wind and solar farms whose fluctuating outputs create far more complex perturbations. Before tomorrow's grids can be engineered, and even before some phenomena in today's grids can be effectively controlled, scientists and engineers must first understand the grid's behavior over a broad spatiotemporal scale — from milliseconds to hours and from tens of meters to thousands of kilometers. Guarding against the worst of those perturbations will require protective measures based on ideas from probability and statistical physics.

Research achievements

Calling upon their physics experience, Backhaus and Chertkov present an overview of grid physics, voltage collapse, generator synchronization, electromechanical waves, new probabilistic measures of grid reliability and the nonlinear and hysteretic dynamics of distribution grids. Revolutionary changes to the electric grid will lead to grids that are more random in behavior and exhibit dynamics requiring new stability criteria that address emerging problems and can be evaluated faster, closer to real time.

The scientists expect that their analysis techniques will provide the fundamental underpinnings of the control and optimization of tomorrow's grid. They describe three technologies that could make a major impact on the future grid:

- probabilistic measures of electrical grid reliability,
- a new criterion for electrical grid dynamic stability and synchronization, and
- a new model of the nonlinear dynamics of electrical distribution grids that reveal the fundamentals of disruptive electrical load behavior.

The research team

The scientists work with an interdisciplinary team of researchers at Los Alamos and universities. The team includes experts in the complementary fields of operations research, computer science, control theory, machine learning and electrical power engineering — all of which are required to solve the problems of tomorrow's grid.

Caption for image below: Satellite view of the United States mainland at night.

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