Improving grid reliability in the face of extreme events

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The nation's power grid remains vulnerable to disruption from extreme events including wildfires, severe storms, and cyberattacks. Variable generation resources and load volatility also present operational challenges to grid stability. To mitigate disruptions before they snowball, grid planners and operators must be able to see these events coming and understand their potential impacts on grid reliability.

However, current tools aren't up to the task of accurately modeling all the scenarios and interdependencies with the accuracy, scale, and speed necessary. A better approach that in turn requires more computing power is needed.

Enter ExaGO, a modeling and optimization platform for solving large-scale, nonlinear power grid optimization problems. Short for exascale grid optimization toolkit, ExaGO is open-source software that can take advantage of high-performance computing and emerging heterogeneous computing platforms to model and forecast the impact of extreme events and operational complexities on power grid reliability.

"The Exascale Computing Project at DOE was looking for specific applications that would be well-suited for this approach to computing," said Shri Abhyankar, senior optimization scientist in the Electricity Infrastructure and Buildings Division at Pacific Northwest National Laboratory (PNNL). "Exascale grid modeling was an ideal candidate application, our sponsors agreed, and we got started with the ExaGO project."

ExaGO is being developed by PNNL under the ExaSGD project, which involves five national laboratories and Stanford University and is funded by the U.S. Department of Energy Office of Science Exascale Computing Project. ExaSGD focuses on developing algorithms and techniques to address these new challenges and optimize the grid's response to many potential disruptive events under different weather scenarios.

Software now available

After only 18 months of research and development, the PNNL team recently released the first stable version of ExaGO software. ExaGO can run on hardware ranging from laptops to exascale supercomputers, allowing high-fidelity grid models to be deployed on new and emerging accelerator-based computing architectures.

"ExaGO is a significant leap forward in power grid modeling," said Slaven Peles, chief scientist for the Optimization and Control group at PNNL and principal investigator for the ExaSGD project. "The ability to quickly model highly complex scenarios at scale and assess their potential impact on power grid reliability is critical to implementing corrective measures in a timely manner."

Heterogeneous architectures

Heterogeneous architecture refers to hardware that, in addition to traditional processing units, also has hardware accelerators such as graphics processing units (GPUs). This architecture provides extra computational power for the computing-intensive task of modeling "stochastic" grid dynamics, which have random probability distributions or patterns that need to be analyzed statistically. ExaGO consists of applications designed to solve large-scale stochastic optimization (nonlinear problems), security-constrained optimization (resource scheduling), and multi-period optimization problems (grid infrastructure interdependencies).

Modeling the impact of variable generation energy resources on grid reliability would be an example of stochastic grid dynamics. This GPU architecture has the advantage of being able to process many pieces of data simultaneously, significantly increasing computing performance for modeling the behavior of complex systems. The platform has already demonstrated unprecedented levels of performance and scalability.

In testing, ExaGO simultaneously solved more than 3,000 instances of alternate current optimal power flow (ACOPF)—a critical system-level grid management calculation to balance real and reactive power—for a simulated 2,000-bus Texas grid in less than 10 minutes. This performance significantly exceeds that of current generation planning tools and enables grid operators to identify optimal responses to multiple simultaneous failures of grid components (known as N-k contingencies), such as those occurring during extreme weather conditions.

Putting the technology to work

So, what can grid operators do with a modeling platform like ExaGO? Much more than they could do with current generation tools, said Abhyankar.

ExaGO can be used to help manage the operational uncertainties from intermittent, distributed energy resources. The software can also be used to accurately assess a multitude of grid operating conditions for maintaining security and reliability or to mitigate frequency deviation during blackouts and other disruptive events. ExaGO can also be applied to optimize day-ahead and real-time power market operations.

Because ExaGO provides a complete and portable transmission grid modeling solution, transmission system operators can optimize their planning using more accurate life cycle estimates for grid assets, which represent billions of dollars in annual investment. Grid operators can also better prepare for extreme weather events, natural disasters, and potential cyberattacks by more accurately forecasting the impacts of those events on grid reliability in advance. These steps also include formulating the most effective emergency response options and identifying the best assets for frequency control to avoid broader, cascading failures of the power system.

"With a platform with these computational capabilities and modeling features in place, the potential applications and new use cases are extensive," said Abhyankar. "Most importantly, with the ability to execute high-fidelity grid modeling and power flow analysis—quickly and at scale—grid operators are better able to keep the lights on when power grid reliability is threatened."

More information: ExaGO is available for general use through open-source licensing on GitLab. For more information about ExaGO, contact Shri Abhyankar at PNNL at shrirang.abhyankar@pnnl.gov.

Provided by Pacific Northwest National Laboratory

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