High-performance computing helps grid operators manage increasing complexity

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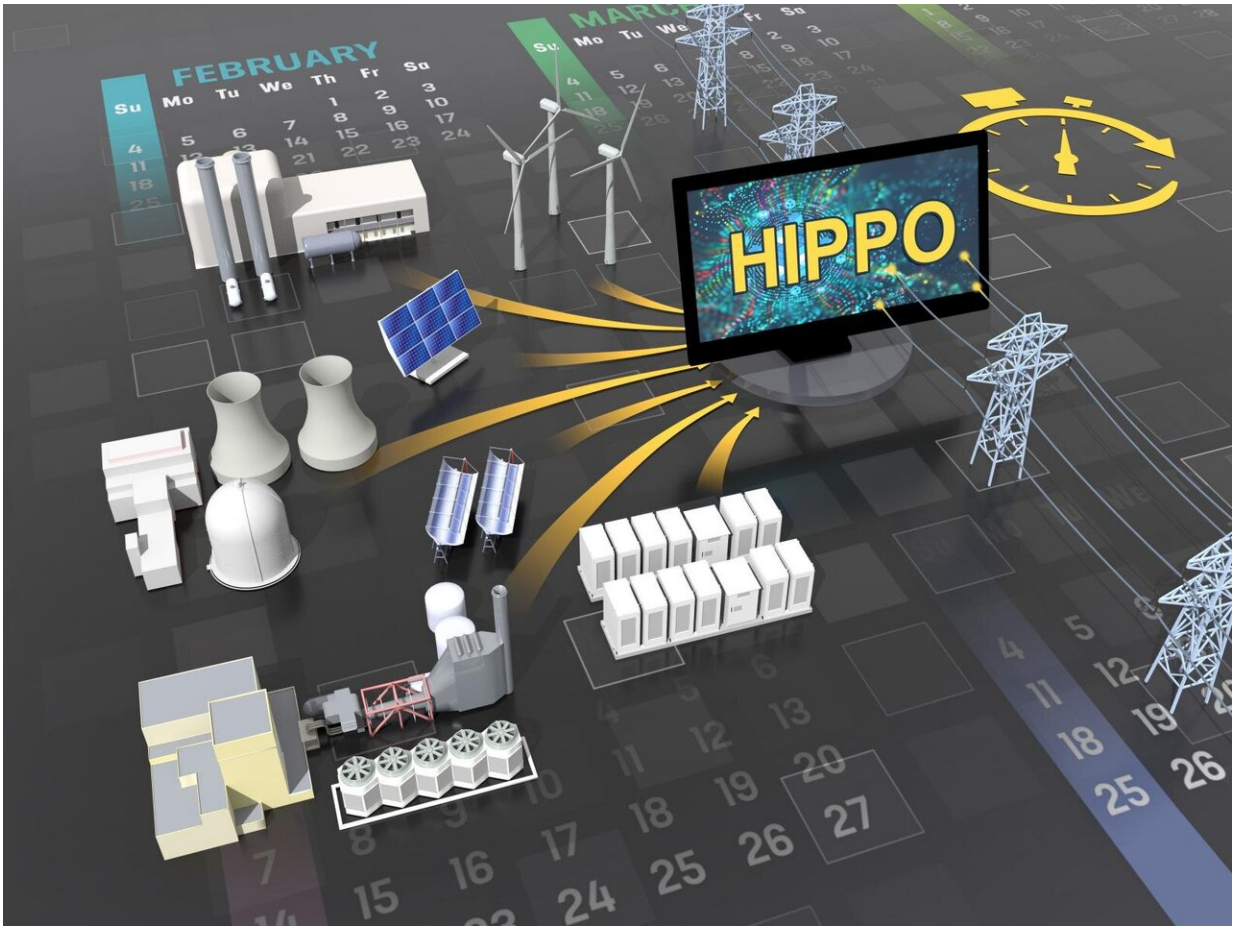

The power grid is evolving with the integration of renewable energy and changing electricity demand patterns. HIPPO calculates increasingly complex resource schedules with greater accuracy and increased speed needed for future electricity markets. Credit: Mike Perkins | PNNL

Making sure there's enough electricity at the lowest price is a critical endeavor undertaken daily by electricity market operators. Grid operators must continually ensure that power supply meets demand in real time. Now, there's an approach that provides more timely and accurate information to make decisions in the day-ahead timeframe. Pacific Northwest National Laboratory (PNNL) developed a new computational tool in collaboration with the Midcontinent Independent System Operator (MISO), which operates one of the largest wholesale electricity markets in the world. Gurobi Optimization, GE Grid Solutions, the University of Florida, and Cognitive Analytics also are partners in the project. The project was initially funded by the U.S. Department of Energy's (DOE's) Advanced Research Projects Agency-Energy through its OPEN 2015 funding opportunity.

Planning and scheduling day-ahead electricity supply used to be a more straightforward process when nearly all the electricity came from a small number of large, centralized power plants. That's no longer the case. Distributed and intermittent energy resources, such as solar, wind, combined cycle, energy storage, and controllable loads, have dramatically increased the complexity of resource planning and scheduling to align electricity supply with forecasted demand. However, the time window in which these calculations and decisions must be made for day-ahead operations remains very compressed.

Typically, a regional independent system operator which manages a wholesale market has only two to three hours to settle bids and offers in the day-ahead market. This includes about 30 minutes to find the minimum costs of delivering electricity while satisfying all generators' limits and conditions. It also includes running complex feasibility tests to assure adequate supply and reliable operations during normal power system operation, as well as thousands of contingency conditions that could occur.

This process is referred to in the industry as "security constrained unit commitment" (SCUC) and has been a continuing technical challenge and an active research area since the 1970s. The accuracy and timeliness of these calculations and decisions directly affect grid reliability for everyone. But the mathematical problems, solved using a technology called Mixed Integer Programming, are extremely large and difficult, and the tight time constraints often exceed the capabilities of the current technology. All these constraints make SCUC calculations one of the most formidable computational challenges facing the power industry today.

Speedy results

The PNNL-led research team addressed these challenges by taking a new approach to the problem. It's an advanced core optimization process called HIPPO, which is short for High-Performance Power-grid Optimization. HIPPO is a computational engine that is significantly faster than current solvers used in the industry to perform complex SCUC calculations.

For decades, grid operators have addressed SCUC as a single optimization process. But HIPPO uses advanced optimization theory, a high-performance computing cluster, and machine learning techniques. HIPPO launches multiple algorithms concurrently—each working in parallel but searching for optimization solutions in different ways that are likely to provide a potentially optimal SCUC solution.

These algorithms, which can be run on multiple workstations or in high-performance computing environments, also communicate with each other and leverage what they each learn during execution. The result is more timely and accurate decision support for grid operators working to balance electricity supply and demand and optimize energy resource utilization over a large geographic or control area.

Put to the test

The research team put HIPPO to the test in a comparison with the current generation production solver used by MISO and found that HIPPO enables grid operators to perform these complex SCUC calculations up to 35 times faster.

"I am proud that after three years, the team, through close collaboration and hard work, was able to transform the proposed ideas into a technology embraced by industry," said PNNL principle investigator Feng Pan. "The increased computation speed will potentially lower electricity costs and increase operational reliability and flexibility, while enabling system operators to consider complex market designs to support a more diversified energy resource portfolio."

Using HIPPO, the time required for complex SCUC calculations can be reduced from up to two hours to less than 20 minutes, while also guaranteeing the cost is within 0.1% of optimal, which means calculating the lowest cost resources that also meet all contingency requirements. HIPPO has now been moved to MISO's private cloud environment for further testing.

"The project demonstrated the power of collaboration among MISO R&D, PNNL, software vendors, and academia," said MISO's principal investigator on the project Yonghong Chen. "In addition to increasing the speed and accuracy of the calculations, HIPPO bodes well for advancing market development for resource portfolio changes that require more complexity for SCUC calculations."

"HIPPO efficiently integrates power system security checks with the SCUC solver to accelerate solve time, while reducing the amount of data that must be exchanged among different solution modules," said GE's Jie Wan. "The performance results were amazing, and GE aspires to

integrate this technique into our product."

"SCUC models are among the most challenging problems that Mixed Integer Programming solvers are asked to calculate," said Edward Rothberg, Chief Executive Officer of GUROBI Optimization. "It was great to be able to work closely with experts in the field to push the technology forward at both the modeling and the optimization solver level."

Provided by Pacific Northwest National Laboratory

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