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# Novel scientific computing method for studying utility-scale renewable power systems

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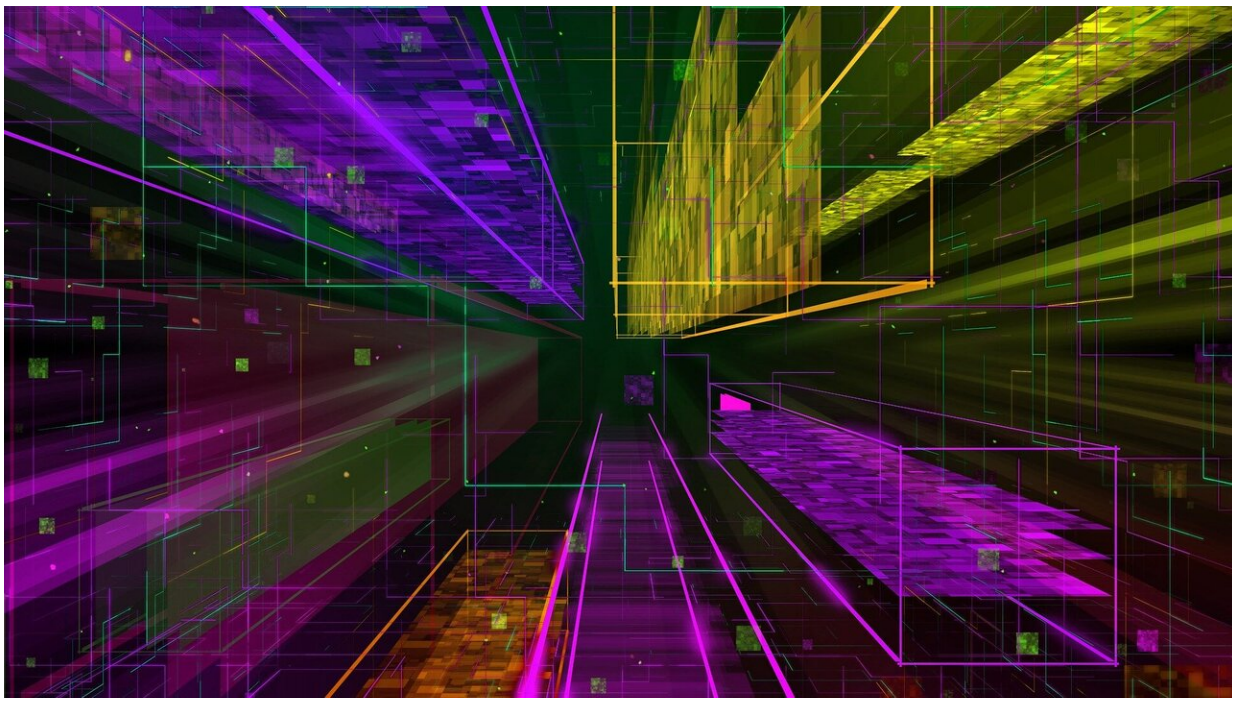

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The United States has 37 gigawatts (GW) of utility-scale solar capacity—enough to power over 4,070,000,000 LED lights—with an impressive additional 112 GW of capacity currently under development.

With so much large-scale solar power already in place, current trends in energy systems clearly point to renewable energy sources and battery energy storage systems being major players in the power grids of the future. But these new technologies bring additional complexities and challenges. Given the obstacles, how can we understand the behavior of modernized grids and the ways in which power system operators and policymakers can ensure their continued reliability on a large scale? NREL analysts, along with colleagues at the University of California, Berkeley (UCB), have published a novel open-source computation analysis approach in an *IEEE Electrification* article that is helping unlock the answer.

"Existing commercial software tools used for modeling have worked well for power system analysis for decades. However, we are in a phase of rapid energy system changes that is placing new demands on modeling needs," said Clayton Barrows, NREL senior researcher and contributing author of the article. "In order to keep pace with these emerging technologies we need transparent software that is easy to modify. Updated and flexible software tools will allow the research community to address computational questions and understand the impacts of new technologies before they hit the market."

## Understanding low-inertia power systems

The introduction of renewable energy sources and battery energy storage systems, as well as the move away from traditional rotating generators, has resulted in unfamiliar power systems with low levels of physical inertia. The power systems of the past were dominated by synchronous machines in which a crucial source of grid stability was physical rotations that behaved according to the laws of physics. Modern power systems, however, have renewable energy sources as well as inverter-based generation where stability is maintained not through mechanical processes but through logic and electronic controls.

All of this has fundamentally changed our understanding of grid stability and behavior—and presented fresh obstacles to studying and predicting these systems. The new NREL- and UCB-developed modeling approach addresses the shortfalls created by the changing energy systems of the emerging grid.

## Closing the modeling gap with scientific computing

Computational tools and simulations are uniquely poised to handle the complexity and scale of power system analysis. Scientific computing allows researchers to map and understand power systems containing widespread renewable energy sources and battery energy storage systems. Computer-aided simulations are replicable, with results that can be validated, and computation models can be scaled to reflect the real-world proportions of our modernized grids.

Scalability and flexibility have previously been the biggest obstacles for researchers in the field. Large-scale experiments have required proprietary models and algorithms that are expensive and time-consuming to set up and are difficult—if not impossible—to fully represent emerging technologies. This inaccessibility ultimately impedes research and innovation in the power systems community, which hinders the deployment of modernized grid systems.

NREL and UCB analysts saw this need and have rolled out a set of open-source simulation tools and a computational approach that can close the access gap.

## Choosing a common language

Developing any simulation tool starts with choosing a programming language. The NREL analysts behind the recent article argue that

Julia—a dynamically typed programming language developed by Bezanson et al. 2017—is the best answer for large-scale power system modeling.

Julia is designed to make high-performance computing more accessible by bridging the gap between scripting languages and high-performance computing languages. Julia makes it easy to write and maintain extremely reliable, well-performing software. And software that is easy to write is also easy to read and reproduce. These capabilities, the NREL analysts determined, make Julia an excellent match to tackle scientific computing challenges in the power systems community.

## Establishing the scalable integrated infrastructure planning framework

With a programming language decided, the NREL team set out to develop fully accessible programming tools that meet the research needs of ever-evolving modern power systems. The result is the Scalable Integrated Infrastructure Planning framework (SIIP)—a first-of its-kind flexible modeling framework that incorporates new solution algorithms, advanced data analytics, and scalable high-performance computing.

Julia features and capabilities are being used extensively in SIIP to provide open-source tools that provide consistent and high-performance data models for utility-scale power systems. SIIP includes three integrated modeling packages:

- PowerSystems.jl provides a reusable and customizable data model that is generic to the implementation details of the mathematical models and is applicable to multiple simulation strategies. It also provides extension capabilities by design that make it easier to integrate into other initiatives.

- PowerSimulations.jl enables steady-state power system modeling activities, including production cost modeling, unit commitment, economic dispatch, automatic generation control simulations, optimal power flow, and others.
- PowerSimulationsDynamics.jl allows for the simulation of power system dynamics by providing an extensive model library, access to several numerical integrators in Julia, and state-of-the-art low-inertia modeling approaches.

The software suites included in SIIP are now freely available to the power systems research community. By addressing shortfalls of previous modeling platforms, SIIP helps move one step closer to breaking down barriers to the development and deployment of modern, renewable-based power systems.

"The goal of SIIP is to create a common platform for electrical engineers to represent new technologies, computational scientists to develop algorithms, and analysts to conduct applied studies. Ultimately, we hope that SIIP will help advance the nation's ability to test and analyze our future grids," Barrows said. "This approach provides a helpful, accessible way to overcome the challenges in studying low-inertia systems, and we're excited to see these tools be applied to investigate a wide range of future renewable grid models."

Access the open-source SIIP software suites and learn more about the SIIP modeling framework being developed by NREL's energy analysts.

**More information:** Rodrigo Henriquez-Auba et al, Transient Simulations With a Large Penetration of Converter-Interfaced Generation: Scientific Computing Challenges And Opportunities, *IEEE Electrification Magazine* (2021). DOI: 10.1109/MELE.2021.3070939

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