



National laboratories are interdisciplinary institutions that tackle important problems from energy and infrastructure to national security. In addition to current discoveries in these technical domains, national labs have a long history of highly impactful breakthroughs. In this column we learn about a current application of differential equations at Pacific Northwest National Laboratory to understand correlated noise that occurs in power systems. We also hear about how the Monte Carlo method for solving complex problems in a variety of disciplines, introduced by Los Alamos National Laboratory, is still being used and advanced there today.

Stochastic Resonance When Uncertainty Meets Dynamics

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Due to the increase in penetration of renewable energy sources and intelligent load devices, power systems are subject to significantly larger uncertainties in power generation and consumption stemming from fluctuating, difficult-to-predict weather conditions and modern demand profiles. Such power fluctuations are characterized by multiple, non-trivial correlation timescales ranging from seconds to minutes. Therefore, the question arises in terms

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of how such fluctuations interact with electromechanical timescales such as inter-area low-frequency oscillation periods that are in the order of seconds [1], and what the effect is of such interactions on the dynamics and stability of power systems. This becomes a fundamental challenge in assessing and optimizing power system operations under uncertainties to ensure reliability, resilience, and security of the critical electric infrastructure. At Pacific Northwest National Laboratory, we are tackling this challenge by combining our unique power system domain expertise and computational mathematics capabilities.

The so-called Probability Density Function (PDF) method is a tool for analyzing the one-point PDF, i.e., the probability of being at a certain configuration at a certain time, of the state of general dynamical systems driven by autocorrelated noises [2]. We have successfully adapted and applied the PDF method to the stochastic differential equations governing power system dynamics. Such PDF-based analysis reveals that power generation fluctuations with a specific correlation time magnify the amplitude of the fluctuations around certain operating conditions [3]. Furthermore, this analysis shows that the resonance correlation time is related to the electromechanical timescales of the power system [4]. This “stochastic resonance” phenomenon illustrates the importance of quantifying and accounting for the effect of the correlation time of stochastic drivers on dynamical systems. This is a foundational discovery for large-scale power system uncertainty assessment. It offers a whole new insight in how to assess and mitigate the impact of uncertainties on power systems and potentially help to answer fundamental questions such as how much renewable energy a power system can

accommodate without losing dynamic stability and how to improve power system controls to enable more renewable energy to be integrated.

The Monte Carlo Method: From Then to Now

J. E. Gubernatis

The work of Ulam and von Neumann shortly after World War II on radiation transport and the additional work of Metropolis et al. [5] a few years later on the melting of solids laid the foundations for most of the Monte Carlo methods used today and give the Los Alamos National Laboratory the honor of being the birthplace of the Monte Carlo method. The Monte Carlo method refers to the use of stochastic procedures to simulate or otherwise solve problems that are too complex to solve deterministically. In the first publication to use the rubric “the Monte Carlo method,” Metropolis and Ulam [6] in fact saw the approach as something scientists would from time to time use to overcome what we today call the “curse of dimensionality,” the often exponential increase in difficulty in analyzing problems in high dimensional spaces.

At Los Alamos, the original work of Ulam and von Neumann grew into the development and maintenance of the Monte Carlo N-Particle (MCNP) simulation code, the international “gold standard” for simulation radiation transport not only for national nuclear security programs but also for nuclear reactor and waste storage applications. The seminal work of Metropolis et al. proved to be exceptionally application neutral so its importance expanded at Los Alamos and elsewhere to hosts of complex problems across all the physical, mathematical, medical, information, financial, computer, and social sciences. Of specific current interest is the application of the Monte Carlo method to large-scale optimization problems in machine learning. A relatively recent growth area is the extension of the method to problems obeying the laws of quantum mechanics. In fact, Metropolis and Ulam credit the Nobel laureate E. Fermi for first noting this possibility.

Today, at Los Alamos, quantum Monte Carlo is being used as a research tool in quantum chemistry, nuclear physics, high-energy physics, quantum field theory, and condensed matter physics.

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