Power Grids

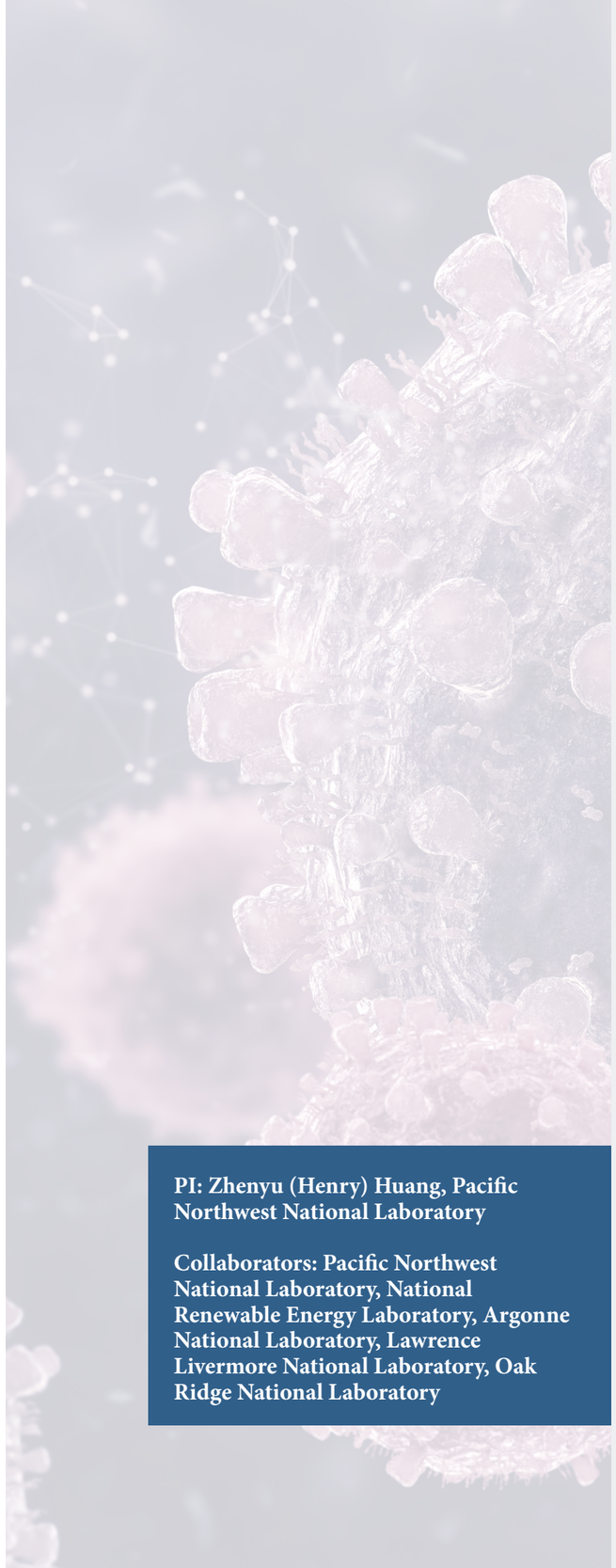
ExaSGD: Optimizing Stochastic Grid Dynamics at ExaScale

A critical national security challenge is the maintenance of the integrity of national power grids under adverse conditions imposed by natural or man-made causes. When the grid is subject to localized stresses, load imbalances can occur between generation sources and global demand. ExaSGD is developing algorithms that can optimize the grid's response to a large number of potential disruption events to compute a risk profile for grid operations. This application will harness the power of exascale computing to help civil planners assess alternative grid management and response strategies to best maintain the integrity of the national power grid under emergency conditions.

Energy delivery systems such as national power grids operate by maintaining a balance between energy supply and demand. Energy is produced at generators and via renewables and other sources, and it is then transmitted through a bulk power system. Attacks via physical or cyber means and hazards on the grid can create an imbalance between supply and demand, which can result in drops in voltage or frequency, both of which can permanently damage very large and expensive components. As a result, great care is taken to operate the grid with very high reliability within narrow operating voltage and frequency ranges.

Recovering from generation/load imbalance can be achieved by shedding load (i.e., deliberately allowing some load to go unserved, creating a partial blackout) to preserve the functionality of the remainder of the power grid. However, the behavior of the power grid can be influenced at many points within the system because of the increasing prevalence of cyber-enabled control and sensing, renewables (e.g., transient wind or solar power), plug-in storage devices (e.g., electric vehicles that can put power into the grid, or remove it), smart meters that can control load at a fine granularity (e.g., throttling home appliances or air-conditioning at times of peak demand), and other sensored elements that can be controlled remotely. The conventional load-shedding approach may miss more efficient strategies that make use of a more complete spectrum of grid elements. A capability for discovering more optimal configurations to recover from generation/load imbalance will improve our national readiness to recover from a variety of hazards to the power grid.

The ExaSGD challenge problem is to optimize the grid's response in a near-term time frame (e.g., 30 minutes per North American Electric Reliability Corporation operating standards) to a variety of underfrequency hazards via physical and control threat scenarios using comprehensive modeling that includes generation, transmission, load, and cyber/control elements. The ExaSGD team is comparing the frequency recovery performance of a complex grid plus control system in the presence and absence of smart devices, stored energy reserves, renewables, and demand response technologies. This will involve at least two calculations of the distribution of severity of frequency response to grid hazards/effects relevant to national grid response. Estimating these distributions involves solving a large number of optimal power flow calculations that consider different underfrequency scenarios. Each optimal power flow calculation requires the solution to a large-scale nonlinear optimization problem. Additionally, this challenge problem will consider the integrated execution of these optimization problems to warm-start subsequent power flow calculations across scenarios.



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Progress to date

- Integrated GridPACK and xGA.
- Generated a renewable energy scenario model.
- Performed optimization of solvers.

ExaSGD is developing an exascale application that can be used to provide near-real-time responses to both physical and man-made stresses on the national energy grid to maintain electricity generation integrity.