Data and Multistage Optimization for the New Grid

I. Satkauskas[a], J. Maack[a], D. Sigler[a], K. Panda[a], S. Bhavsar[a], M. Reynolds[a], W. Jones[a]

[a] National Renewable Energy Laboratory, Golden, CO

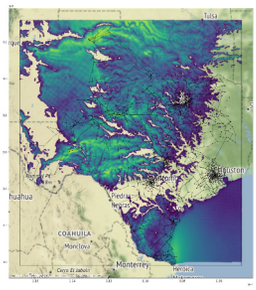

Figure 1: Capacity factors over the ACTIVSg2000 test system. Sites selected via thresholding and factoring in other exclusions.

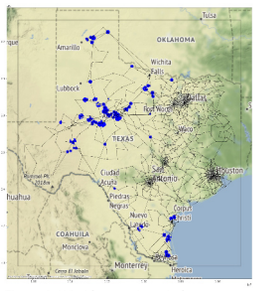

Figure 2: Wind farms selected after thresholding and exclusions using locations of buses with wind farms from ACTIVSg2000.

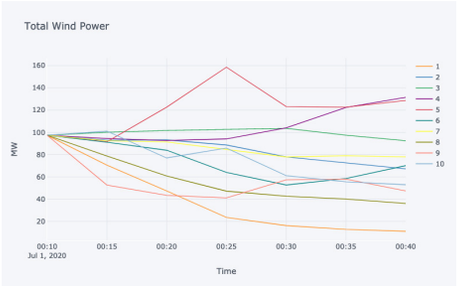

Figure 3: 10 aggregate wind power scenarios for the ACTIVSg2000 test system. Powerscenarios provides timeseries scenarios for every wind farm on a test system with a user-selected number of 5-minute time periods.

Powerscenarios

Powerscenarios [1] uses the NREL WIND Toolkit, along with geographical inputs to build realistic synthetic wind farms on test systems and generate high fidelity wind power scenarios for stochastic operations and planning.

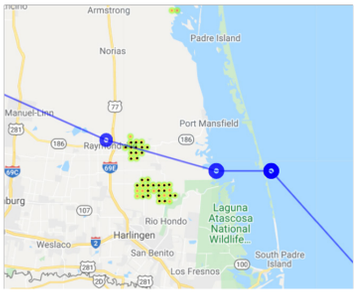

Figure 4: Path of Hurricane Dolly and interaction with synthetic wind farms on ACTIVSg2000. Black dots represent damaged wind sites, red dots indicate undamaged.

Figure 5: Resulting power outputs as Hurricane Dolly passes by windfarms. Note cutoffs where power drops to zero due to high wind speeds, and that the rated power is less after the hurricane passes due to infrastructure damage.

Extreme events and asset damage models

Powerscenarios and ExaGO can help planners prepare for extreme events by enabling the simulation of grid operations through extreme events such as a hurricane strikes [2]. WIND fields from the WIND toolkit can also be fed into infrastructure damage models, giving planners a useful tool for developing realistic contingencies.

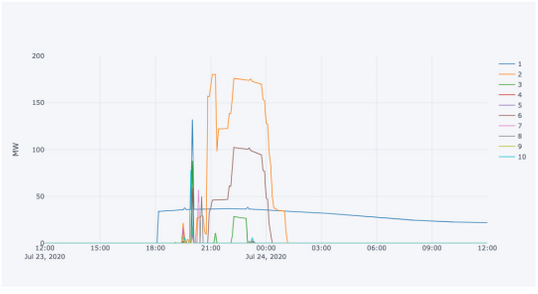

Figure 6: Loss of load due to infrastructure damage caused by Hurricane Dolly. Damage includes substation damages, line damages, and wind farm damages.

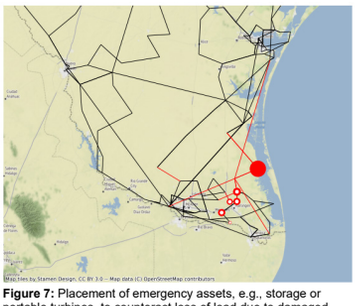

Figure 7: Placement of emergency assets, e.g., storage or portable turbines, to counteract loss of load due to damaged infrastructure. White circles denote small battery capacity, large red circle denotes larger battery capacity.

Multistage optimization for emergency asset placement

Using multistage stochastic programming, we can combine operational models containing damaged infrastructure with a stage dedicated to placing emergency assets such as energy storage or portable turbines. The result is a more resilient system in the face of an imminent extreme event.

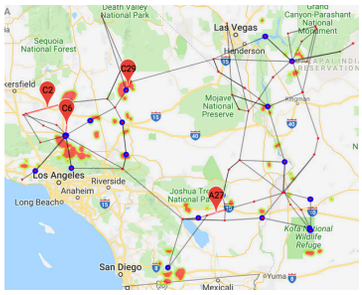

Figure 8: Line expansion decisions from a 3-stage approach using DC physics and progressive hedging. Future algorithms will use higher fidelity AC physics and security constraints.

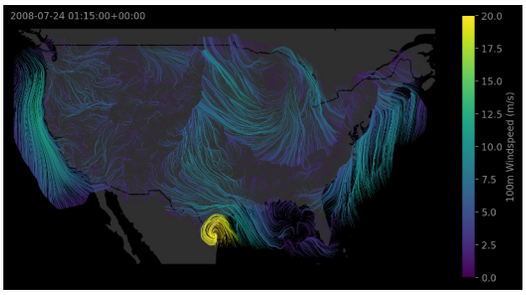

Figure 9: NREL WIND Toolkit wind field at 100m during Dolly's landing. Data generated using WRF, but more specific tools, such as HWRFx, can be used to generate data for specific extreme events such as hurricanes.

Future of exascale for grid operations and planning

Left: exascale computing will enable the use of multi-stage infrastructure planning algorithms utilizing large security constrained stochastic operational models, like those computed using ExaGO, with high-fidelity models of renewable output uncertainty.

Right: As applications of AI in power systems proliferate, data sets describing everything from regular operations to extreme events will be essential. Powerscenarios can be used with tools such as WRF and HWRFx to generate large AI training datasets targeting grid applications.

Exascale computing resources will enable high-fidelity simulations of resilient grid operations, providing an ideal tool for training reinforcement learning-based controllers for applications such as critical load restoration (see, e.g., [3] and [4]).

References

[1] Powerscenarios: realistic data-driven renewable energy scenarios for stochastic grid operation problems. https://github.com/nrel/powerscenarios

[2] I. Satkauskas, J. Maack, M. Reynolds, D. Sigler, K. Panda, and W. Jones, "Simulating Impacts of Extreme Events on Grids with High Penetrations of Wind Power Resources." *To appear in 2022 IEEE/PES Transmission and Distribution Conference & Exposition (T&D).*

[3] X. Zhang, A. T. Eseye, M. Reynolds, B. Knueven and W. Jones, "Restoring Critical Loads In Resilient Distribution Systems using A Curriculum Learned Controller," *2021 IEEE Power & Energy Society General Meeting (PESGM)*, 2021, pp. 1-5, doi: 10.1109/PESGM46819.2021.9637834.

[4] X. Zhang, A. T. Eseye, B. Knueven and W. Jones, "Restoring Distribution System Under Renewable Uncertainty Using Reinforcement Learning," *2020 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm)*, 2020, pp. 1-6, doi: 10.1109/SmartGridComm47815.2020.9302946.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This research was supported by the Exascale Computing Project (17-SC-20-SC), a collaborative effort of the U.S. Department of Energy Office of Science and the National Nuclear Security Administration. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

2022 Exascale Computing Project Annual Meeting
Virtual Event
May 2-6, 2022
NREL/PO-2C00-82655