Offshore 2022 WINDPOWER
OCTOBER 18-19 | PROVIDENCE, RI

Resilience and Extreme Weather Analysis for Offshore Wind

F. Bereta dos Reis, P. Royer, M. Elizondo, B. Vyakaranam, P. Etingov, H. Huang
Pacific Northwest National Laboratory, Richland, WA, US

Pacific Northwest NATIONAL LABORATORY

BACKGROUND

For the Atlantic Offshore Wind project, we conduct comprehensive stability and reliability analyses. It explores how severe weather can effect the integration of offshore wind (OSW) resources, including OSW generation, as well as how these weather events may affect the bulk electricity system. Lack of accurate simulation to identify evolving large OSW interconnected grid behavior under extreme weather conditions could result in massive consequences. To address this, we developed procedures to perform resilience and extreme weather analysis for OSW.

OBJECTIVE

Evaluate the effects of extreme weather on the grid for OSW integrations.

Identify extreme weather events for further evaluation using Electrical Grid Resilience and Assessment System (EGRASS).

Evaluate the impact of Hurricanes and Tropical storm on the power system assuming large OSW install capacity of 92,785.12 MW on the Eastern US.

Perform resilience and extreme weather analysis.

METHODS

The approach leverages publicly available data. That is: 1) GIS information for the Eastern interconnection; 2) The wind data utilized is from the National Hurricane Center (NHC); 3) Transmission line environmental impact assessment; and 4) Wind turbine manufacture data.

Data limitations

- Tower population
  - Available GIS information for Eastern Interconnection provides the line path.
  - No tower population.
- OSW
  - Specific of OSW turbine is not know.

Approach

- Tower
  - Convert wind speed to wind gust
  - Evaluate expected number of tower failure
- OSW
  - Convert 10 m wind speed to hub height wind speed.
  - Evaluate period where the turbine is not available given above cut-off wind speed.

ASSUMPTIONS

- *Tower population*
  - *Multiple transmission line environmental impact assessment an average span is assumed for lines based on nominal voltage.*
  - *Transmission tower population: 25,556*
- *OSW-- total East coast Off-Shore wind capacity is 92,785.12 MW*
- *OSW -- Multiple Offshore wind turbines select a cut-off wind speed, and the hub height is a random uniform sample from 119-150 m.*
- *Hurricane Sandy 2012 data is utilized for assessing the impact on the grid and Off-shore wind generation*
  - *Wind gust gain of 1.287*
  - *Based on NHC 6-hour storm data*
    - *Start reference hour -- 2012-10-26 18:00:00*
    - *End hour -- 2012-10-30 00:00:00*
    - *Duration – 78 hours*
  - *Two high-wind models*
    - *For Towers: Linear decrease in windspeed between storm center and 64 knot wind swath perimeter*
    - *For OSW turbines: Linear decrease in windspeed between storm center and 30 knot wind swath perimeter for off-shore sites*

RESULTS

Result summary

- *Tower*
  - *The expected number of impacted towers for Hurricane Sandy is 7.44 towers. The small number is expected given the wind speed of the event are not sufficiently strong to have a larger impact.*
- *OSW*
  - *The offshore population within hurricane swaths possesses hub winds speeds above cut-off wind speed -- Capacity of 84,997.52 MW*
  - *Cut-off does not occur simultaneously but progresses through the duration of the event*

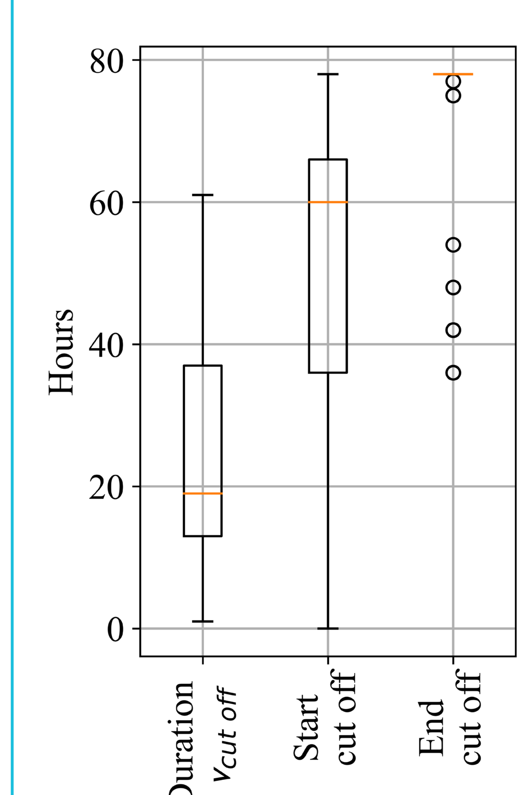

Figure 2: Summary OSW generation cut-off simulations for high wind from Hurricane Sandy 2012 data

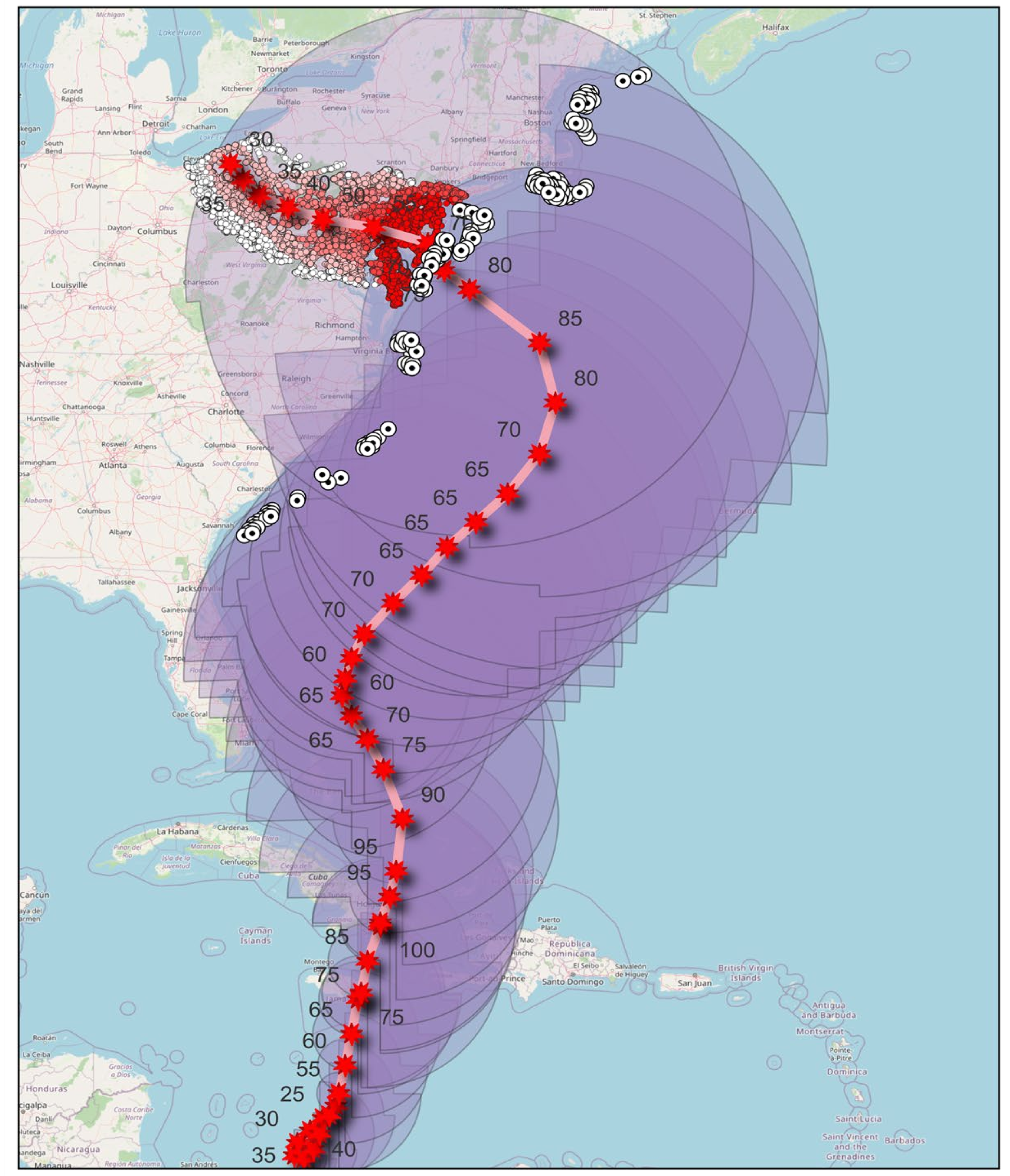

Figure 1: Hurricane Sandy wind speed data overlapped with OSW farm locations and land-based transmission towers.

- Off Shore Wind Sites
- Storm Path Center (6 hr intervals)

Estimated Windspeed at Synthetic Towers (knots)

- 0 - 14.4
- 14.4 - 25.3
- 25.3 - 39.1
- 39.1 - 66.6
- 66.6 - 71.9
- 34 knt Wind Swaths

Table: Sensitivity analysis for expected land-based transmission tower failure taking Hurricane Sandy as based and assuming increased wind sensitivities

Wind Gain	Expected Number of Tower Failure	Expected Preliminary Number of Lines Impacted	Max Gust Wind (mph)	Hurricane Category
1.0	7.44	3	106.5	1
1.2	39.13	12	127.8	2
1.4	205.25	62	149.1	3
1.6	1033.34	315	170.4	4

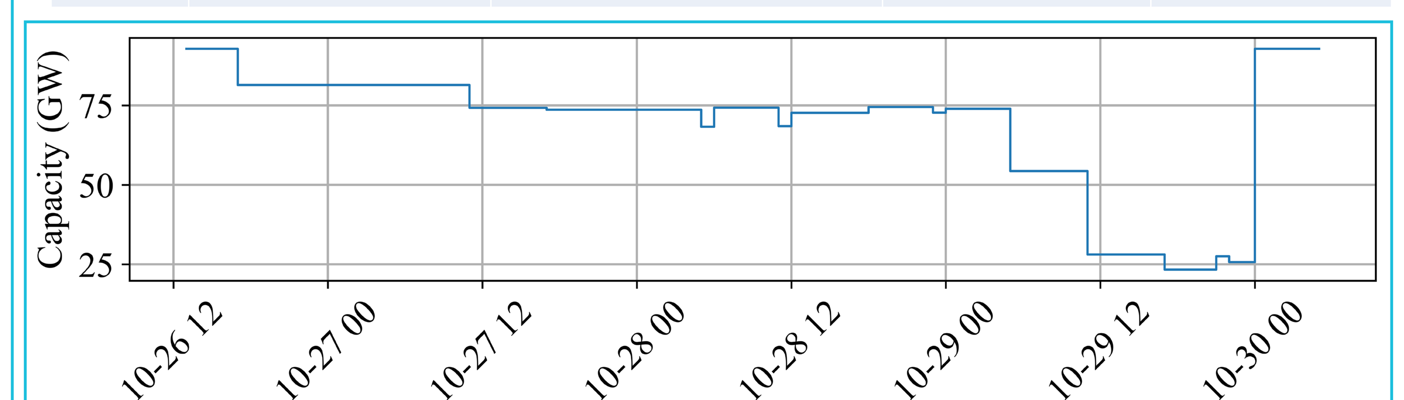

Figure 2: Progression through time of OSW generation capacity affected by cut-off wind speeds from simulations of Hurricane Sandy 2012

CONCLUSIONS

- We have implemented EGRASS to generate grid contingency sequences and operational impact estimations due to hurricanes
- Assumptions on infrastructure characteristics
  - Land-based grid fragility – collaboration with ISO's and Utilities
  - Offshore grid fragility – collaboration with developers and vendors
  - Offshore wind operational characteristics, particularly cutout speeds – collaboration with developers and vendors
- Next steps
  - Run grid impact simulation in PNNL's Dynamic Contingency Analysis Tool (DCAT) – extracting insights for OSW grid integration
  - Potential future step (currently out of scope): leverage PNNL RAFT tool to bring in hurricane events derived from future climate

ACKNOWLEDGEMENTS

This work is supported by the U.S. Department of Energy (DOE) Wind Energy Technologies Office (WETO). The project team especially thanks Jian Fu and Cynthia Bothwell from DOE WETO for their continuing support, help, and guidance.

REFERENCES

Elizondo M.A., X. Fan, S.H. Davis, et al. 2020. Risk-Based Dynamic Contingency Analysis Applied to Puerto Rico Electric Infrastructure. PNNL-29985. Richland, WA: Pacific Northwest National Laboratory.

Royer, P.D., Du, W. & Schneider, K. Rapid Evaluation and Response to Impacts on Critical End-Use Loads Following Natural Hazard-Driven Power Outages: A Modular and Responsive Geospatial Technology.Int J Disaster Risk Sci13,415–434 (2022). F.

Bereta dos Reis, P. Royer, V. Hiren Chalishazar, S. Davis, M. Elizondo, Jeffery Dagle, A. Nassif, A. Sadikovic, E. Ntakou, O. Soto, 2022. Methodology to Calibrate Fragility Curves Using LimitedReal-World Data, in IEEE Power & Energy Society General Meeting (PESGM).

Quanta Technology, "Cost-Benefit Analysis of the Deployment of Utility Infrastructure Upgrades and Storm Hardening Programs," Satell. Commun., vol. 3021, pp. 1–108, 2009.

Gaertner, E., et al. "Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine Technical Report." (2020).

CONTACT INFORMATION

Bharat Vyakaranam: BharatGNVSR.Vyakaranam@pnnl.gov