Resilience to Storm Conditions of Power Systems with Large Dependencies on Offshore Wind

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Introduction

- Major offshore wind power installations are expected
- Extreme weather events are expected to increase in frequency and intensity, driven by climate change
- Impacts on power system caused by severe weather conditions, focus on cut-off wind speeds

Purpose

- Effects on power system caused by cut-off wind speeds
- Penetration levels: 1 up to 6 offshore wind farms
- Parameters of interest:
  - Disconnected load
  - Length and magnitude of power outages
  - Actual power supply from offshore wind farms
  - Actual power supply from other generators
  - Imported and exported power

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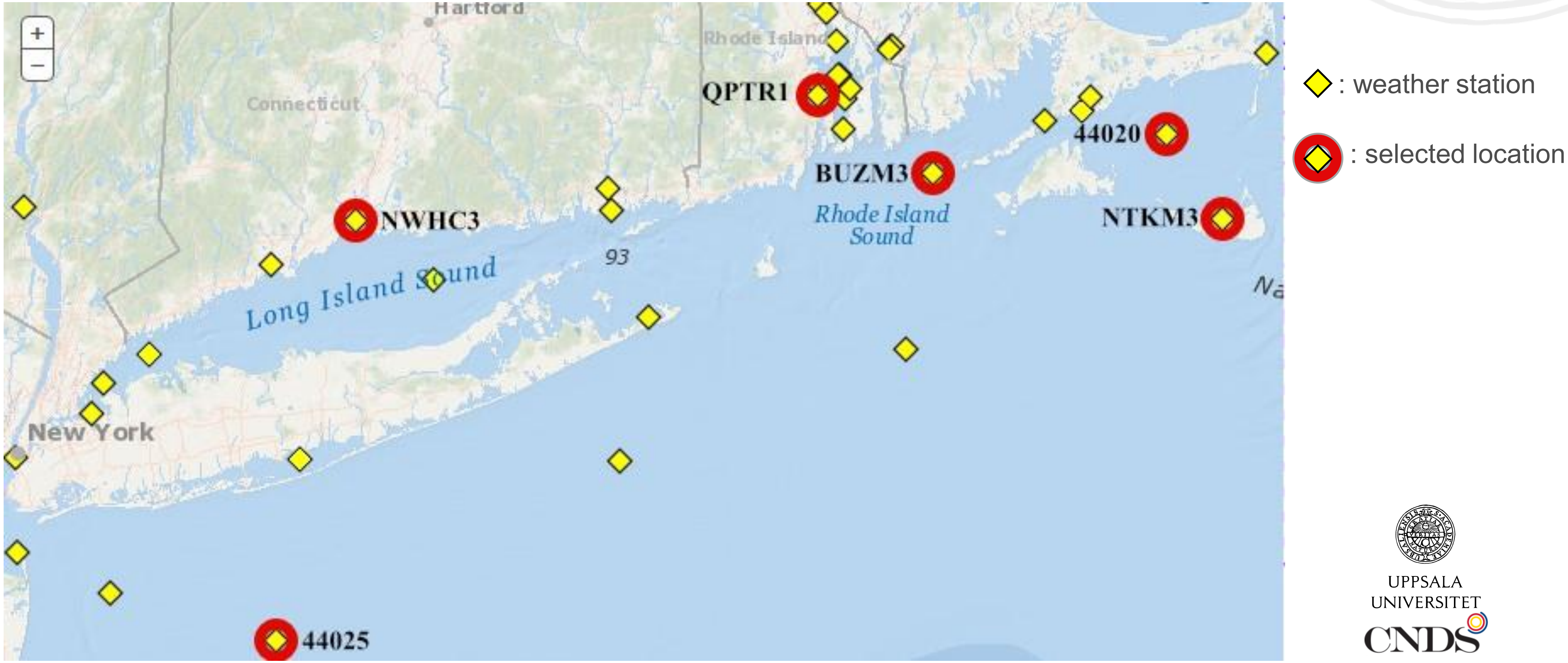
Method - data

- Geospatial wind data from four historical extreme weather events:
  - Hurricane Sandy (2012)
  - Winter Storm Nemo (2013)
  - March 2018 nor'easter (2018)
  - October 2021 nor'easter (2021)

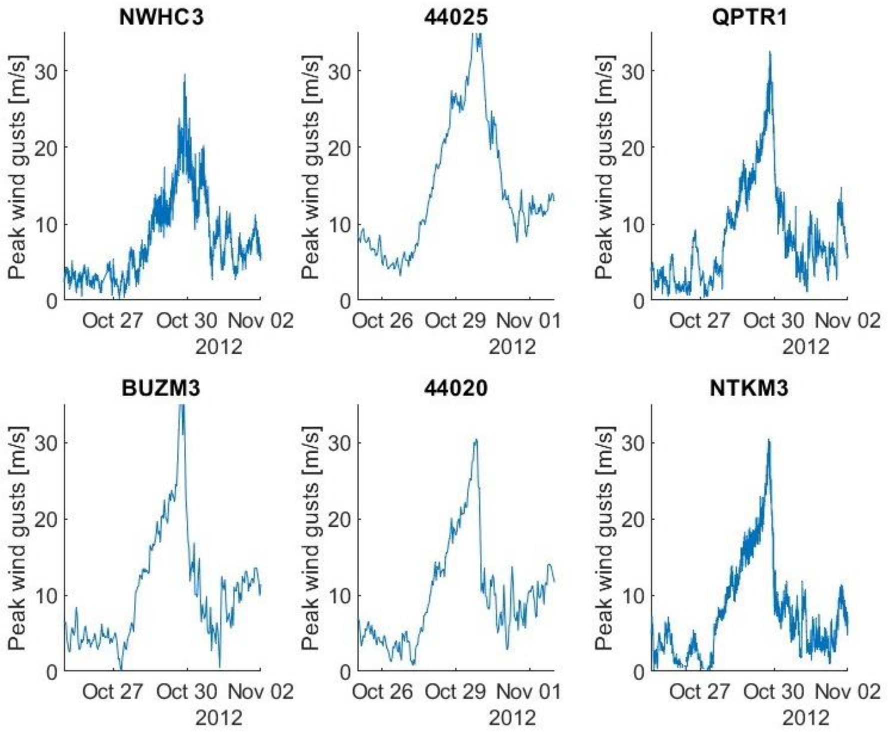
Method - data

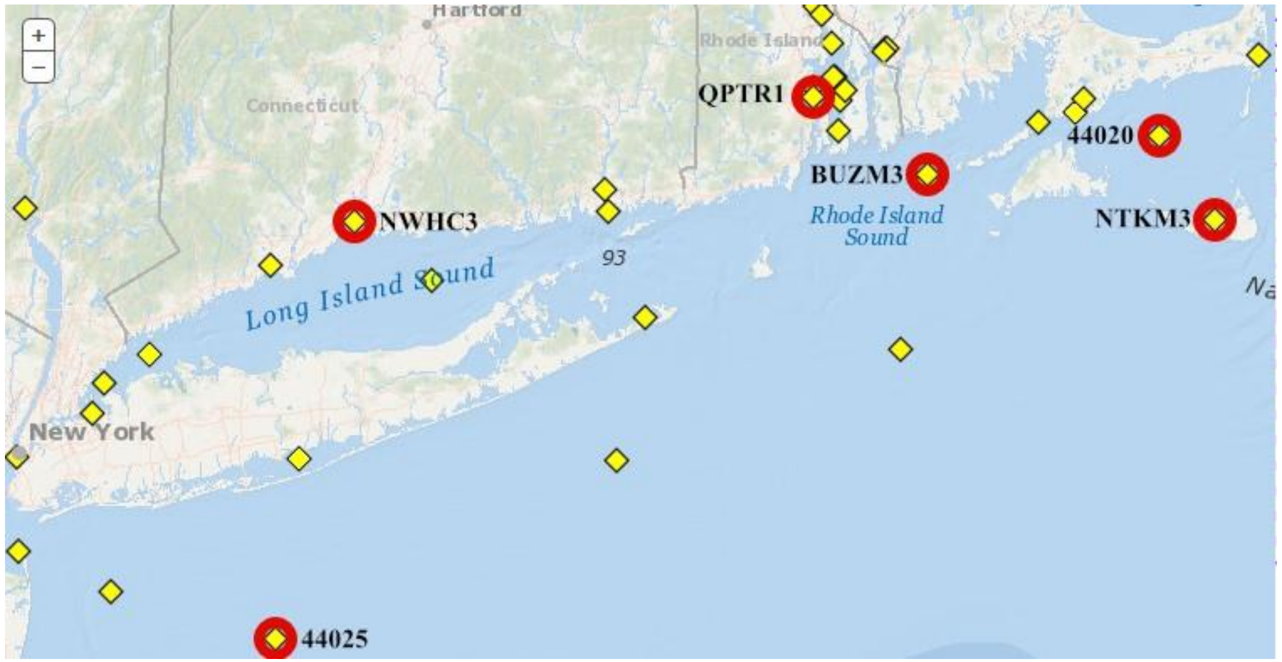
- Six locations along the southern New England coast



Method - data

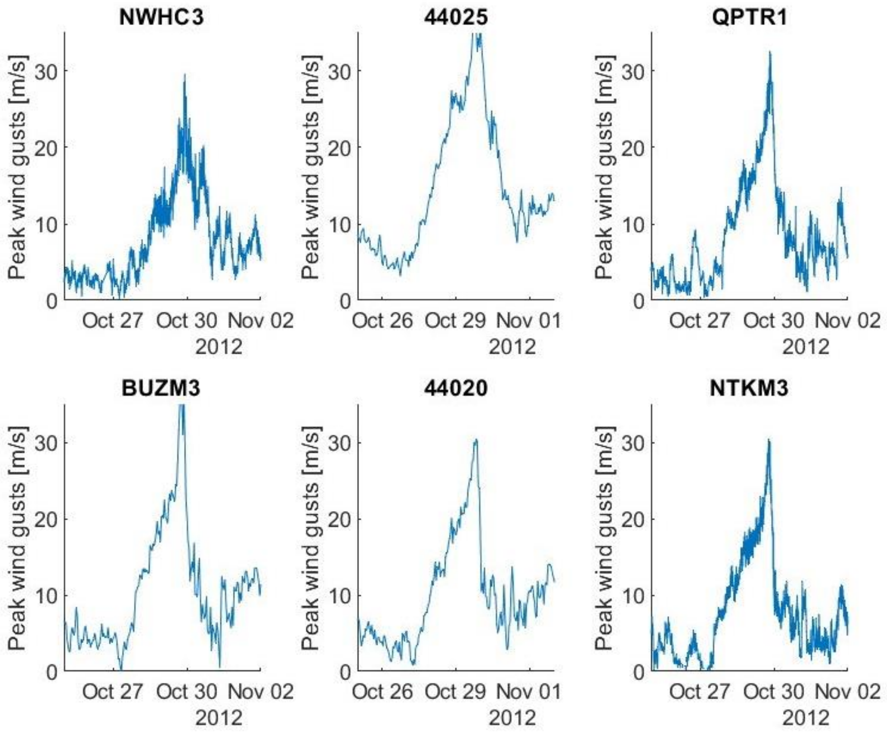
- Wind data scaled to an altitude of 100 meters
- Six minutes resolution, wind gusts
- Installed wind power capacity four times higher than original installed capacity
- Wind profiles converted to power generation profiles

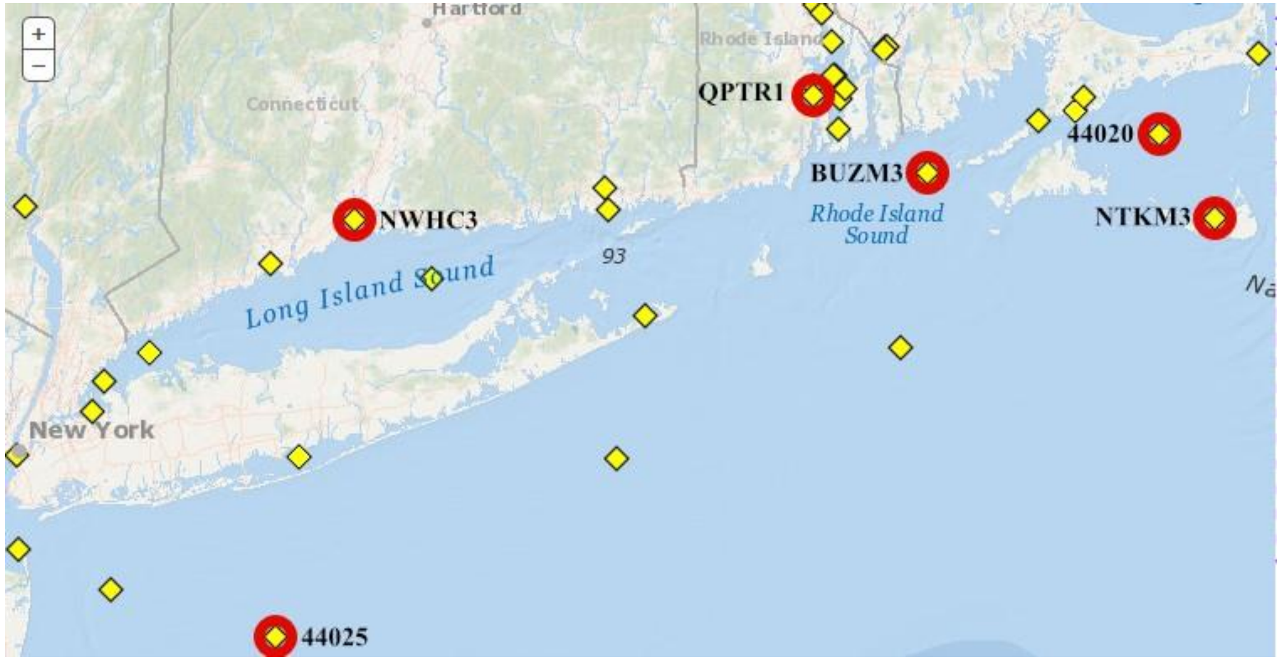




Method - data

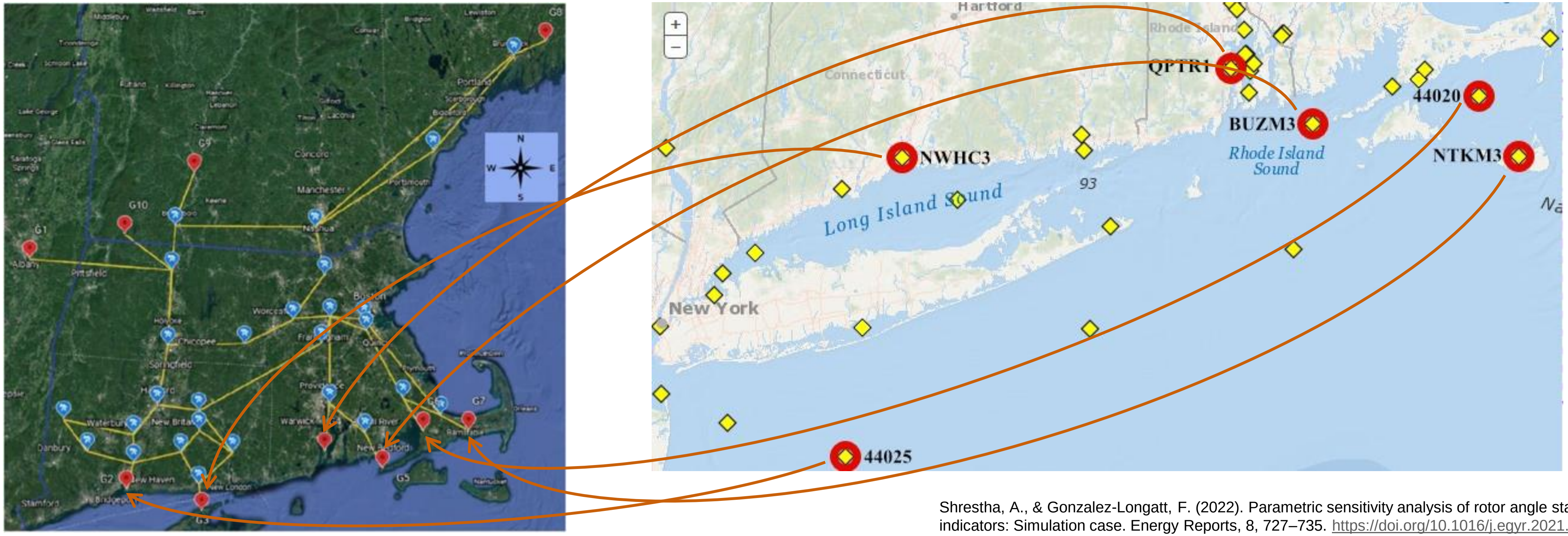
- Rated: 12 m/s, Cut-off: 25 m/s, Curtailed capacity: 23-25 m/s
- Assumed that all wind turbines in a single offshore wind farm behave as one
- Assumed constant load demand





Method - grid model

- New England IEEE39 bus system
- Import and export through slack bus
- Replaced original generators with wind farms
- Penetration levels: 1 - 6 generators replaced by offshore wind farms



Shrestha, A., & Gonzalez-Longatt, F. (2022). Parametric sensitivity analysis of rotor angle stability indicators: Simulation case. Energy Reports, 8, 727–735. https://doi.org/10.1016/j.egyr.2021.11.233.

Method - simulations

- Quasi-dynamic simulations using MATPOWER
- FDXB AC power flow analysis in each time step
- Four strategies to find a converged solution
  - Reduce largest load -10%
  - Reduce largest generator -10%
  - Reduce largest load -10%, conventional generation profile from last converged solution
  - Reduce largest generator -10%, loads taken from last converged solution
- Still no converged solution interpreted as a blackout
- Start-up time of two time steps (12 minutes) were assumed

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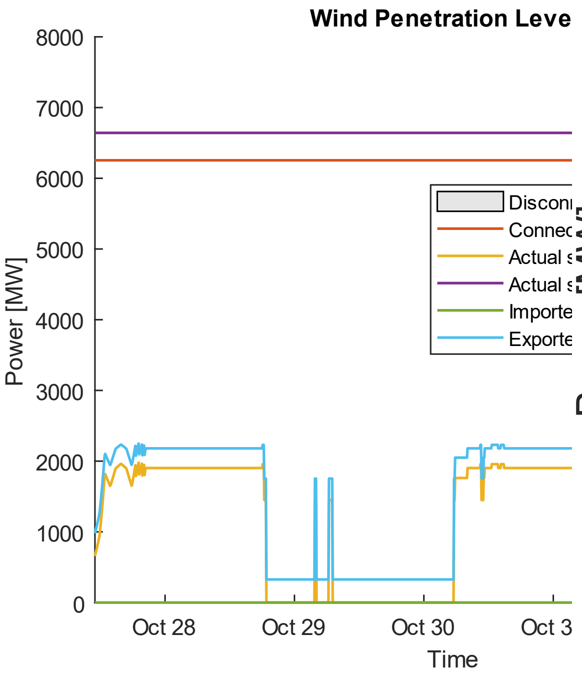
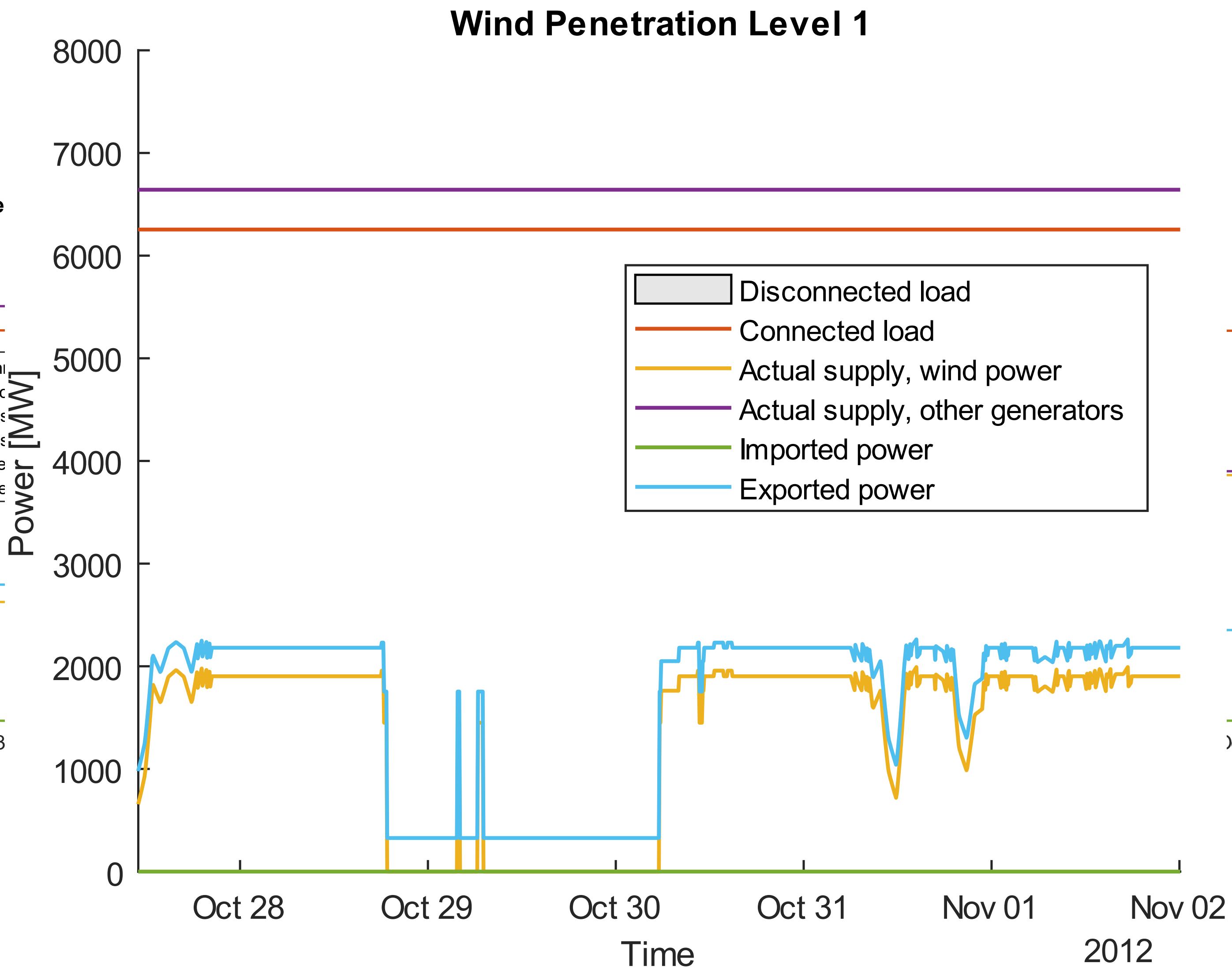
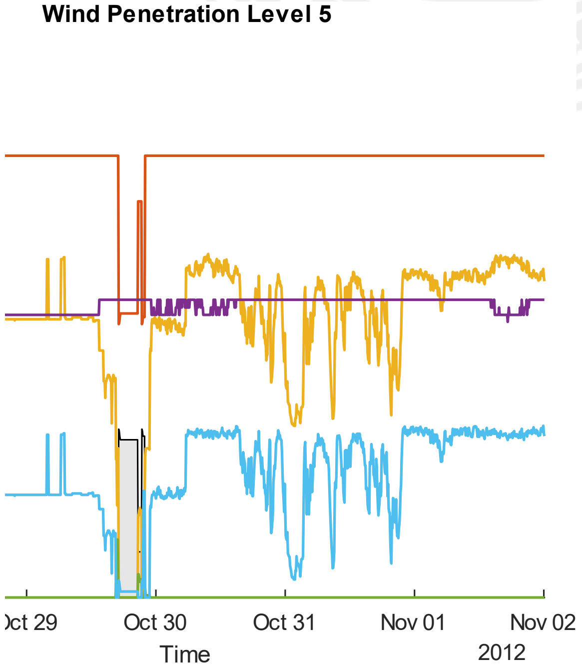
Results

- Results from all four storms show similar characteristics
- Focus on Hurricane Sandy (2012)

Hurricane Sandy (2012)







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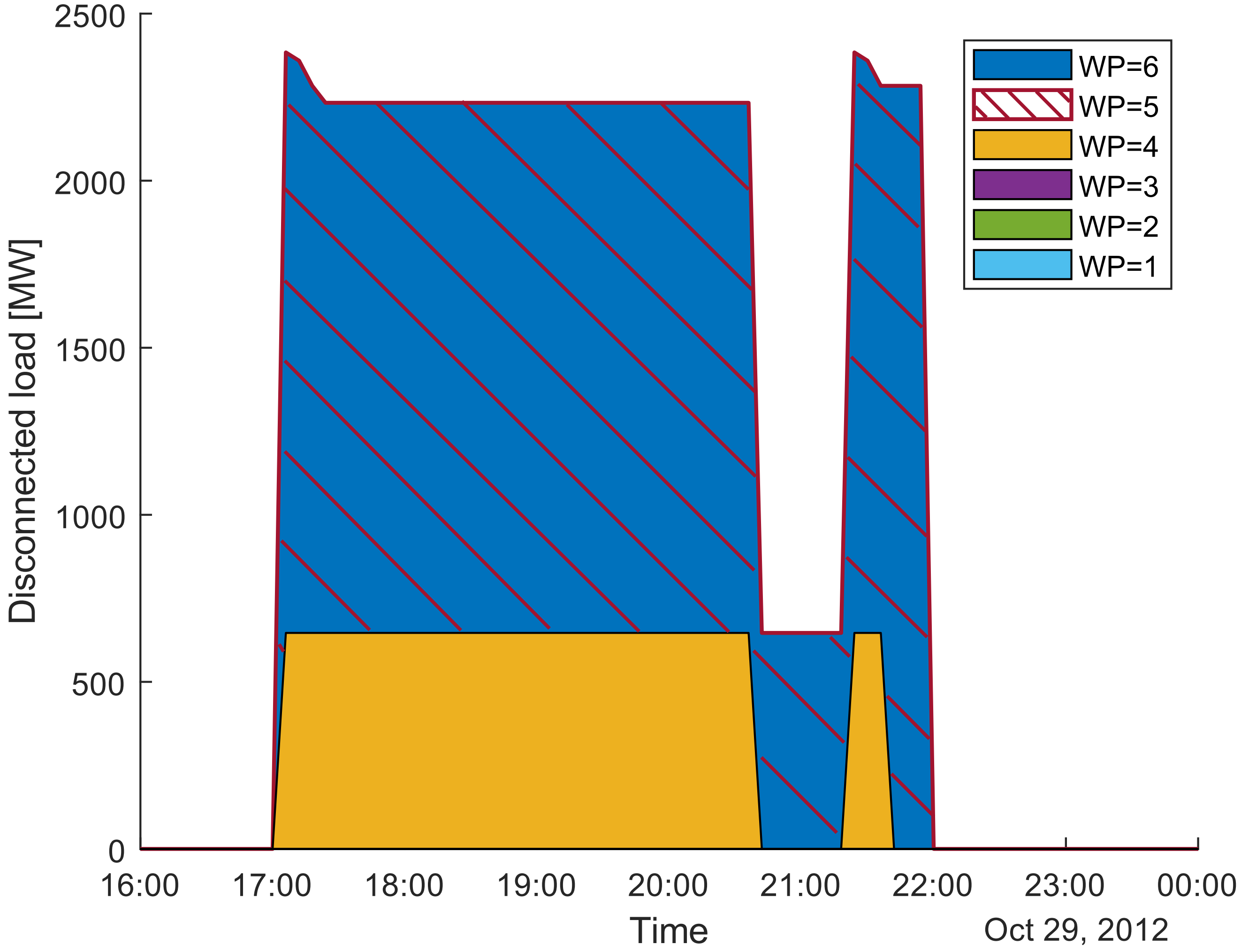
Hurricane Sandy (2012)



- Wind penetration 1, 2 & 3
  - No disconnected load
- Wind penetration 4
  - About 700 MW disconnected load during a total of 4 hours
- Wind penetration 5 & 6
  - Identical profiles – 6th wind farm connected to slack bus
  - Major power outage during storm peak
  - About 2 300 MW (1/3 of total load) disconnected load during a total of 4.5 hours
  - About 700 MW disconnected load during 0.5 hours
- Non-linear effect

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Conclusions and Future Work

- The length and magnitude of the power outages are non-linear with respect to the number of offshore wind farms – a threshold.
- Case study of Hurricane Sandy shows that 1/3 of the total load in the New England 39-bus system gets disconnected as consequence of the lack of power generation (5 or 6 conventional generators replaced by offshore wind farms).

- Implement a dynamic and realistic consumer load profile.
- Integrate storage and/or reserve capacity in the model.

Questions?

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