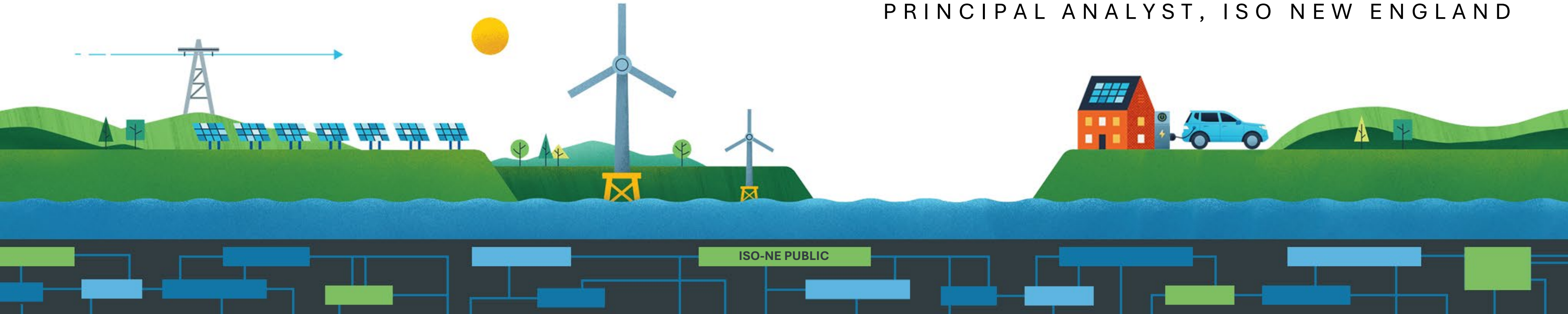
APRIL 23, 2025 | HOLYOKE, MA

Meeting the Challenges of Operating a Fast-Evolving Grid

With New Simulation and AI Capabilities

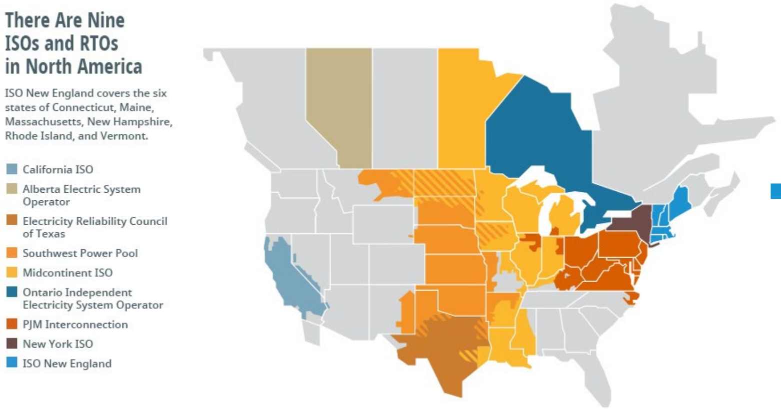
Mingguo Hong

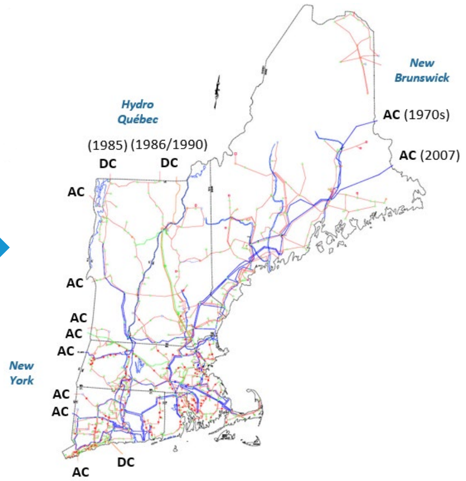
PRINCIPAL ANALYST, ISO NEW ENGLAND



Overview of the New England Footprint

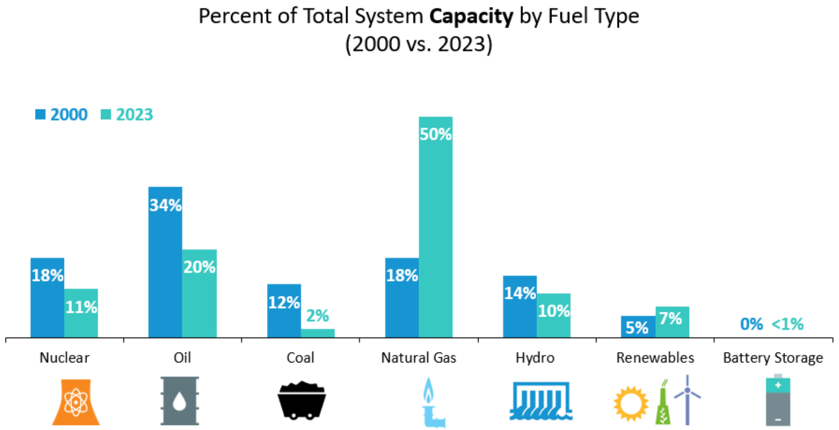
- ISO New England is a summer-peaking system with about 25,600 MW of averaged peak since 2000.
- In 2023, 13% of energy needs were met by imports from 3 neighboring power systems.
- New England is situated at the end of fuel supply chain with fuel shortage risks in winter.

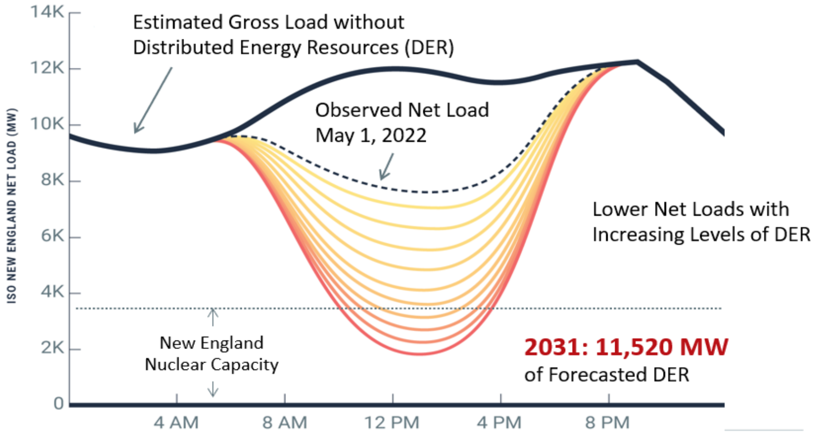




Installed Generation Capacity Changes and Behind-the-Meter Solar

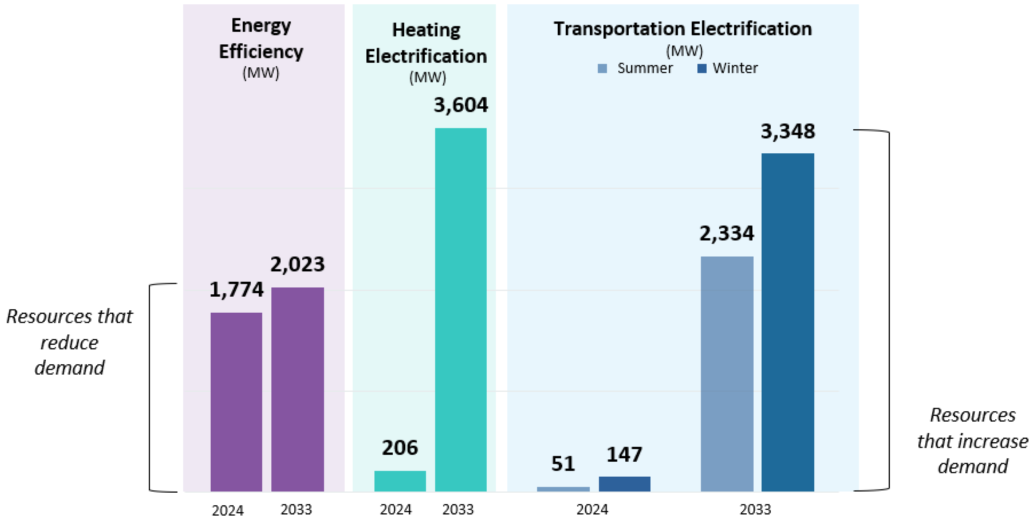
- The region's installed generating capacity shifted from nuclear, oil, and coal to natural gas.
- By 2028, the daily peak behind-the-meter solar will cause the netload to drop below nuclear generation capacity.
- The ISO Is leading efforts to account for solar resources in the distribution systems.

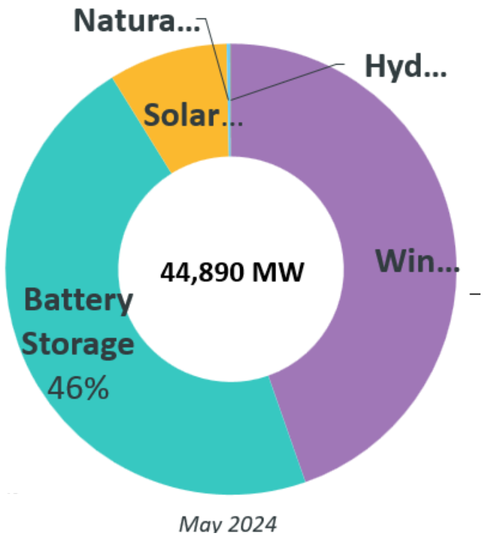




Ten-Year Outlook for Electricity Use and Current Interconnection Queue

- There is a significant increase in load forecast due to electrification.
- Interconnection requests mainly consists of renewable and storage resources.





Planning and Operational Challenges

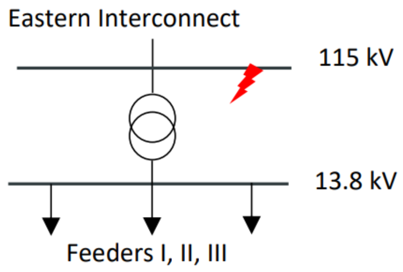
- Resource and transmission planning needs to conduct studies that capture the impact of the Inverter-Based-Resources (IBR) on system stability and reliability.
- There are growing needs to model uncertainties in forecasts of load, solar and wind generation, and design electricity market products that help to mitigate the uncertainties while maintaining power supply and demand balance.

Call for New Simulation Tools

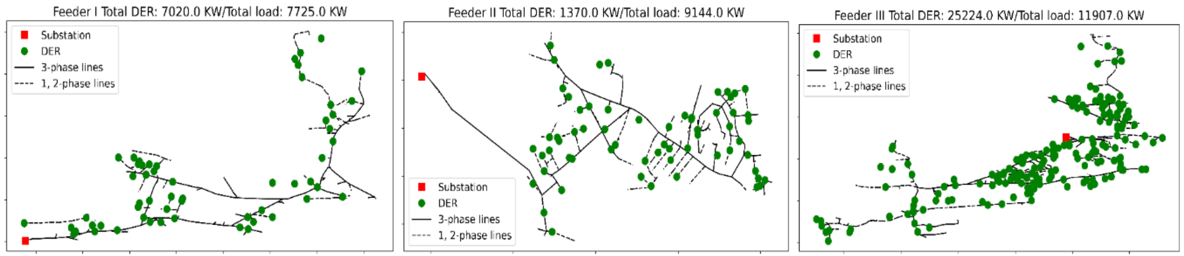
- Current dynamic simulation tools for transient and voltage stability studies
  - Phasor-domain transient stability study tools: Inaccurate positive-sequence representation of the distribution systems as DER aggregates or composite load models.
  - EMT simulation tools: Slow, poor scalability, lack of IBR OEM model details.
- Need a phasor-domain simulation tool that
  - Models both the transmission and the distribution system networks.
  - Models IBRs with levels of detail that support both accuracy and performance.

Transmission-Distribution Co-simulation (Joint project with PNNL, National Grid and VELCO)

- Phasor-domain electromechanical simulation for the T-D systems using off-the-shelf solvers while exchanging voltage and power flow data at the T-D boundary per numerical simulation time-step.
- Achieves reasonably accurate solutions that describe the dominant system response trajectories following network events such as a fault.



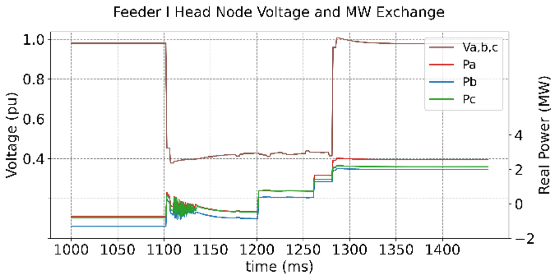
Full Transmission Model in PSS/E

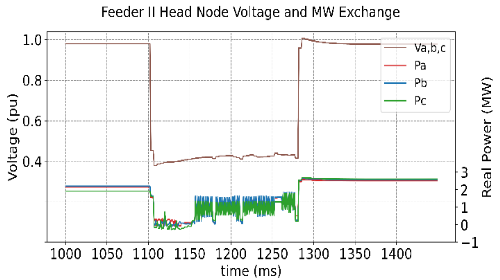


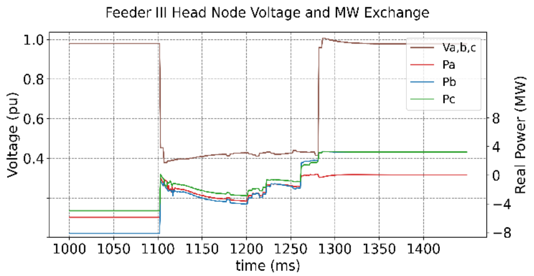
Distribution Feeder Models with DERs in GridLAB-D

T-D Co-Simulation Case Study: DER Voltage-Ride-Through During Fault

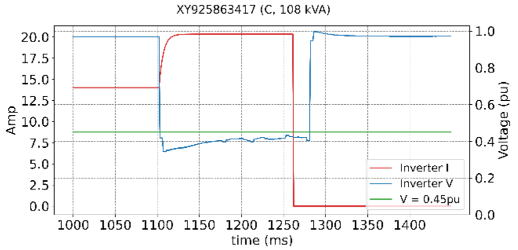
Voltage and power exchanges at the T-D boundary:

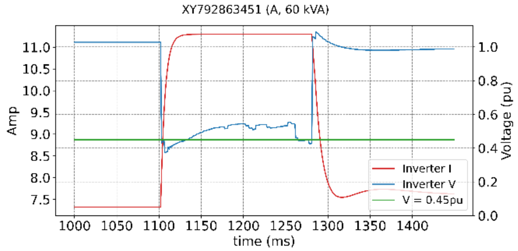






DER responses - tripping vs. ride-through:

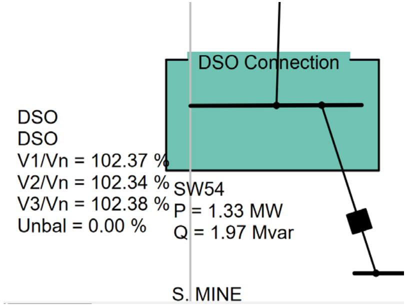


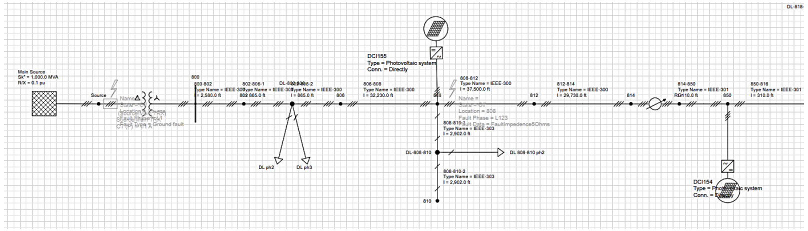


Integrated T-D Simulation: A Joint Project with Siemens

- Key Futures:
  - A phasor-domain dynamic simulation tool.
  - Three-phase modeling of transmission and distribution systems.
  - Three-phase and single-phase inverter models.

- Advantages and disadvantages
  - Ability to simulate unbalanced networks and unbalanced fault events.
  - Fast simulation time.
  - Limited model libraries for the transmission system.





Uncertainty Modeling with Copulas

- The Copula *C* expresses the cumulative joint distribution of random variables as a function of the cumulative marginal distribution of the variables.

$$F_t(y_1, y_2, \dots, y_n) = C\big(F_1(y_1), F_2(y_2), \dots, F_n(y_n)\big)$$

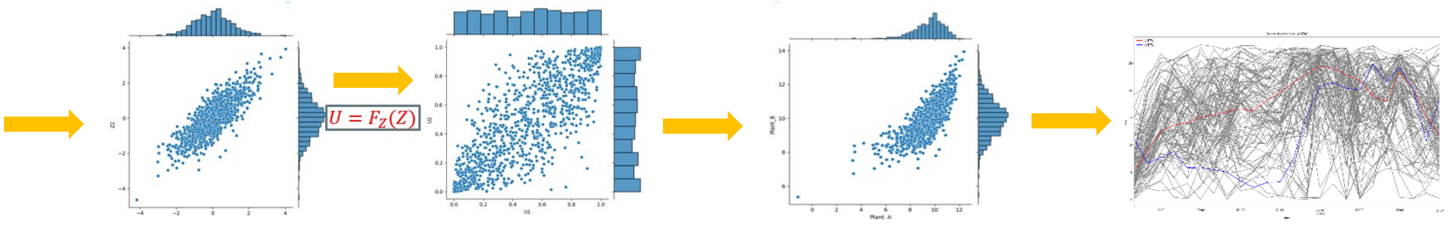
- Copula can help create forecast scenarios with spatiotemporal correlation:

S = {(MW_load(z, t), MW_solar(z, t), MW_wind(z, t)) | (z, t)}

for evaluating system operational risk under given weather forecast.

Covariance matrix

Cov	A	B
A	1	0.8
B	0.8	1



What Can AI Do?

- Traditional AI and Generative AI have found many areas of applications in sciences and technologies. They are transforming our lives daily. How much help can they provide to power system operators?
- There have been several successful research projects at the ISO New England that proves the effectiveness of AI in voltage control, DER aggregate modeling, load and renewable forecasting, etc.
- Regardless of the known challenges (confidentiality of operational data and complexity of power system scenarios), AI can and will play critical roles in power system decision making - from providing advisory assistance to close-loop control.