U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Wind Models – A DOE's Perspective

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U.S. Department of Energy

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Wind Office Program Overview

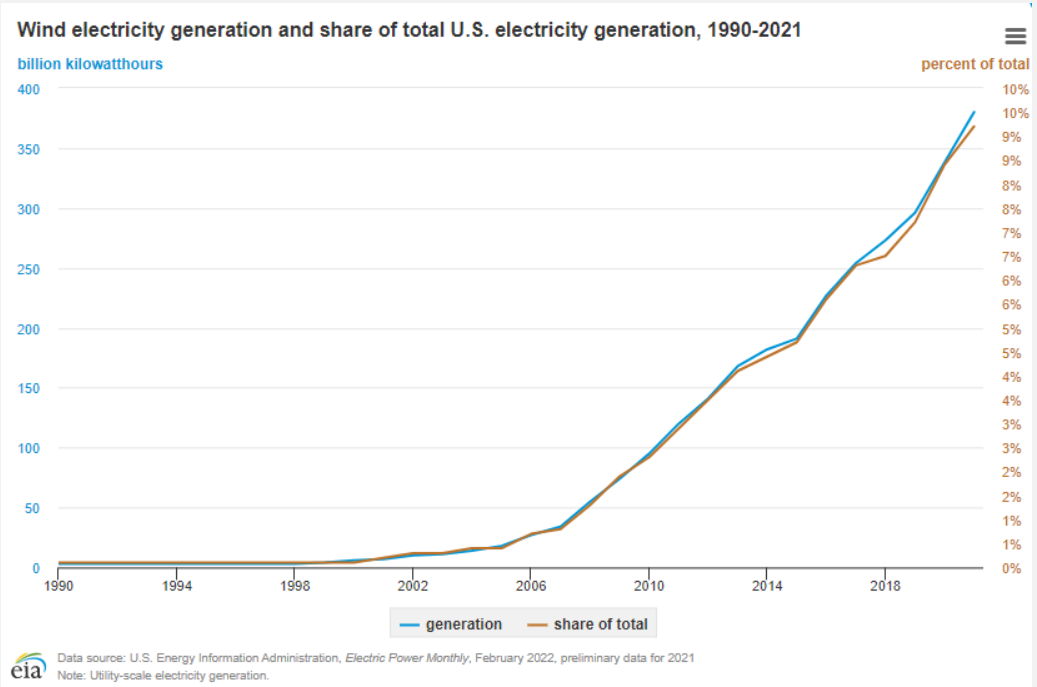
Focus Areas

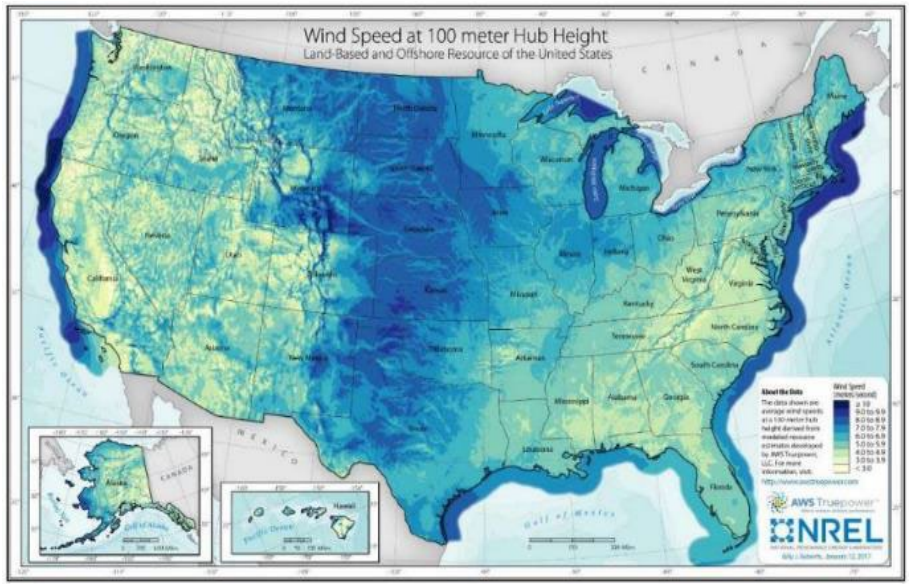
- Offshore Wind
- Land-Based Wind
- Distributed Wind
- Systems Integration
- Data, Modeling, and Analysis

Top Line Priorities

- Aggressive Cost Reduction
- Scaling and Light-Weighting
- Environmental and Siting Solutions
- Transmission Access and Grid Reliability and Resilience

U.S. Wind Industry: Past, Now, Future





Current U.S. Land-Based Wind:

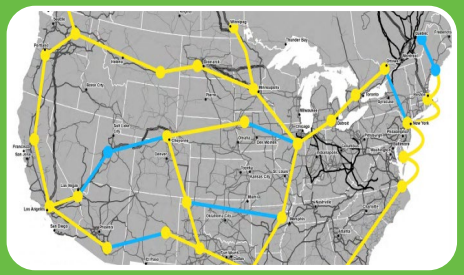
- A 13,413 megawatts (MW) of U.S. wind capacity was installed in 2021, Cumulative total 135,885 MW installed
- Provides 20%+ of electricity in 11 states, 30%+ in Iowa, South Dakota, Kansas, Oklahoma, and North Dakota
- Instantaneous penetration records are much higher: 88.5% SPP, 69% ERCOT,

Accelerating Wind Energy Deployment to meet Decarbonization Goals:

- At least 700 GW new capacity of land-based wind by 2035*
- The Administration's 30 GW of Offshore Wind by 2030, which could unlock a pathway to 110 GW or more by 2050
- Floating Offshore Wind Shot** will enable 15 GW of floating offshore wind by 2035

* https://www.nrel.gov/analysis/100-percent-clean-electricity-by-2035-study.html
**https://www.energy.gov/eere/wind/floating-offshore-wind-shot

Wind Systems Integration Challenges

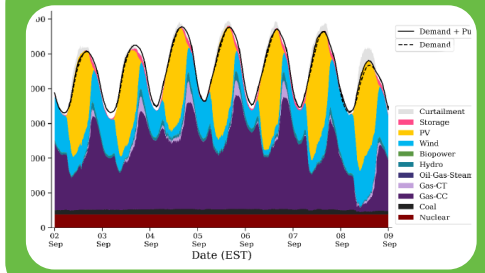


Transmission Adequacy and Access

- Planning and permitting long lines take very long time due be complex regulatory processes in U.S.
- Limited POI and landing points require proactive planning for long- term deployment needs while not slowing down near-term projects.
- Advancement in transmission technologies such as HVDC is critical.

Impact of Inverter Based Resources on Grid stability, Resiliency, and Security

- Rising concerns of grid stability due to higher shared of inverter-based resources.
- Increasing extreme weather events threaten grid resilience.
- Wind can be controlled to provide grid services; however, market participation is still very limited

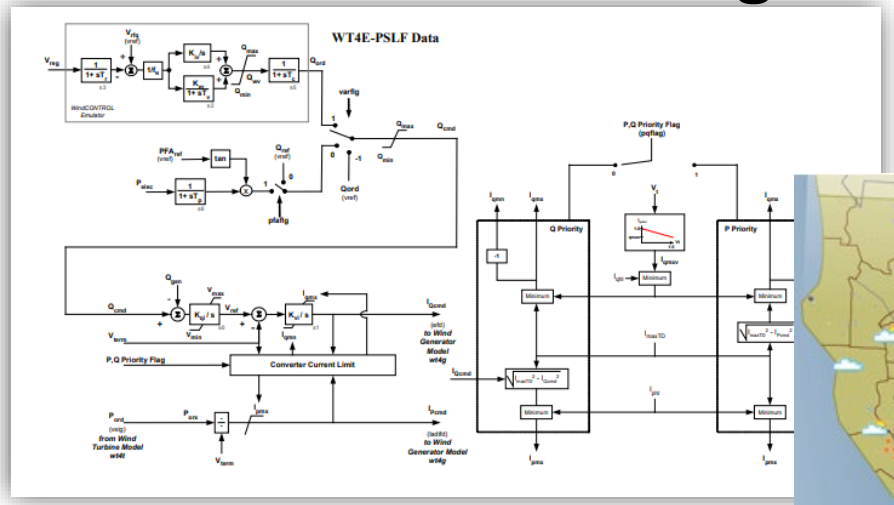


Uncertainty and Variability of Weather-based resources

- Growing wind and solar resources demand better forecast and greater system flexibility.
- Wind hybrid systems have unique values that are not fully explored.

Accurate Models are Essential

Modeling

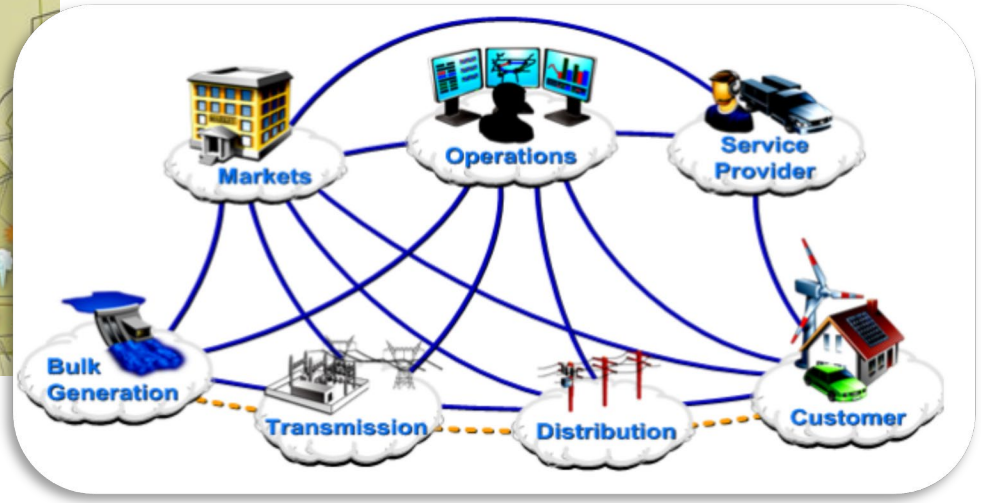


Source: WECC

Studies

Source: CAISO

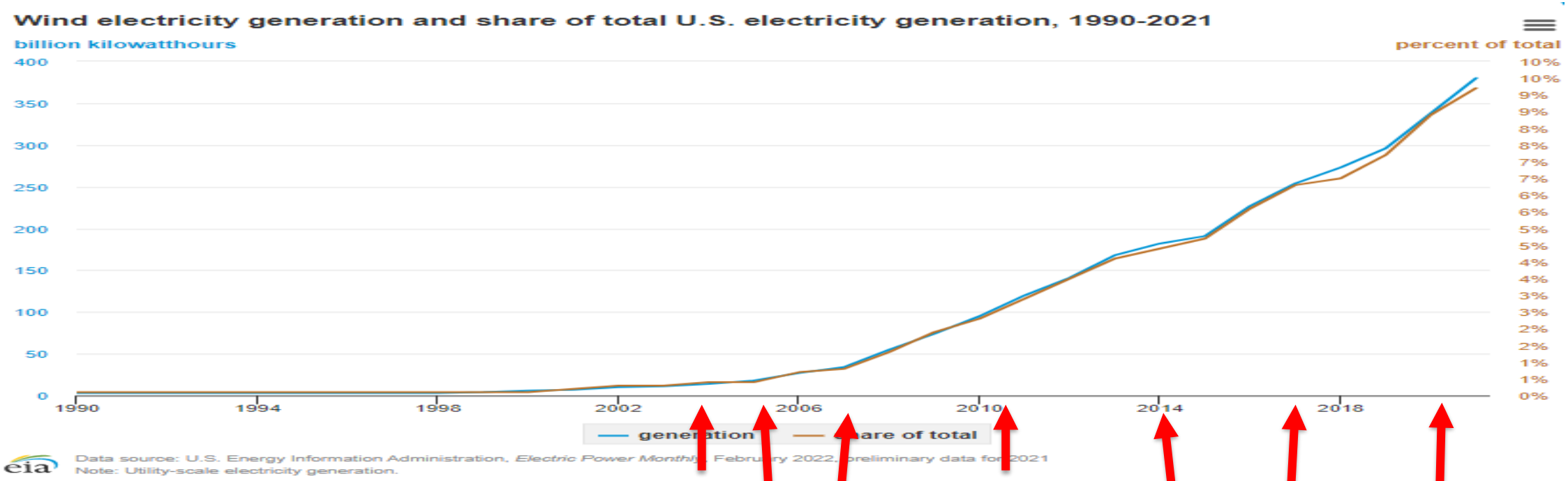
Reliability Decisions



Source: DOE/GMLC

Courtesy of Ryan Quint

Evolution of Generic Positive Sequence Models



WECC Wind Generation Modeling TF

ERCOT dynamic models of WTG

WECC 1st generation wind models

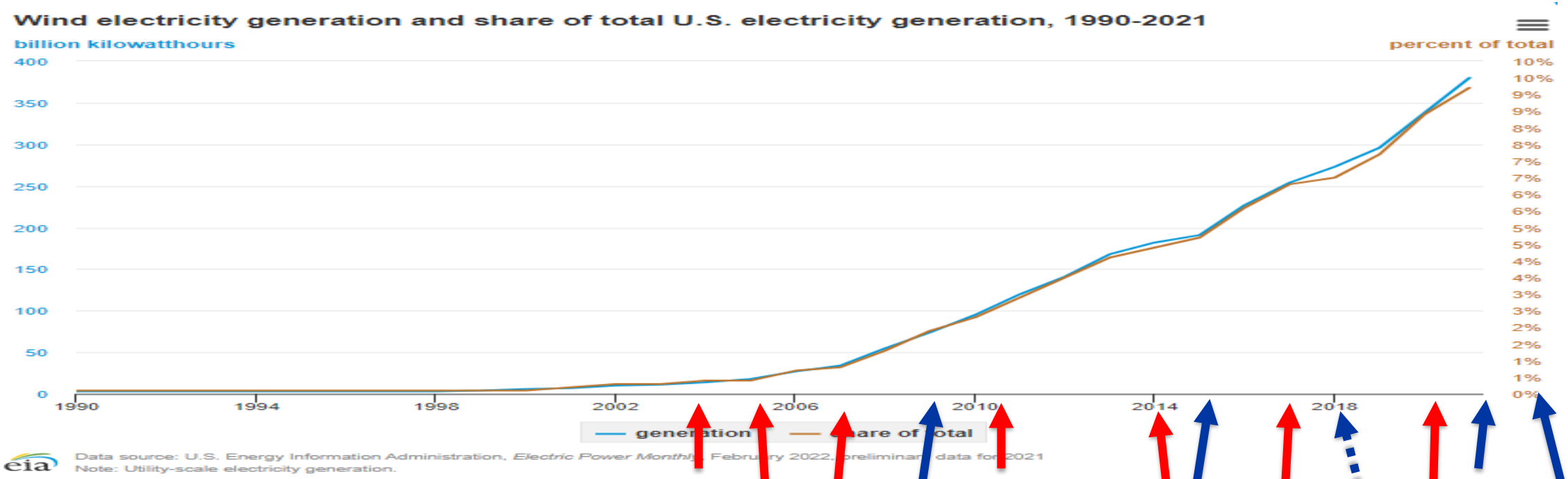
- Some issues with 1st generation models
- NERC report on needs of generic models on
- *WECC Renewable Energy Modeling TF*

WECC 2nd generation models

WECC Weak Grid Option Modeling update

WECC Renewable Energy Modeling WG

The Need for EMT Models



WECC Wind Generation Modeling TF

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WECC 1st generation wind models

ERCOT SSR Event

Some issues with 1st generation models

- NERC report on needs of generic models on
- *WECC Renewable Energy Modeling TF*

WECC 2nd generation models

ERCOT request EMT models for new IBRs

WECC Weak Grid Option Modeling update

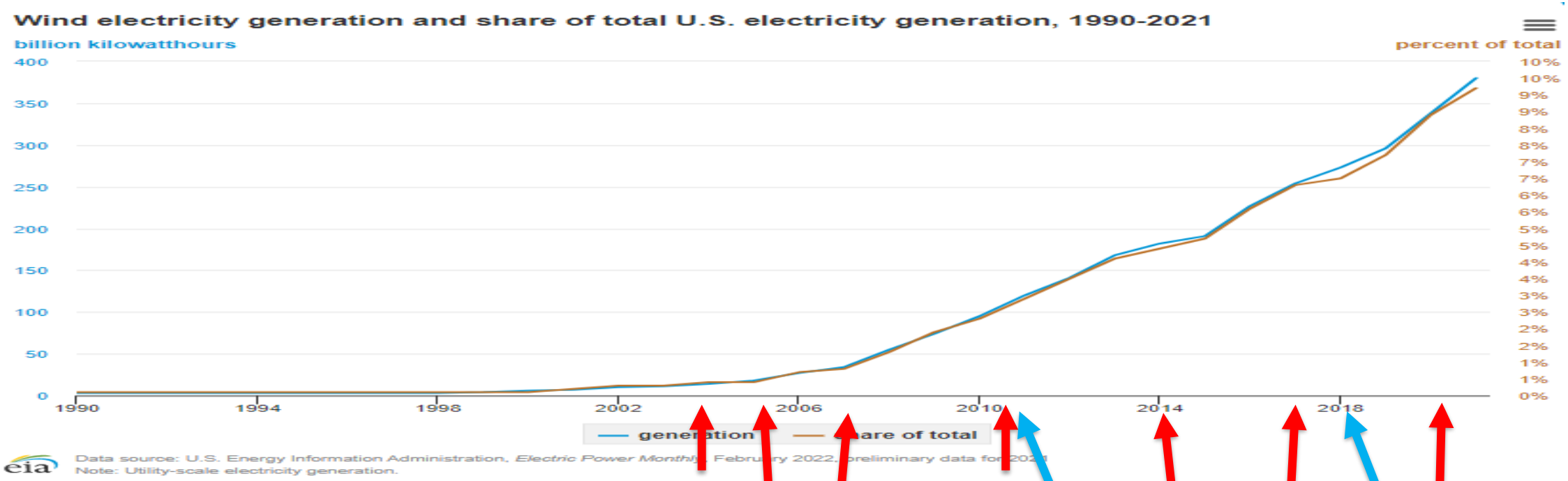
AEMO EMT model request

WECC Renewable Energy Modeling WG

CAISO EMT Model req.

NERC IRPS supports EMT models in MOD, TPL, FAC standards request

Short Circuit Models



WECC Wind Generation Modeling TF

ERCOT WTG dynamic model development

WECC 1st generation wind models

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Wind plant Short Circuit behavior report

WECC 2nd generation models

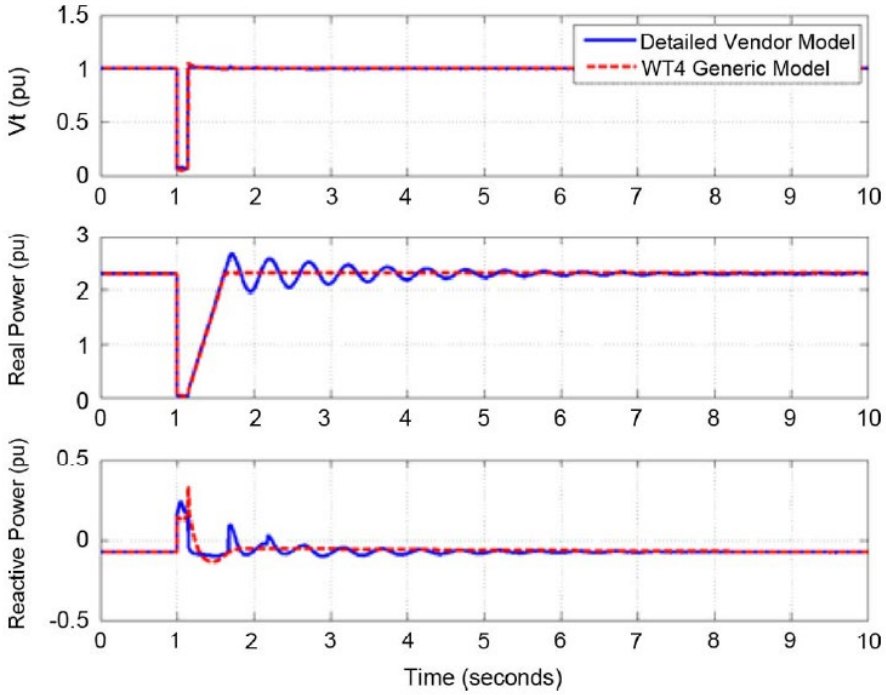
WECC Weak Grid Option Modeling update

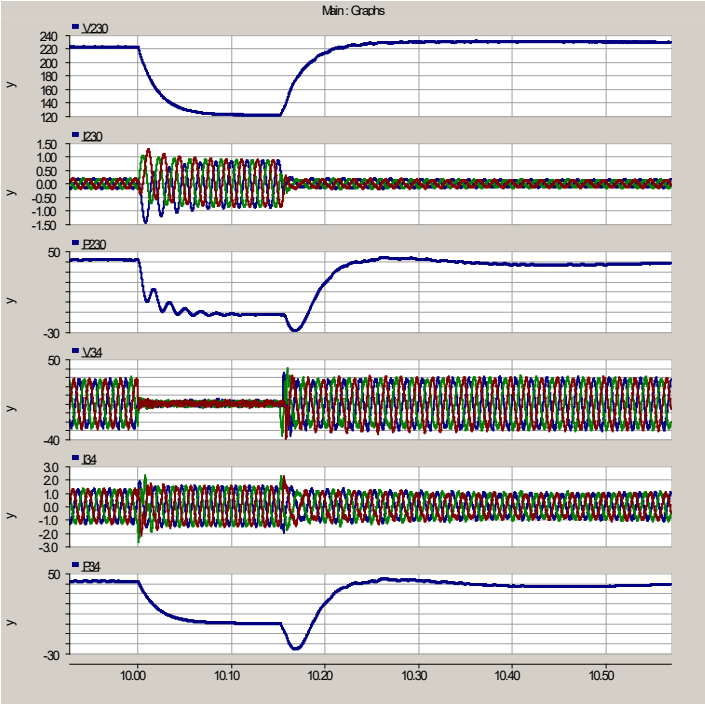
WECC Renewable Energy Modeling WG

Generic IBR Short Circuit Model for commercial tools

Measurement Based Model Validation

- Define the model and model structure
- Collect recorded/measured data from the actual device
- Compare the simulated response of the device to the recorded response and repeat





NERC Recent Wind Event Report

- Fault-induced generation loss events

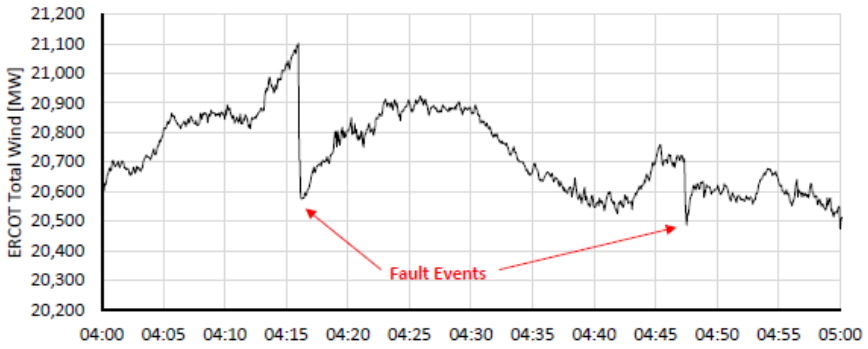
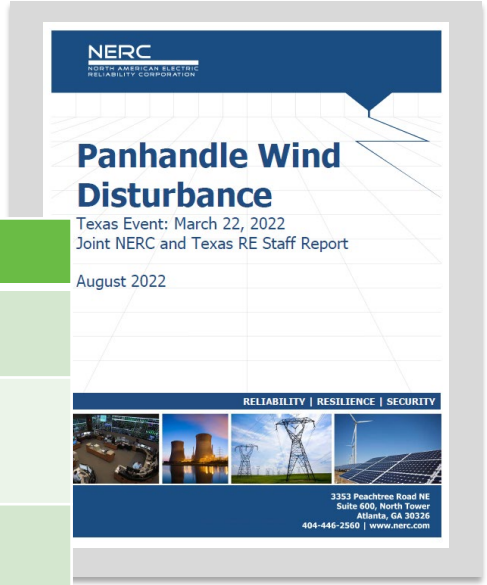


Table 1.1: Causes of Reduction for Fault 1 and Fault 2

Cause of Reduction	Fault 1 Reduction [MW]	Fault 2 Reduction [MW]
Consequentially Tripped	273	–
Plant Controller Interactions	138	144
AC Overvoltage Tripping	135	64
Dynamic Active Power Reduction	82	128
Subsynchronous Oscillation Tripping	64	55
Pitch Converter Faults	57	17
Not Analyzed	14	–
Uninterruptible Power Supply Failure	2	–

- Recommendations

Recommendations	Applicability
Improvements to Interconnection Process	FERC
Need for Performance-based Generator Ride Through Standards	NERC
Reinforcement of Need for Standard to Complement PRC-004 on Analyzing and Mitigating Abnormal Performance Issues	NERC
Follow up with Affected Facilities Owners for Corrective Actions	ERCOT
Detailed Model Quality Review	ERCOT
Model Validation Effort	ERCOT



Demand for Refined Wind Models when IBR penetration grows

- **Generic Positive Sequence Model**
  - Improvement with new wind turbine/plant controls
  - Offshore wind models with HVDC export cables
  - Wind hybrid models
- **Short circuit model**
- **EMT models for fast controls**
- **Model Validation**

Thank you!

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