Energy Systems Integration Group (ESIG) i2X Workshop

Model Validation based on Events

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What is ERCOT?

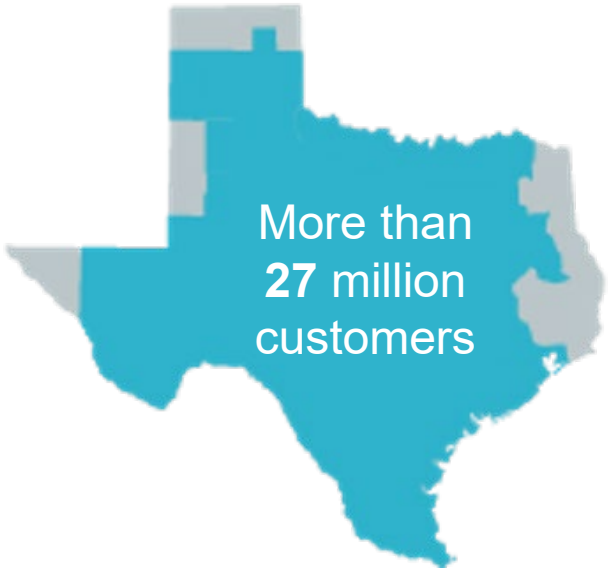
The Texas Legislature restructured the Texas electric market in 1999 and assigned ERCOT four primary responsibilities:

- **Maintain system reliability**
- **Facilitate a competitive wholesale market**
- **Ensure open access to transmission**
- **Facilitate a competitive retail market**

ERCOT is a nonprofit organization regulated by the Public Utility Commission of Texas, with oversight by the Texas Legislature.

ERCOT is not a Market Participant and does not own or maintain generation or transmission/distribution wires.

ERCOT Facts



85,508 MW

Record peak demand (August 10, 2023)

115,596+ MW

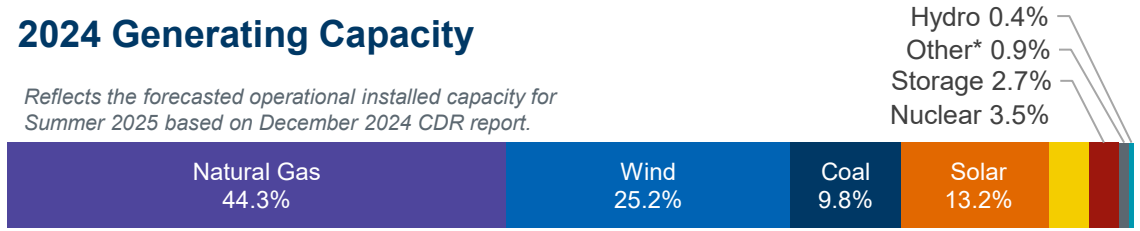
Expected capacity for summer 2025 peak demand (May 2024 CDR)

$3.8 billion

Transmission projects endorsed in 2024

2024 Generating Capacity

Reflects the forecasted operational installed capacity for Summer 2025 based on December 2024 CDR report.



The sum of the percentages may not equal 100% dues to rounding.
**Other includes biomass-fired units and DC tie capacity.*

2024 Energy Use

** Other includes solar, hydro, petroleum coke (pet coke), biomass, landfill gas, distillate fuel oil, net DC-tie and Block Load Transfer important/exports and an adjustment for wholesale storage load.*

1 MW of electricity is enough to serve about 250 residential customers during ERCOT peak hours.

39,518 MW

Wind

of installed wind capacity as of May 2025, the most of any state in the nation

28,550 MW
Generation Record
(March 3, 2025)

69.15 %
Penetration Record
(April 10, 2022)

30,305 MW

Solar

of utility-scale installed solar capacity as of May 2025

25,041 MW
Generation Record
(March 10, 2025)

54.23%
Penetration Record
(March 1, 2025)

~76 % (~36,966 MW)

Preliminary **Wind + Solar** Penetration Record (March 1, 2025)

10,193 MW

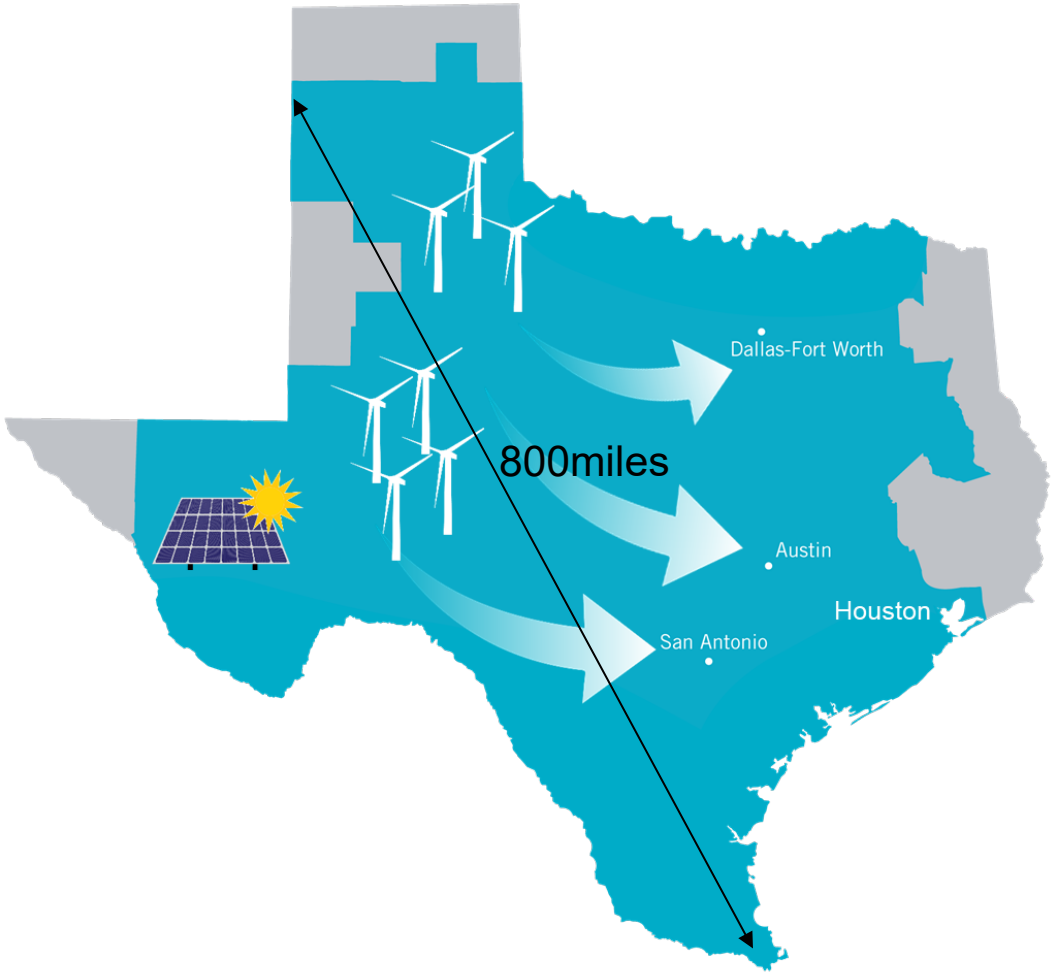
Battery Storage

of installed battery storage as of May 2025

4,963 MW
Storage Discharge Record
(March 10, 2025)

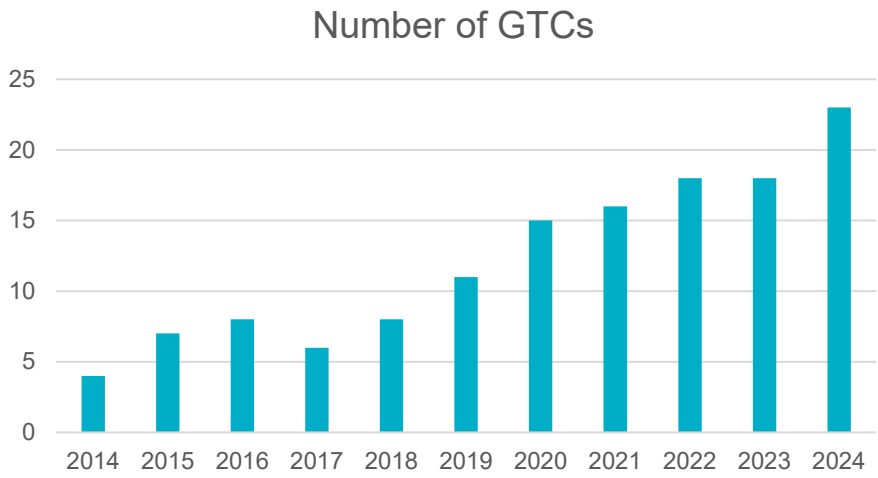
Stability Concerns

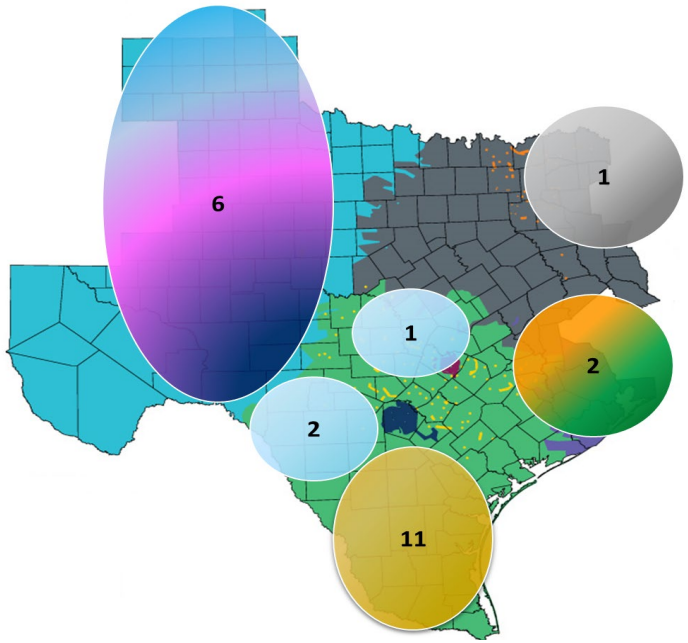
- Most wind and solar generation are in West Texas
  - Long distance transfer to load centers
  - Limited/no online synchronous generators in West Texas during high IBR output periods
  - Increasing stability concerns observed in Planning and Operations studies
- Similar issues are also manifesting themselves in South Texas
- More instability issues are expected as the total IBR capacity increases from the current ~80GW to ~130GW by 2027



Increasing stability constraints

- A Generic Transmission Constraint (GTC) is a tool that ERCOT uses to manage stability limitations in real-time operations.
- ERCOT has seen an increase in stability constraints in recent years, particularly in West Texas and South Texas, which has led to an overall increase in the number of GTCs
- These stability constraints can limit power transfers below the physical thermal ratings of transmission lines
- Most of GTCs are based on off-line PSS/e studies
- ERCOT is in the process of implementing real-time stability assessment tool (TSAT) to identify and determine the proper stability constraints based on the real time system conditions





Dynamic Model Requirement

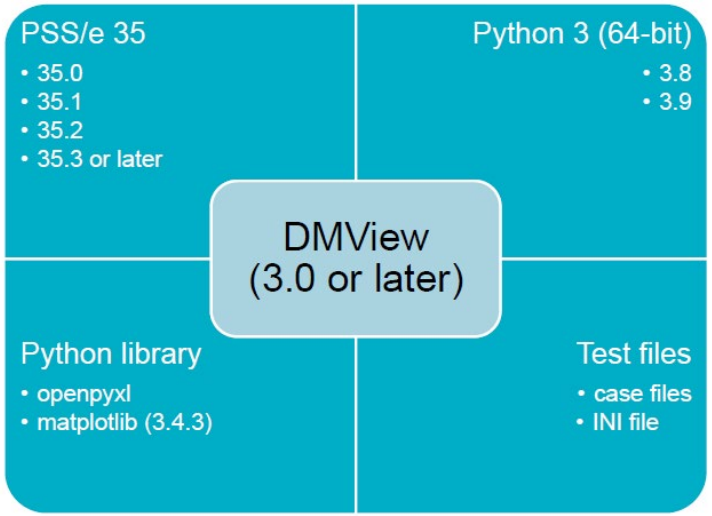
- Simulation Software:
  - PSS/e & TSAT: Positive sequence RMS model
    - Time step: 1-4 ms
    - Maximum bandwidth of 10Hz
    - Large system transient stability studies
  - PSCAD: instantaneous EMT model
    - Time step: 5-50 us
    - Can accurately capture the detailed and fast inverter control
    - High frequency related studies such as SSR

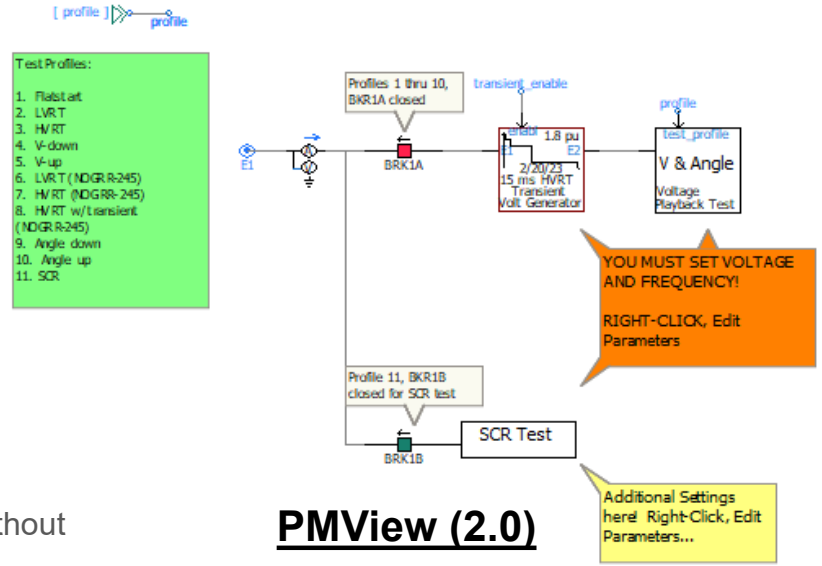
Dynamic Model Requirement

- Consistent response between PSS/e and PSCAD is required for IBR model testing and benchmarking (“MQT”)
- Model Parameter Verification
  - Provide evidence that tunable model parameters match what is implemented in the field
- Unit Model Validation for PSCAD Model
  - Benchmark the PSCAD model again actual hardware measurement
  - A hardware type test. Not a site-specific test

Model Quality Test (MQT)

- ERCOT required MQT for IBRs
  - Flat Start
  - Volage Step Down/Up 3%
  - Frequency Step Up 0.3Hz
  - Frequency Step Down 0.3Hz with and without headroom
  - HVRT (high voltage ride-through)
  - LVRT (low voltage ride-through)
  - SCR (short-circuit ratio)
  - PAJ (phase angle jump, only applied to PSCAD)
- Simulation based MQT Tools
  - PSS/e: DMView (https://sites.google.com/view/dmview/home)
  - PSCAD: PMView (https://sites.google.com/view/pmview/home)
  - TSAT: Powertech MQT Case Preparation Tool (https://www.dsatools.com/news)



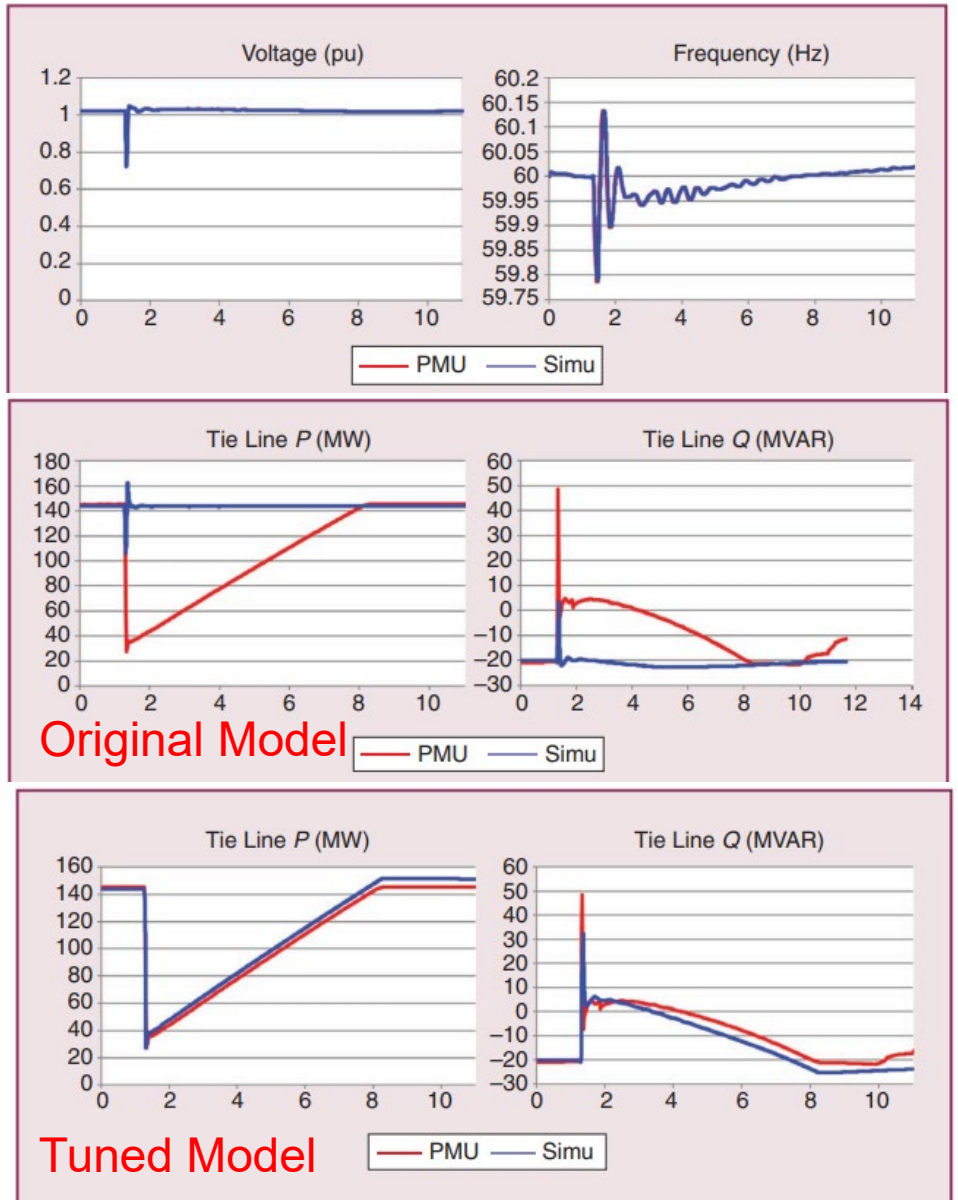


PMView (2.0)

PMView and DMView are non-commercial tools freely offered “as-is” without any warranty or implied functionality

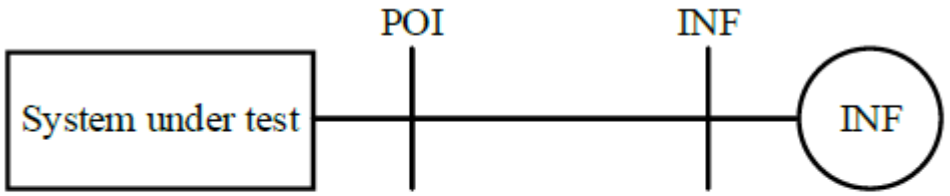
Dynamic Model Validation – PSSE & DMView

- Compare model response with the recording data to validate the model as part of post-event analysis
- DMView can playback the voltage & frequency as recorded by PMU and compare with simulation (model) response

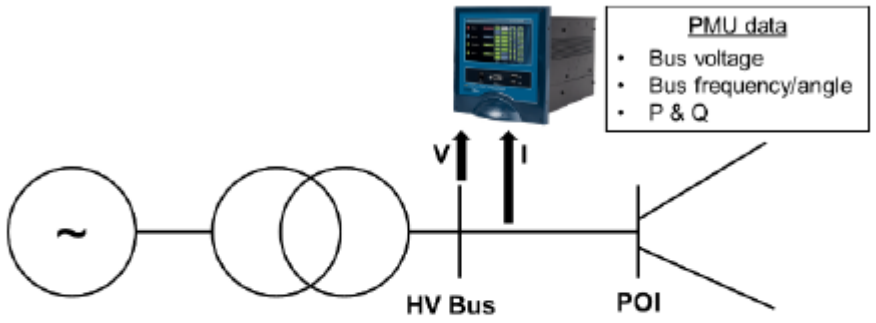


Reference: D. Ramasubramanian et al., "Techniques and Methods for Validation of Inverter-Based Resource Unit and Plant Simulation Models Across Multiple Simulation Domains: An Engineering Judgment-Based Approach," in IEEE Power and Energy Magazine, vol. 22, no. 2, pp. 55-65, March-April 2024, doi: 10.1109/MPE.2023.3343679.

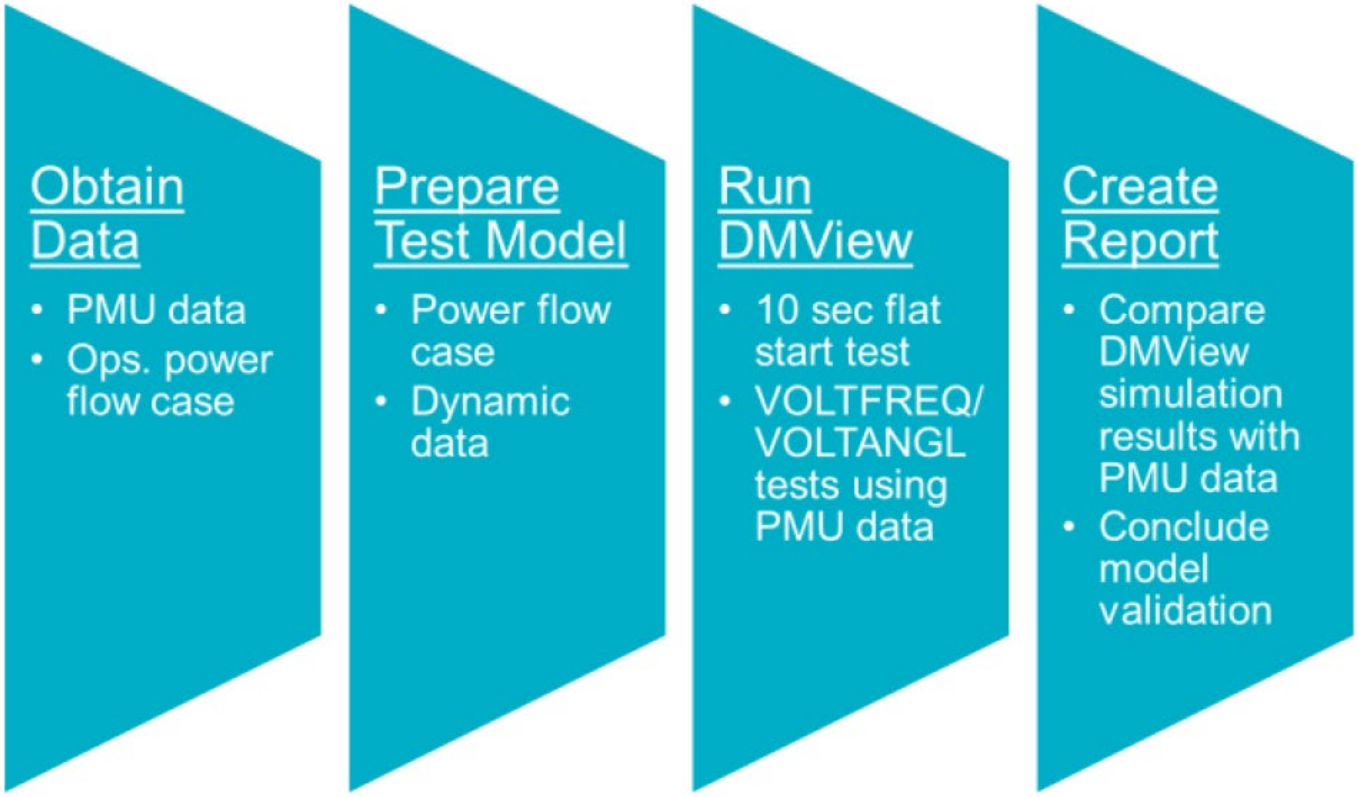
Dynamic Model Validation – PSSE & DMView



System Configuration for DMView Test



System Configuration for Voltage and Frequency Test



Dynamic Model Validation Process

Reference: Yunzhi Cheng, "Dynamic Model Validation Using DMView and PMU", available at: https://sites.google.com/view/dmview/home

Dynamic Model Validation – PSSE & DMView

PMU Global Time	Bus_Voltage_Magnitude (positive sequence RMS, kV)	Bus_Voltage_Angle (positive sequence RMS, degree)	Bus_Frequency (Hz)	Tie line P (positive sequence, MW)	Tie line Q (positive sequence, MVar)

PMU Data Template for DMView

```
[Build FS]
Build_FS_flag = 1

[Input files]
input_path = CASEs\Test
unconv_casefile = test.sav
model_file_lst = ['test.dyr']

[Tests]
Test1_FS = ['FS', '10']
Test2_VOLTFREQ = ['VOLTFREQ','DATAs\\Model_Validation_Data_Request_test.xlsx']

[Settings]
Plot_Flag = 1
Plot_INF_GEN_Flag = 0
MV_START_ROW = 5000
MV_END_ROW = 5700
MV_FLAG = 1
```

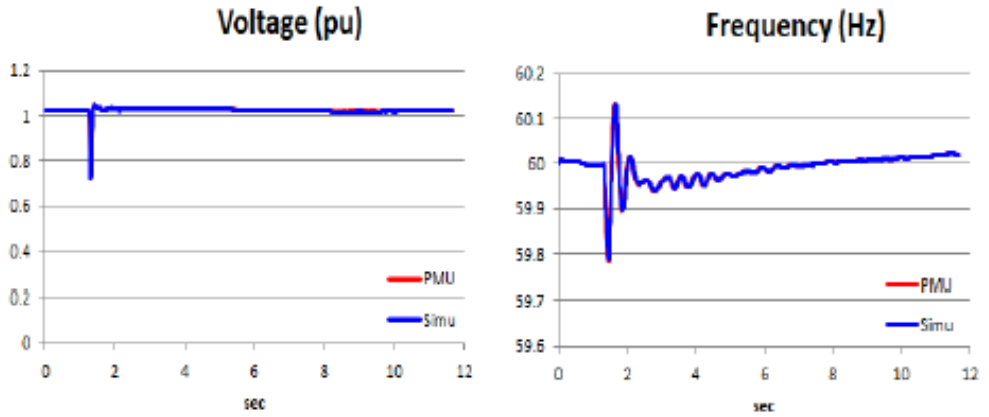
Test project model

PMU Data

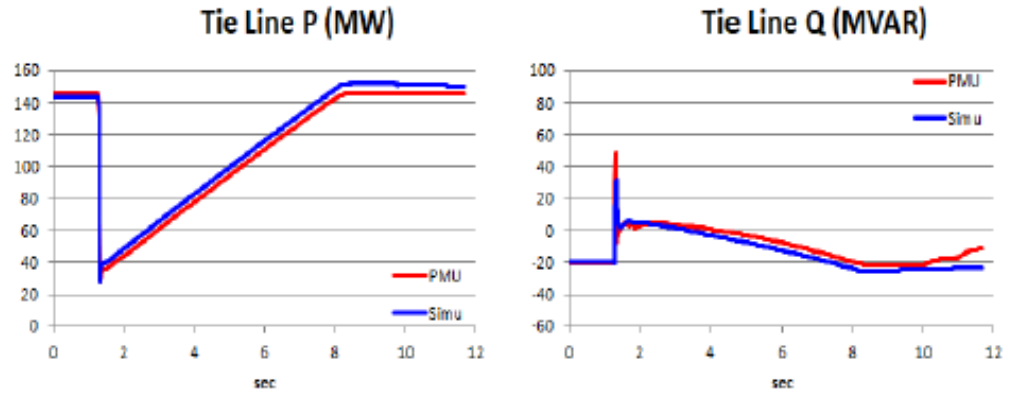
Specify PMU data rows for the study period

Enable Model Validation (MV) mode for DMView

An INI Example for DMView



Voltage and Frequency Profile of the Disturbance



Tie Line Active Power and Reactive Power Response

Reference: Yunzhi Cheng, "Dynamic Model Validation Using DMView and PMU", available at: https://sites.google.com/view/dmview/home

Dynamic Model Validation – PSCAD & PMView

Why Validate the PSCAD model?

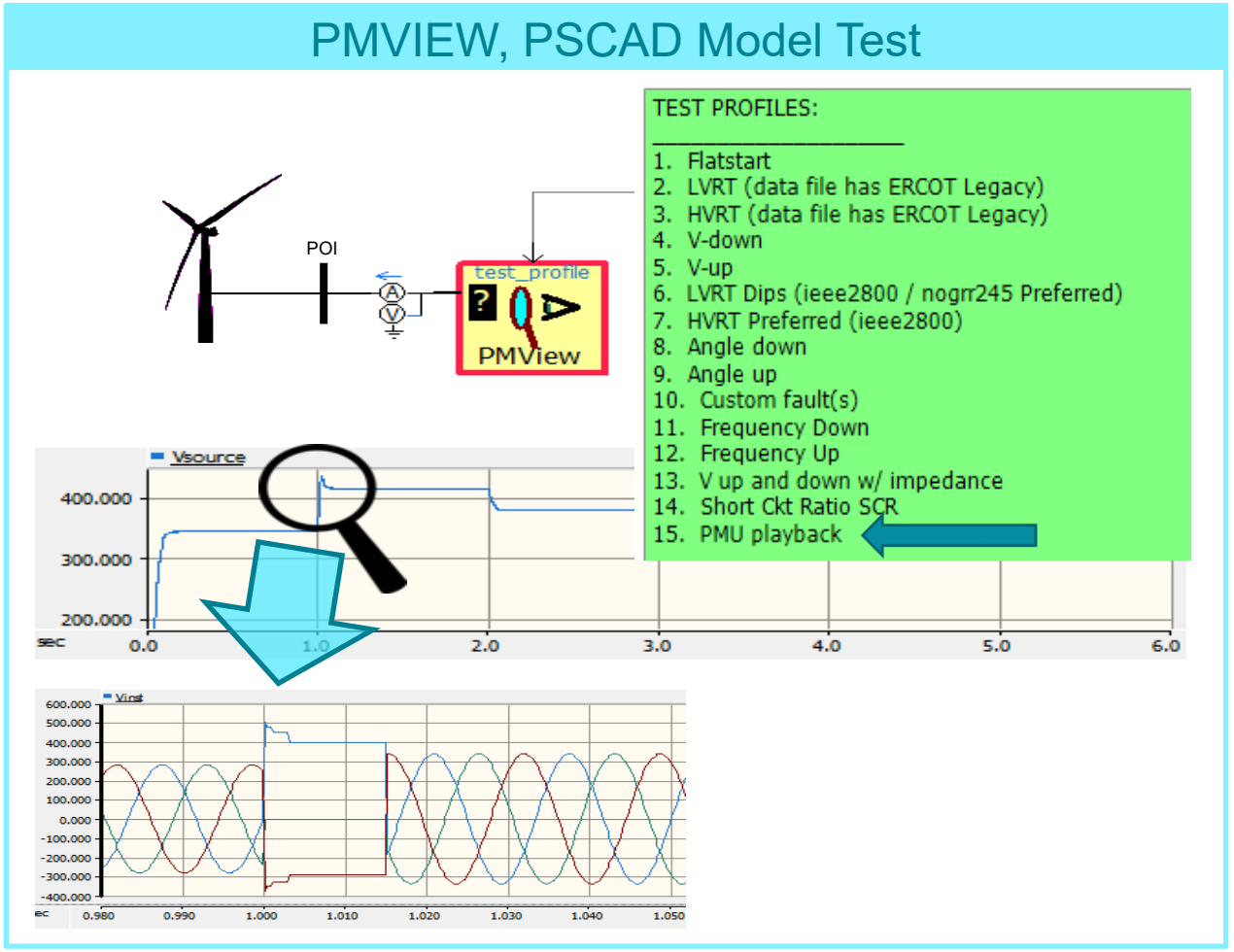
- Best to test a 3-phase model
  - Most grid voltage disturbances are unbalanced
  - Positive-sequence model validation may not be sufficient to validate IBR models, unlike synchronous generator

- PSCAD model is often used like a “gold standard” to benchmark other models. Validation helps ensure confidence in all derivatives.

EMT models are often treated like a “gold standard” but maybe this title is a bit undeserving unless the model is heavily verified & validated & emulates the hardware firmware code

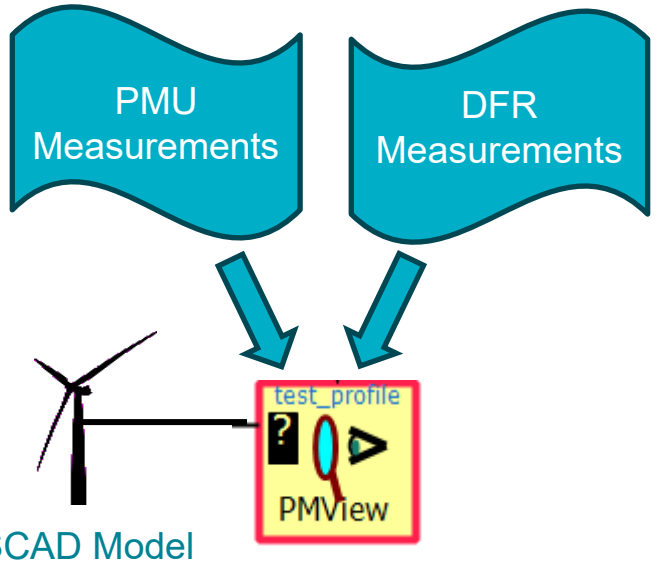
Dynamic Model Validation – PSCAD & PMView

- PMView for PSCAD model testing
  - Tool can test a variety of customizable profiles (voltage / angle / frequency) for MQT
  - Tool also useful for model validation



Dynamic Model Validation – PSCAD & PMView

- Use both PMU and DFR data



PSCAD Model

PMView plays back the PMU measurements as a 3-phase balanced sinusoidal voltage source and plays back the DFR measurements as individual voltage sources

Relative Time	Instantaneous kV		
	Va	Vb	Vc

DFR Template

PMU Global Time	Bus_Voltage_Magnitude (positive sequence RMS, kV)	Bus_Voltage_Angle (positive sequence RMS, degree)	Bus_Frequency (Hz)	Tie line P (positive sequence, MW)	Tie line Q (positive sequence, MVar)

PMU Data Template for DMView and PMView

Setting up DFR Playback in PMView

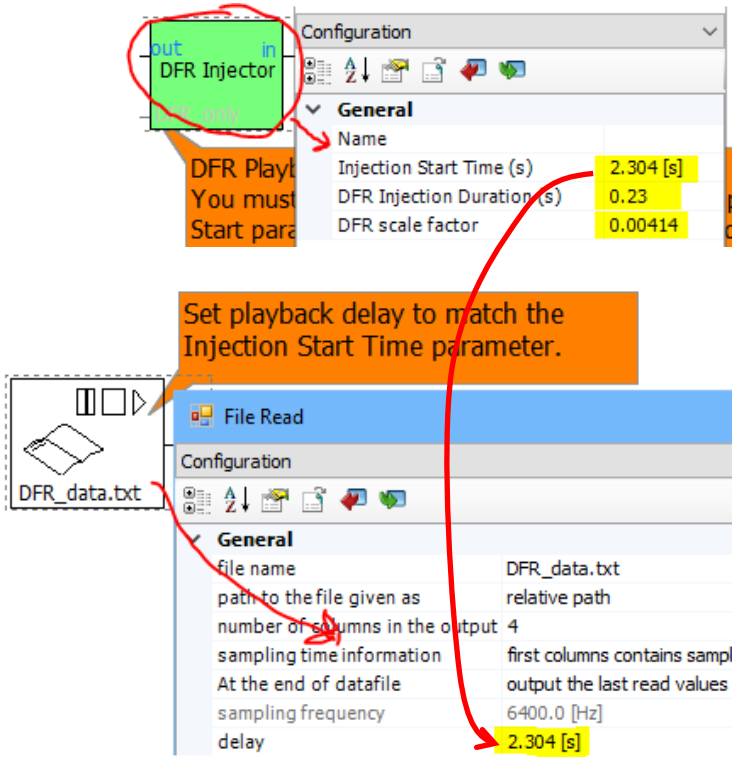
- DFR recordings are typically much shorter than PMU
  - PMVIEW seamlessly switches between the two input data streams
  - User needs manually adjust offsets to align the streams to avoid a phase jump when switching between PMU and DFR playback
  - PMView instruction manual includes a tutorial
  - With a little practice, it's easy using the adjustment knobs in PMView and checking the comparison plots

PMU data →

DFR data →

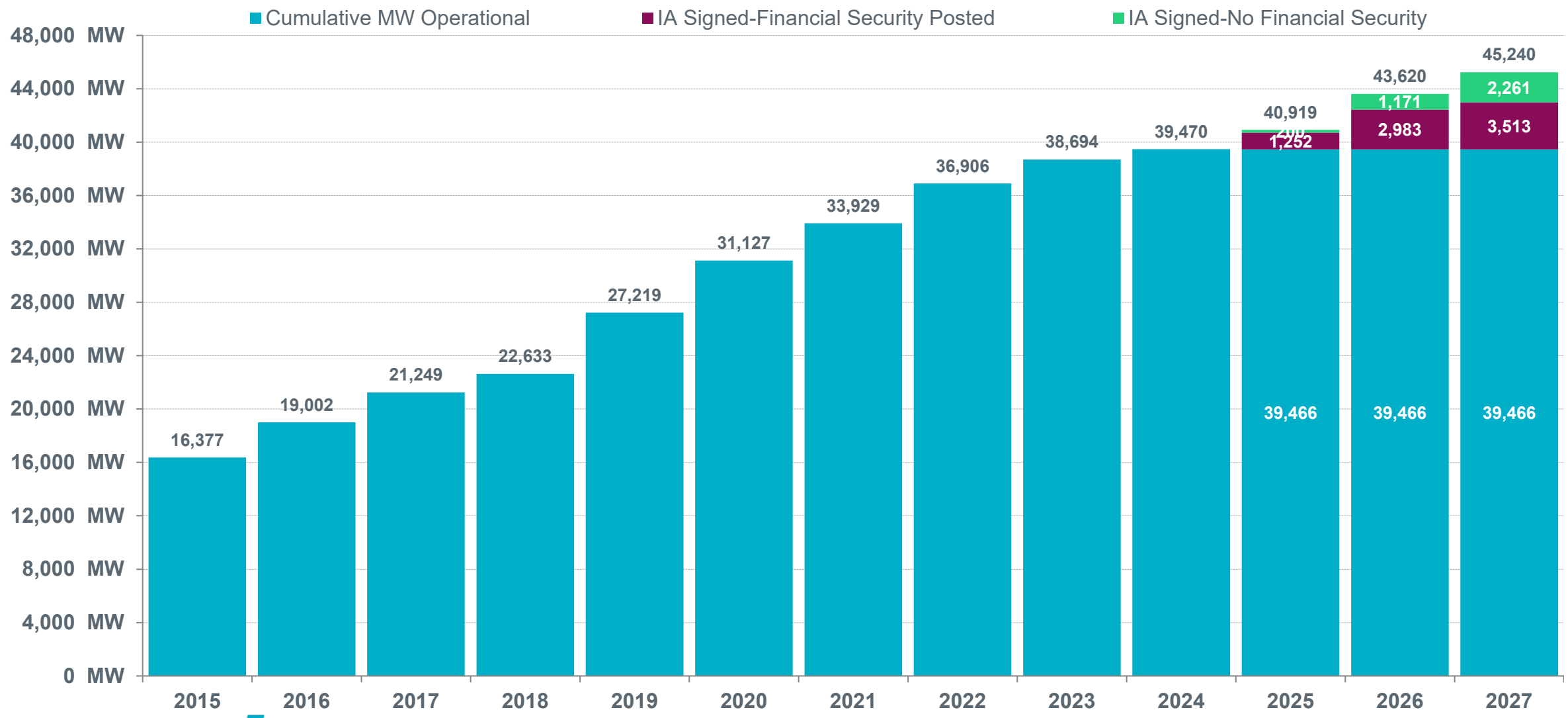
(Phase angle alignment)

Scaling and offset control the alignment

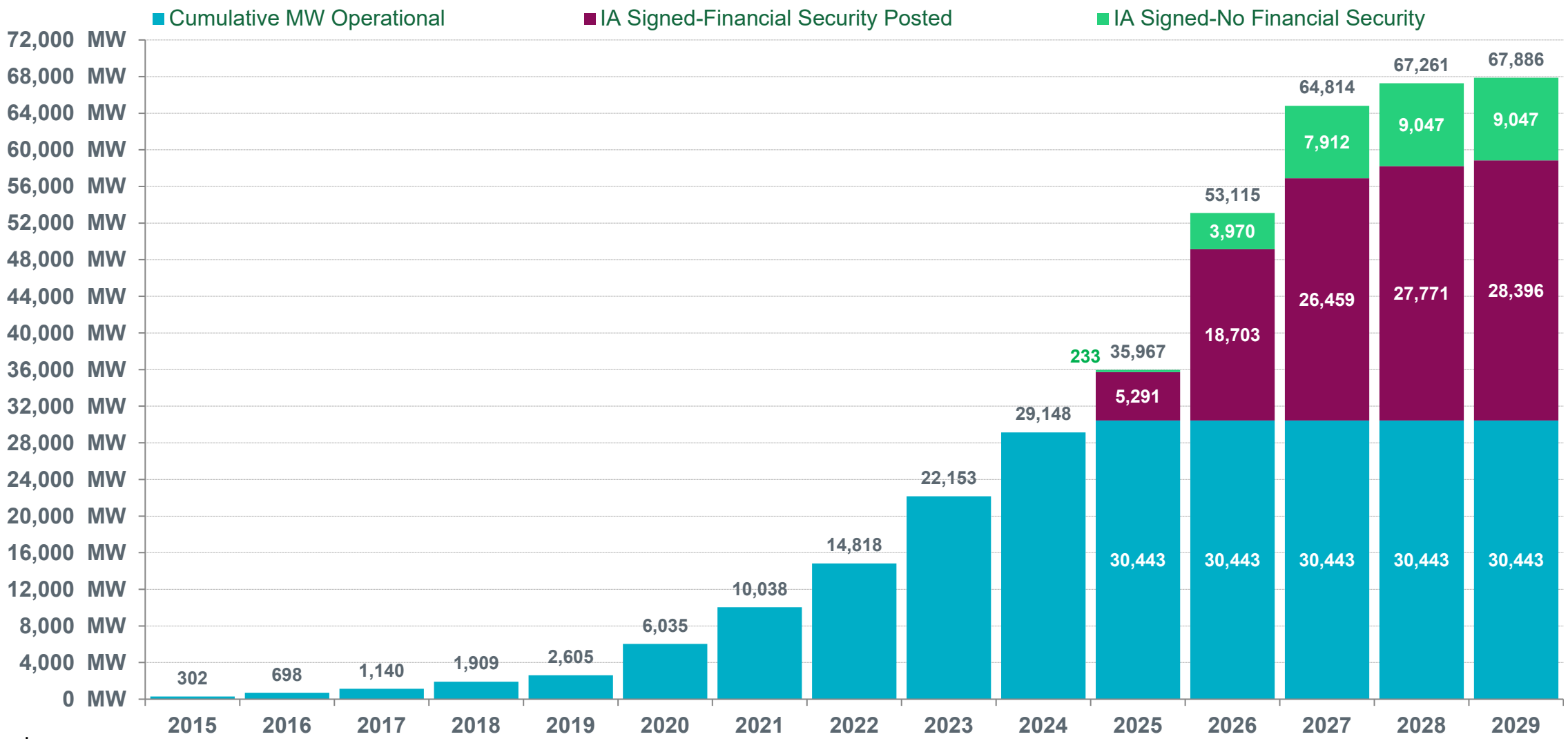


Appendix

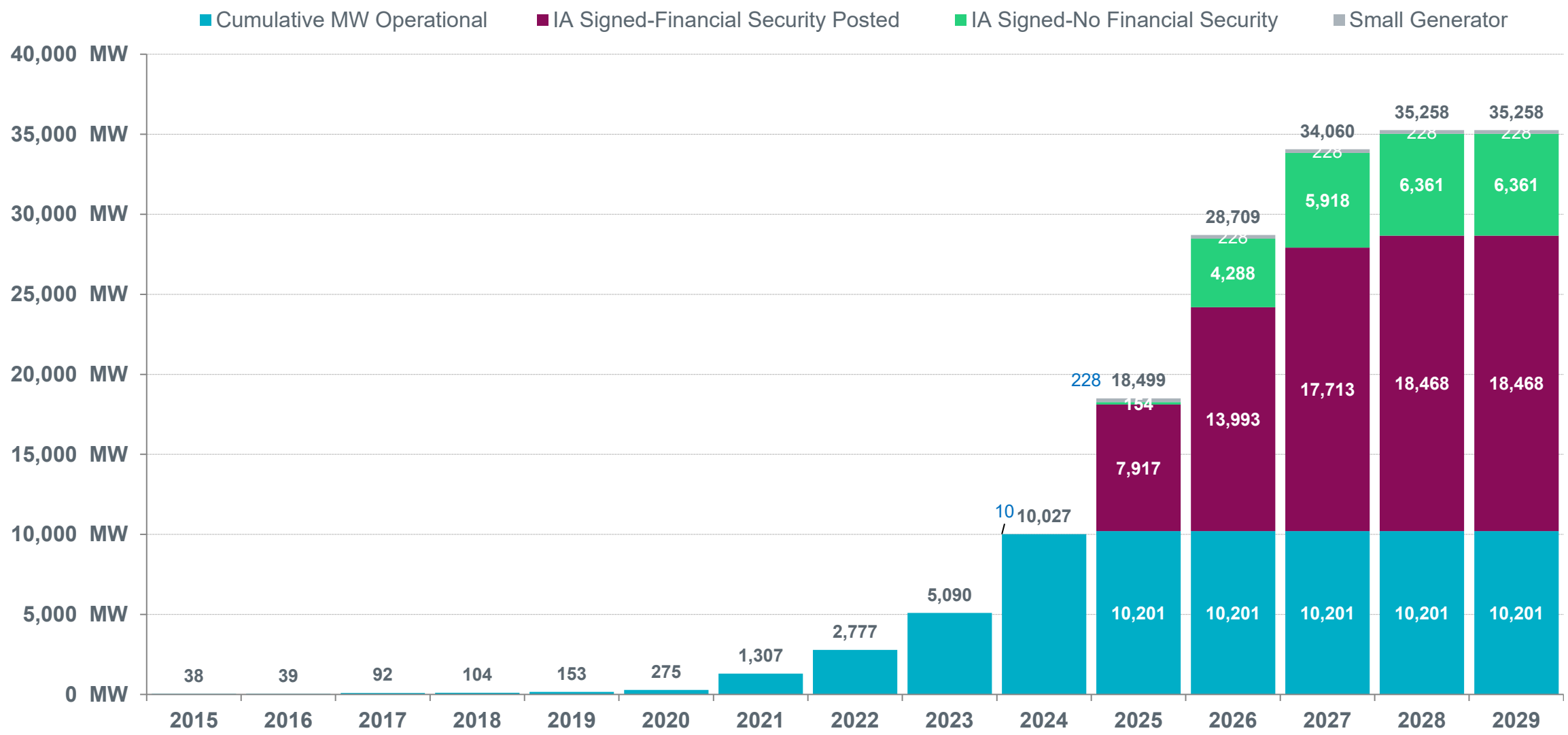
ERCOT Wind Additions by Year (as of Jan. 2025)



ERCOT Solar Additions by Year (as of Jan. 2025)



ERCOT Battery Additions by Year (as of Jan. 2025)



Questions?