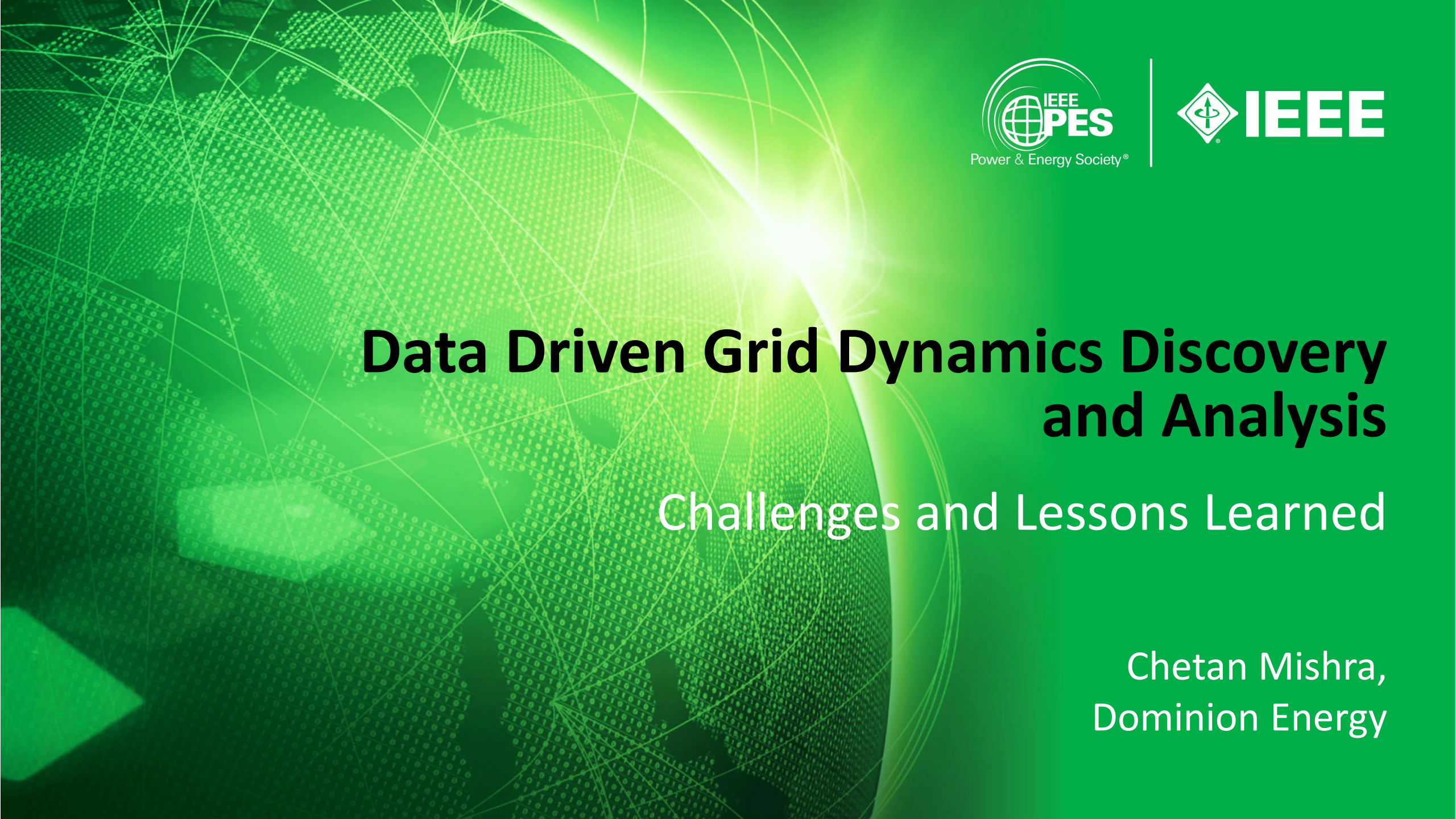


Data Driven Grid Dynamics Discovery and Analysis

Challenges and Lessons Learned

Chetan Mishra,
Dominion Energy

Our Team

Engineering Analytics and Modeling

- Chetan Mishra (Power System Eng.)
- Benjamin Diller (Software Eng.)
- Jaime Delaree (Supervisor)
- Kevin D. Jones (Manager)

Dominion Energy®

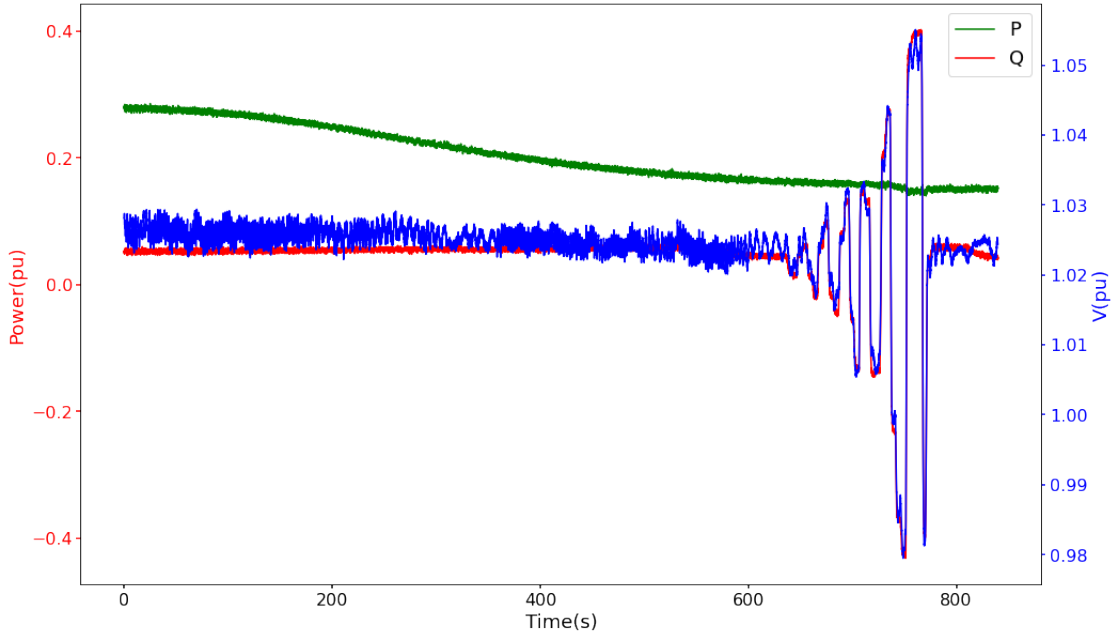
Partners

Prof. Luigi Vanfretti

Rensselaer ALSET lab why not change the world?®

Changing Grid and Stability Issues

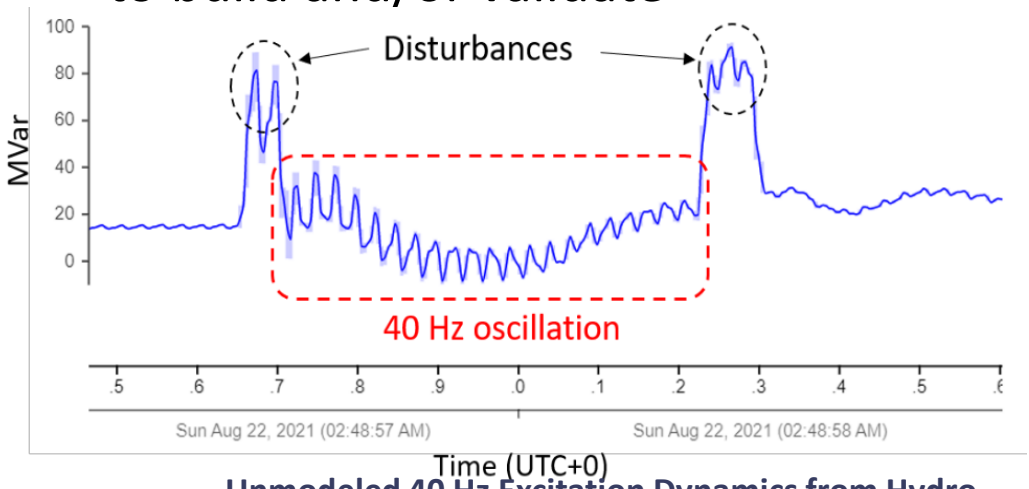
- For traditional power systems, stability is mainly about how tightly coupled are the synchronous machines
  - Not been an issue for Dominion (500 kV backbone)
- Emerging issues from poorly tuned controllers
  - Set it and forget it mentality
  - Insufficient performance monitoring (no incentive) => often undetected until its too late



Unstable Voltage Controller with Stable Inverter at Transmission Solar

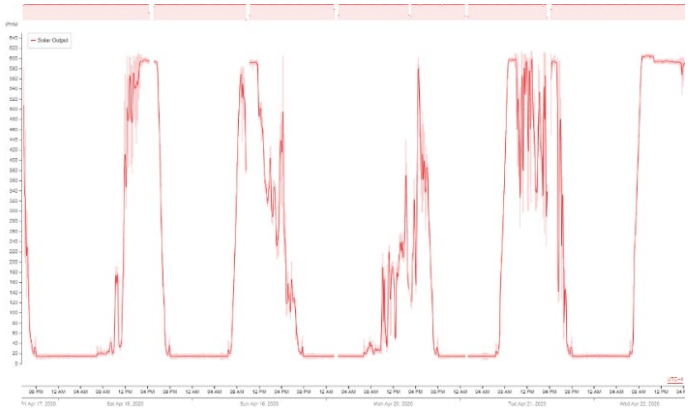
Modeling Challenges

- Power industry heavily relies on models for planning and control specifications
- Traditional generator and associated control models are well understood
  - BUT not all internal components modeled in detail
- Detailed dynamic load models are hard to build and/or validate



Unmodeled 40 Hz Excitation Dynamics from Hydro

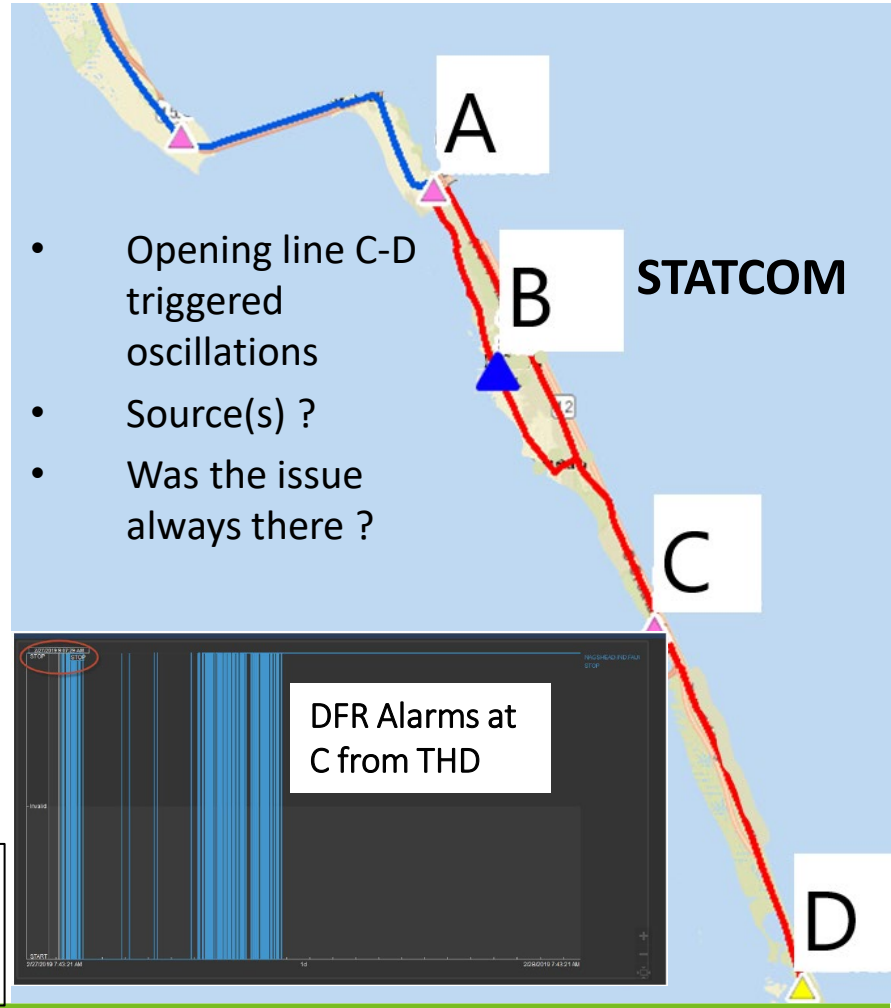
- Models for real-world FACTS
  - Black box models in EMT software
  - Controller replica in RTDS (black box)
  - Not always updated
- Renewable Gen Models
  - Usually not available
  - Generic models rarely help troubleshoot
  - Complicated by protection
  - Short term uncertainty is not modeled in system dynamic models



Typical Solar Output

Research Problem

- **Goal: Inferring Dynamic Behavior from Measurements**
- **Motivation**
  - Tuning pre-existing models
  - Augmenting models with new information
  - Identifying problematic controllers that models fail to capture
  - Understanding what cannot be modeled
  - Address emerging issues before they become widespread
  - Gaining intelligence on operation and planning in the “new grid”



C. Mishra, L.Vanfretti, D.Yang, C.Wang, X.Xu, K.D.Jones, R.M.Gardner, "Analysis of STATCOM Oscillations using Ambient Synchrophasor Data in Dominion Energy", ISGT 2022.

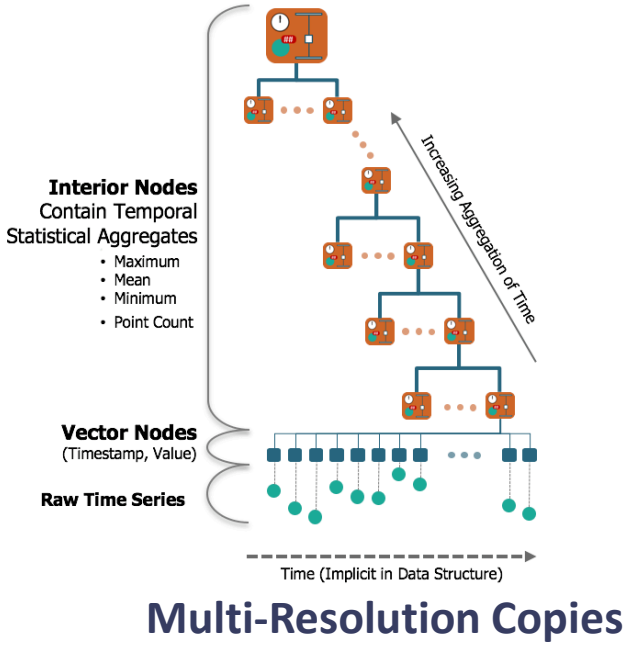
Challenges and Lessons Learned

Need For A Good Data Platform

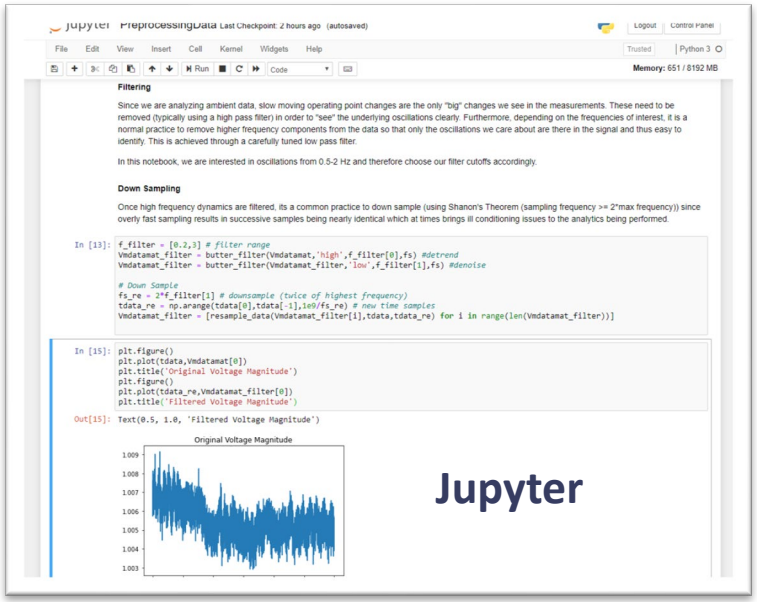
PredictiveGrid™ PingThings

- Efficient data retrieval and visualization for long term analysis
- Low cost for experimentation
- Easy sharing for collaboration
- Familiar programming environment with easily available tools

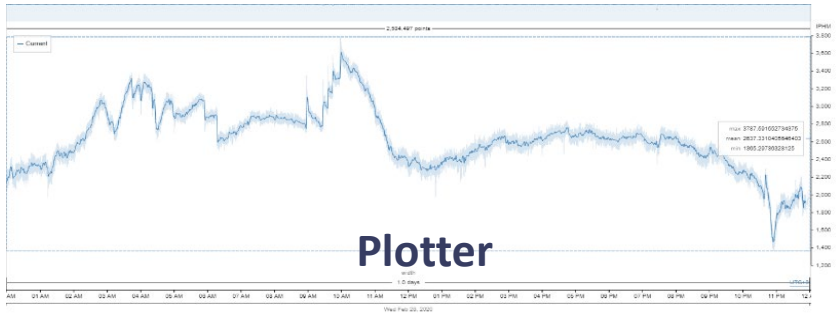
https://www.pingthings.io/platform.html



Multi-Resolution Copies



Jupyter

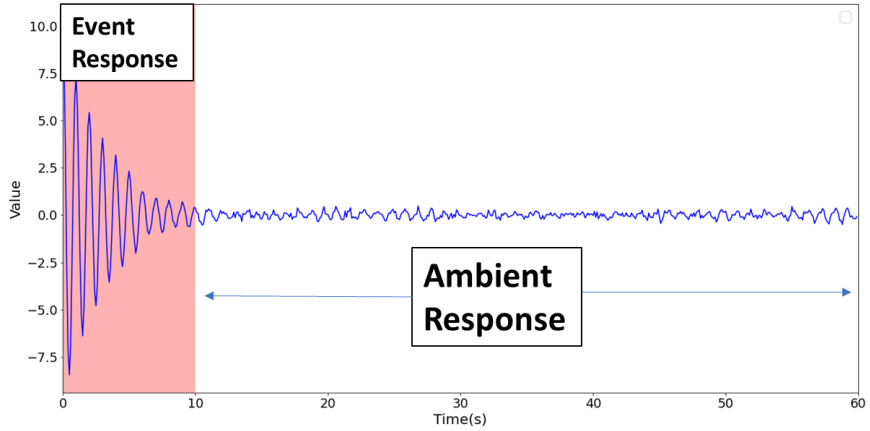


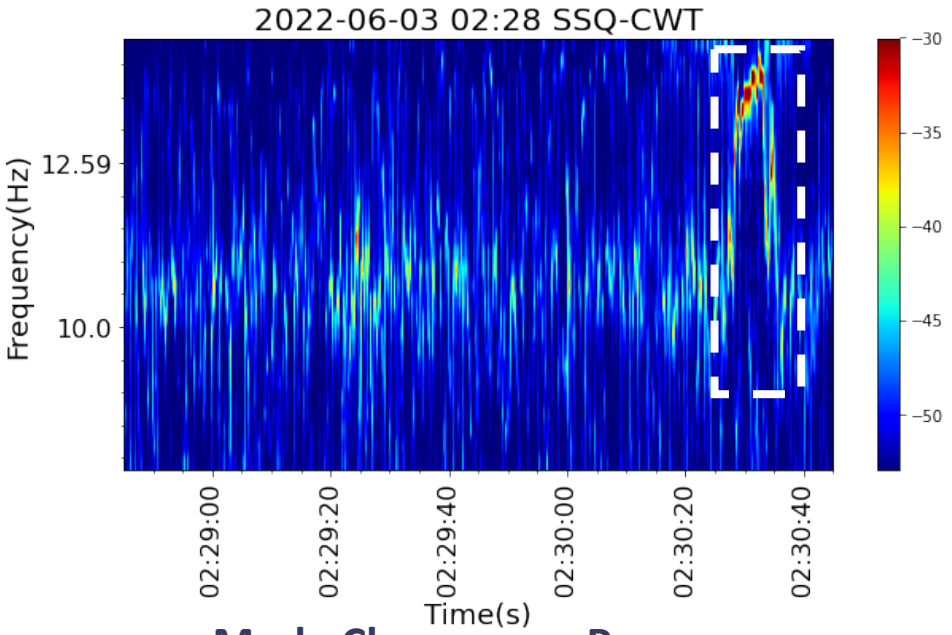
Plotter

Ambient Data is Highly Underrated

Searching for Clues

- System response to events/large disturbances exposes valuable information
  - Perfect for model validation
  - Not enough of them to gain intelligence about the system
- System mostly in ambient conditions
  - Great for gaining insight into persistent behavior
  - Difficult to extract meaningful information
- Most large controller issues leave clues
  - Need to give importance to anomalous behaviors regardless of the magnitude

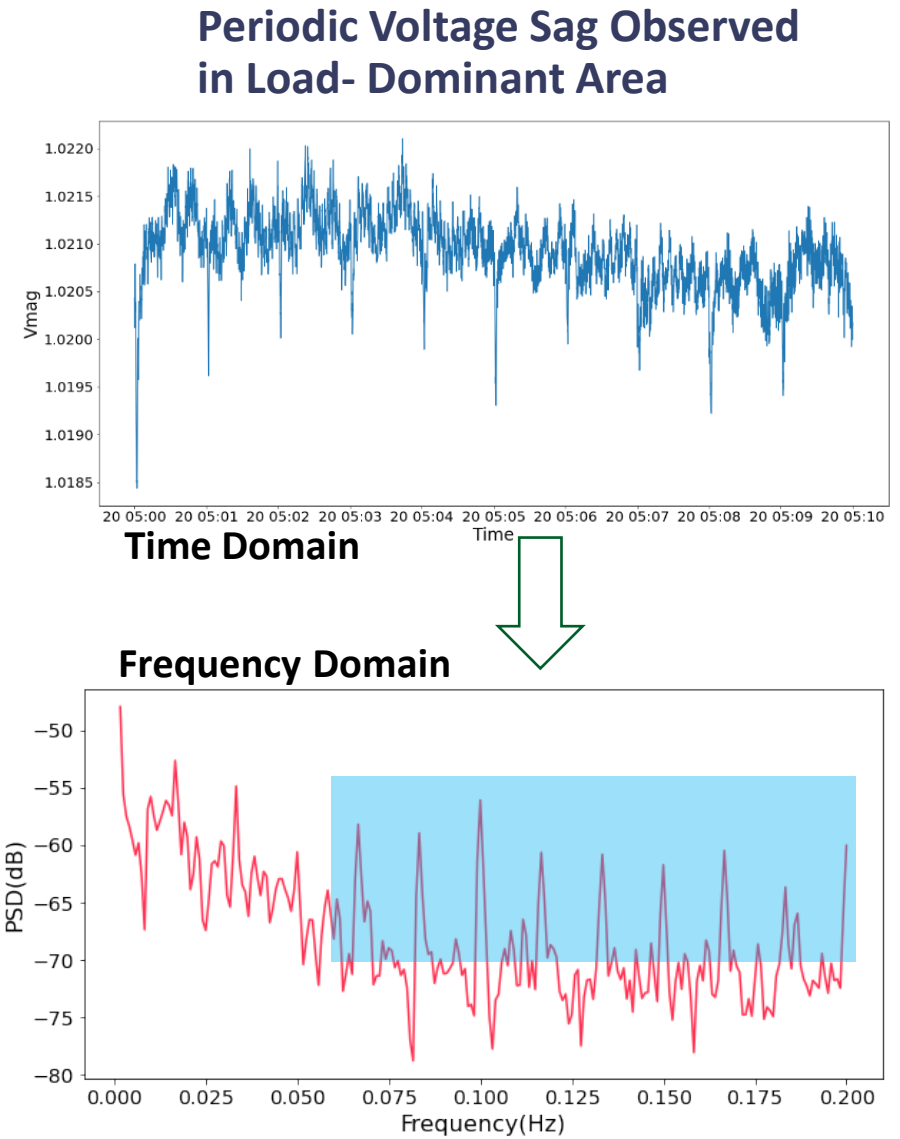




Mode Change as a Precursor

How to Characterize and Extract Dynamic Behavior ?

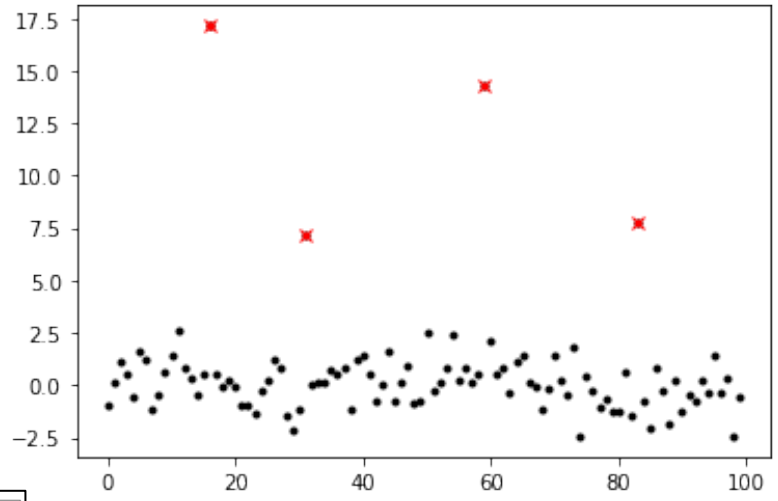
- Goal is to extract distinct dynamic behaviors from measurements and associate them to devices/processes
- Choosing appropriate basis for signal decomposition
  - Needs to account for prior knowledge of underlying system dynamics…introduces bias !
  - In case of no prior knowledge of the system ?

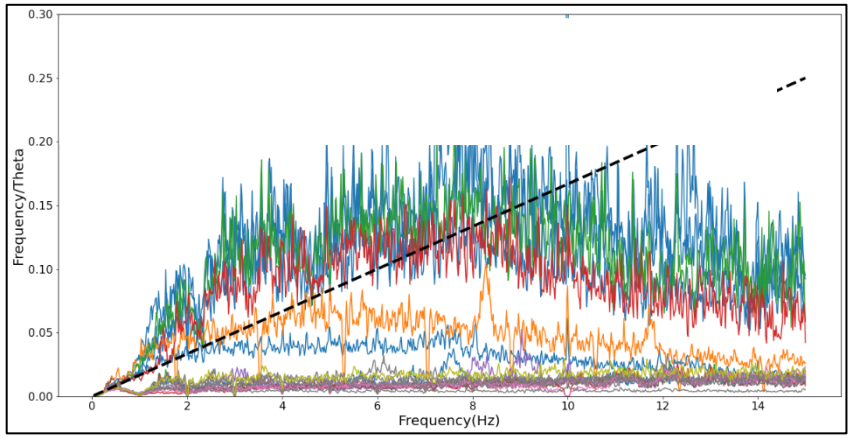


Data Fidelity

- Analysis is as good as the data
- Quality issues can be subtle, require domain knowledge to understand

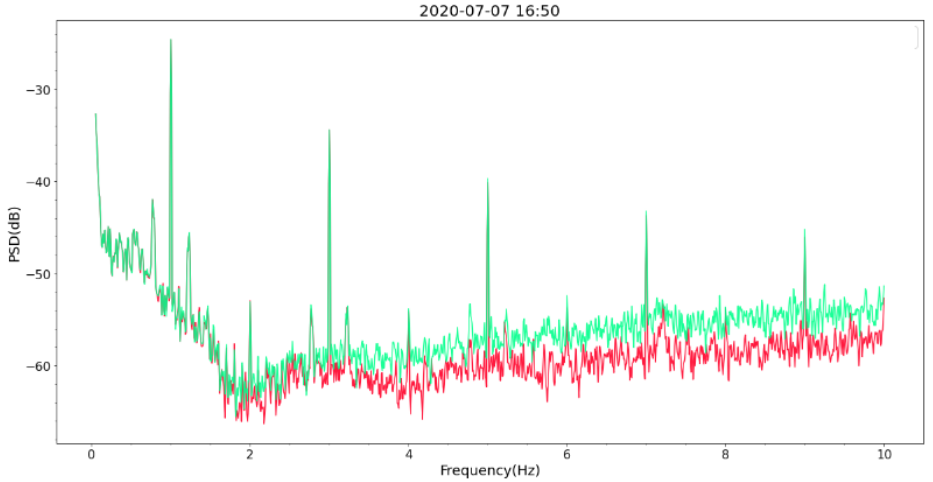
Bad Data is Not Just Gaps or Gross Errors !





Frequency Estimates from Different DFR Vendors

C. Mishra, L. Vanfretti and K. D. Jones, "Designing Time Derivatives in the Frequency Domain for Ambient PMU Data Applications". IEEE PESGM 2022.

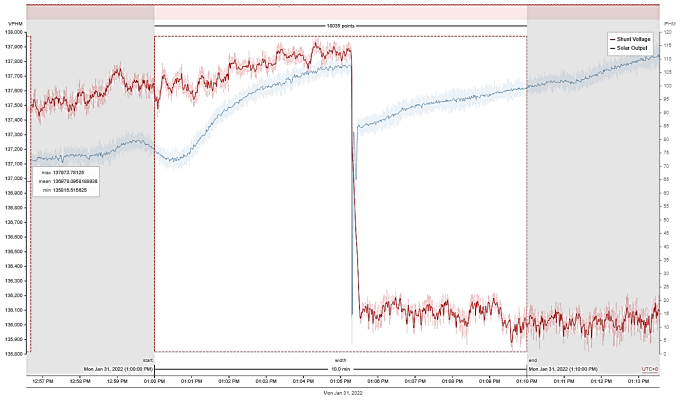


Effect of Device Clock Issues on Spectrum

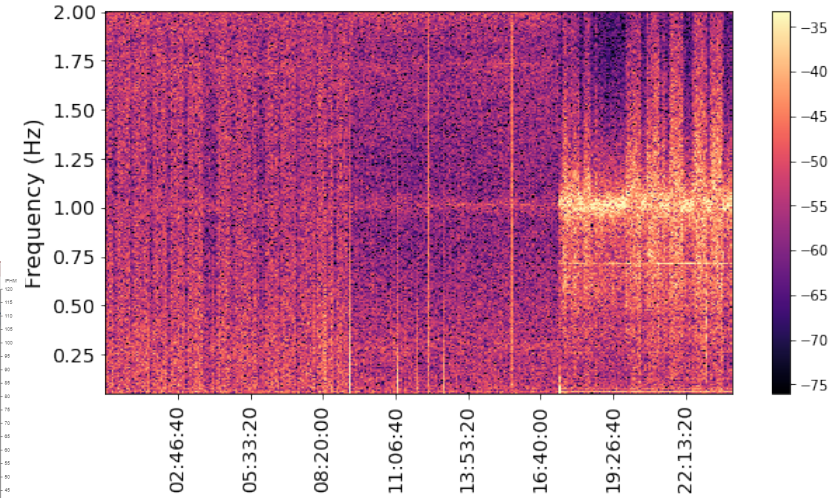
de Castro Fernandes, Marcelo & Mishra, Chetan & Vanfretti, Luigi & Jones, Kevin. (2021). A Novel Method for Despiking Spectra from Synchrophasor Measurements. IEEE PESGM 2021.

Long Term Data Analysis

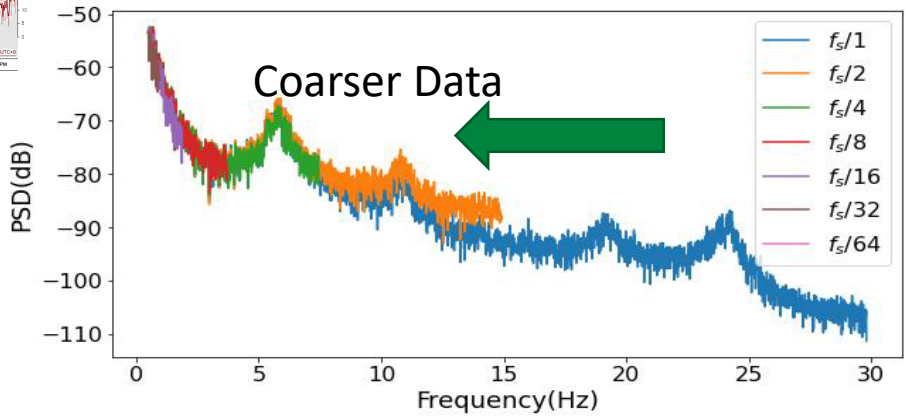
- Can’t rely on a single event to make strong inference
  - Need to collect all possible evidence in the historical data – was it large enough to trigger DFR ?
  - Important to leverage the underlying data structure
- No prelabeled dataset !
  - Unsupervised detection
  - Domain knowledge to characterize what to look for



Solar Trips Offline on Shunt Switching



STATCOM Control Mode Change



Multi-Resolution Data Enables Fast Mode Screening

X.Xu, C. Mishra, C.Wang, L.Vanfretti, K.D.Jones, R.M.Gardner, "Fast Oscillation Detection and Labeling via Coarse Grained Time Series Data for ML Applications", ISGT 2022.

Key Takeaways

- Real world power system data analytics problems are extremely complex
  - Necessary to understand the underlying mechanism
  - Ambient data is rich in information but challenging to work with
  - Data quality issues can be subtle
  - Problems cannot be assumed solved without real world data tests
- Need for a platform that enables rapid prototyping
- Unsupervised labeling critical to long term data analysis

Thank You !

chetan.mishra@dominionenergy.com