Fast Oscillation Detection and Labeling via Coarse-Grained Time Series Data for ML Applications

Xin Xu, Chetan Mishra, Chen Wang, Kevin D. Jones, R. Matthew Gardner
Engineering Analytics & Modelling
Dominion Energy

Luigi Vanfretti
Rensselaer Polytechnic Institute

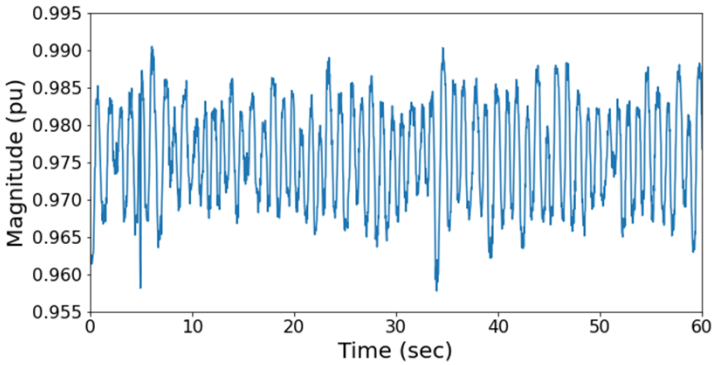
Sean Murphy
PingThings, Inc.

Dominion Energy

Background and Motivation

- 230 kV STATCOM Oscillation observed in current magnitude
  - Disappears randomly.
  - Can we use ML to identify the quantities of interest for analysis?

- Challenges: No prelabeled data.
  - Unsupervised learning: gather the training data requires domain knowledge (on detecting oscillation).
  - Can we automate and accelerate the oscillation detection for long-term analysis (years of synchrophasor data)?



1 Hz oscillation in current magnitude

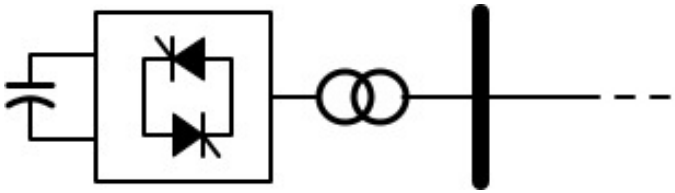
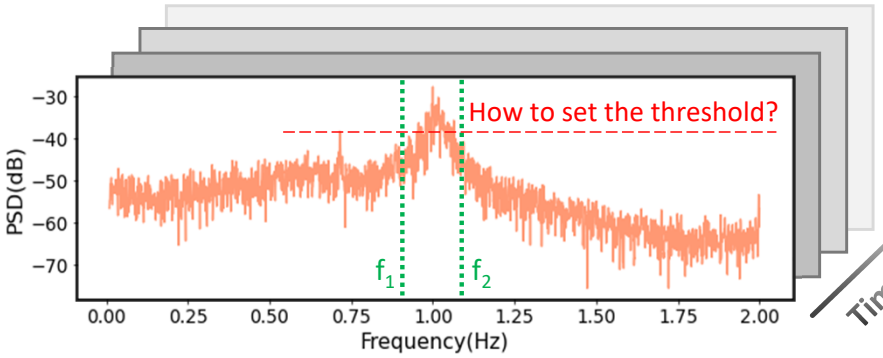


Diagram of STATCOM

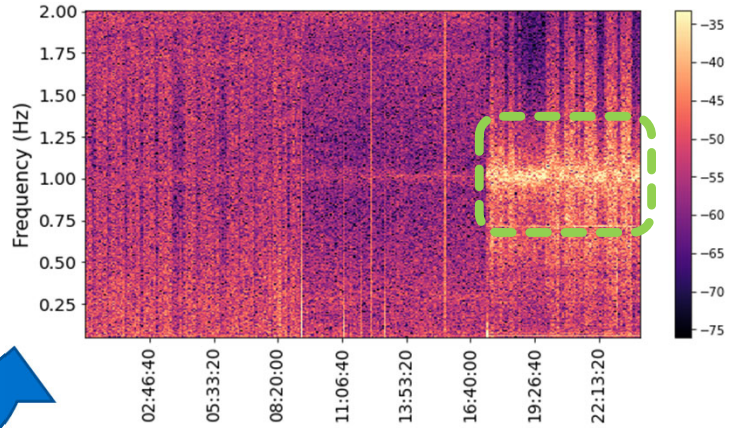
Dominion Energy

Spectral Analysis Based Oscillation Detection

- Spectral analysis provides a family of tools for oscillation detection in frequency domain.
  - Power spectrum density (PSD): the distribution of power in frequency domain.
  - Spectrogram: a visual representation of the spectrum of frequencies of a signal as it varies with time.
- Idea: set threshold to detect the energy peaks.
  - Extract full resolution data is slow.
  - How to determine a proper threshold.



PSD and oscillation detection

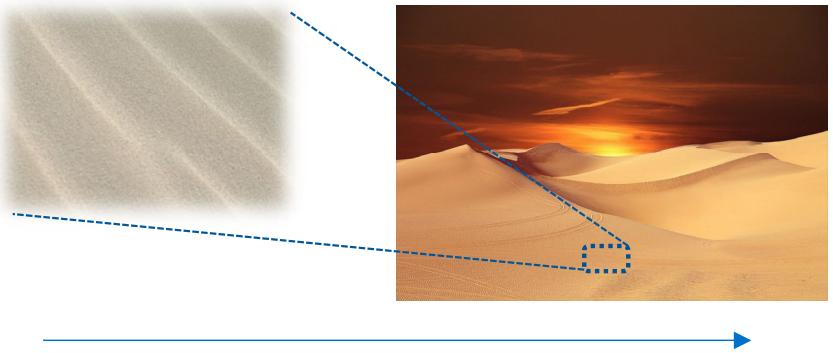


Spectrogram on time-frequency domain (f_s=30 Hz)

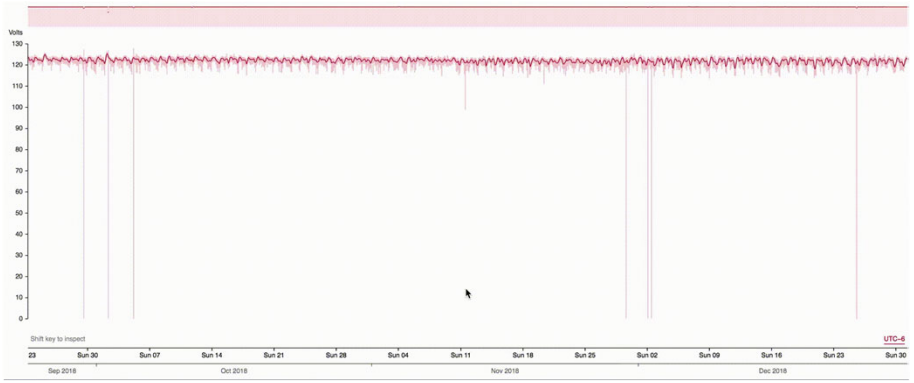
Dominion Energy

Coarse Grained Data from Berkeley Tree

- Extract full resolution data is time consuming.
- The synchrophasor data of Dominion Energy is organized in Berkeley Tree Database (BTrDB), which stores statistical averages of synchrophasor data at increasingly coarse resolutions.



Fine-Grained *Coarse-Grained*

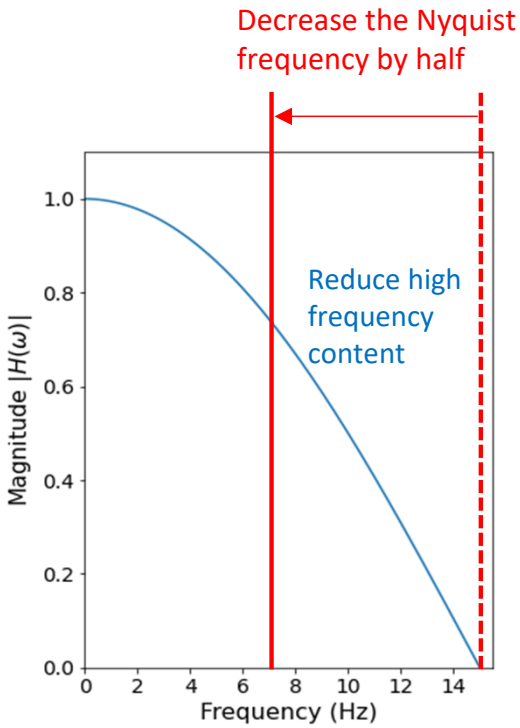


Berkeley Tree Database (BTrDB)

Dominion Energy

Coarse Grained Data from Berkeley Tree

- How to get coarse grained data?
  - 2-sample moving average filter
  - Down sampling for every other sample.
- Repeat this process to get coarser data.
- Preserve the spectral peaks up to the Nyquist frequency while reducing the effect of aliasing.

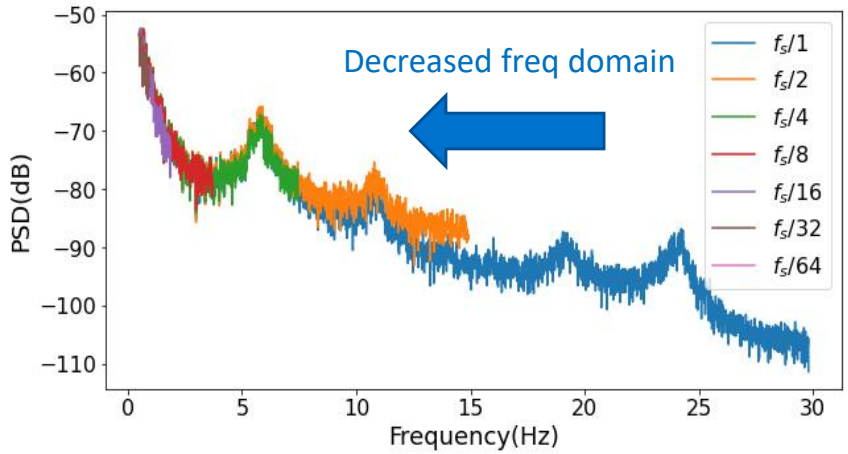


Frequency response (f_s=30 Hz)

Dominion Energy

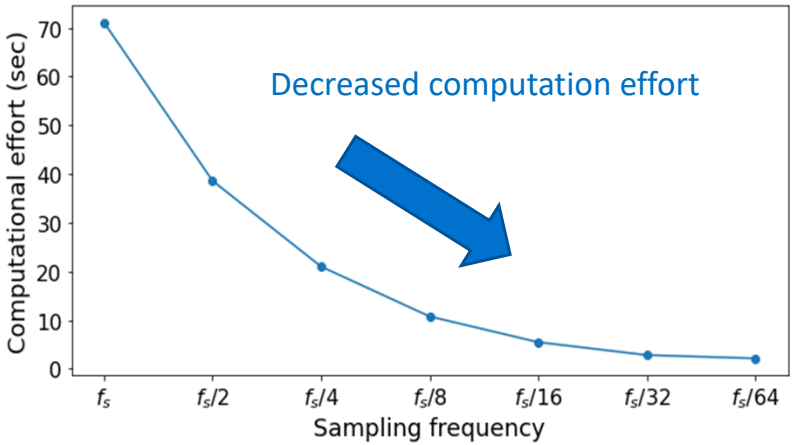
Coarse Grained Data from Berkeley Tree

- Validation:
  - Synchrophasor data from Dominion territory, sampling rate f_s = 30 Hz.
  - Window length: 20 mins.



Spectral analysis with coarse grained data

- Coarser grained data exponentially reduces the sampling rate, and also the computation effort

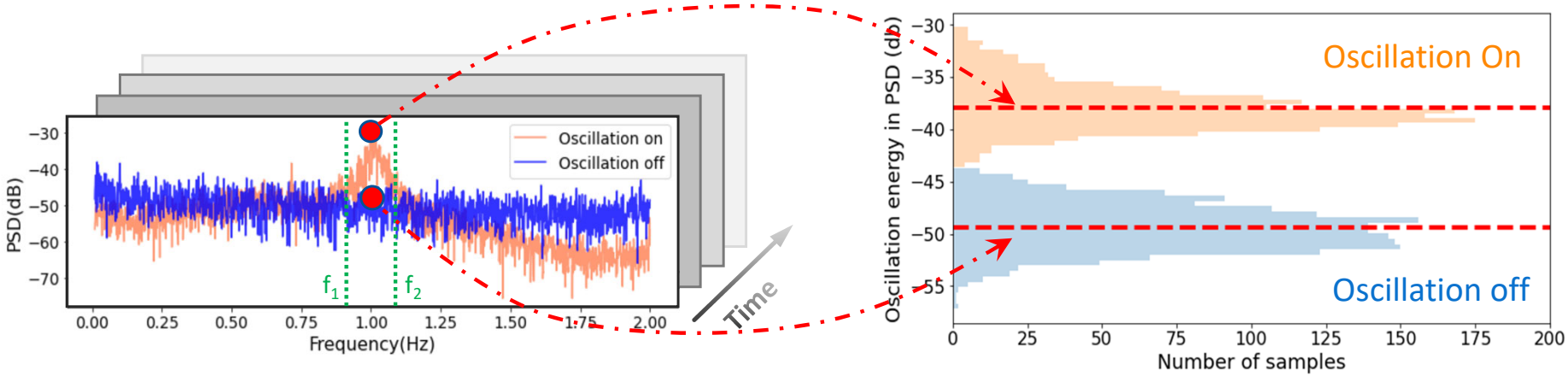


Computation effort

Dominion Energy

Oscillation Energy Clustering

- If detecting the energy level around the interested frequency for enough long time, we will know how the oscillation energy distributes.
- K-means clustering is used to determine the clusters in the oscillation energy data, based on which the threshold can be determined.

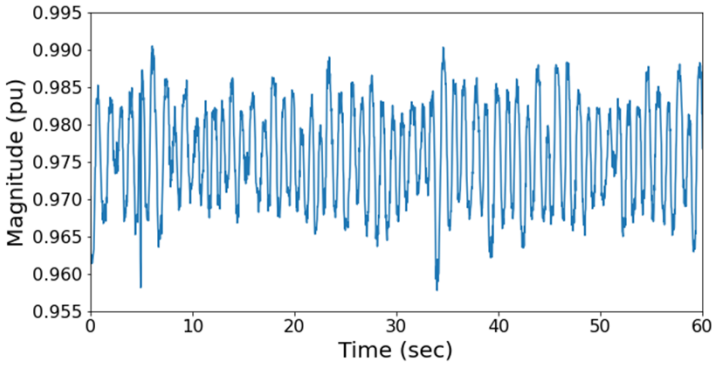


Oscillation Energy Histrogram

Dominion Energy

Case Studies

- STATCOM in Dominion Energy territory
- Sampling rate f_s =30 Hz.



1 Hz oscillation in current magnitude

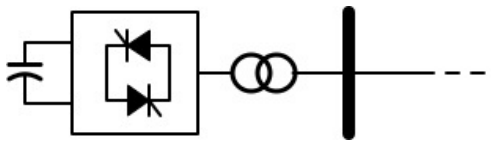
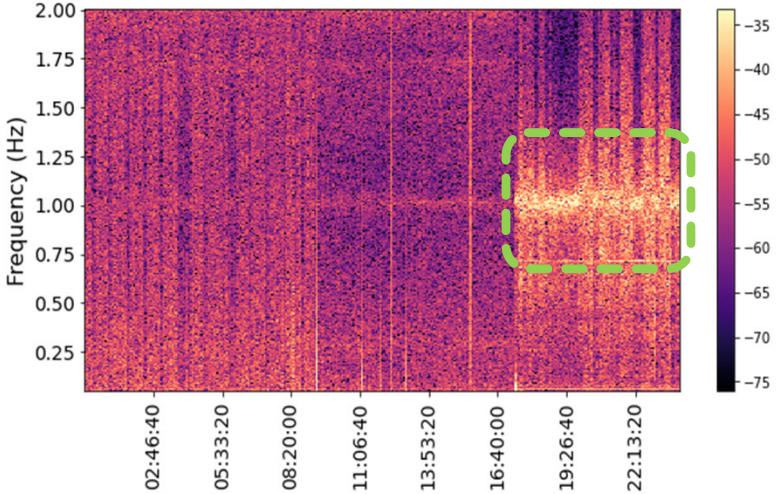


Diagram of STATCOM

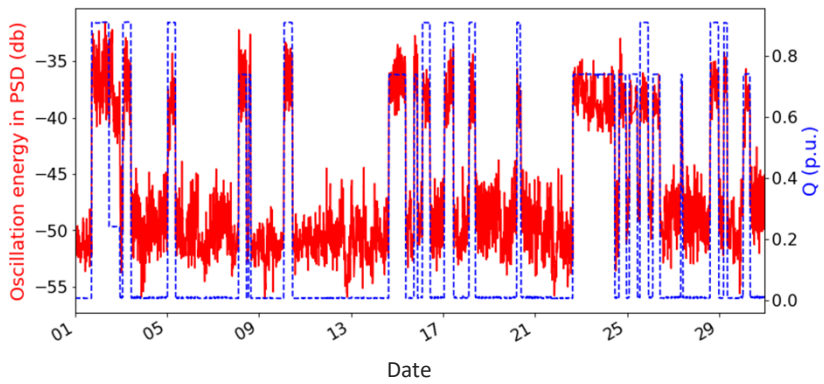


Spectrogram

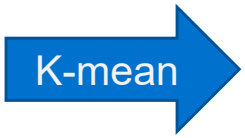
Dominion Energy

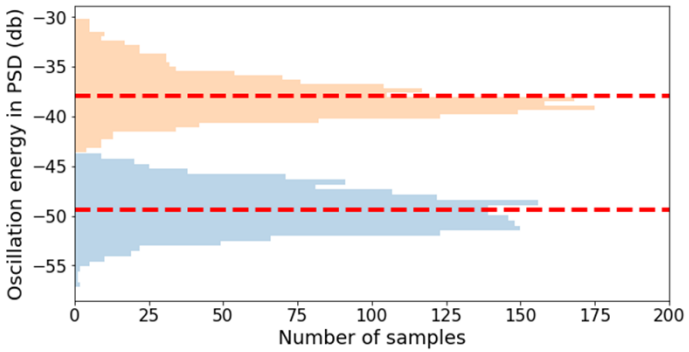
Case Studies on Dominion

- Using coarse grained data, we can obverse frequency contents up to 1.875 Hz.
- Oscillation energy distribution of 1 Hz mode for 30 days.



Oscillation energy distribution vs STATCOM Q





Oscillation Energy Distribution

Dominion Energy

Conclusions

- Coarse grained data and clustering method facilitate fast oscillation detection and machine learning based power system applications.
- The coarse grained data can keep the spectral peaks up to the Nyquist frequency.
- Proper use of coarse grained data can exponentially reduce the computation time, which enables fast oscillation detection.
- Clustering methods like K-means clustering can identify the cluster center oscillation energy distribution of a mode of interests.
- When excited, the 1 Hz oscillation around the STATCOM is found to be correlated to the Q output.

Publication

- Xin Xu, Chetan Mishra, Chen Wang, Kevin D. Jones, R. Matthew Gardner, Luigi Vanfretti, Sean Murphy, "**Fast Oscillation Detection and Labeling via Coarse Grained Time Series Data for ML Applications**", IEEE PES ISGT NA 2022 (Accepted).

Thank you