



Real Time Inertia Monitor Based On Pumped Hydro Operation Signatures

NASPI April 2023

Presented by Yilu Liu

Work performed by Hongyu Li, Eric Zhan, Candice Chen

The University of Tennessee
Oak Ridge National Laboratory

Contact : liu@utk.edu

Work funded by DOE WPTO and CURENT Industry Consortium



Northeastern



Rensselaer

TUSKEGEE

Motivation

Accurate inertia estimation is important.

Higher renewable penetration → lower inertia → lower frequency nadir

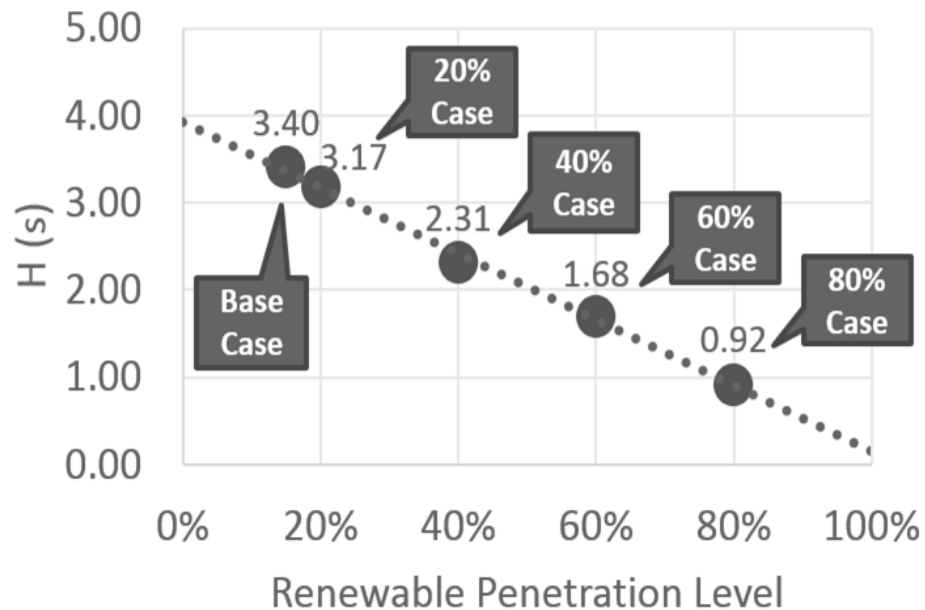
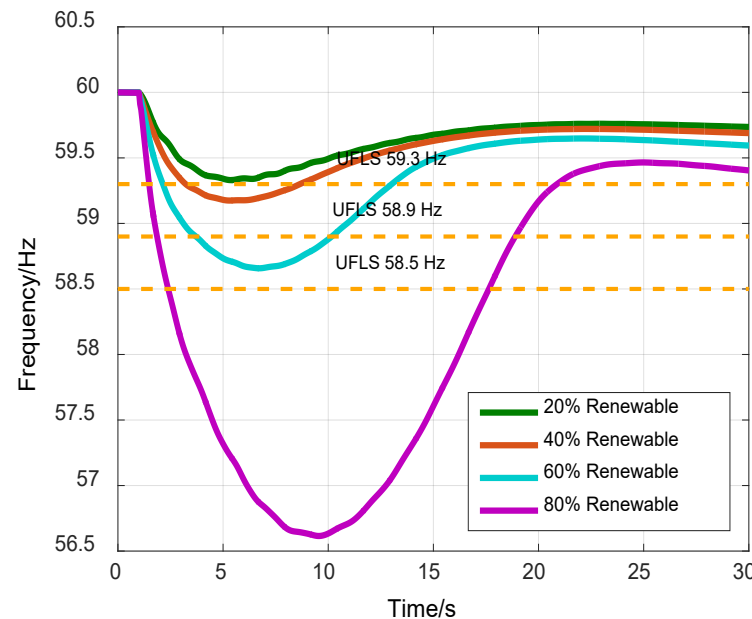
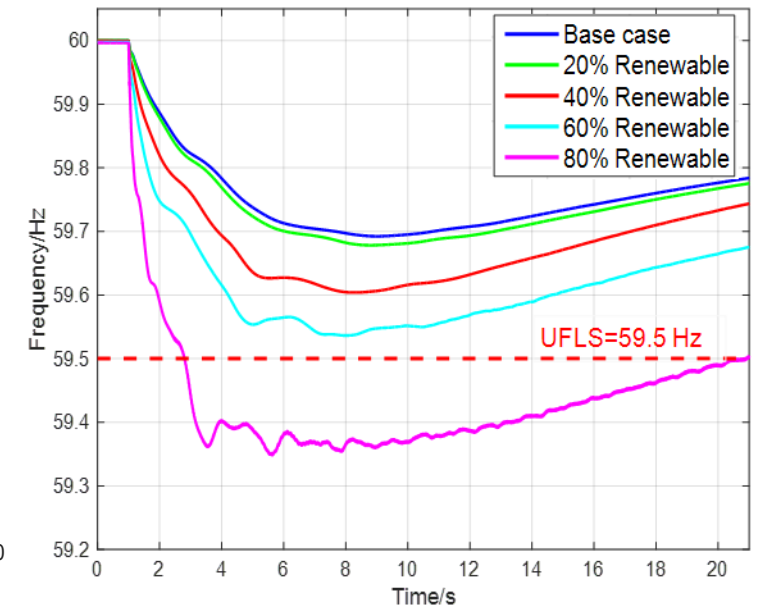


Fig. System equivalent inertia at different renewable penetration levels [SuNLAMP]



a. The ERCOT simulated frequency responses (2,750 MW generation loss)

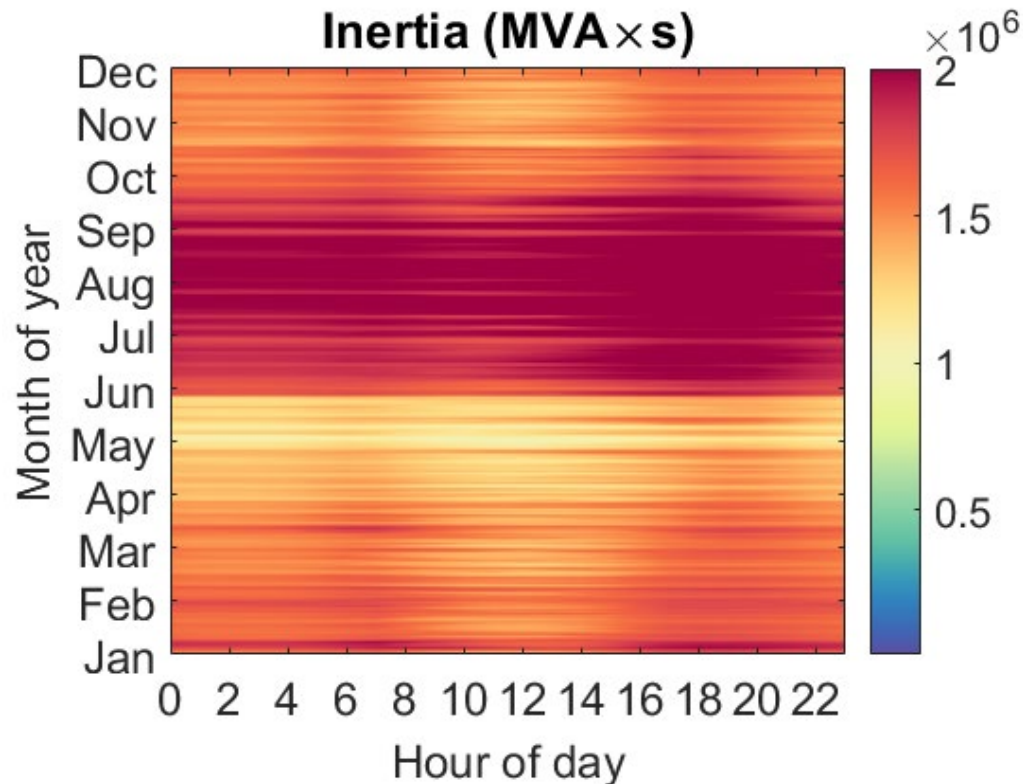


b. The WECC simulated frequency responses (2,625 MW generation loss)

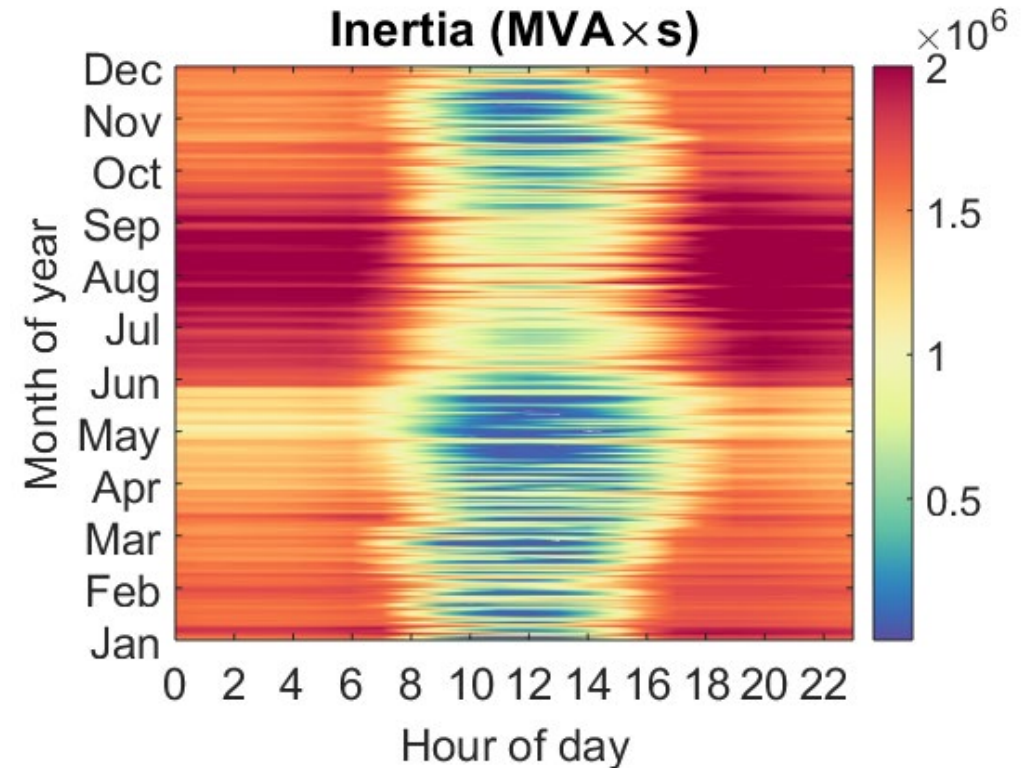
Fig. Frequency response under different renewable penetration levels

Motivation

Renewable energy increase will significantly amplify the volatility and uncertainty of system inertia.



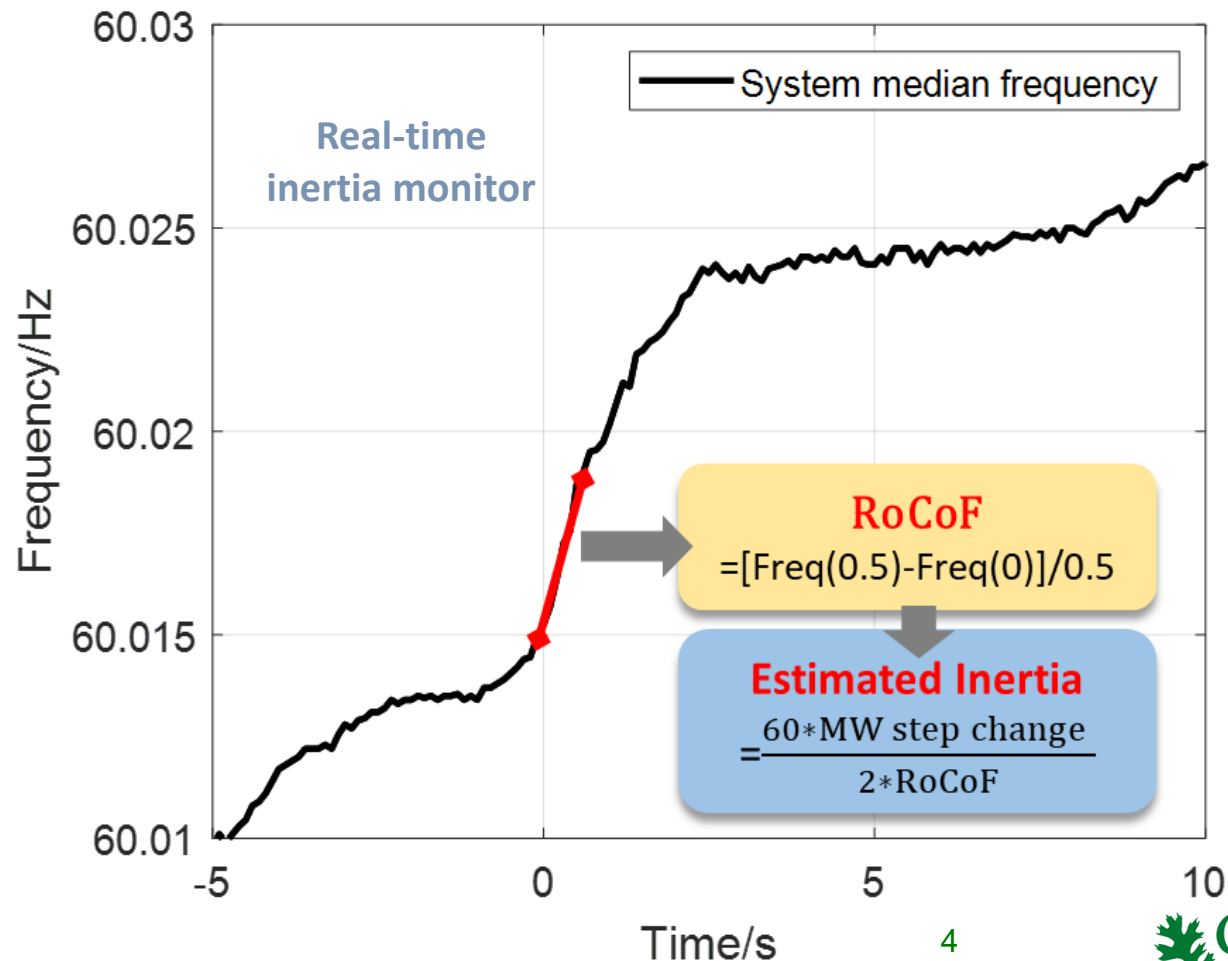
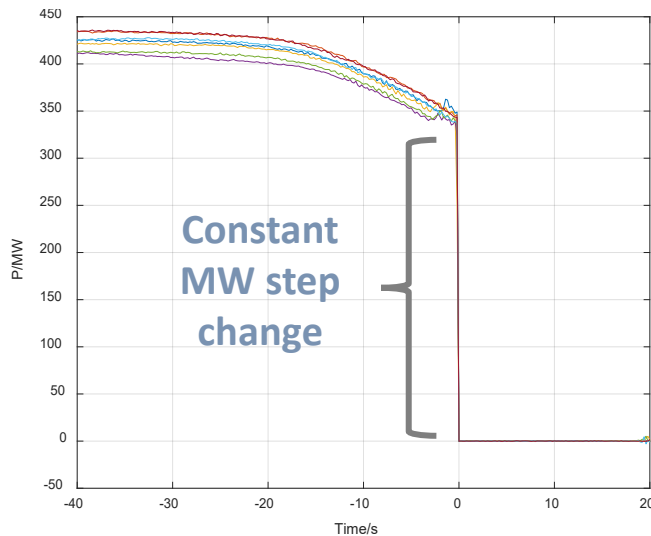
Inertia change in the EI system in one year
with **10%** PV penetration



Inertia change in the EI system in one year
with **50%** PV penetration

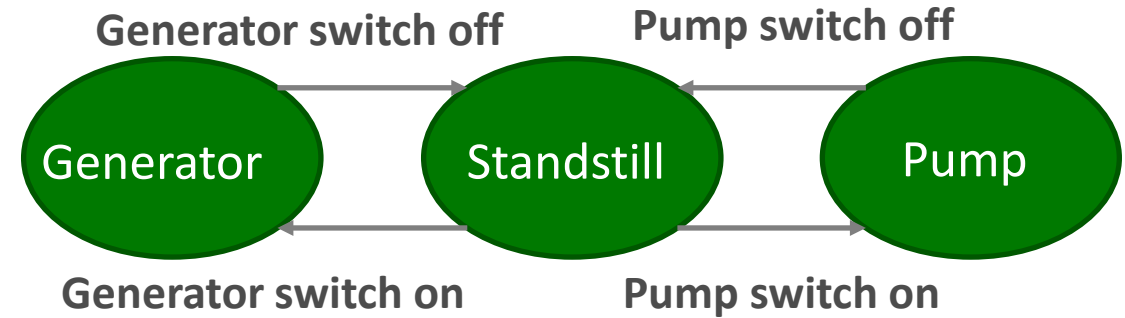
Inertia Estimation Using Pump Turn-Off Signatures

- **Target:** Our work aims to develop the low-cost, real-time, and passive monitor to quantify system effective inertia based on pump storage plants operation switching signatures.

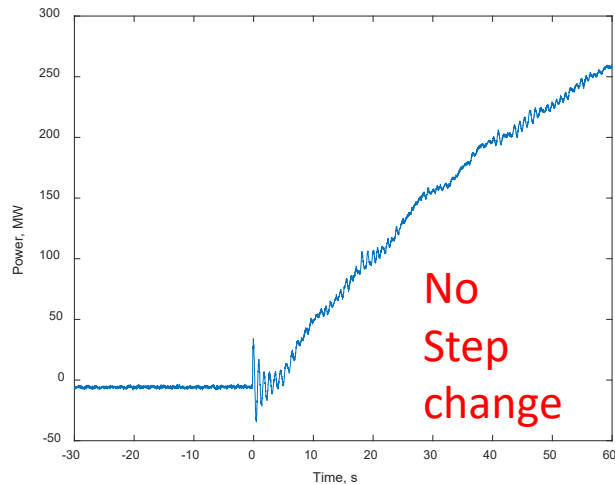


PSH Event Analysis – Four Types of Events from PSH

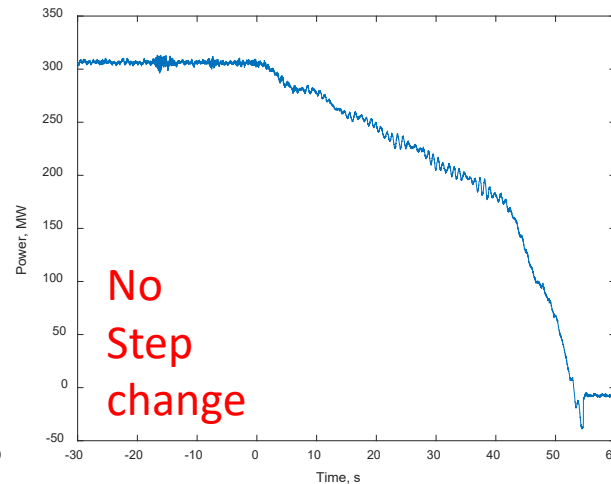
- RoCoF-based inertia estimation needs the power step change in the event, but pump switch-on, generator switch-off, and generator switch-on don't have power step change.



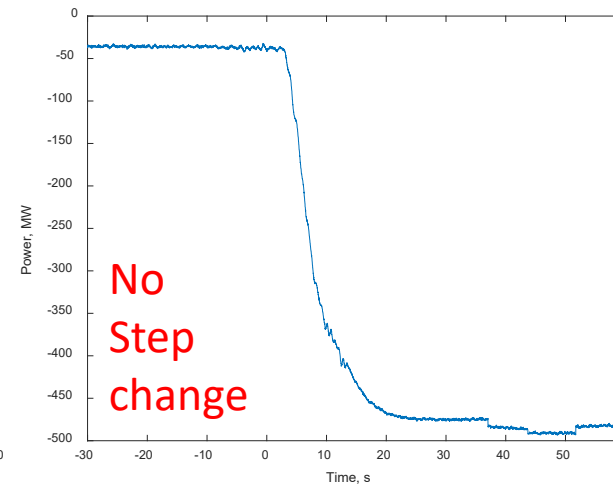
Generator switch on



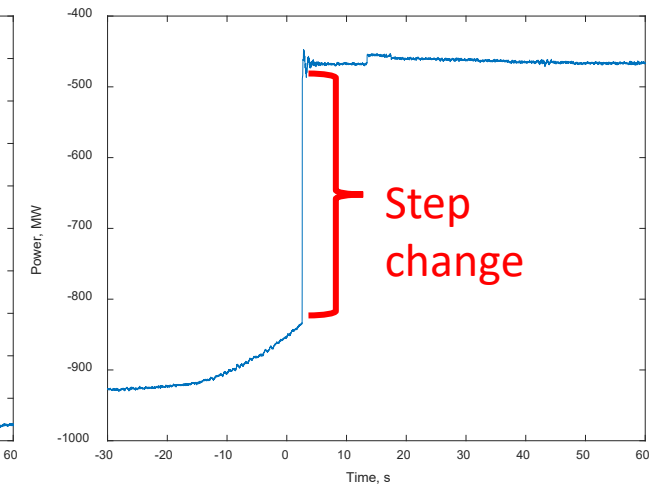
Generator switch off



Pump switch on

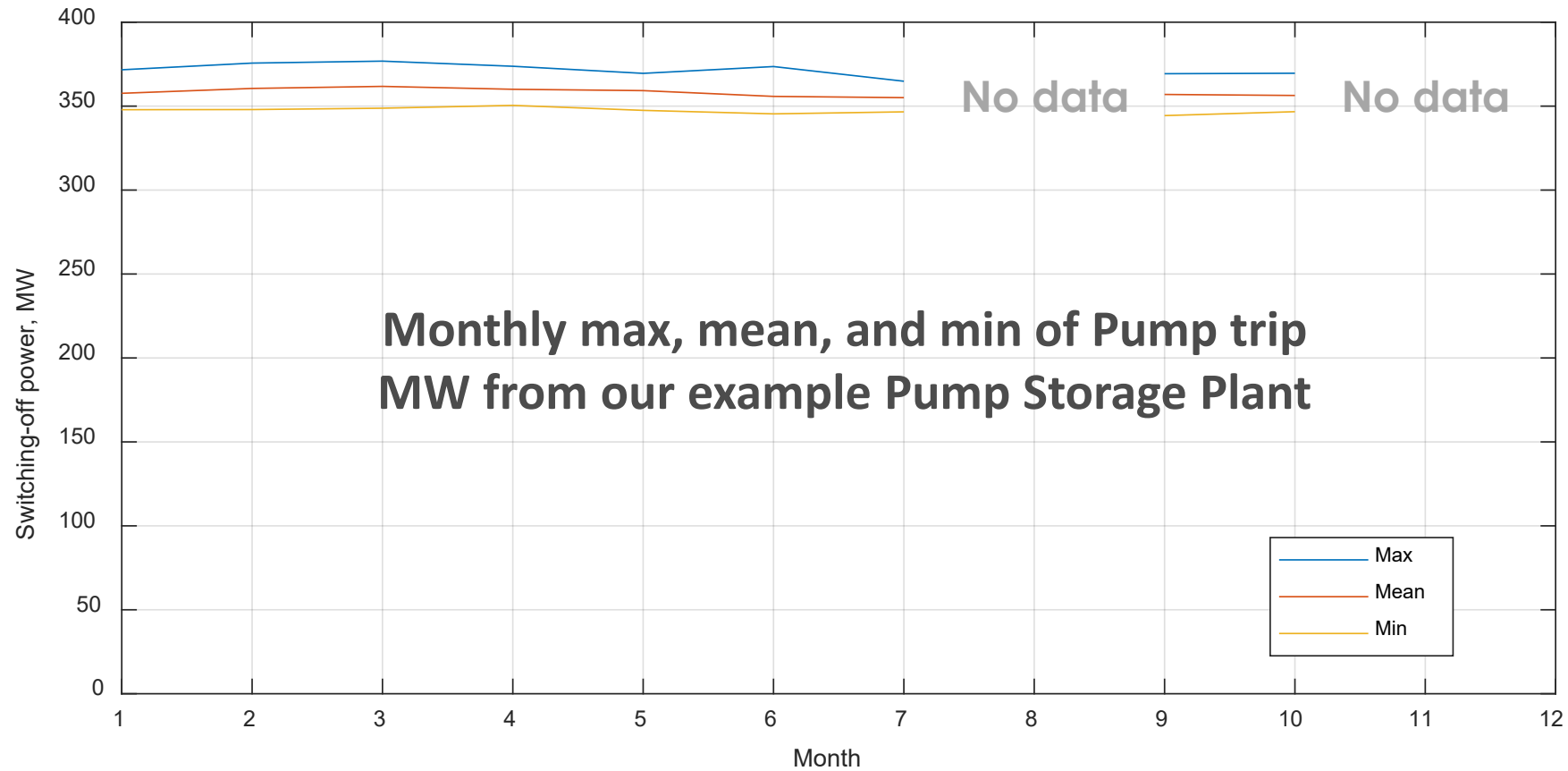


Pump switch off



PSH Event Analysis – Switching-off MW Analysis

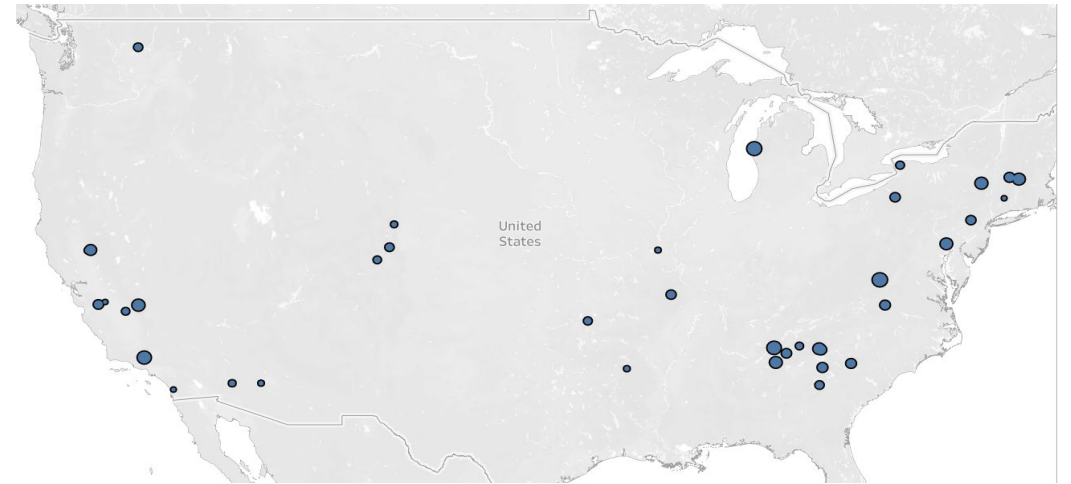
- Pump switching-off MW doesn't change too much over one year period



Pump Storage Plant for WECC Inertia Estimation

Reasons for using WECC as the example:

1. Accurate inertia value of WECC provided by NERC.
2. The pump storage plant has enough capacity in WECC.
3. The pump storage plant has large number of detected switching-off events based on FNET database.



Three Grid Monitors Deployed Near the Pump Storage Plant

Three monitors were deployed near the pump storage plant. Two UGA-POW monitors can measure POW waves.

FDR

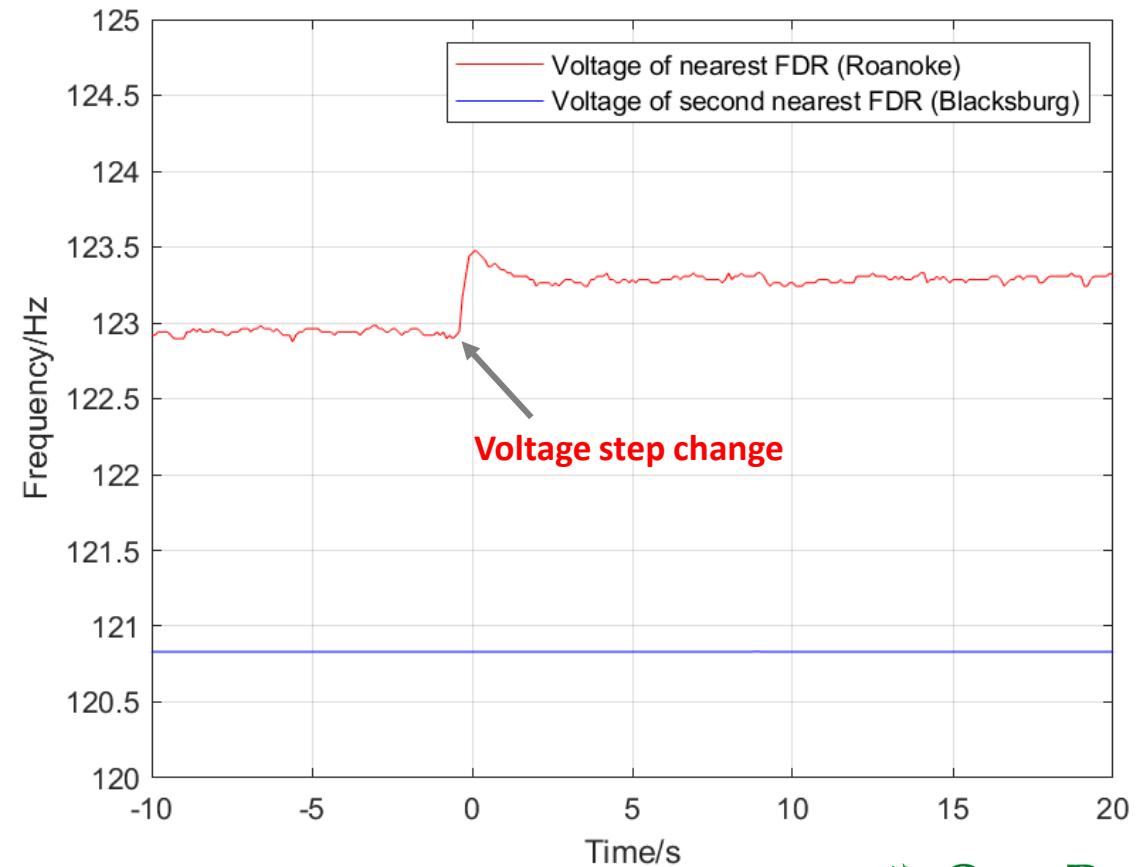
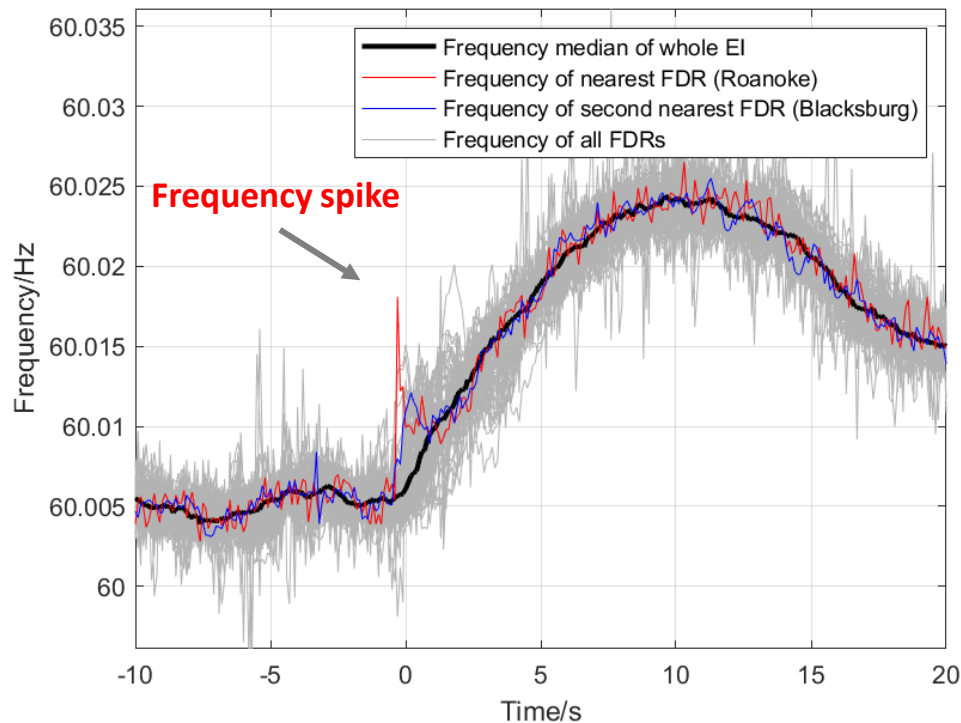
Measured Signal	Resolution (points/s)
Frequency	10
Voltage	10
Angle	10

UGA-POW

Measured Signal	Resolution (points/s)
POW voltage	1440
Frequency	120
Voltage	10
Angle	10

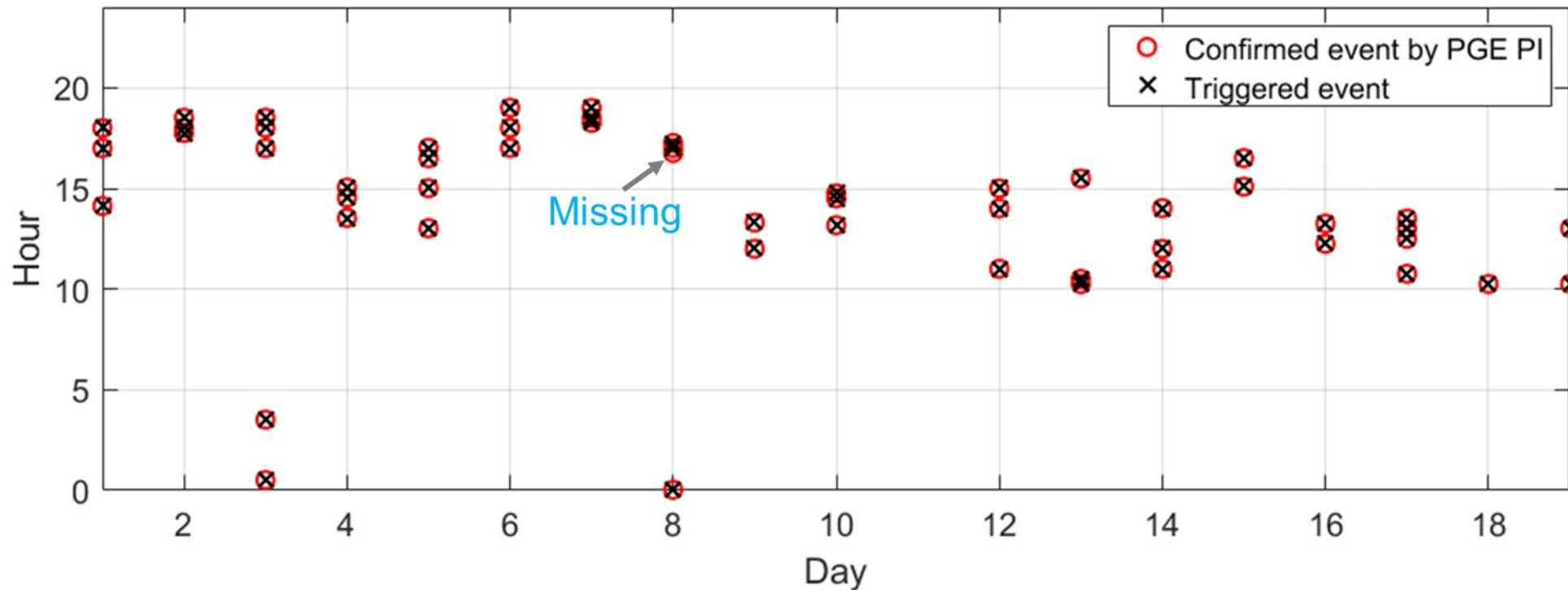
Measurement Patterns in Local Frequency and Voltage

- The following patterns are used for trigger design
 - Local frequency spike
 - Local voltage step change



Trigger Performance Testing Using PGE Confirmed Data

- No false alarm → Detection Accuracy=100%
- Only one detection missing → Missing Rate in Confirmed Events=1/53=1.89%
 - Reason: data loss



Inertia Estimation Validation Using NERC Confirmed Events

- Validation is based on 42 confirmed cases of WECC Pump plant from NERC (2015.12~2019.10).
- Inertia estimation equation: $Inertia = \frac{MW}{RoCoF/60}/2$
- NERC inertia data is used as the background truth inertia in this validation.

Error index	RoCoF window size								
	0.1s	0.2s	0.3s	0.4s	0.5s	1s	2s	3s	4s
Median absolute error rate	28.1%	8.9%	8.25%	8.3%	13.22%	29.8%	52.8%	68.9%	82.7%
Average absolute error rate	28.7%	10.6%	9.9%	10.8%	13.6%	28.6%	52.3%	68.3%	80.2%
Max absolute error rate	55.0%	26.8%	26.1%	33.2%	35.8%	56.7%	84.2%	103.7%	109.63%

Online Inertia Estimation and Demonstration

