Pacific Northwest
NATIONAL LABORATORY

Avoiding Bias in Mode Estimates Due to Transients

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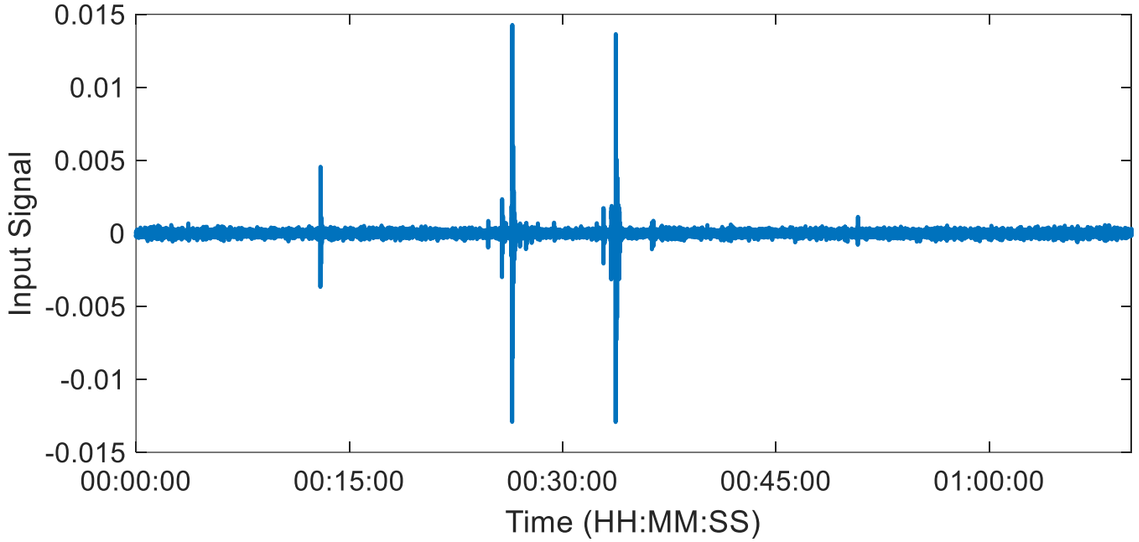
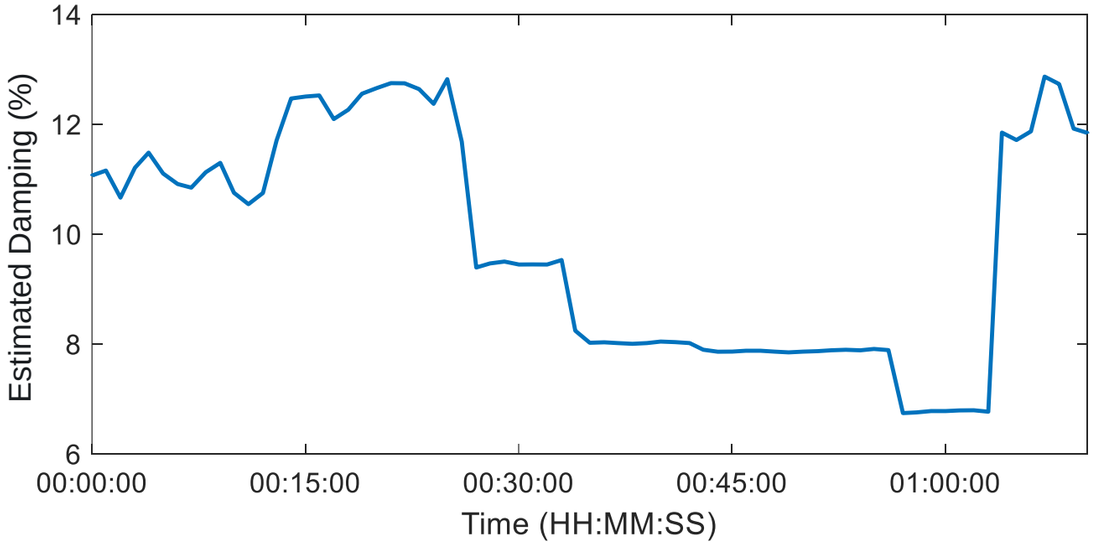
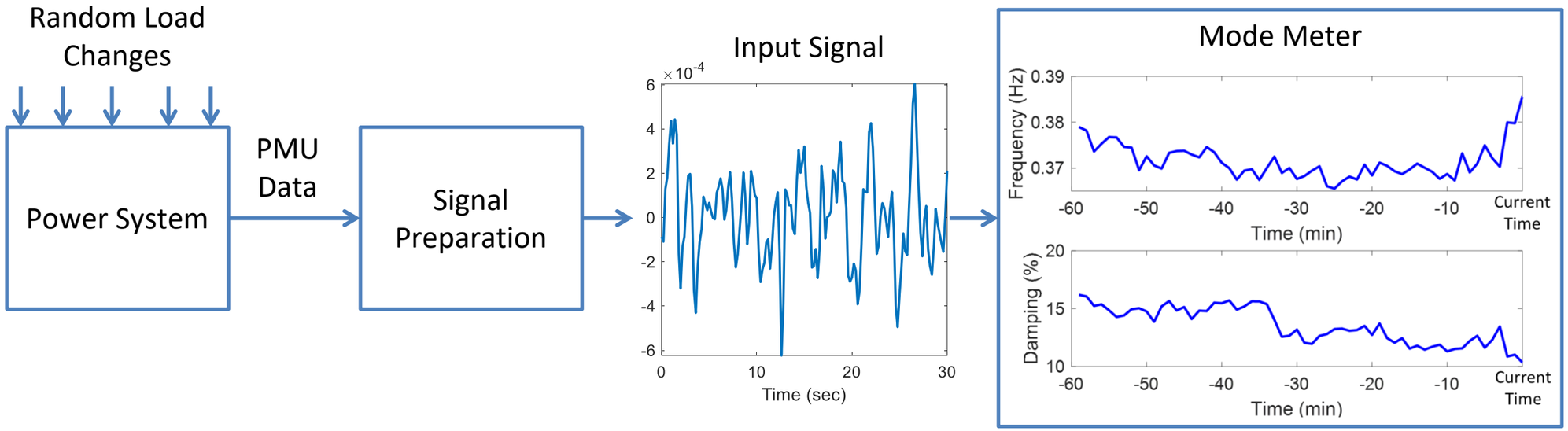
Introduction

- BPA identified bias in mode meter estimates following system disturbances
- PNNL developed a modification to address the problem
- SEL implemented the modification in Synchrowave Operations

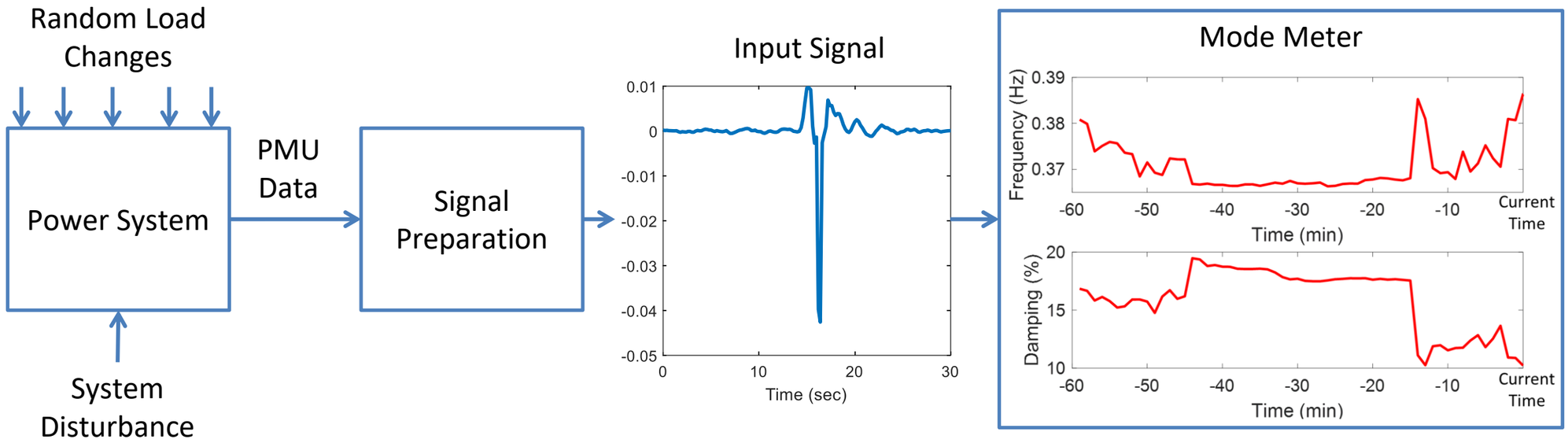




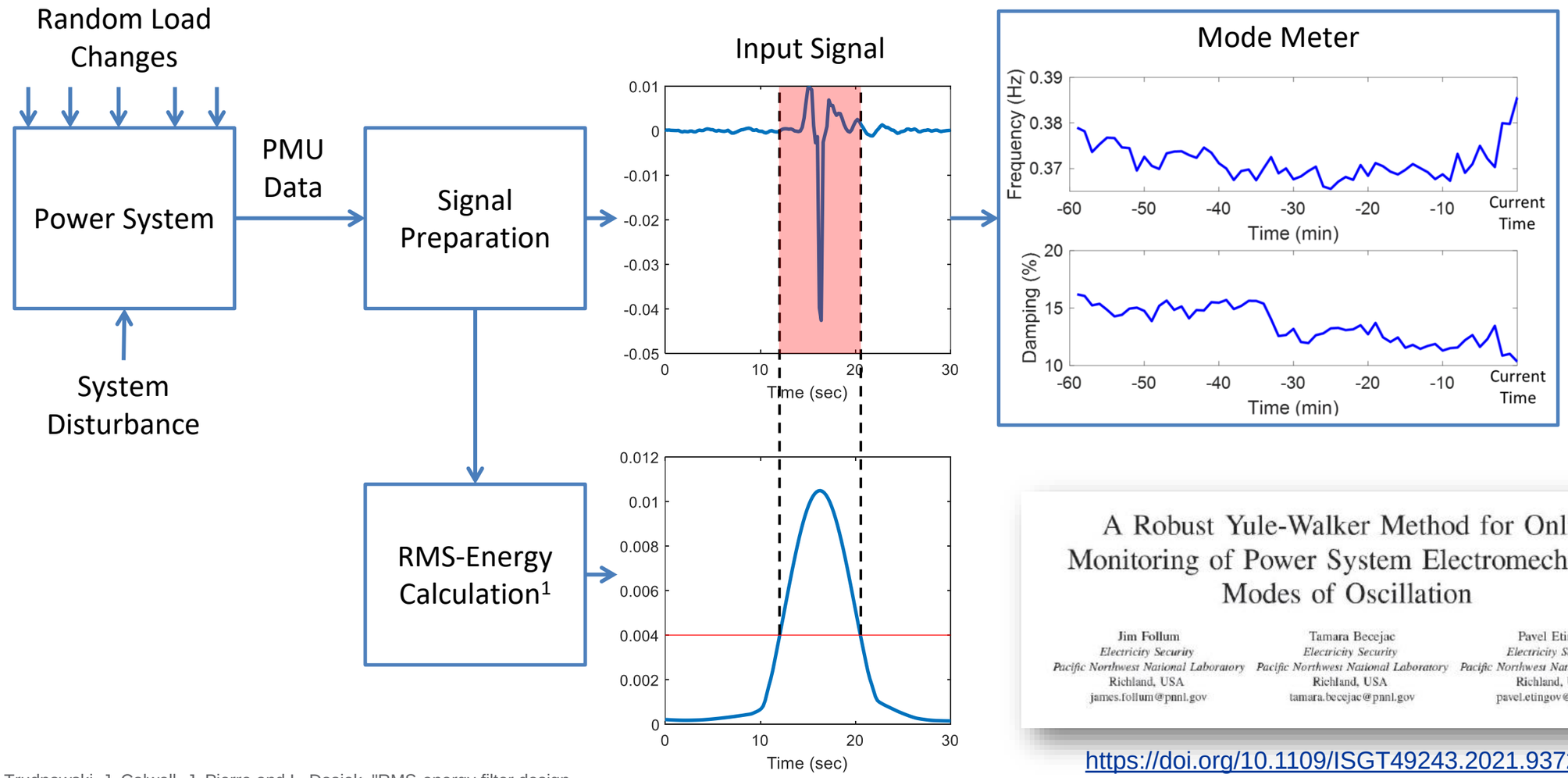
Mode Meter Operation



Bias Identified by BPA Following Disturbances



Avoiding Bias



A Robust Yule-Walker Method for Online Monitoring of Power System Electromechanical Modes of Oscillation

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https://doi.org/10.1109/ISGT49243.2021.9372152

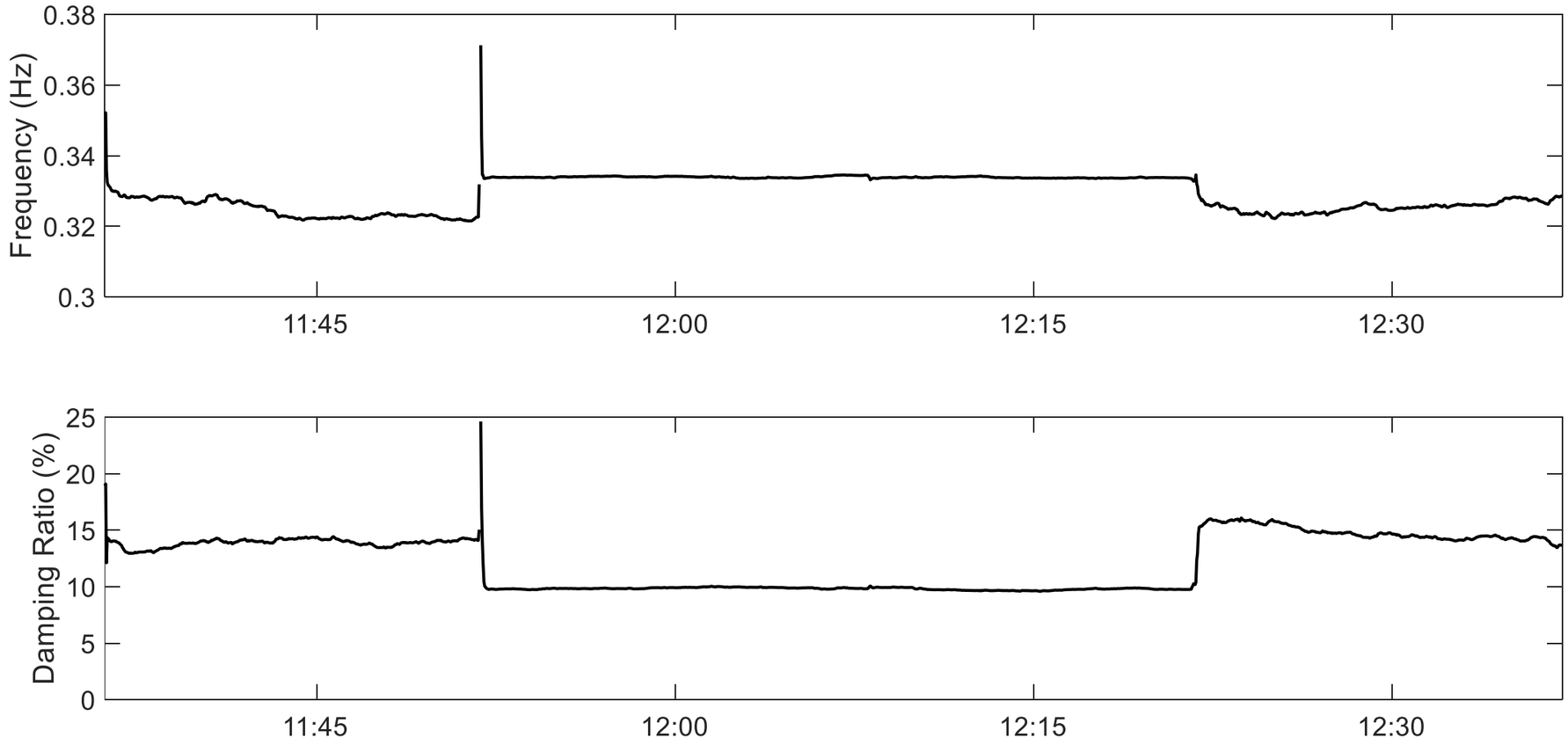
[1]M. Donnelly, D. Trudnowski, J. Colwell, J. Pierre and L. Dosiek, "RMS-energy filter design for real-time oscillation detection," 2015 IEEE Power & Energy Society General Meeting, Denver, CO, USA, 2015, pp. 1-5, doi: https://doi.org/10.1109/PESGM.2015.7286192.

Evaluation of the Synchrowave Operations Implementation

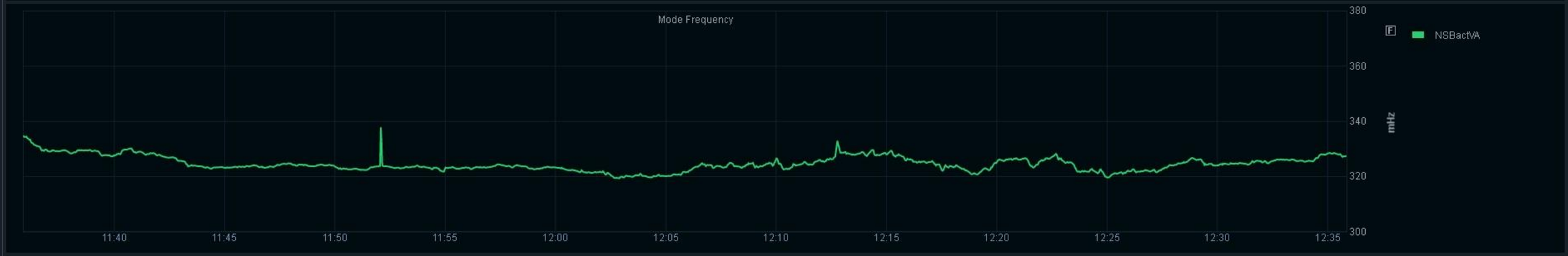
- PMU data provided by BPA
- Synchrowave Operations configured to track North-South B mode
- Considered 21 cases where conventional mode meter was biased
- Compared:
  - Conventional mode meter implemented by PNNL
  - Modified mode meter implemented by PNNL
  - Modified mode meter in Synchrowave Operations

Note: timestamps throughout the presentation have been modified and do not correspond to the actual events

Case 1: Conventional Algorithm

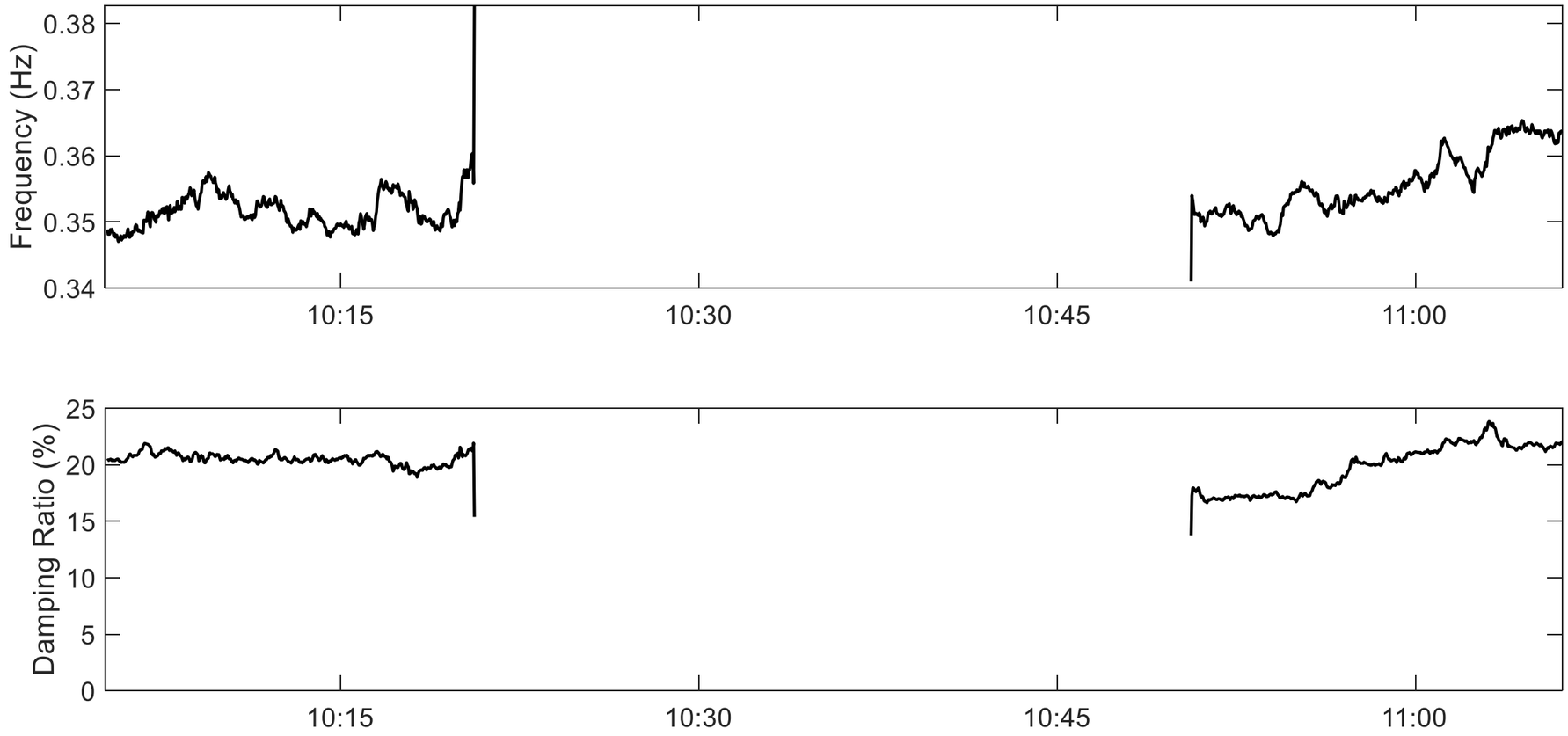



Frequency
60.05
60
59.95
59.9
Hz
NorthSub
11:40 11:45 11:50 11:55 12:00 12:05 12:10 12:15 12:20 12:25 12:30 12:35


Mode Frequency
380
360
340
320
300
mHz
NSBactVA
11:40 11:45 11:50 11:55 12:00 12:05 12:10 12:15 12:20 12:25 12:30 12:35


Mode Damping
25
20
15
10
5
0
%
NSBactVA
11:40 11:45 11:50 11:55 12:00 12:05 12:10 12:15 12:20 12:25 12:30 12:35

Case 2: Conventional Algorithm



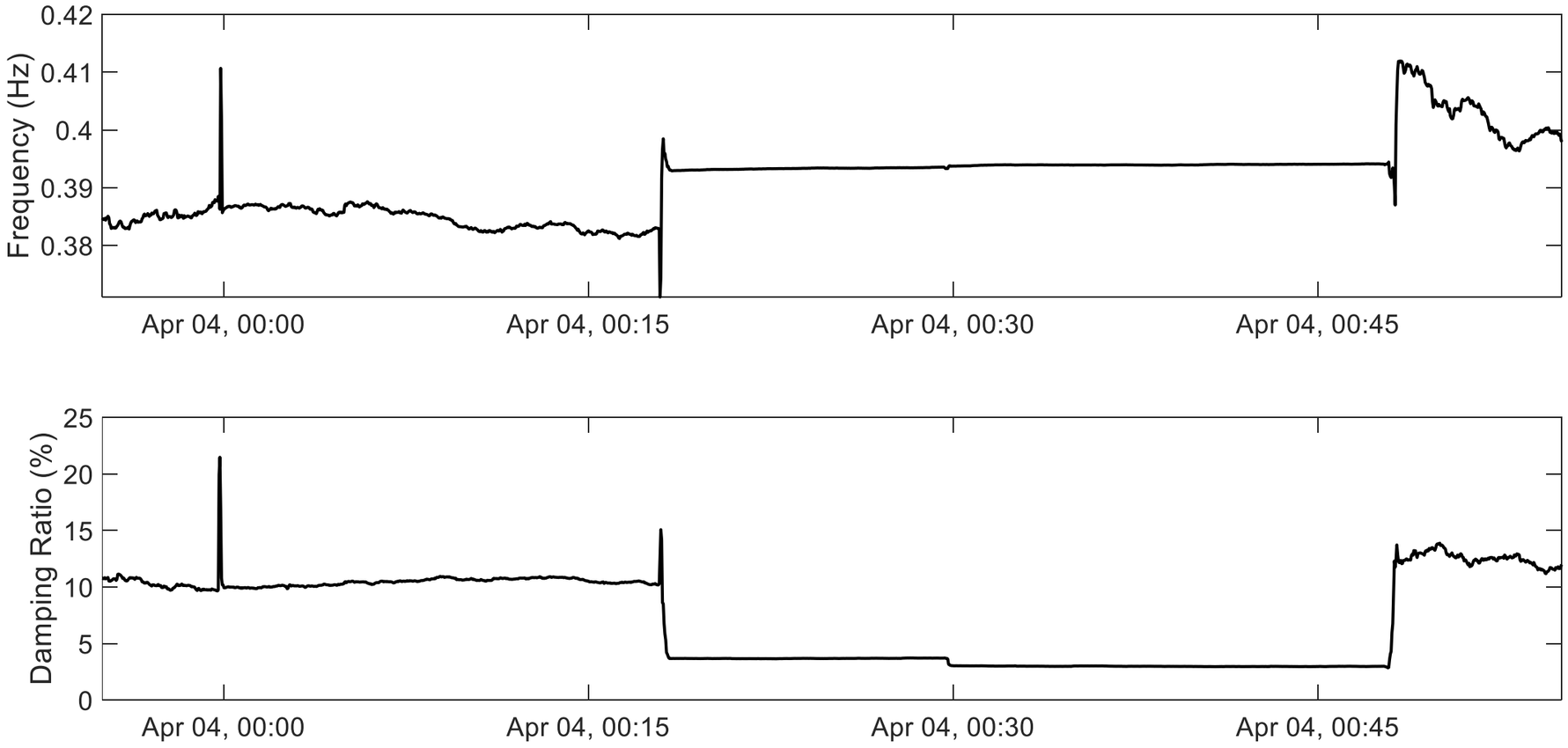
Historical Data
02 03 04 05 06 07 08 09 10 11

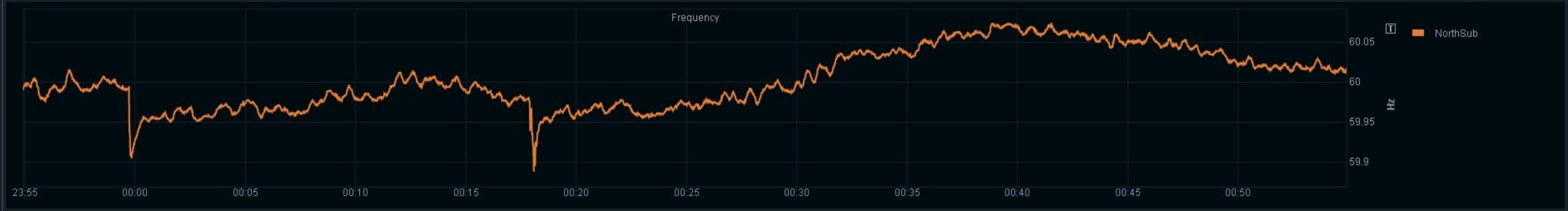
Historical Data
1h
Hour Chart Range

User + | Frequency | Angle | Power
General | Oscillation | Voltage | All

Dashboards
MMresults2 MMresults
+ Panel + Dashboard

Case 3: Conventional Algorithm

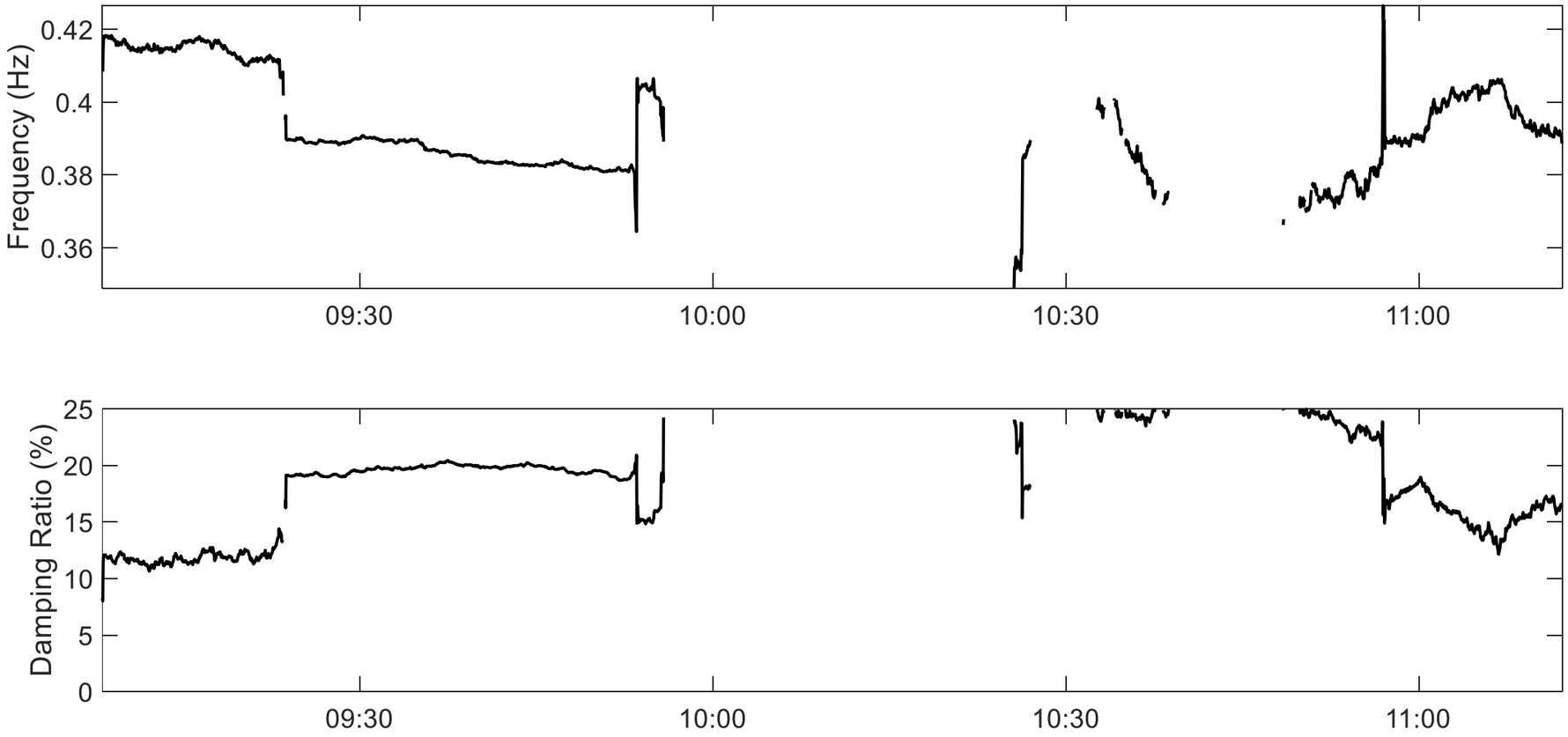


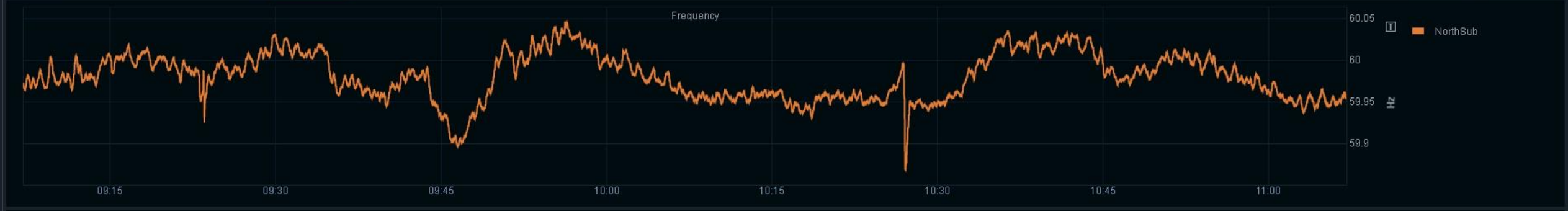

Frequency
T NorthSub
60.05
60
59.95
59.9
Hz
23:55 00:00 00:05 00:10 00:15 00:20 00:25 00:30 00:35 00:40 00:45 00:50


Mode Frequency
F NSBactVA
420
410
400
390
380
370
mHz
23:55 00:00 00:05 00:10 00:15 00:20 00:25 00:30 00:35 00:40 00:45 00:50


Mode Damping
F NSBactVA
25
20
15
10
5
0
%
23:55 00:00 00:05 00:10 00:15 00:20 00:25 00:30 00:35 00:40 00:45 00:50

Case 4: Conventional Algorithm

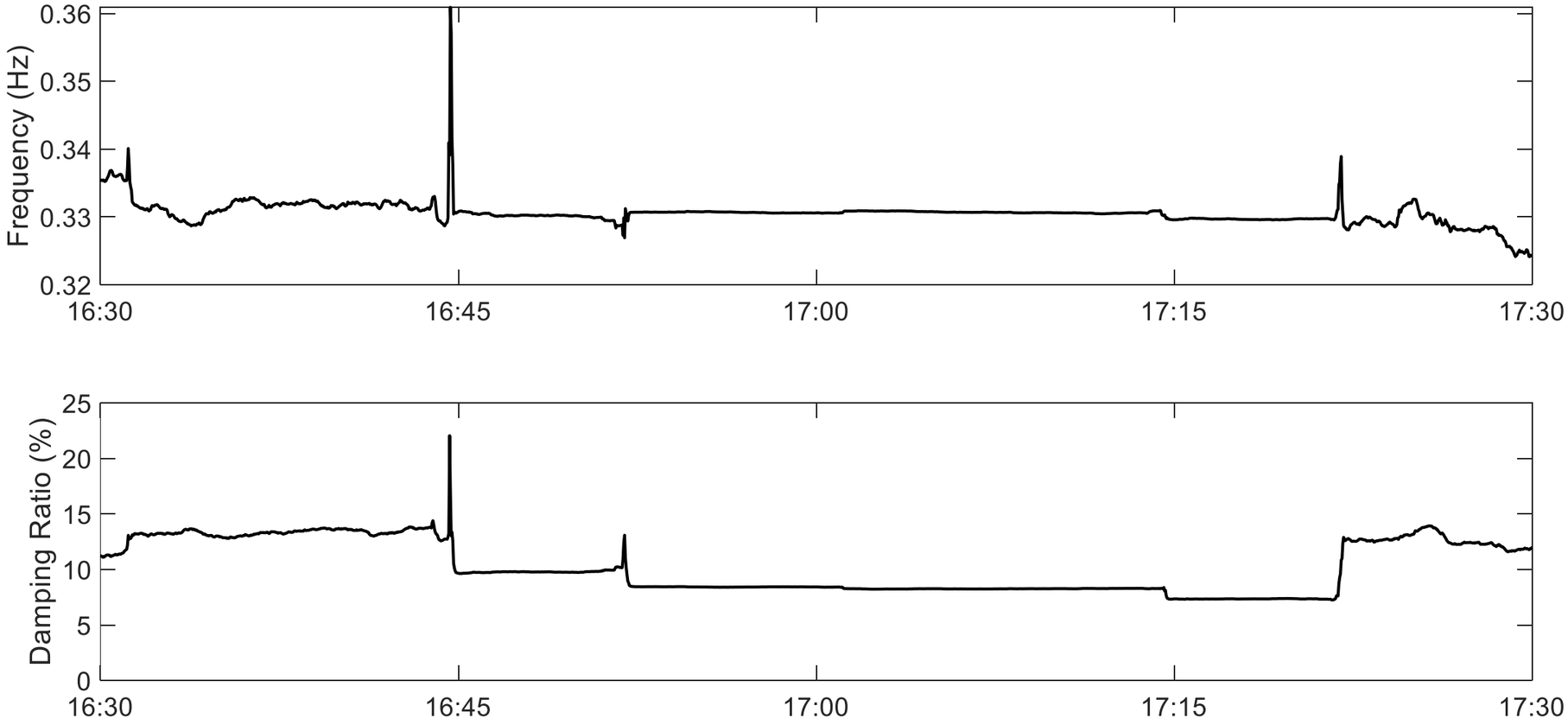



Frequency
60.05
60
59.95
59.9
Hz
T
NorthSub
09:15 09:30 09:45 10:00 10:15 10:30 10:45 11:00


Mode Frequency
420
400
380
360
mHz
F
NSBactVA
09:15 09:30 09:45 10:00 10:15 10:30 10:45 11:00


Mode Damping
25
20
15
10
5
0
%
F
NSBactVA
09:15 09:30 09:45 10:00 10:15 10:30 10:45 11:00

Case 5: Conventional Algorithm

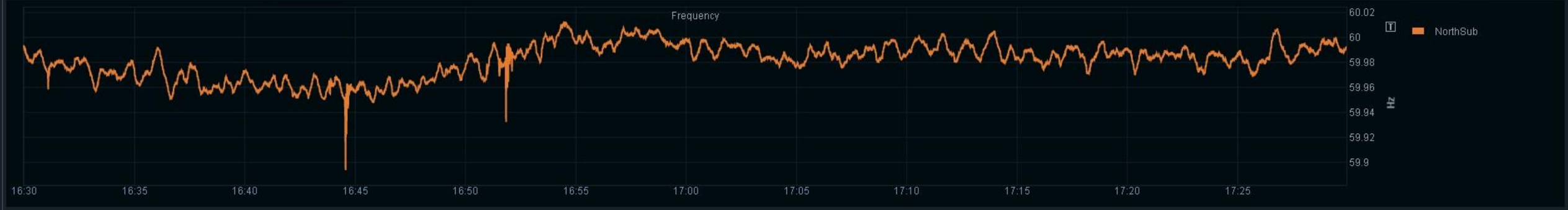


Historical Data
08 09 10 11 12 13 14 15 16 17

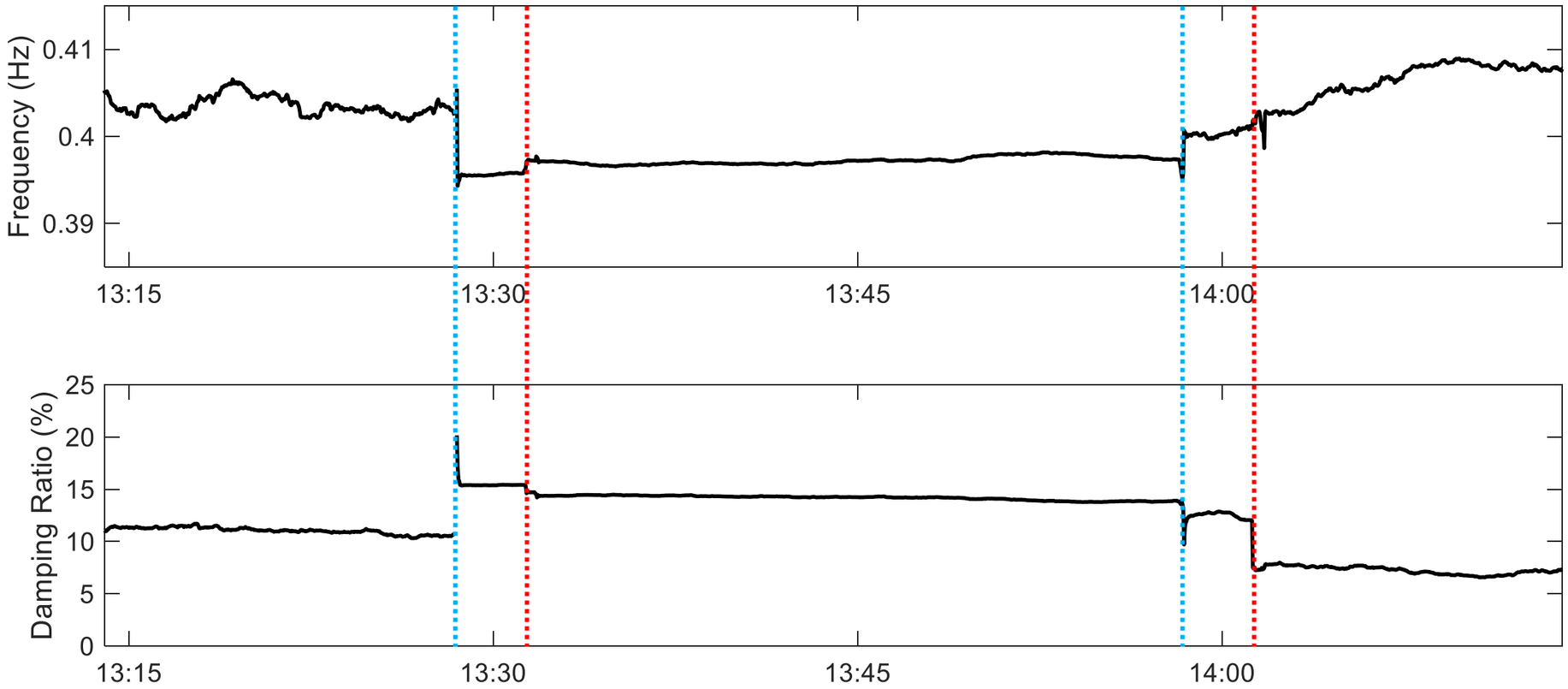
Historical Data
1h
Hour Chart Range

User + | Frequency | Angle | Power
General | Oscillation | Voltage | All

Dashboards
MMresults2 MMresults
+ Panel + Dashboard



Case 6: Conventional Algorithm




SEL
Synchrowave Operations
foll154
Historical Data
05
06
07
08
09
10
11
12
13
14
Historical Data
1h
Hour Chart Range
User
Frequency
Angle
Power
General
Oscillation
Voltage
All
Dashboards
MMresults2
MMresults
Panel
Dashboard
Frequency
NorthSub
60.05
60
59.95
59.9
59.85
Hz
13:15
13:20
13:25
13:30
13:35
13:40
13:45
13:50
13:55
14:00
14:05
14:10
Mode Frequency
NSBactVA
415
410
405
400
395
390
385
mHz
Manages first event
Mode Damping
NSBactVA
25
20
15
10
5
0
%
Biased by second event


SEL
Synchrowave Operations
foll154
Historical Data
05
06
07
08
09
10
11
12
13
14
Historical Data
1h
Hour Chart Range
User
Frequency
Angle
Power
General
Oscillation
Voltage
All
Dashboards
MMresults2
MMresults
Panel
Dashboard
PAD
NorthStn_SouthStn.N...
18
16
14
12
10
13:15
13:20
13:25
13:30
13:35
13:40
13:45
13:50
13:55
14:00
14:05
14:10
Mode Frequency
NSBactVA
415
410
405
400
395
390
385
mHz
Manages first event
Mode Damping
NSBactVA
25
20
15
10
5
0
Biased by second event

Findings and Future Work

- The modified mode meter avoids bias due to transients
- Mode estimates from Synchrowave Operations closely match those from PNNL's implementation
- Future work:
  - Evaluate potential updates to the transient detection algorithm to handle sequential disturbances
  - Evaluate PNNL's algorithm for avoiding mode meter bias due to forced oscillations

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Thank you