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Machine Learning Techniques for Oscillation Baselining in the Western Interconnection

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NASPI Engineering Analysis Task Team Breakout

Introduction

- Objective: Identify relationships between:
  - Operating conditions
    - Power flow
    - Generation
    - Voltage angle differences
  - Mode parameters
    - Frequency
    - Damping
- Desired Outcomes
  - Understand how operational decisions impact system stability
  - Improve alerts based on mode meters by incorporating system conditions
    - Mode meters operate on a window of past data, leading to delayed mode estimates
    - System conditions can be reported in real time

Previous Work

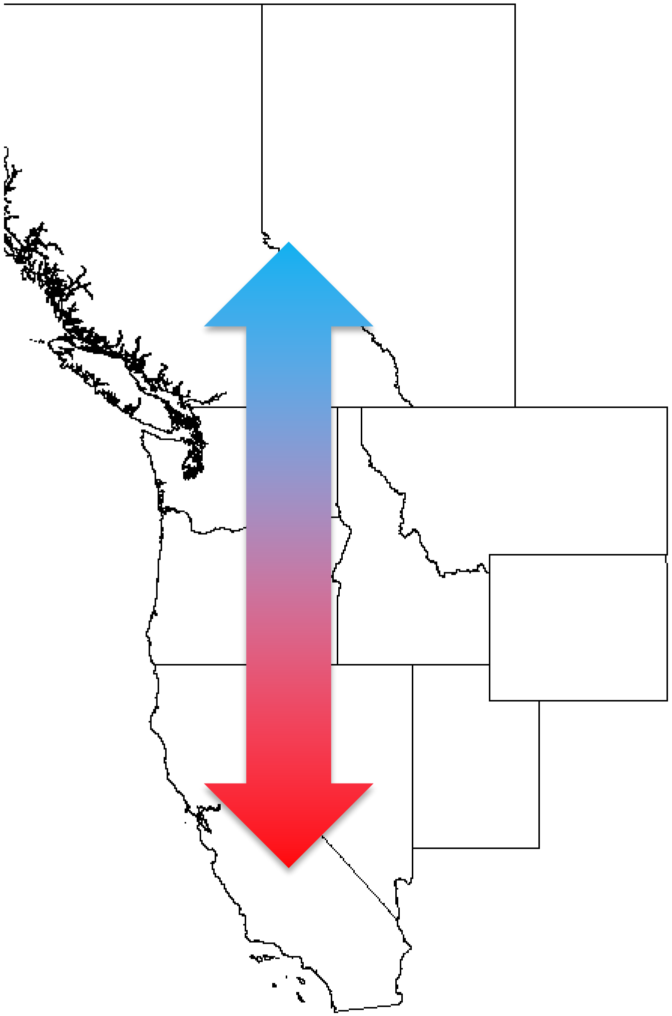
- Based on transient simulations of a full WECC model in PSLF
- Obtained mode estimates from 250 ringdowns
- Examined relationships between mode estimates and operating conditions
- Limitation: large system events are relatively rare, making field-validation difficult

Approach

- Analyze ambient PMU data
  - As the normal response of the power system to load changes, this data is very common
  - Mode-meter algorithms provide continuous estimates of system modes
    - BPA has had a mode-meter in continuous operation for several years
  - System conditions can be easily extracted
  - 38 days were analyzed
- Leverage the Archive Walker tool
  - Developed by PNNL for BPA as part of their Technology Innovation program
  - Includes data input, cleaning, and processing, along with event detection
  - Mode-meter functionality was integrated

Approach

- Modes of interest
  - **North-South A (NSA)**
  - North-South B (NSB)
- System conditions
  - 17 voltage angle pairs
  - Flow along 7 major corridors
  - Generation from 6 conventional generators (coal and hydro)
  - Generation from 3 wind farms
- Analysis methods
  - Correlation analysis
  - Analysis of Variance (ANOVA)



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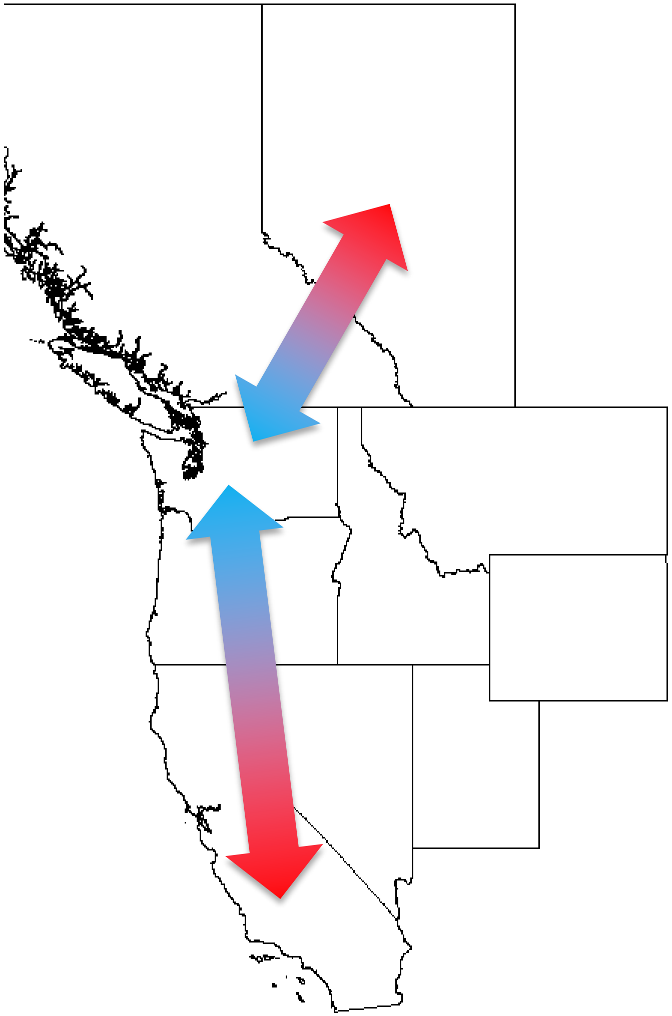

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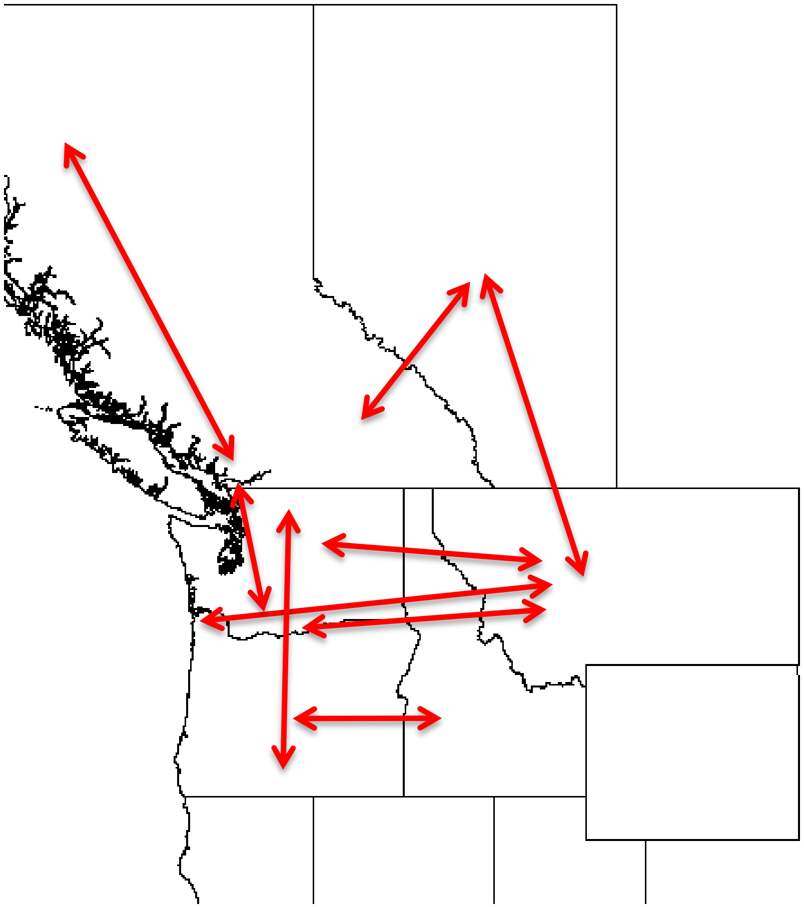

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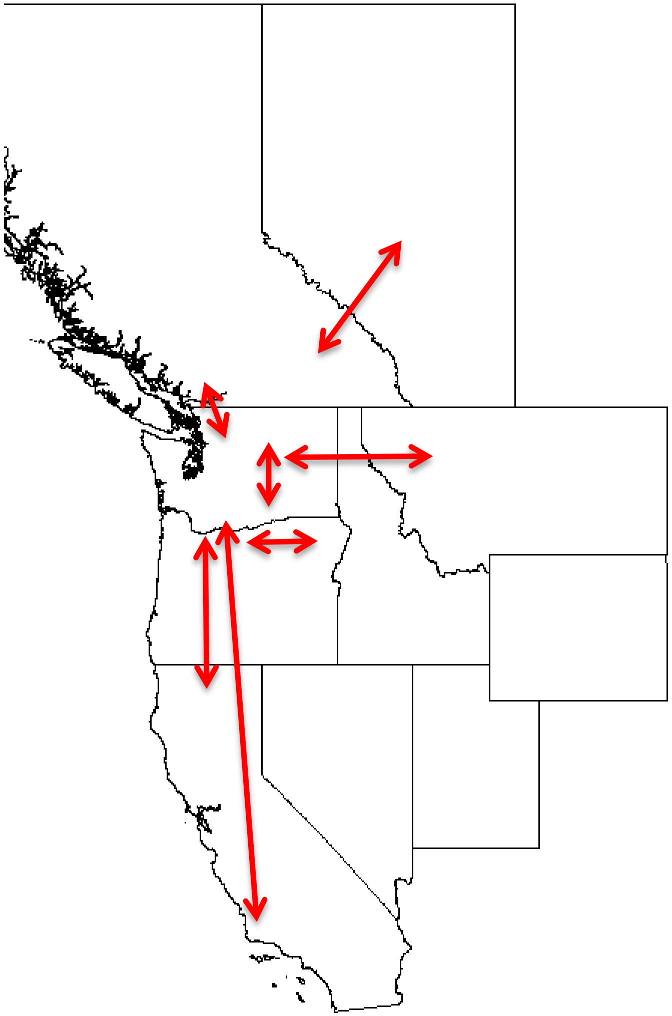

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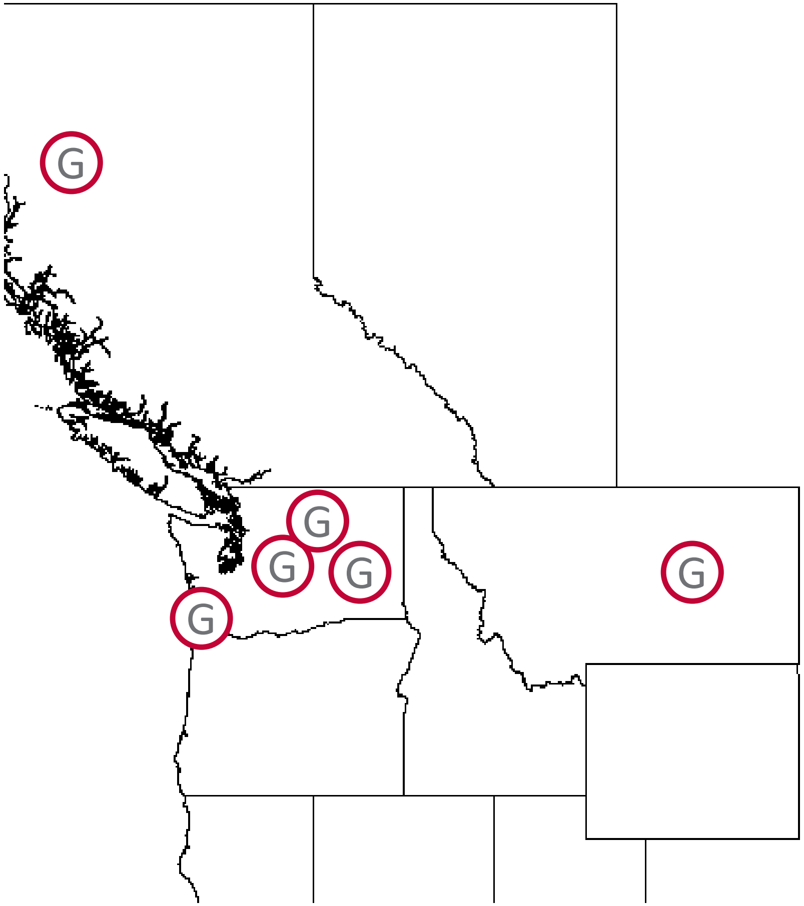

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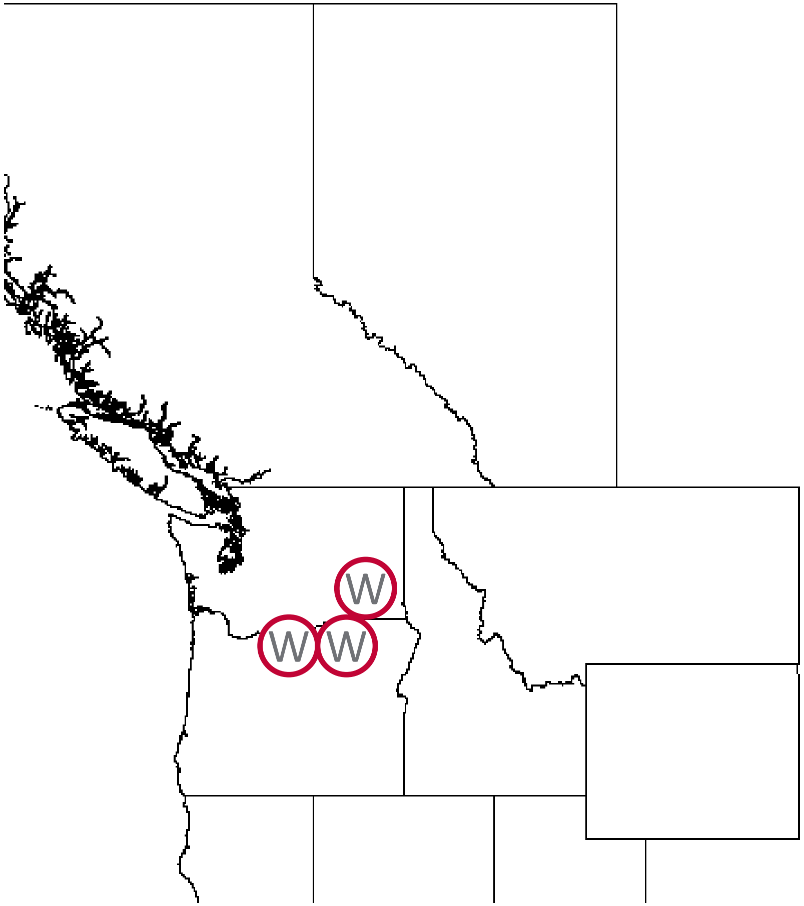

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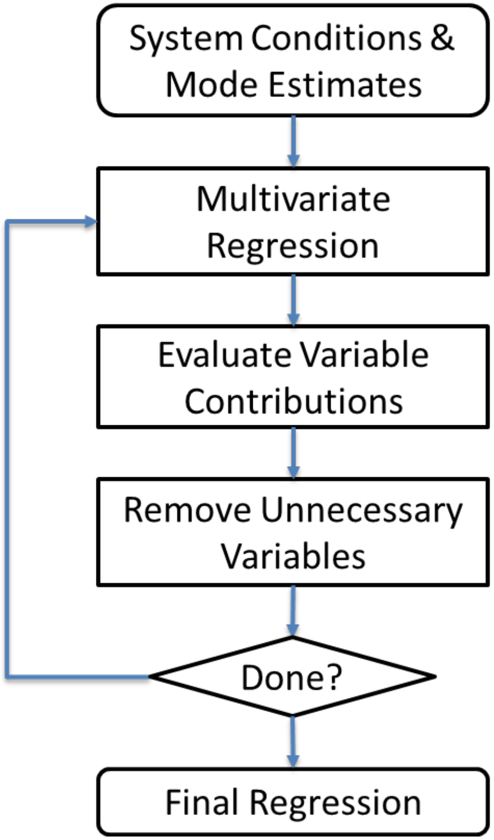
ANOVA:



Results
Correlation Analysis

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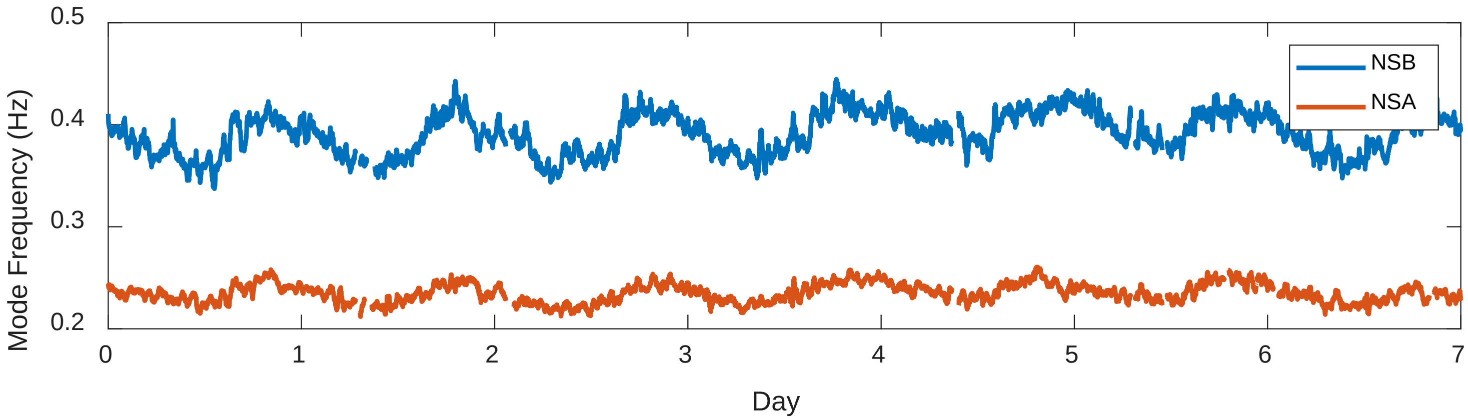
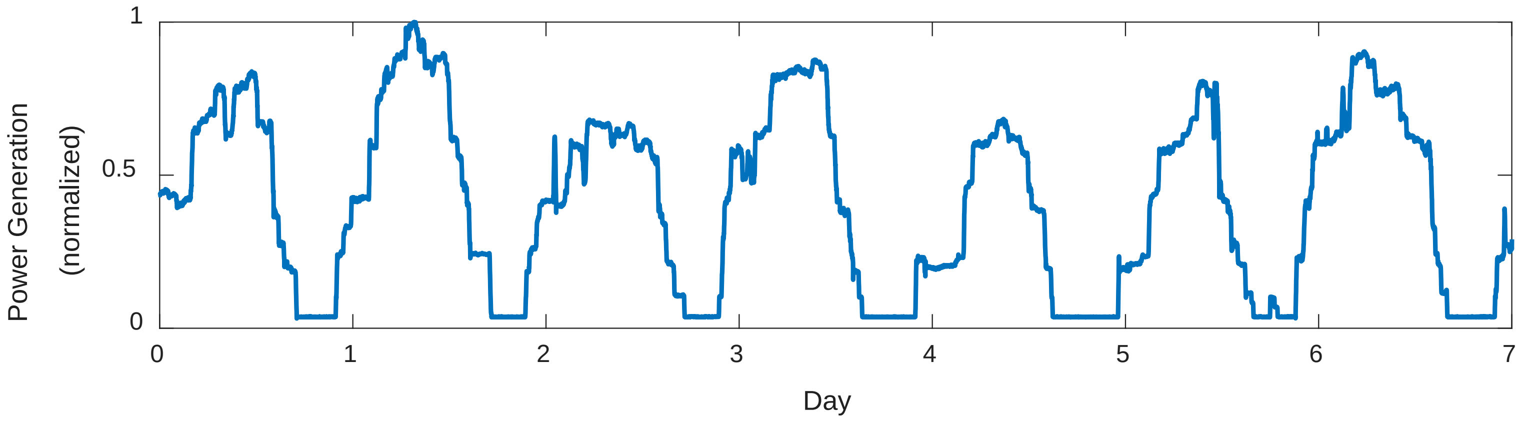
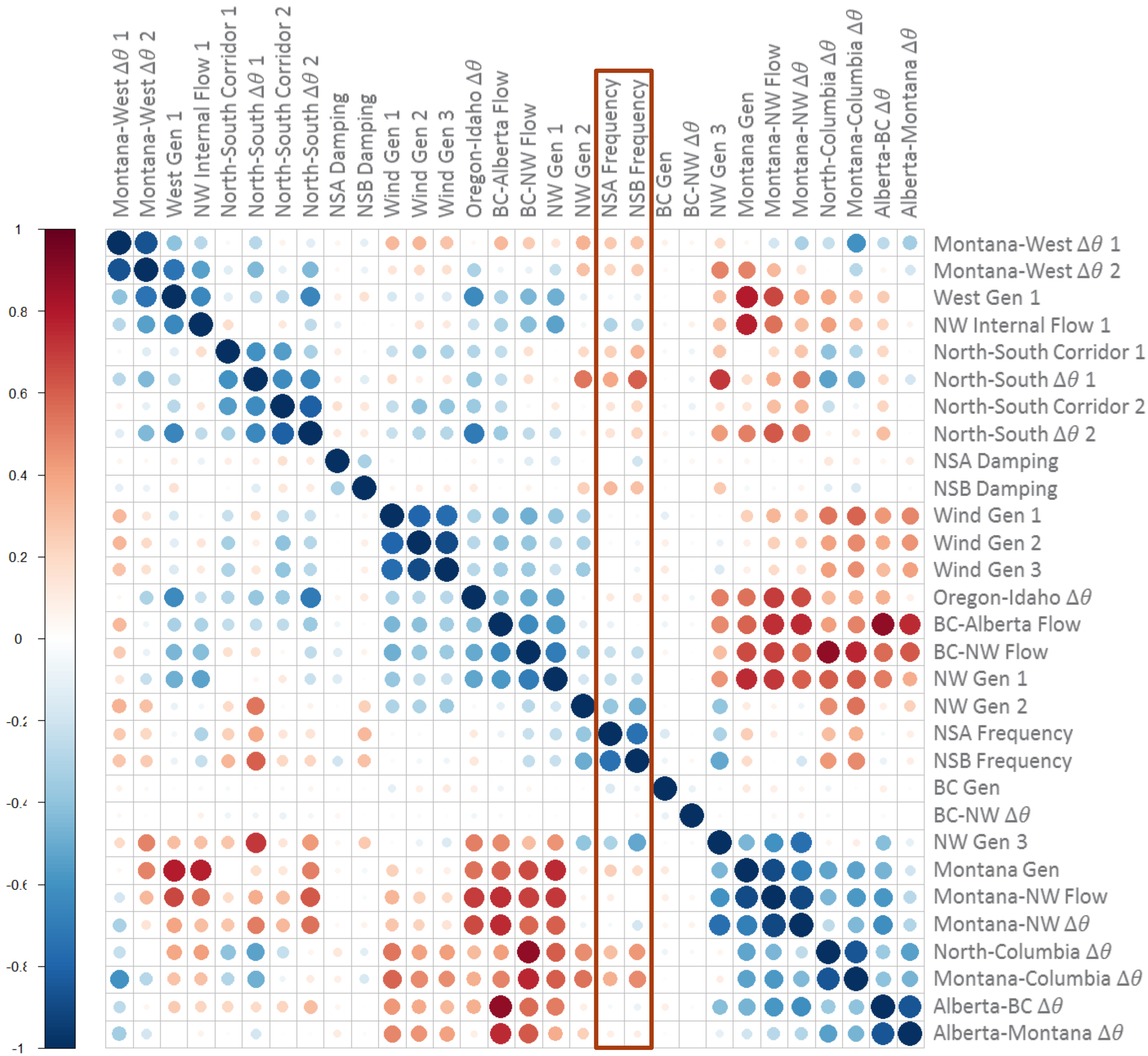
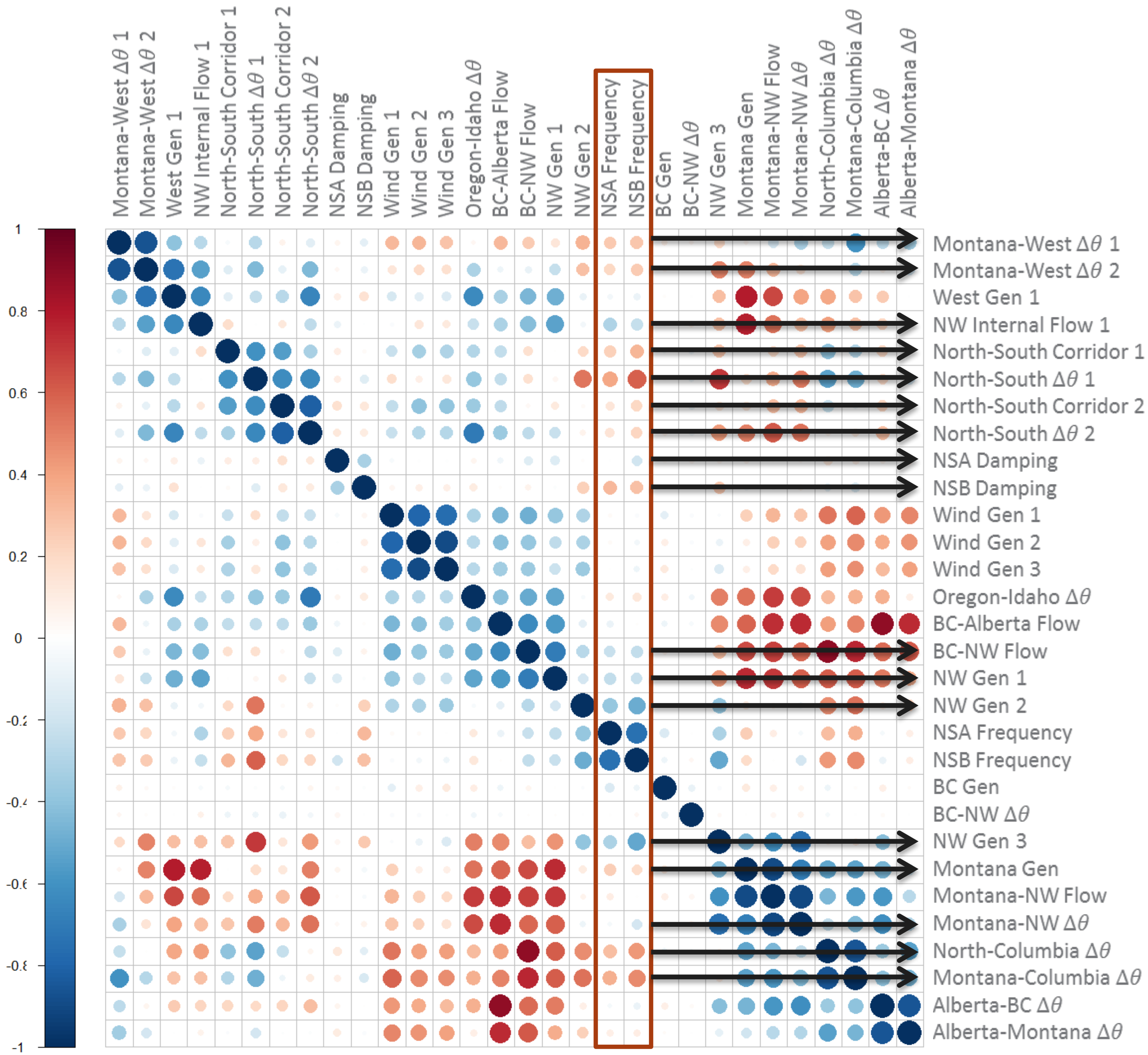





Montana-West Δθ 1
Montana-West Δθ 2
West Gen 1
NW Internal Flow 1
North-South Corridor 1
North-South Δθ 1
North-South Corridor 2
North-South Δθ 2
NSA Damping
NSB Damping
Wind Gen 1
Wind Gen 2
Wind Gen 3
Oregon-Idaho Δθ
BC-Alberta Flow
BC-NW Flow
NW Gen 1
NW Gen 2
NSA Frequency
NSB Frequency
BC Gen
BC-NW Δθ
NW Gen 3
Montana Gen
Montana-NW Flow
Montana-NW Δθ
North-Columbia Δθ
Montana-Columbia Δθ
Alberta-BC Δθ
Alberta-Montana Δθ
1
0.8
0.6
0.4
0.2
0
-1



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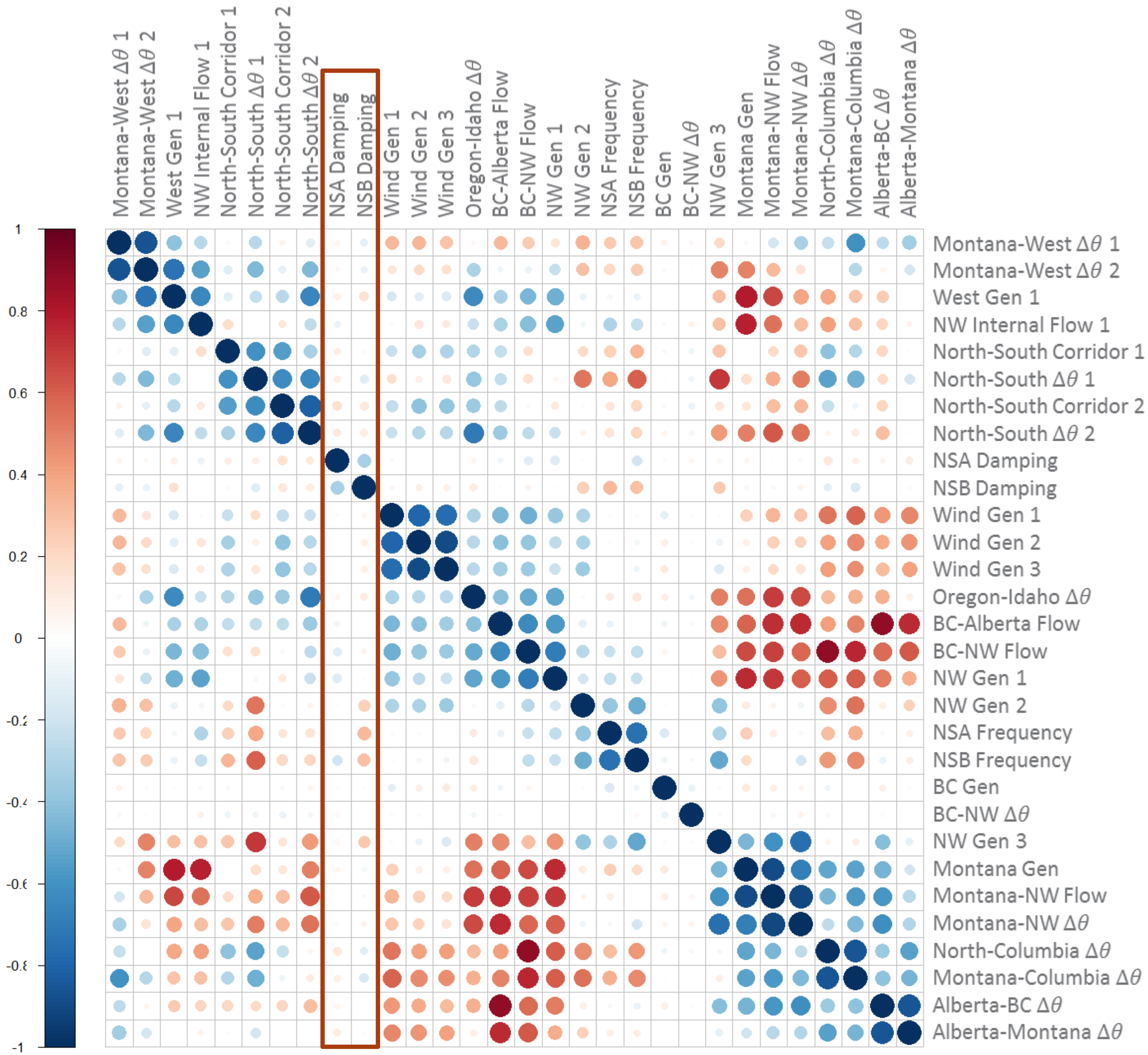

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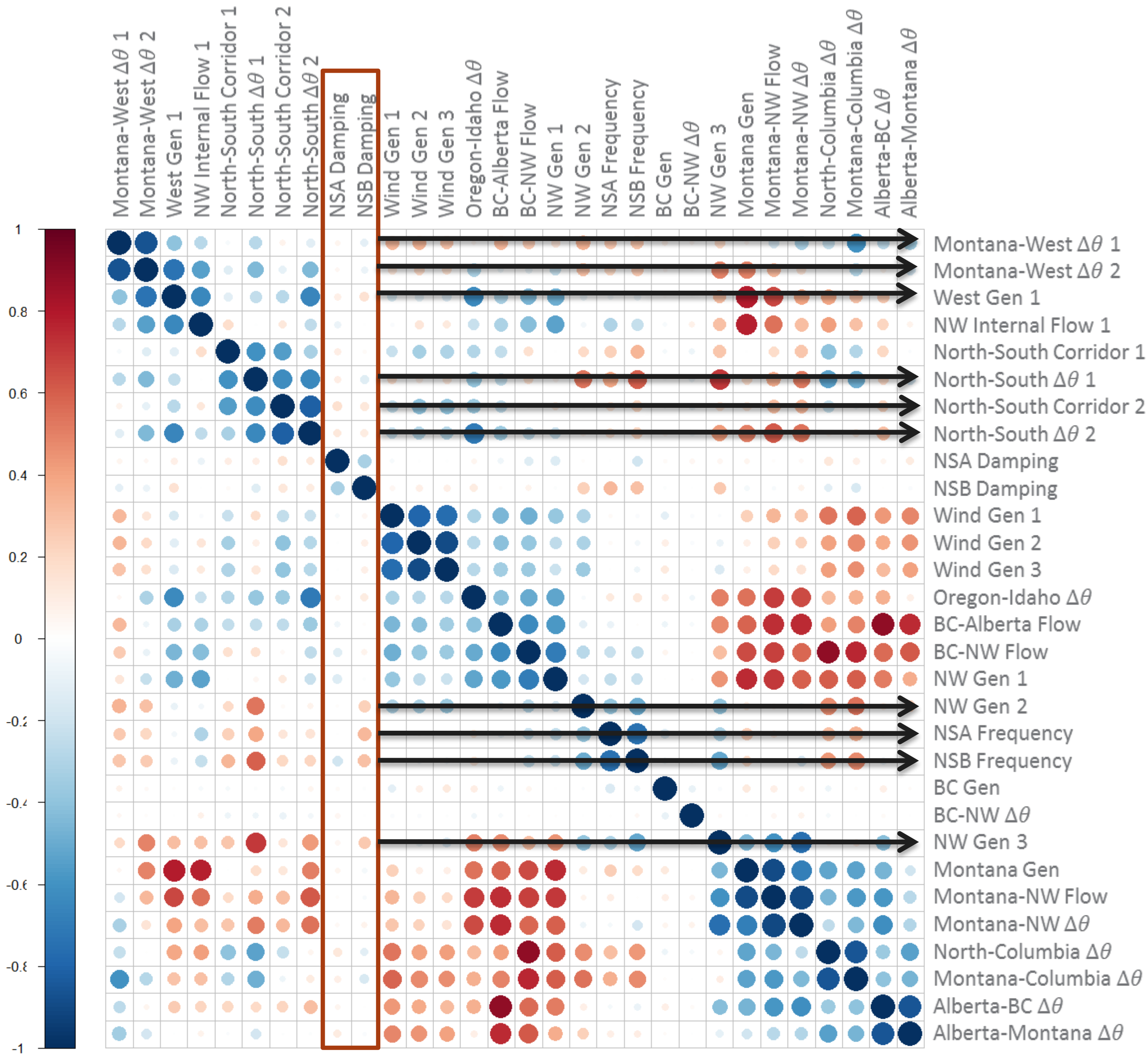
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0.6
0.4
0.2
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Results
ANOVA Factor Ranking: NSA

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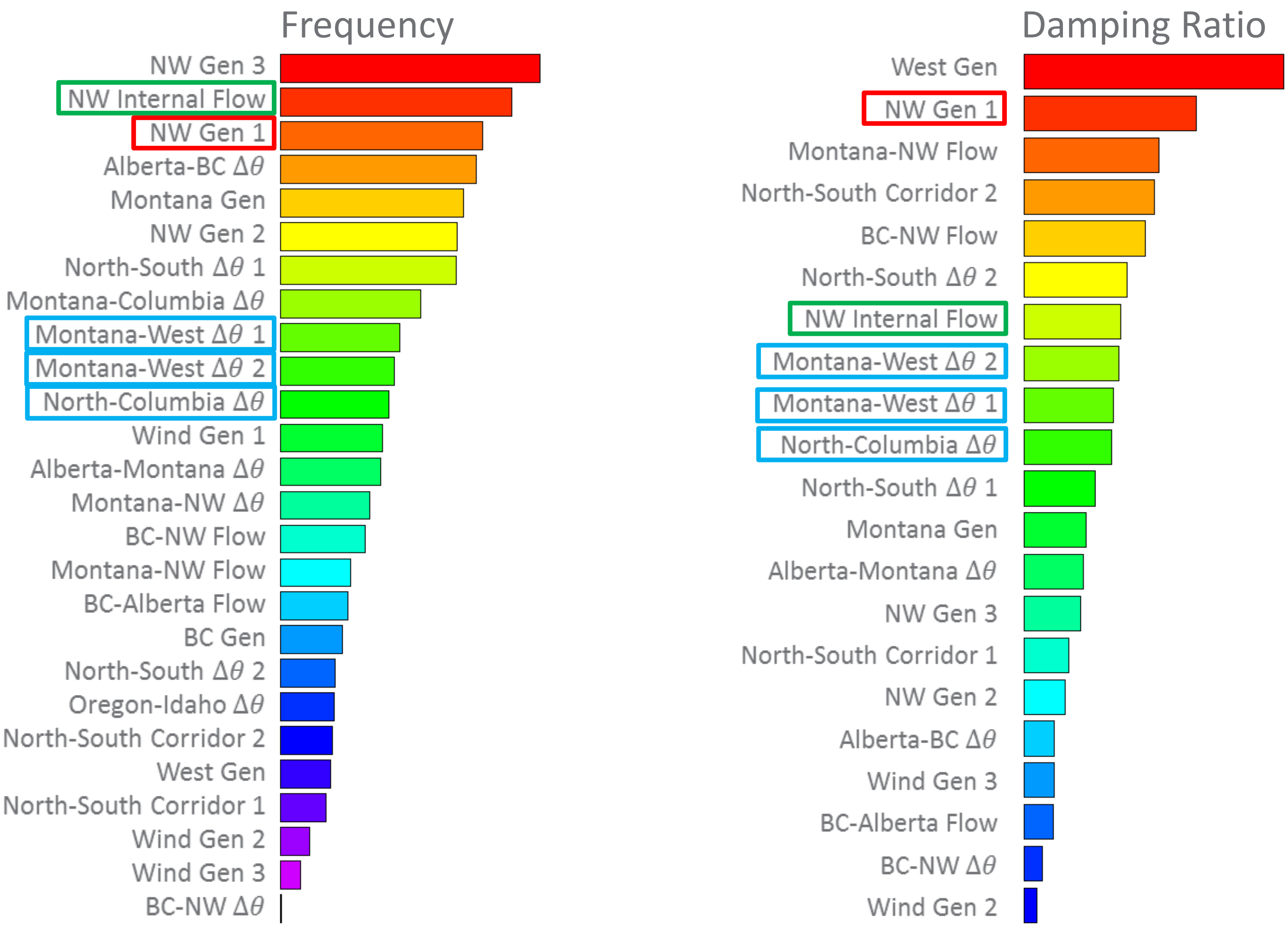

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ANOVA Factor Ranking: NSB

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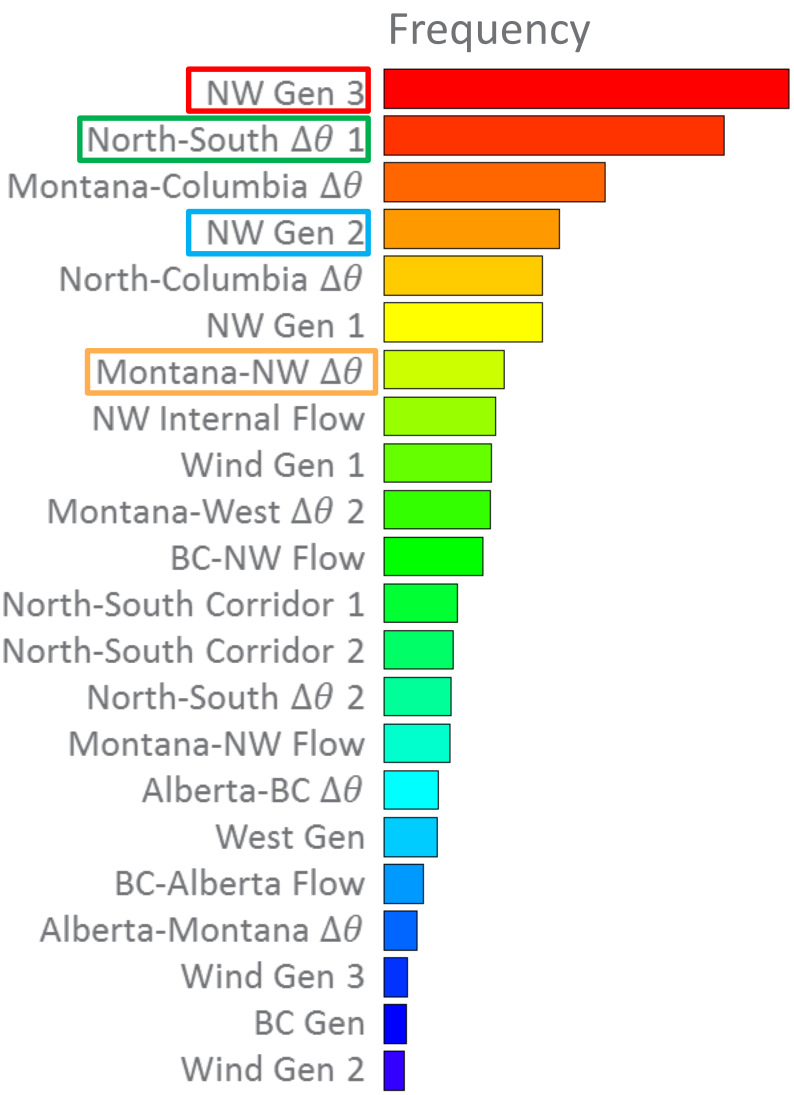
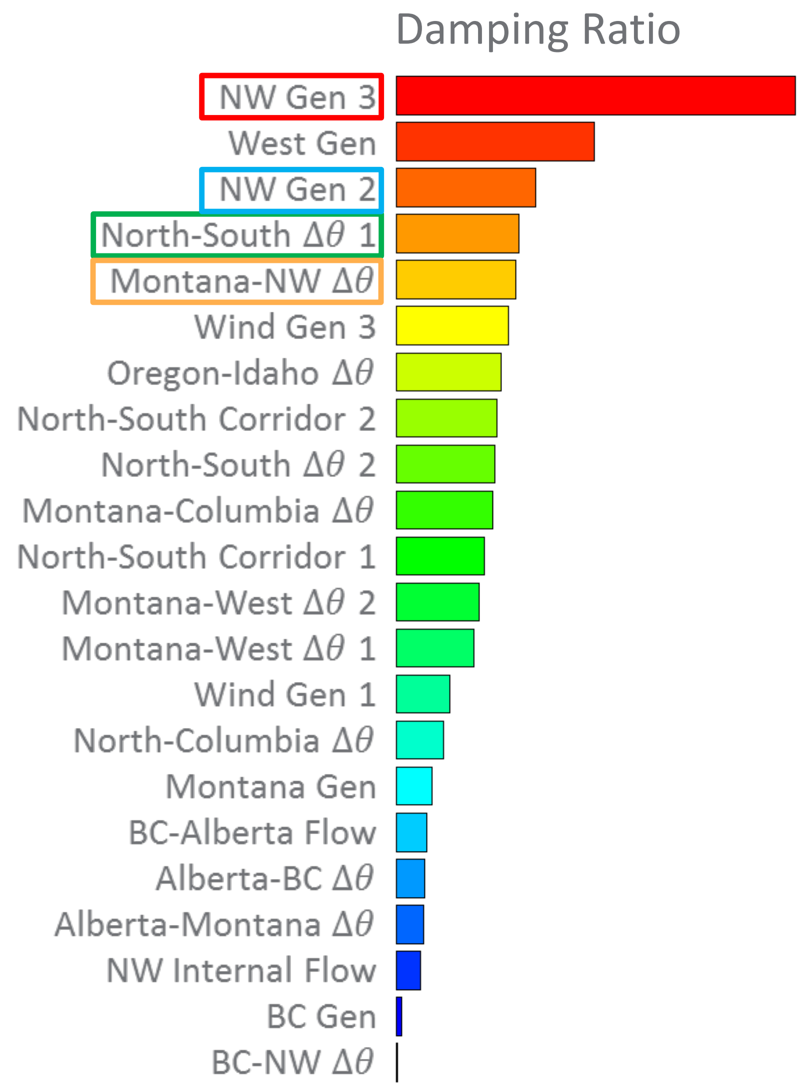


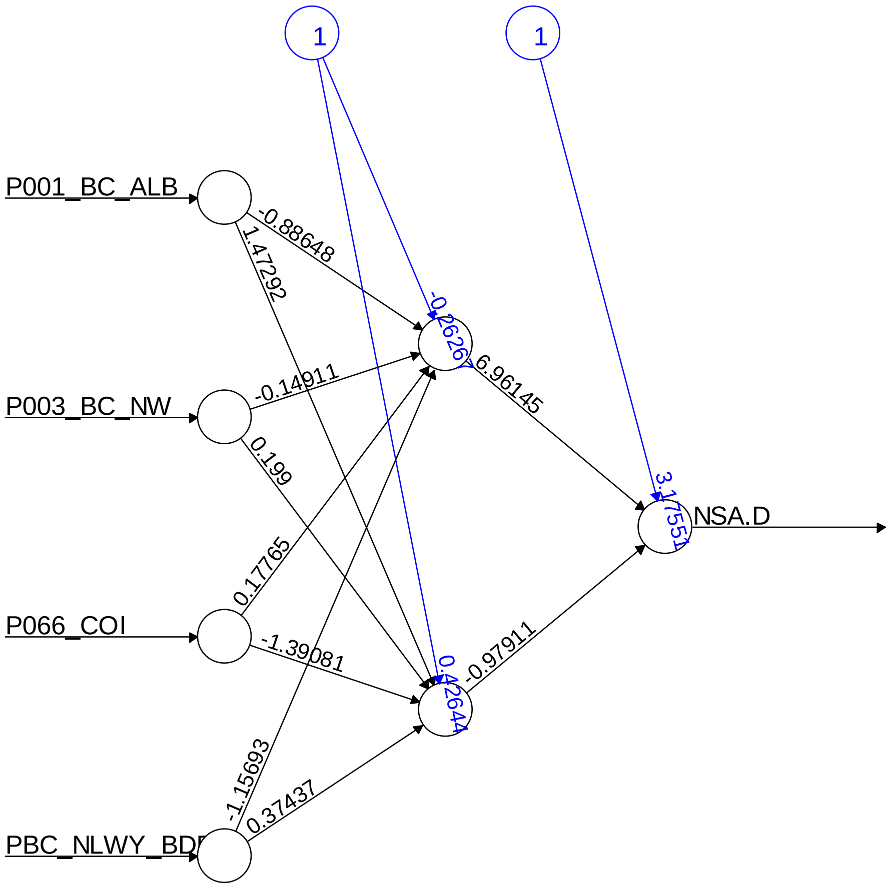


Conclusions

- Correlation and ANOVA methods successfully identified which system conditions are most closely related to two electromechanical modes
- Results are supported by engineering knowledge
- The applied methods do not reveal the nature of relationships
  - Example: Say a generator's output is correlated with a mode's damping. Are they correlated because the generator impacts damping or because damping is low when the system is heavily loaded?

Next Steps

- Apply machine learning methods
  - Artificial Neural Network
  - Support Vector Machine
- Improve mode estimation
  - Weaker modes difficult to track
  - Address performance issues following system events
- Extend to other system modes
  - Montana-Northwest
  - British Columbia
- Develop updates to stability alerts



Questions/Additional Information

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For further information, please feel free to contact:

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