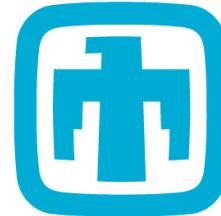


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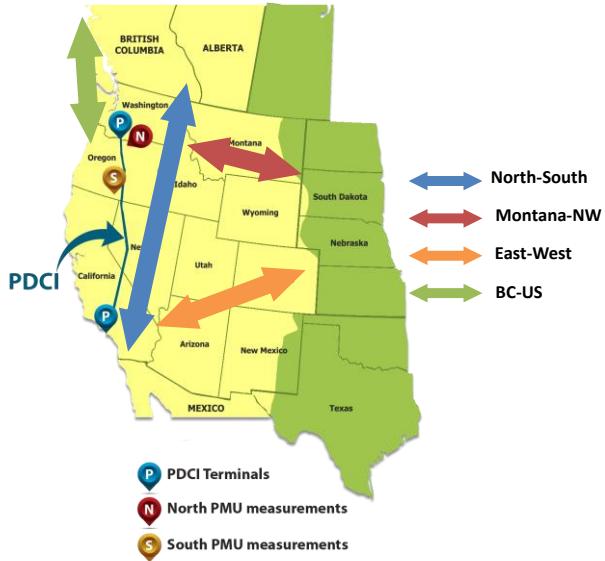
**Sandia
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Time Delay Definitions and Characterization in the Pacific DC Intertie Wide Area Damping Controllers

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Background

- Part of a wider project to develop a wide area damping controller in the Western Interconnection by modulating the Pacific DC Intertie
 - We implemented a controller that uses PMU measurements from dispersed locations within the western interconnection
 - In this paper we classified and analyzed in detail the delays in the flow of information of the controller
 - We expected to find more uniformity in the delays and be defined by traditional probability functions

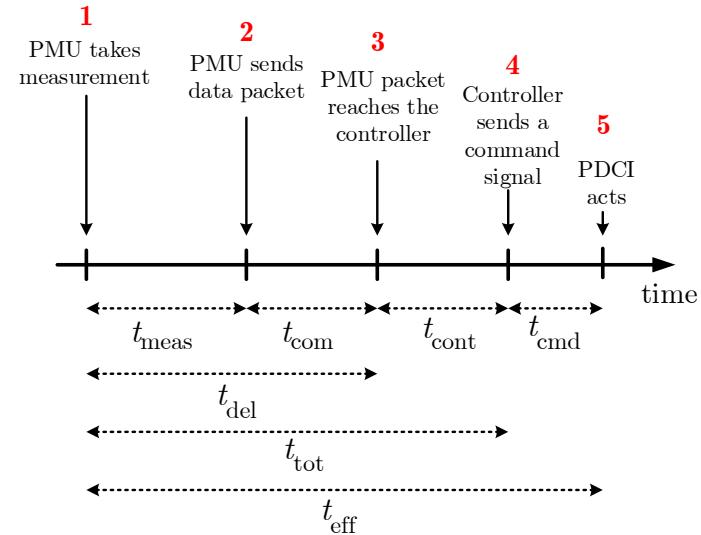
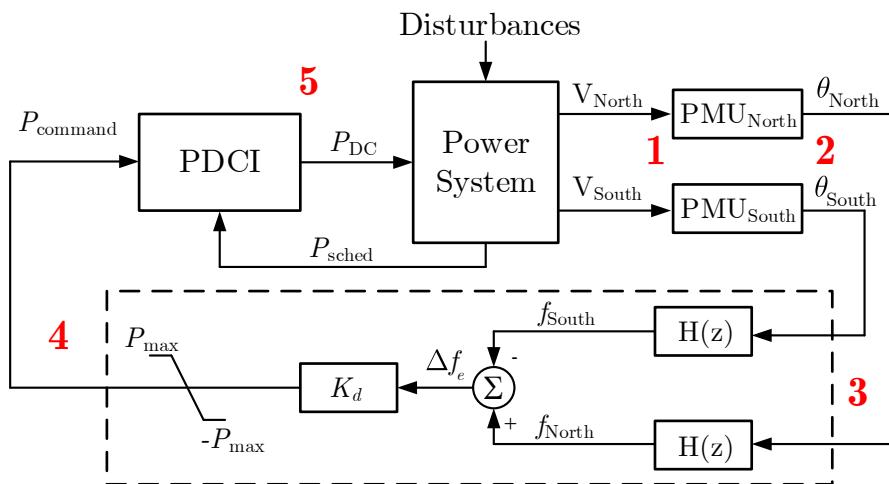


The map illustrates the Western Interconnection with various measurement and control points. Key features include:

- PDCI Terminals:** Indicated by blue circles labeled 'P' in California, Oregon, Washington, and British Columbia.
- North PMU measurements:** Indicated by red circles labeled 'N' in Oregon and Washington.
- South PMU measurements:** Indicated by orange circles labeled 'S' in California.
- Information Flow:** Four colored arrows indicate data transmission paths:
 - North-South:** Blue arrow pointing from California to British Columbia.
 - Montana-NW:** Red arrow pointing from Montana to the Northwest.
 - East-West:** Orange arrow pointing from California to the East.
 - BC-US:** Green arrow pointing from British Columbia to the US.

Definition of Delays

- Flow of information in the controller



t_{meas} – Measurement (PMU) Delay

t_{com} – Communications Delay

t_{del} – Signal Delay

t_{cont} – Control Processing Delay

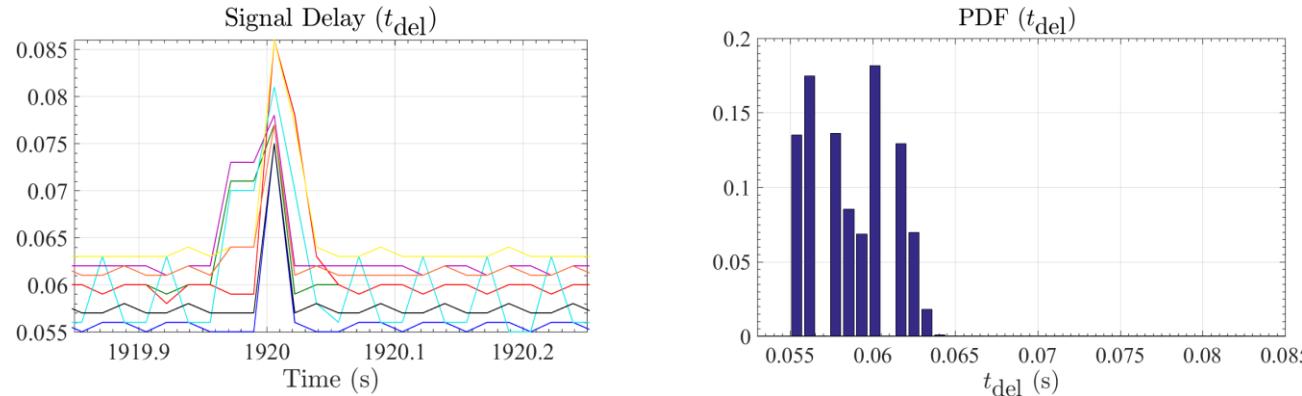
t_{tot} – Total Controller Delay

t_{cmd} – Command Delay

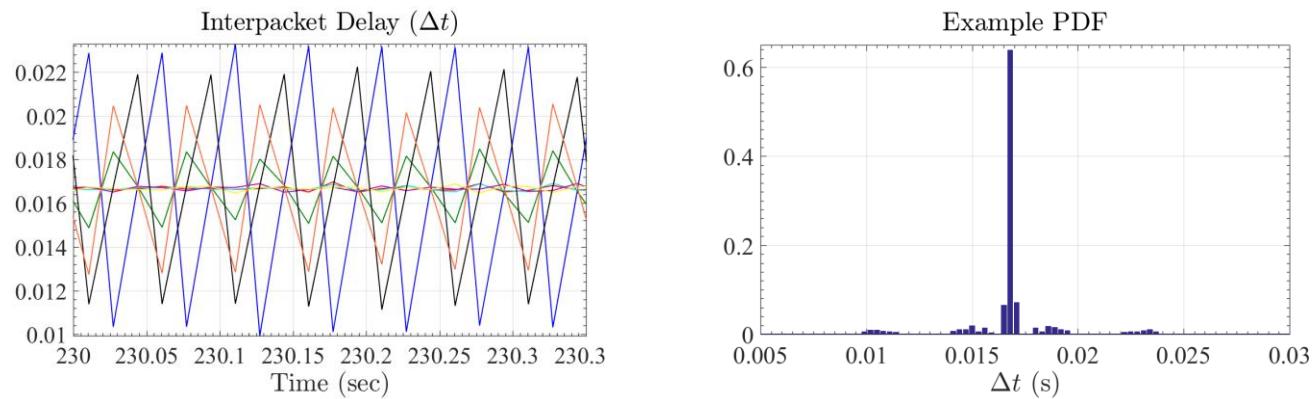
t_{eff} – Effective Delay

Measurement of Delays

Signal Delay Average of 60ms, range [55,88] ms.

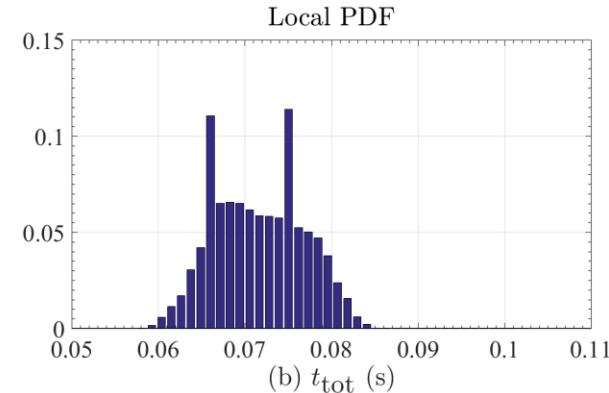
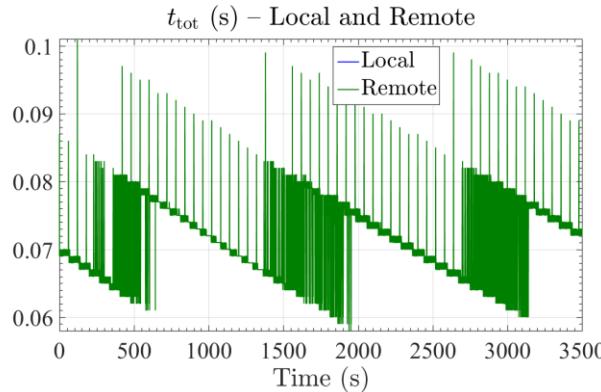


Interpacket Delay Average of 16.6ms, sometimes “oscillate”



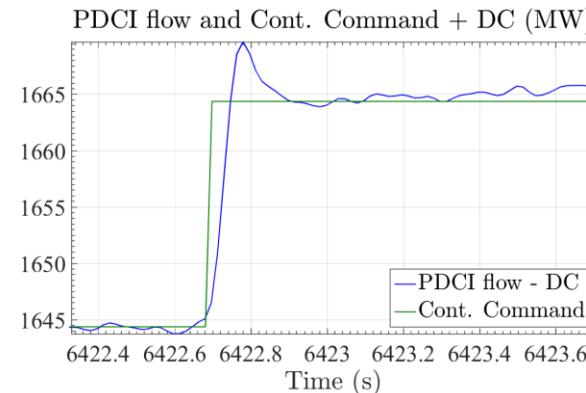
Measurements of Delays

Total Delay: average of 71ms, periodicity due to drifting of clocks



Command Delay: estimated at 11ms

Effective Delay: average of 81ms
and a maximum of 113ms



Conclusions

- Delays are within the expected range to be used for real time control
- A classification of delays in a Wide Area Control System (WACS) was proposed
- Delay behavior was analyzed for each stage and components of the WACS
- **Future work:** propose a detailed model of the delays (be able to replicate them)