SAND2016-6870C

Exceptional service in the national interest

Sandia National Laboratories

Supervisory System for a Wide Area Damping Controller Using PDCI Modulation and Real-Time PMU Feedback

B. Pierre[1], R. Elliott[1], D. Schoenwald[1], J. Neely[1], R. Byrne[1], D. Trudnowski[2], J. Colwell[2]

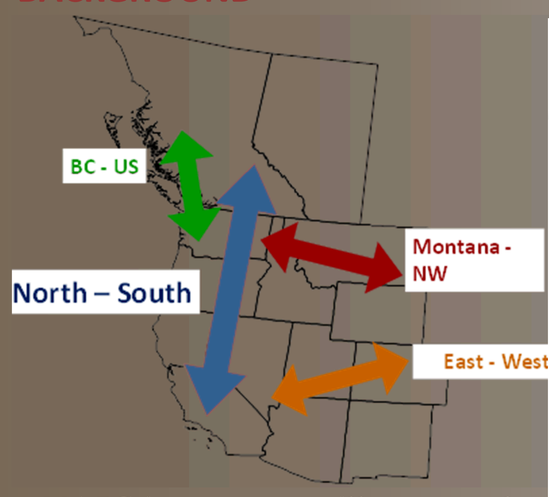
[1]*Sandia National Laboratories, Albuquerque, NM 87185 USA*

[2]*Montana Tech, Electrical Engineering Department, Butte, MT 59701 USA*

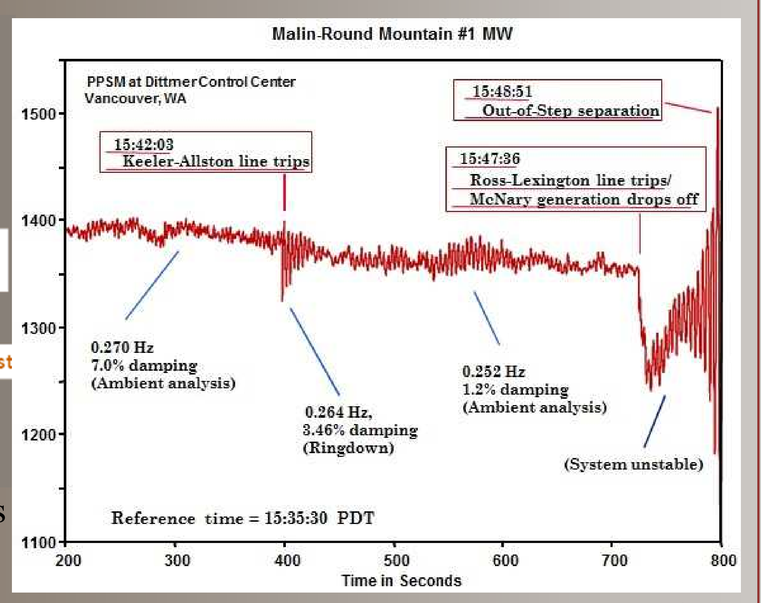
ACKNOWLEDGEMENT – The authors gratefully acknowledge the support of BPA Technology Innovation Office (Dr. Jisun Kim, Project Mgr., Dr. Dmitry Kosterev, Technical POC), DOE Transmission Reliability Program (Mr. Phil Overholt, Program Manager), and DOE Energy Storage Program (Dr. Imre Gyuk, Program Manager).

OVERVIEW – This poster describes a control scheme to mitigate inter-area oscillations through active damping. The control system uses real-time phasor measurement unit (PMU) feedback to create a power command signal to modulate real power flow (up to ± 125 MW) over the Pacific DC Intertie (PDCI) within the western North American Power System (wNAPS). A hardware prototype has been developed to implement the control scheme. To ensure safe and reliable performance, the prototype integrates a supervisory system to ensure the controller operates as intended at all times. The supervisory system is deployed across 3 hardware platforms.

BACKGROUND



wNAPS inter-area oscillatory modes



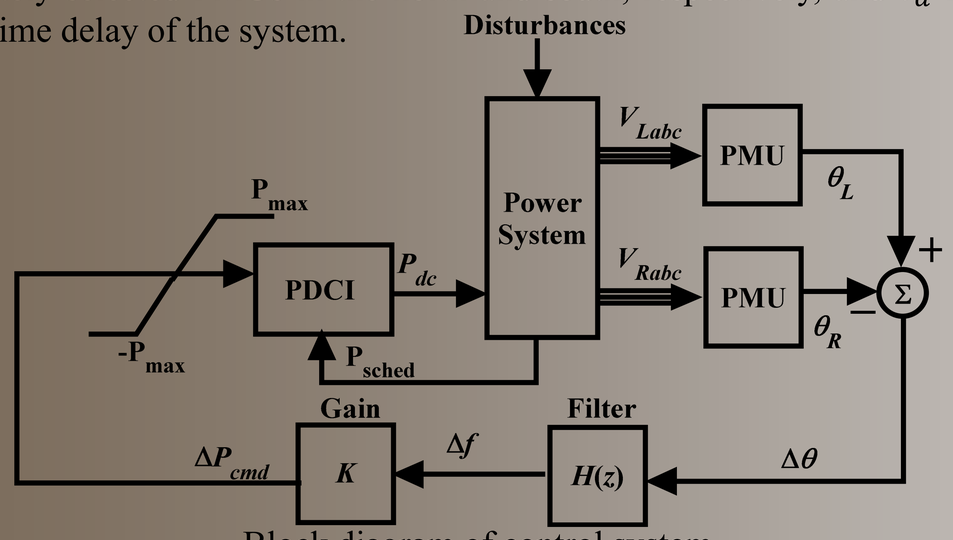
August 10, 1996 Western Power System Breakup

DESCRIPTION OF CONTROL METHOD

The power command may be modeled as:

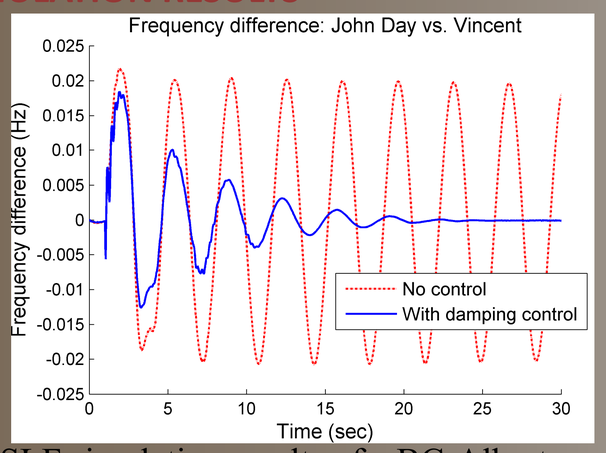
$$\Delta P_{cmd} = K(f_{Local}(t-\tau_d) - f_{Remote}(t-\tau_d))$$

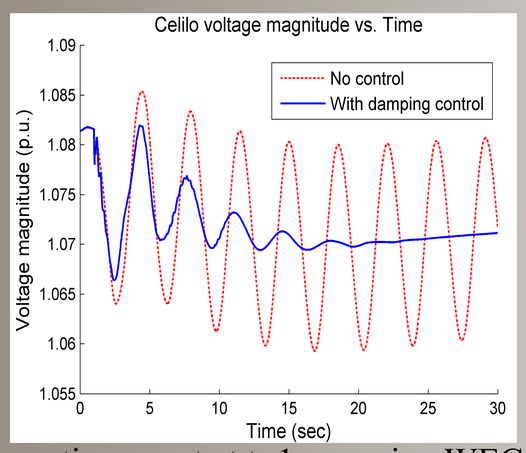
where K is typically in units of MW/mHz, f_{Local} and f_{Remote} are computed using appropriately selected PMUs in the north and south, respectively, and τ_d is the PMU network time delay of the system.



Block diagram of control system

SIMULATION RESULTS





PSLF simulation results of a BC-Alberta separation event at t=1 sec using WECC 2013 Heavy Summer base case.

SUPERVISORY SYSTEM

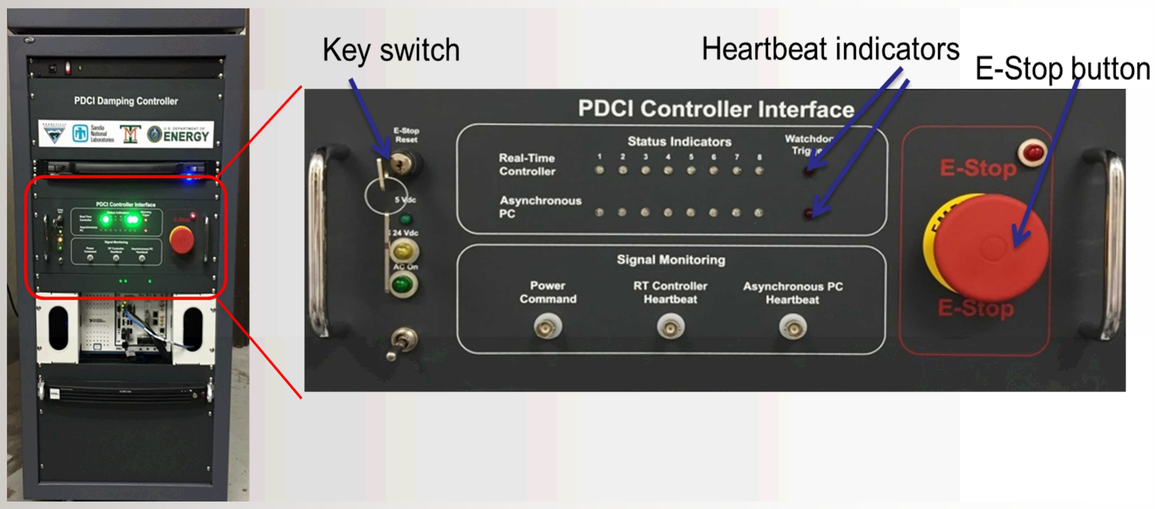
Supervisor

Asynchronous Control Loop
- Automated probing
- Transfer function estimation
- Gain and phase margin estimation
- PDCI monitoring

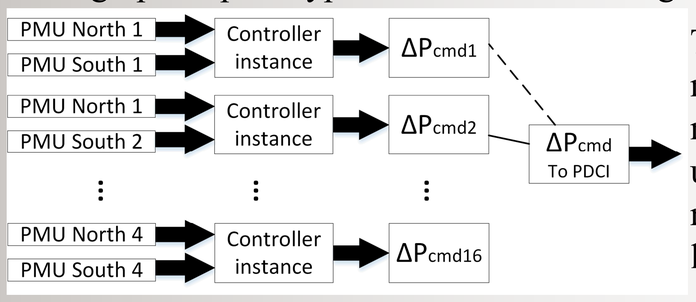
Real-time Control Loop
- State machine arch.
- Bumpless transfer (SW)
- Oscillation detection
- Separation detection
- Frequency tol. detection

Watchdog Circuit
- Watchdog circuit for async. and RT loops
- Emergency stop button
- Bumpless transfer (HW)
- Reinitialization procedure

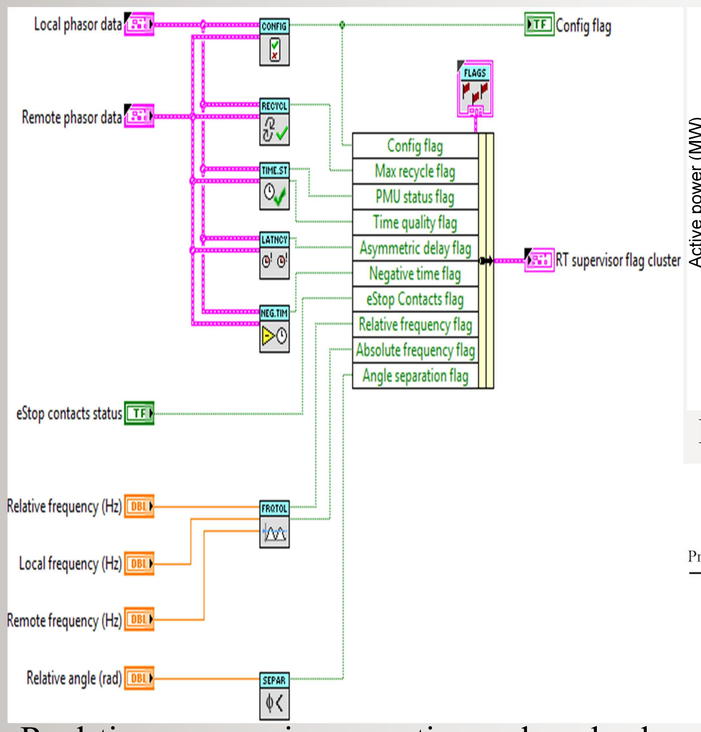
Primary functions of the three hardware platforms in the supervisory system.



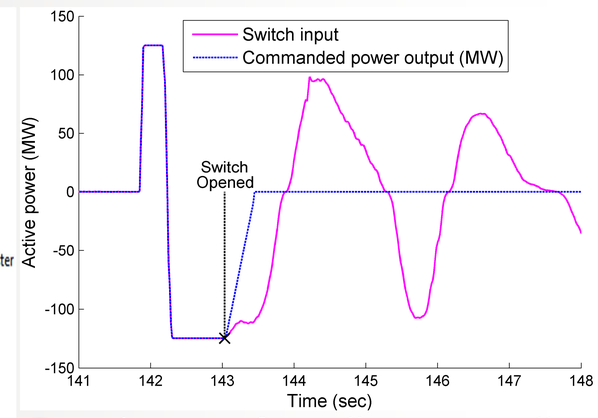
Photograph of prototype controller with enlargement of front panel of watchdog circuit



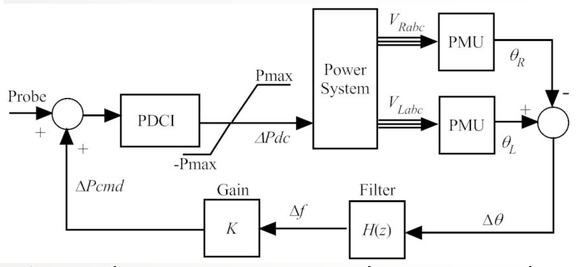
The controller acquires 8 PMU measurements each update cycle (16.7 ms), computes 16 feedback pairs, and uses a priority table to select the most robust feedback pair, given observed latencies and other data quality issues.



Real-time supervisor continuously checks input data to determine grid conditions, and it immediately disarms controller if an abnormal condition is detected..



Bumpless transfer to disarm controller.



Asynchronous supervisor requires periodic low-level probing to monitor phase and gain margins to ensure no modes are being destabilized.

SUMMARY

- Real-time PMU data employed in feedback control strategy to damp inter-area modes
- First grid-deployed control system in North America to use real-time PMU feedback
- Supervisory system monitors damping performance and ensures "Do No Harm" to grid
- Supervisory system is implemented over 3 hardware platforms and 3 time scales
- Carefully designed and phased closed-loop tests will start in September 2016
- Theory ➔ grid-deployed prototype in ≈ 3 years

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2016-C