BPA Updates:

Pacific Northwest – California Studies

Synchrophasor RAS

Out-of-Step Protection on COI

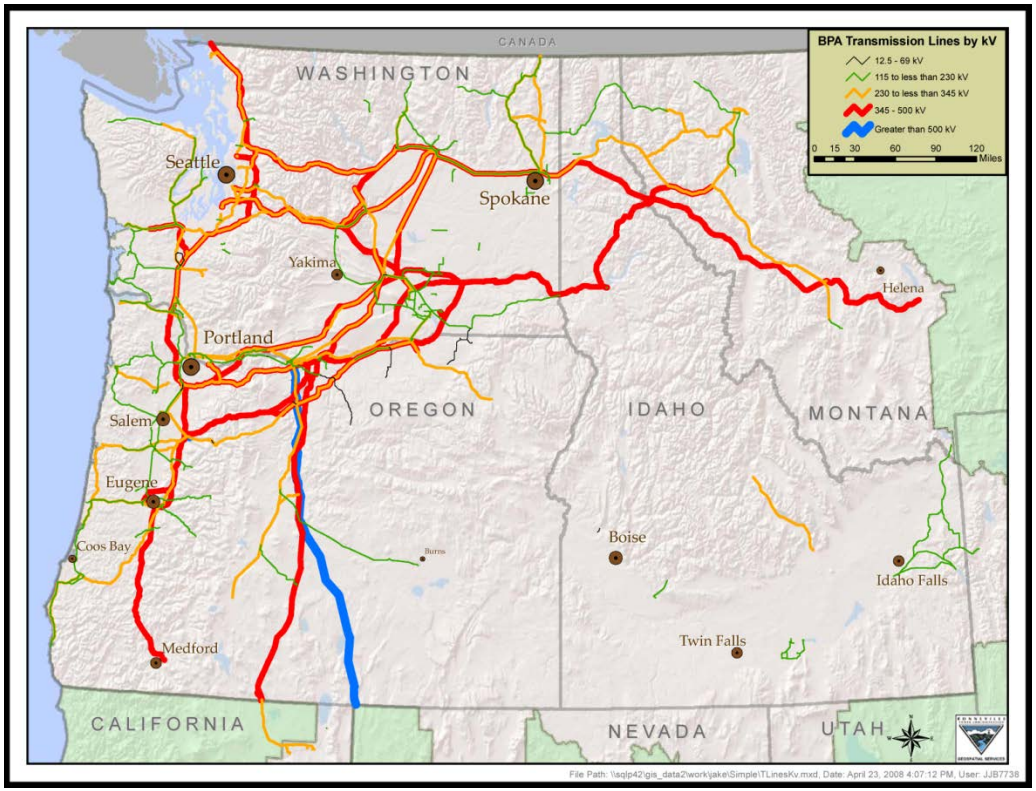
Hydro Generation Black-start Experience

Presented at 2018 IPCGRID Workshop

by Dmitry Kosterev, Sam Hirsi, Steve Yang

Bonneville Power Administration

BPA Overview



- Bonneville Power Administration (BPA) is a federal Power Marketing Agency in Pacific Northwest
- BPA markets power from 31 Federal dams and the Columbia Generating Station Nuclear Plant
- BPA operates more than 15,000 miles of transmission, including 4,735 miles of 500-kV lines

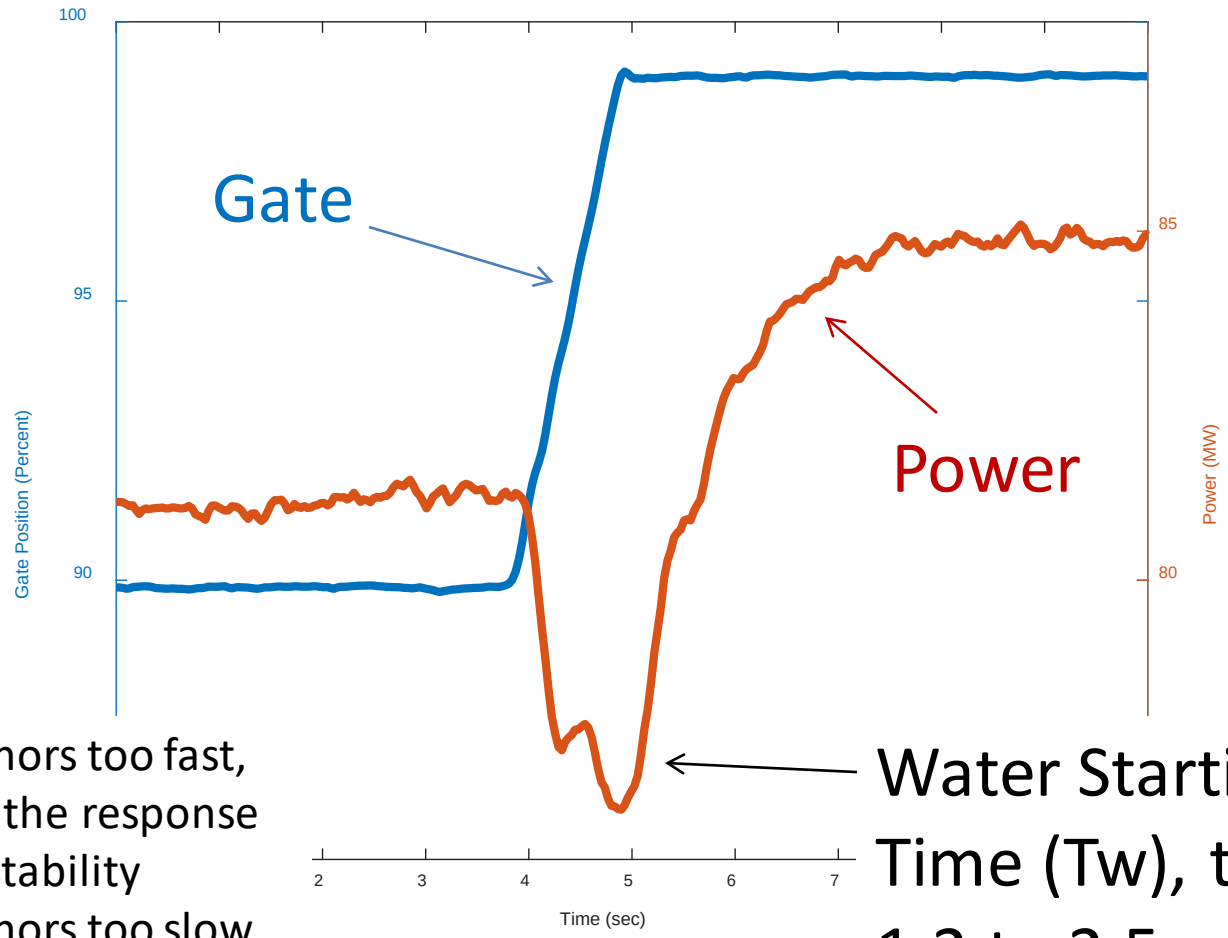
- US Army Corps of Engineers operates 21 federal dams and US Bureau of Reclamation operates 10 federal dams, including Grand Coulee
- Total nameplate capacity of Northwest Federal Hydro is 22,458 MW

Presentation Outline

- **Recent black-start experience in BPA** – Dmitry Kosterev and Steve Yang
- **Pacific Northwest – California Transfer Capability studies** – Dmitry Kosterev and Sam Hirsi
- **Synchrophasor RAS** – Dmitry Kosterev
- **Update on COI out-of-step protection** – Sam Hirsi

Hydro Generation Black-Start Experience

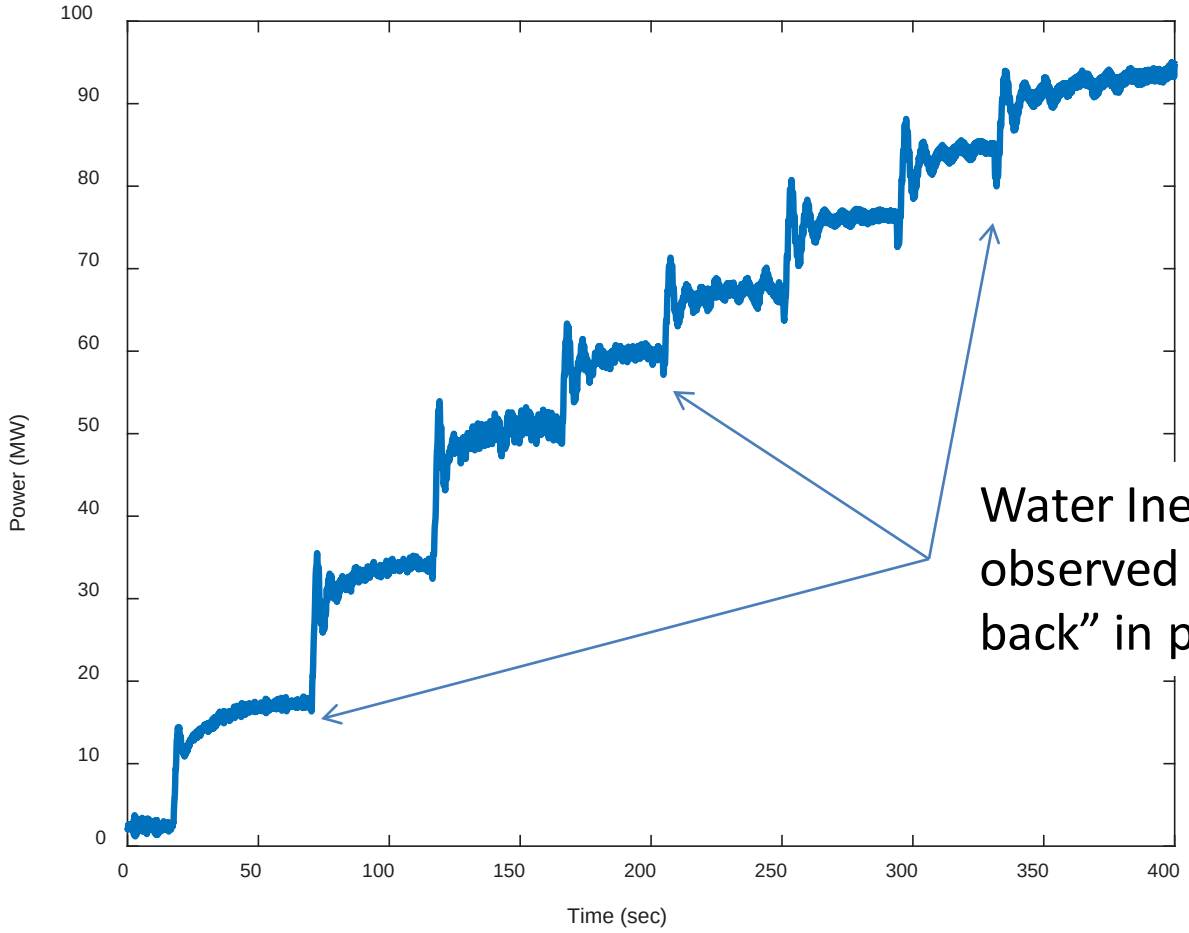
Water Starting Time - Tw



If you set governors too fast,
It will overdrive the response and result in instability
If you set governors too slow, the frequency control will be sluggish

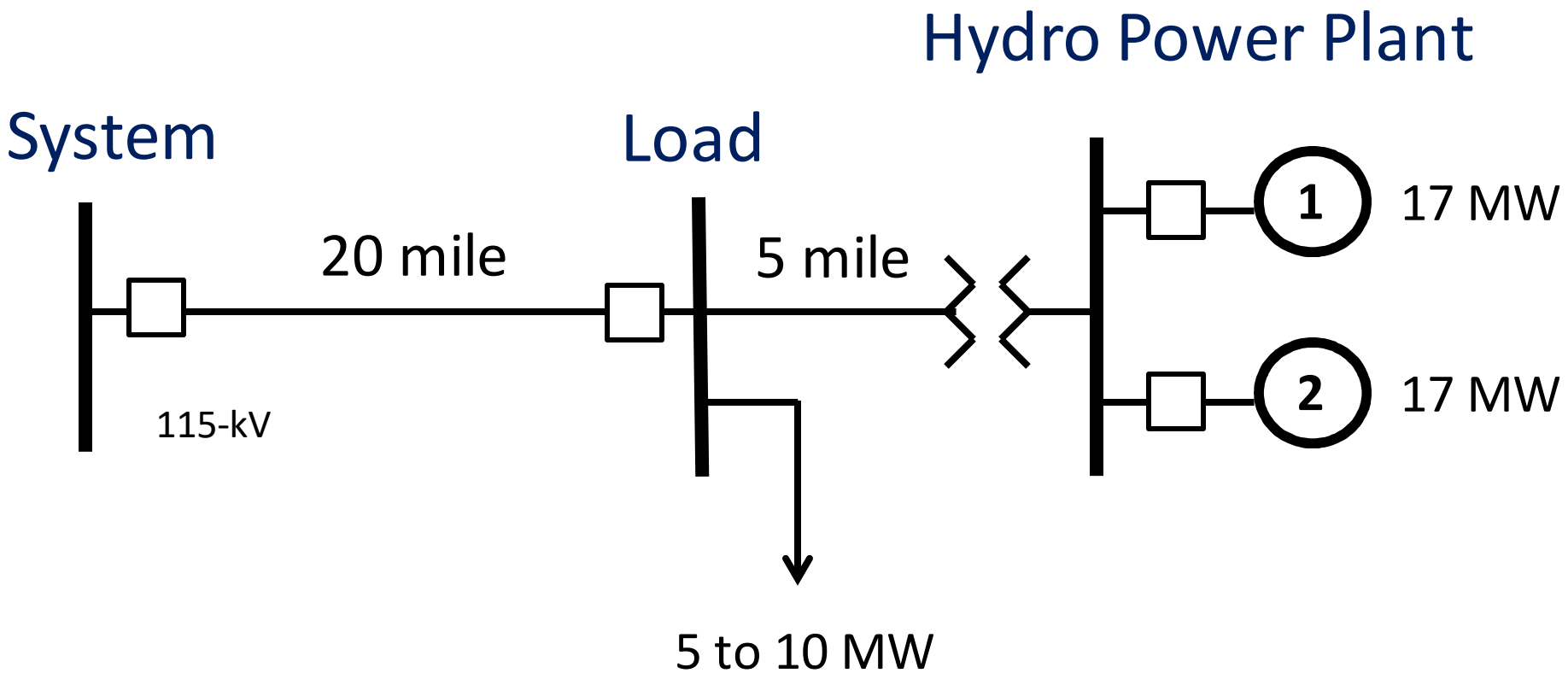
Water Starting Time (Tw), typically 1.2 to 2.5 sec

Water Starting Time effect is more pronounced at higher water flows / power output



Water Inertia is observed as a “kick-back” in power response

Recent Experience – A Remote Power Plant



Islanding Instability Event in April 2017

Generator went unstable at about 8.5 MW load

Governor Tuning

- The hydro power plant is operated by the US Army Corps of Engineers (USACE)
- USACE and BPA performed joint studies to improve turbine-governor models and to tune the governors for stable isolated operation following April 2017 event
- US ACE and BPA retuned the governors and conducted system islanding tests to confirm stable operation in September 2017
- US ACE and BPA also installed disturbance monitoring equipment at the plant

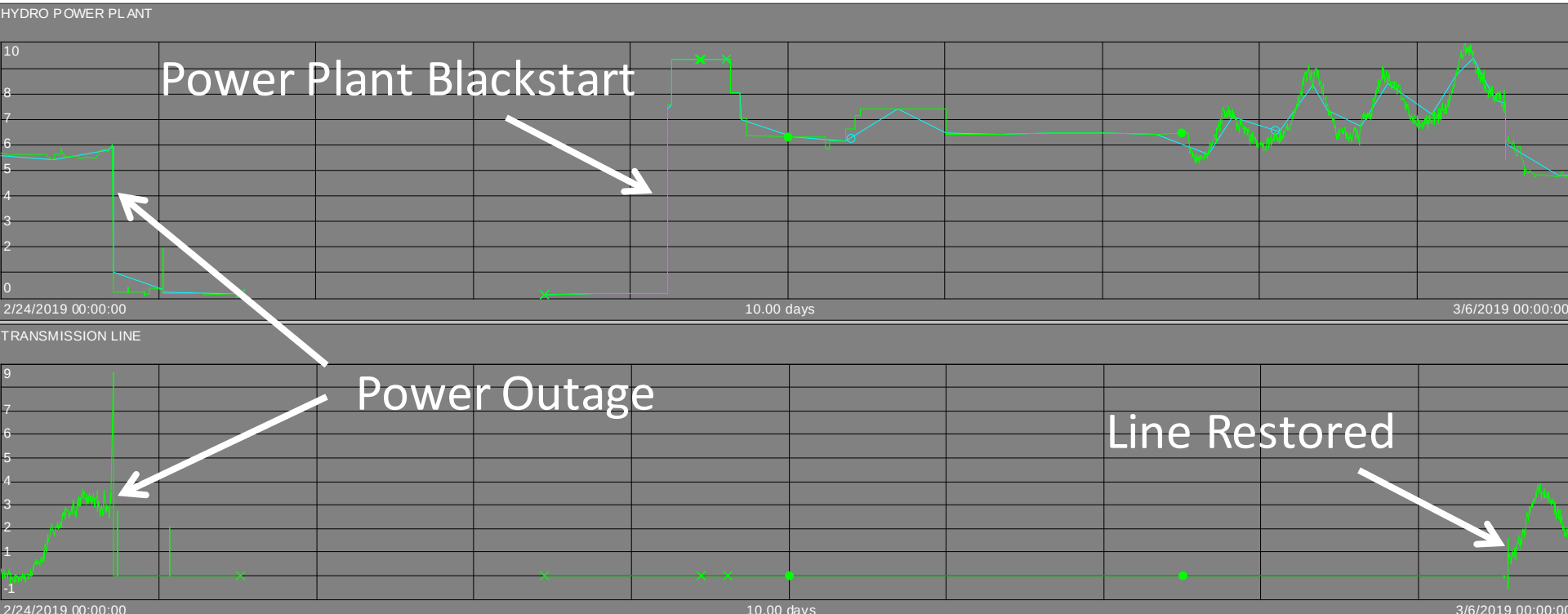
2019 Winter Storm

- Winter storm hit Pacific Northwest in late February
- High winds and snowfall caused multiple trees to fall on the BPA 115-kV transmission lines on February 24, causing the power outage with freeing temperatures
- Road conditions made the restoration challenging

Credit: EWEB

Blackstart and Restoration

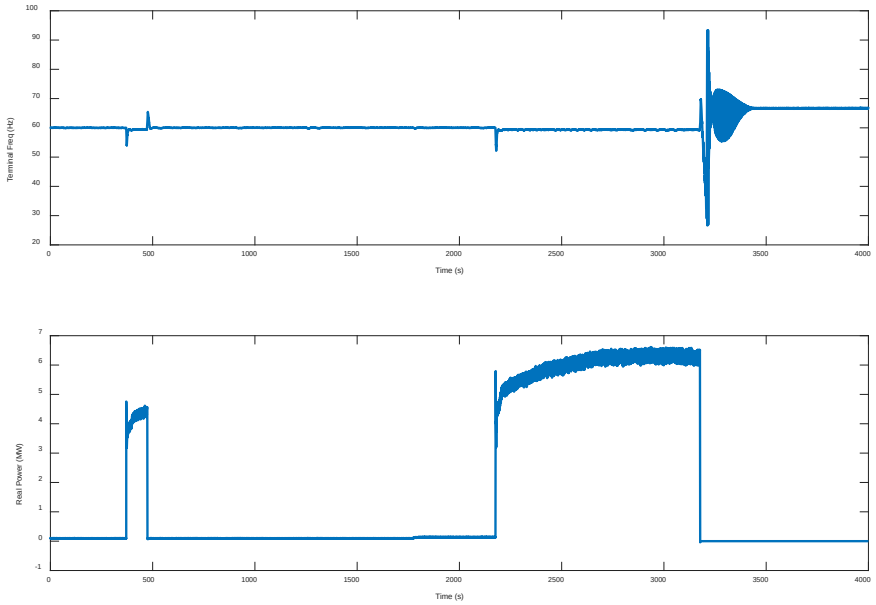
- The 5-mile transmission segment between the hydro dam and the town was put back in service by the late afternoon on February 27
- Plant operator performed successful black-start and restored power to the town early next morning, initial power pick-up was about 10 MW
- The main 20-mile segment of the 115-kV line was cleared and energized on March 5



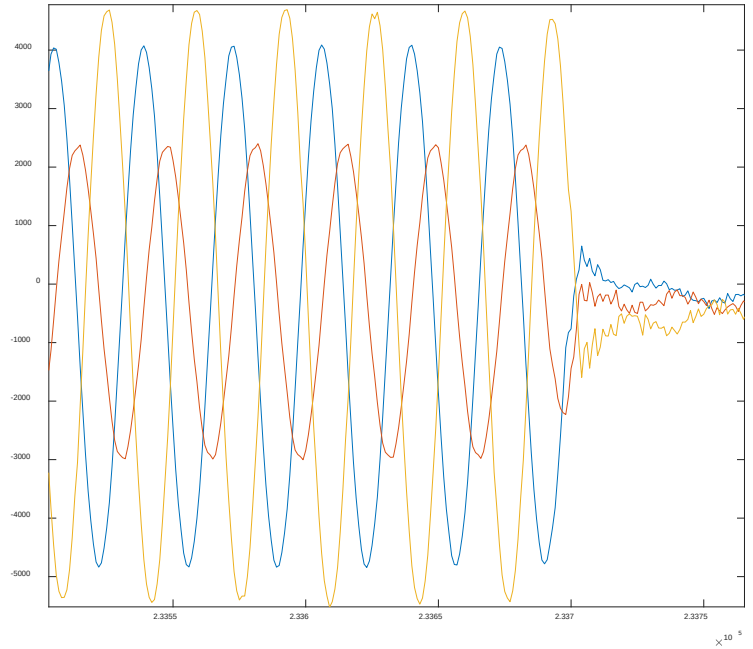
Lesson's Learned

Generator tripped several times on load imbalance

Generator frequency and power

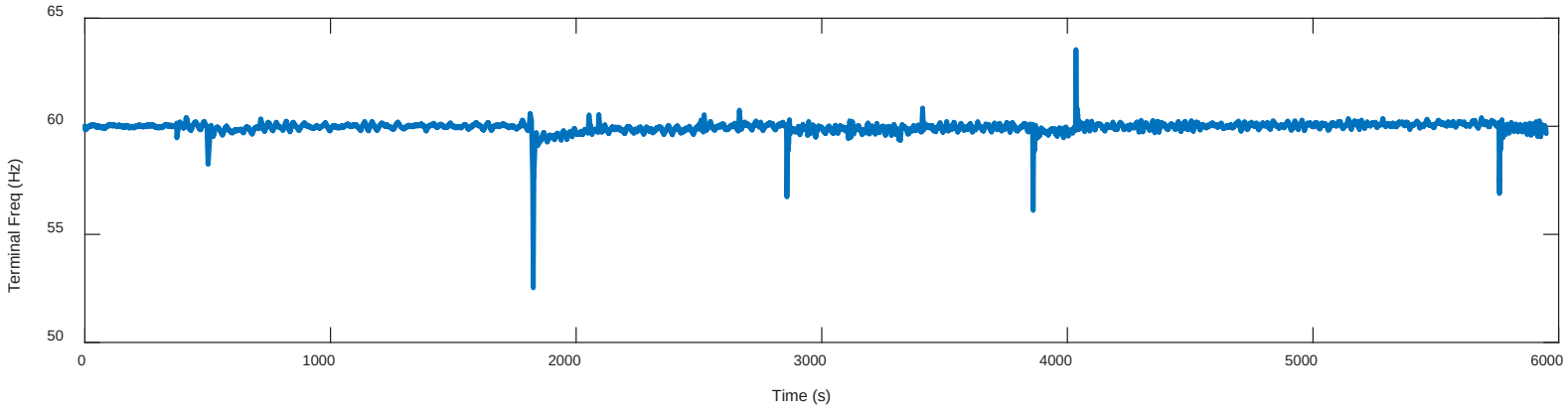


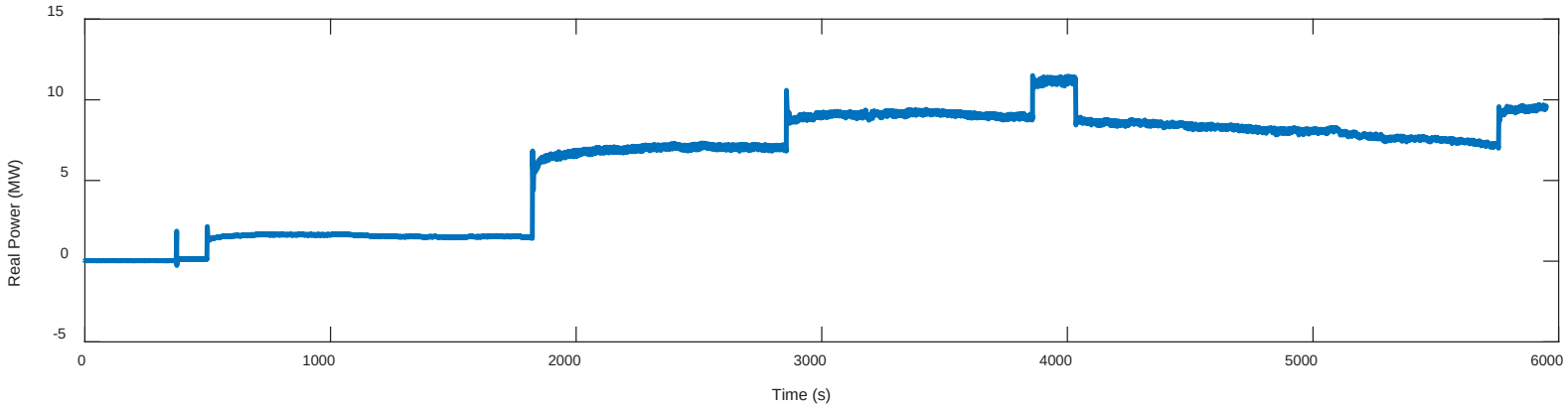
3-phase currents



Lesson's Learned

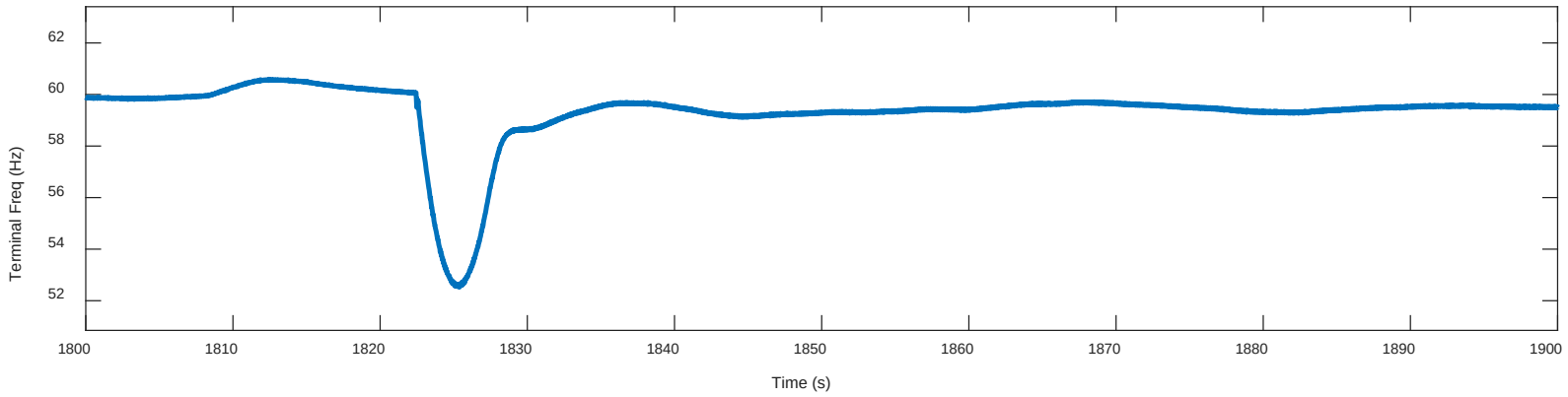
New governor setting provided stable response with loads over 10 MW, which would have been unstable with old settings

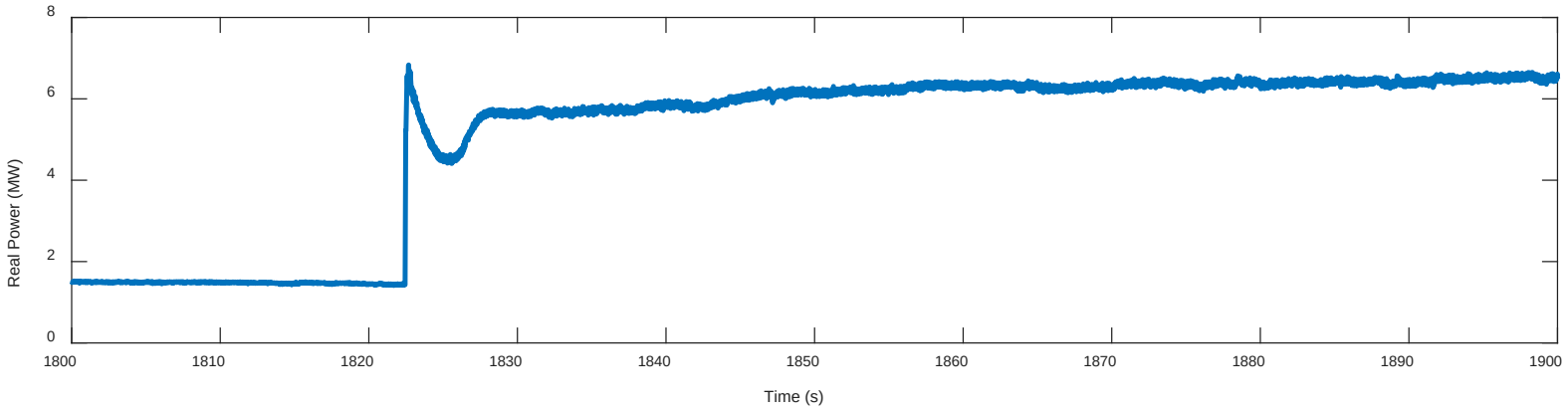




Lesson's Learned

Large load steps cause large frequency drops
25% load step caused frequency drop to 52 Hz





Conclusions

- Tuning hydro governors for isolated operation is essential for successful black-start
  - Most of the tuning is done based on studies
  - Good models are essentials
  - Knowledge of water starting times and generator inertia are critical
- Load imbalance could cause generator trips during isolated operations
  - Balancing load on single-phase feeders may be problematic
  - Have more generators on-line?
- Large load steps will cause large frequency deviations
  - Minimize the load steps
  - Or have more generators on-line?

Pacific Northwest – California Transfer Capability Study

CAISO: Jeff Billington, Ebrahim Rahimi, Irina Green, David Le
BPA: Dmitry Kosterev, Sergey Pustovit, Anita Heredia, Nick Haggerty, Sam Hirsi

California Public Utility Commission and California Energy Commission sent a letter to CAISO in February of 2018 requesting CAISO to perform a sensitivity case in CAISO 2018-19 Transmission Planning Process – Increased Capabilities for Transfers of Low Carbon Electricity between the Pacific Northwest and California

http://www.caiso.com/Documents/CPUCandCECLettertoISO-Feb152018.pdf

CA-NW Interties

- **California – Oregon Intertie** = three 500-kV AC lines between CA and OR, rated at 4800 MW North to South and 3650 South to North
- **Pacific HVDC Intertie** = bi-pole 500-kV DC lines between The Dalles, OR and Los Angeles, CA. PDCI is rated at 3210 MW North to South and 2000 South to North
- The interties were built in 1960s, upgraded over the years, to enable **seasonal energy exchange** between NW and CA to take advantage in diversity of loads (NW-winter peaking, CA-summer peaking) and resources (NW-hydro, CA-thermal)
- With resource changes in CA, can the interties enable more efficient **daily energy exchange**
  - Sunlight hours – CA sends solar oversupply to NW, NW can store water
  - Sunset hours – NW sends power to CA

CAISO Study Scope

- Increase transfer capability on COI and PDCI
  - Reliability studies
  - Economic studies – production cost modeling
- Dynamic Transfer Capability
- Sub-Hourly Scheduling on PDCI
- Assigning Resource Adequacy to Northwest Hydro

Intertie Transfer Capability Increase

COI TODAY:

- COI path is rated at 4,800 MW North to South today => We can schedule up to 4,800 MW on COI
- In real time, we observed occasions when actual flows on COI exceeded 5,100 MW due to unscheduled flows => real-time tools are used to manage the system

CA-NW RELIABILITY STUDIES

- COI path rating of 5,100 MW North to South is achievable if we reduce performance requirements for N-2 common corridor contingencies as allowed by NERC Standards, and treat them as extreme events and "conditionally" credible – we are working through WECC processes
- Confirmed sufficient South to North capabilities

ECONOMIC ASSSESSMENT

- Production cost studies show COI congestion in all NW hydro scenarios (high ~ 1,500hrs/year, medium ~350hrs, even low)

Dynamic Transfer Capability (DTC)

TODAY:

- "Unlimited" 15-min schedules on COI
- California runs 5-min Energy Imbalance Market
- More NW parties are joining CAISO EIM
- "5-minute" schedules are limited to 600 MW of DTC

NEAR-TERM OPTIONS:

- Optimize use of the existing DTC – real-time management, nomograms, etc.

LONG-TERM – AUTOMATION:

- Automate AC RAS Arming – in Progress
- Automate reactive controls – in Studies
- Voltage stability safety nets – SP RAS is implemented

PDCI Sub-Hourly Schedules

TODAY:

- Schedules are changed manually

BPA-LADWP SUB-HOURLY PROJECT:

- The project is kicked off in January 2019
- Automation of operator actions, AGC
- Automate DC RAS Arming – in Progress
- Study impact on AC network voltages

Timeline

- CAISO team ran very effective stakeholder engagement process – regular conference calls, webinars, presentations, draft reports, study case review, etc.
- Draft report is:

  http://www.caiso.com/Documents/AppendixH-Draft2018-2019TransmissionPlan.pdf
- Finalize the report for CAISO Board approval on March 27-28, 2019
- The final report is expected to be published on March 31, 2019

Synchrophasor RAS

Synchrophasor RAS

- BPA invested about $50M in the synchrophasor infrastructure over the last decade: $30M in the field installations, $8M control center upgrades, and about $10M in R&D
- BPA system was designed to enable real-time controls

- SP RAS research started in mid-2000s by Carson Taylor, and later by a panel of voltage control experts
- SP RAS was implemented during 2010-13 capital project – met WECC RAS requirements
- SP RAS was approved by WECC as a "safety net," operated in monitoring mode for a couple of years, went live in May 2017
- SP RAS was approved by WECC and Peak RC as a Wide-Area Protection Scheme in November 2018

Synchrophasor RAS

- SP RAS takes wide-area PMU measurements from four substations
- SP RAS has three algorithms to assess stability risk
- SP RAS sends signals to 11 substation to enable fast reactive switching to support system voltages

- **SP RAS removed voltage stability limitation for COI DTC**
  - **BPA used to freeze DTC within 400 MW of the COI limit**

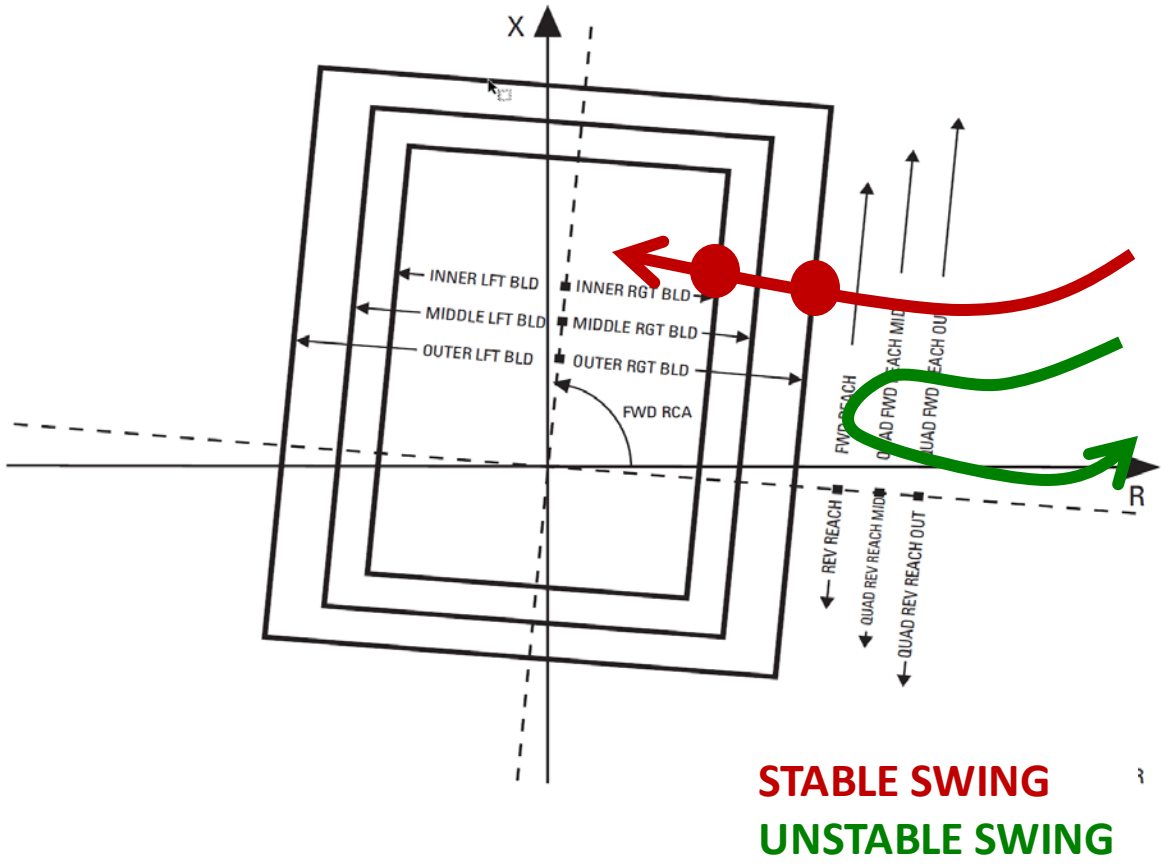
- We had no SP RAS operations up to date
- The closest event to trigger SP RAS was a fault in Southern California that resulted in tripping and momentary cessation of solar PV plants and caused large power swing on COI

COI Out-of-Step Protection Improvements

Out-of-Step Protection Studies

- The studies/models are required by several NERC Standards
  - PRC-026-1 - Relay Performance During Stable Power Swings
  - TPL-001-4 - Transmission System Planning.
  - CIP-014-2 - Physical Security
  - MOD-032-1 - Data for Power System Modeling and Analysis
- Out-of-Step Tripping is used to ensure a controlled system separation for unstable power swings on COI
- BPA Transmission Planning performed Out-of-Step studies in 2018 and proposed revisions to the settings
  - A wide range of system conditions were studies
  - Numerous marginally stable and unstable power swings were simulated
- The new settings were implemented in GE L90 relays on Captain Jack – Olinda 500-kV line

Out-of-Step Tripping

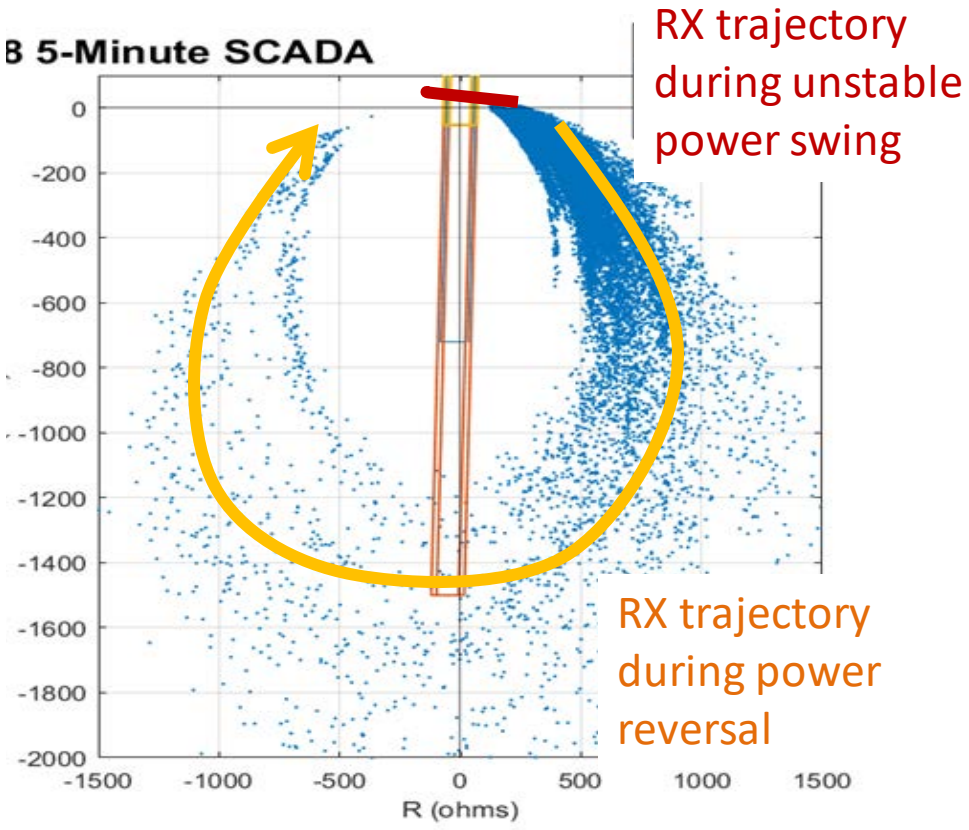


Timer starts when impedance (RX) trajectory crosses outer blinder

A relay action is issued if the timer expired by the time RX trajectory crossed the inner blinder

Out-of-Step Tripping Operation

- Out-of-step relays operated several times in January 2019 when the COI flow reversed its direction



What we found:

- Line current blocking was too low (line current is high during unstable power swings and low during power reversals)
- Relay box zone was stretched too low catching power reversals (due to high reactive power ~400 MVAr)

- Out-of-step relays settings were updated to be more secure

Thank You