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Challenges of Power Electronics for the Future Grid

Reliability Concerns for the Future

Robert W. Cummings 23 August 2022

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Disclaimer and Credits

- All graphics and information used in this presentation are from various reports and presentations given by NERC – all are in the public domain.
- The opinions expressed in this presentation are those of Robert W. Cummings from 45 years of experience in the electric power industry:
  - 6 years – Central Vermont Public Service (System Planning – Gen. and Transmission)
  - 8 years – Public Service Company of New Mexico (Operations Engineering and Wide Area Planning)
  - 8 years – East Central Area Reliability Coordination Agreement (ECAR – Manager of Transmission Services)
  - 23 years – North American Electric Reliability Corp. (NERC – retired in 2020 as Senior Director of Engineering and Reliability Initiatives)

Student of the System

- I am a Student of the System
  - 45 years of observing how the system behaves, especially during abnormal conditions
  - Constantly observing how the system reacts
  - Everything happens for a specific reason – there is no such thing as a “sympathy trip”
  - Think Interconnection-wide – that is the way the system reacts
  - Don’t try to bend the physics – Kirkoff’s Law is immutable
- Principal Investigator in over 15 major system disturbances (and many near-misses)
  - First forensic analysis – Western Interconnection disturbance 29 February 1984
  - 2003 Northeast Blackout through 2015 Washington, DC Area Low Voltage Disturbance
  - Contributor on Inverter-Based Resource disturbances 2016 through Present

The Changing Grid

Where we ~~are~~ were

- The electric grid of North America is a system of central generating stations with large rotating machines – we've had over 100 years to learn how the physics works
- Load consisting of synchronous motors, resistive loads, and incandescent lights

Where we are going

- A system of smaller distributed resources**, largely connected through inverters (IBRs)**
- A large portion of resources are variable (wind and solar) with much lower capacity factors
- Energy storage systems will be essential to continuous power availability
- **Variable speed drive motors** connected by power electronics
- Lighting rapidly moving to LEDs – far less incandescent, CFL, or mercury vapor lights
- Chargers for everything from phones to electric vehicles
- Quantum leaps in power requirements for electrifying transportation

So…how do we get from here to there without adversely effecting reliability?

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Reliability Begins at Device Design – What we have seen

- Desired characteristics and *capabilities* must be ***designed*** into the devices
- Reliability Starts during the Interconnection Process
  - User-defined models reflective of actual installed (planned) equipment, controls, settings, modes, and protection is critical
  - **Models must match actual equipment behavior**; otherwise, reliability studies are useless
  - Suite of **accurate models** is **critical to** conducting adequate **BPS reliability studies**
  - Each model type plays a unique role in different types of reliability studies
- Observed threats to reliability – What we have seen
  - **Inexperience** of the Industry with IBRs and their control systems
  - **Behavior of Inverters on Utility Scale –** momentary cessation faster than system protection for faults
  - **Lack of accurate models** for IBRs – Models do NOT reflect reality
    - Shades of BAD MODELING of synchronous machines before the 1996 Western Blackout (9 States)
  - IBR reactions to **common switching surges**

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Threats to Reliability from Inverter-Based Resources

- What don't we know yet
  - **Inexperience** of the Industry with IBRs and their control systems
  - **Inter-area oscillations** modes and mode shapes changing by IBRs supplanting synchronous generation
  - IBR **controls interaction**
  - **Common mode failures** for IBRs over large areas
  - **Behavior of IBRs during protracted faults** (remote breaker failure protection clearing in around 20 cycles)
  - **Locating source(s) of Forced oscillations** caused by digital control system and their INTERACTIONS
  - **Relay loadability** – possible on HV and LV transmission (solved on EHV systems)
  - **IBR behavior during** FIDVR (Fault-Induced Delayed Voltage Recovery) events

Modeling Issues

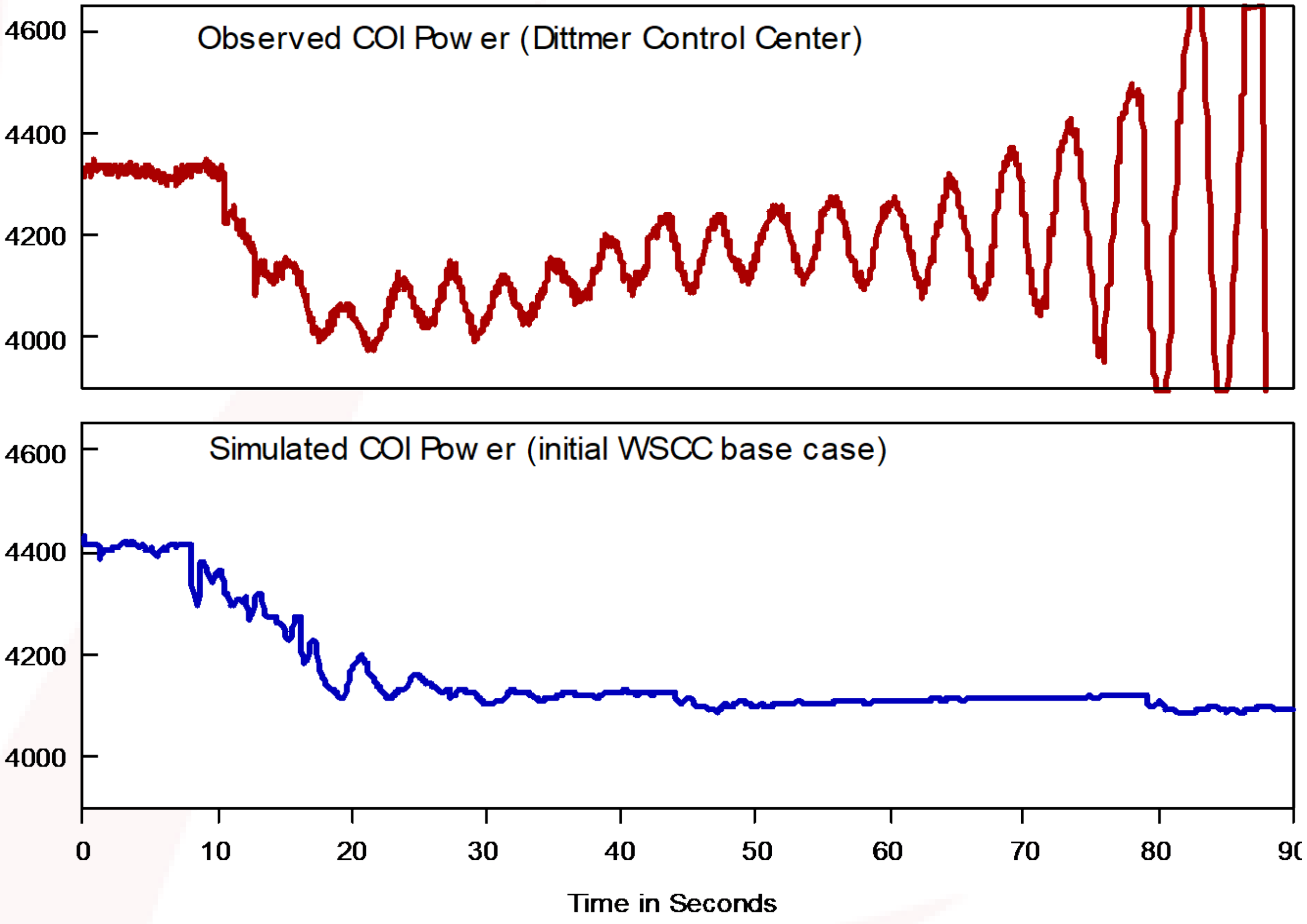
You can't always believe models

10 August 1999 WSCC Blackout – Models vs Reality

- Don’t be overly dependent on models!

Real event

Dynamic simulations



No confidence in dynamics database

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Major Recommendation and Modeling Issues – 1996 WSCC Blackout

- **DO NOT operated the system in unstudied configurations and loading levels!**
- Dynamic models are terrible…called for establishment of generator testing to obtain as-built physical characteristics and control parameters.
- If something in not modeled, how can you predict system behavior or interaction????

1996 Dynamics Modeling Issues

- Missing models
- Data errors
- Models may not match field equipment and settings
- Issue of "proprietary models"
- No models for many wind farms (PV was not prevalent yet)
  - No good indication of where wind farms are connected

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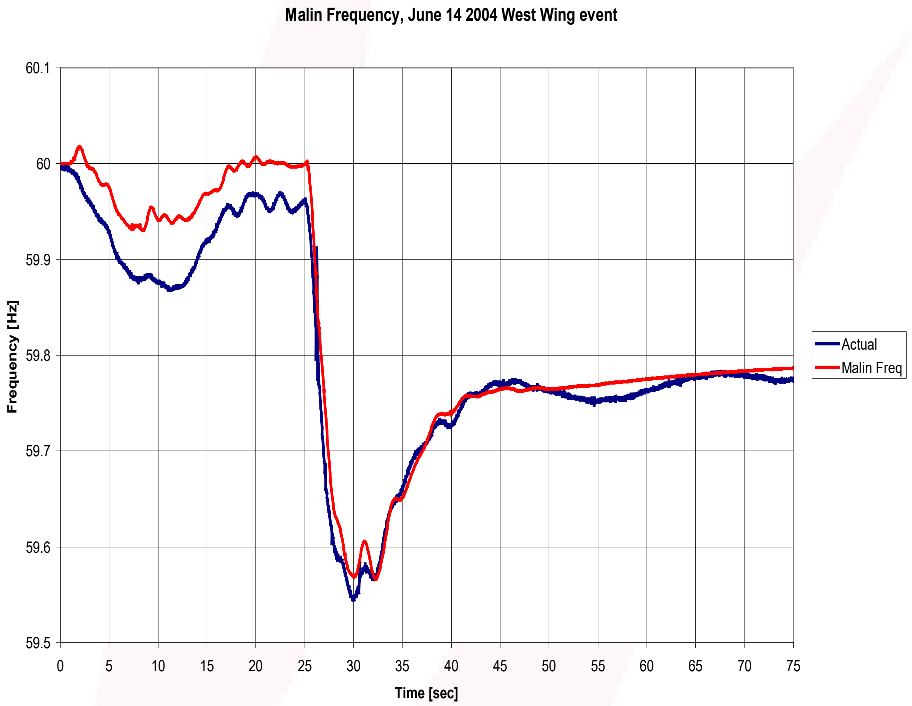
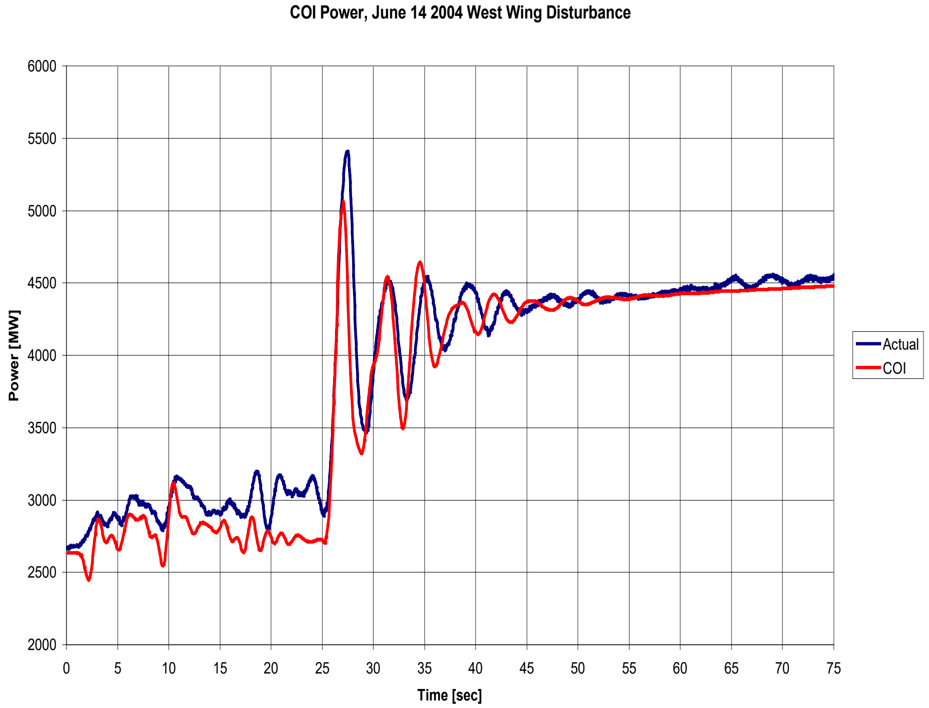
Improved Confidence after Machine Testing – Simulations – of 14 June 2004 Event

Frequency Response



COI Power Flows



Real event

Simulations

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Basic Tenets of Modeling and Predictive Studies

- To predict performance, you MUST able to understand the system's behavior.

- To understand the system's behavior, you MUST observe and measure its actual behavior.

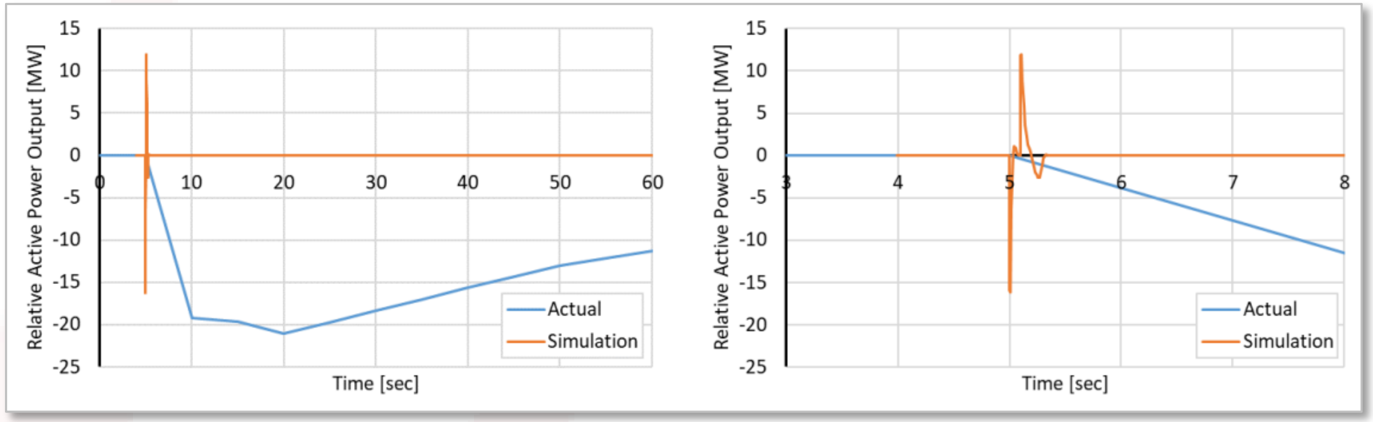
- Once you understand the system's behavior, you MUST be able to model it, both as individual models and as a full Interconnection

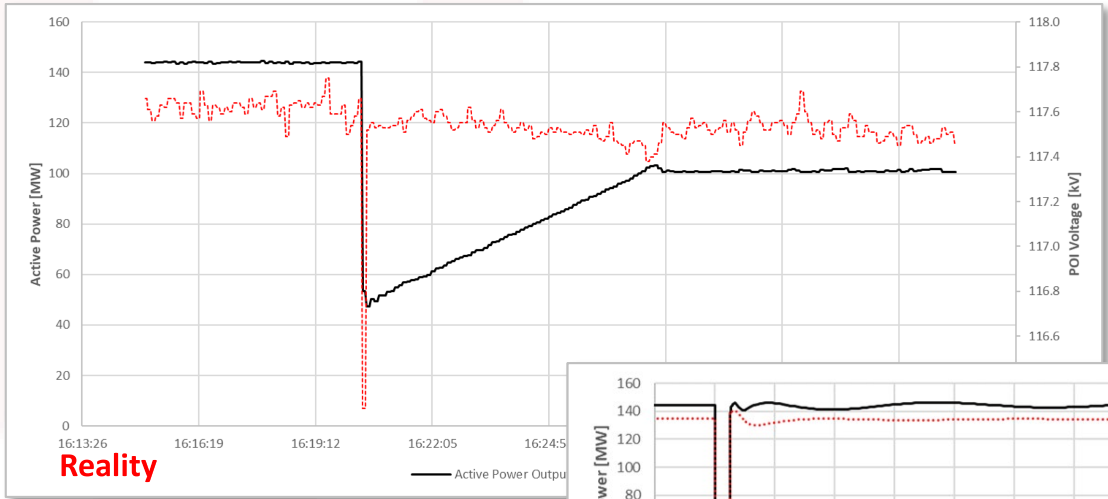
- Once you are able to model the system's behavior, you can predict its performance. If you can't model it, you cannot predict system behavior

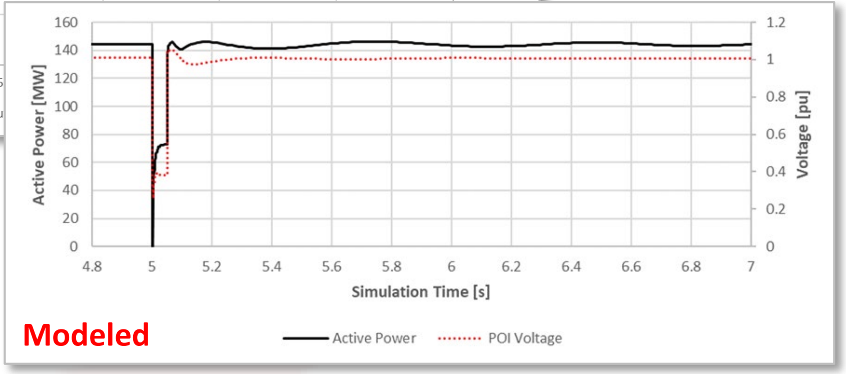
Model Validation for Recent WECC IBR Disturbances

Accurate modeling is critical to BPS reliability

Inaccurate Models = Inaccurate Studies = Inaccurate Reliability Decisions







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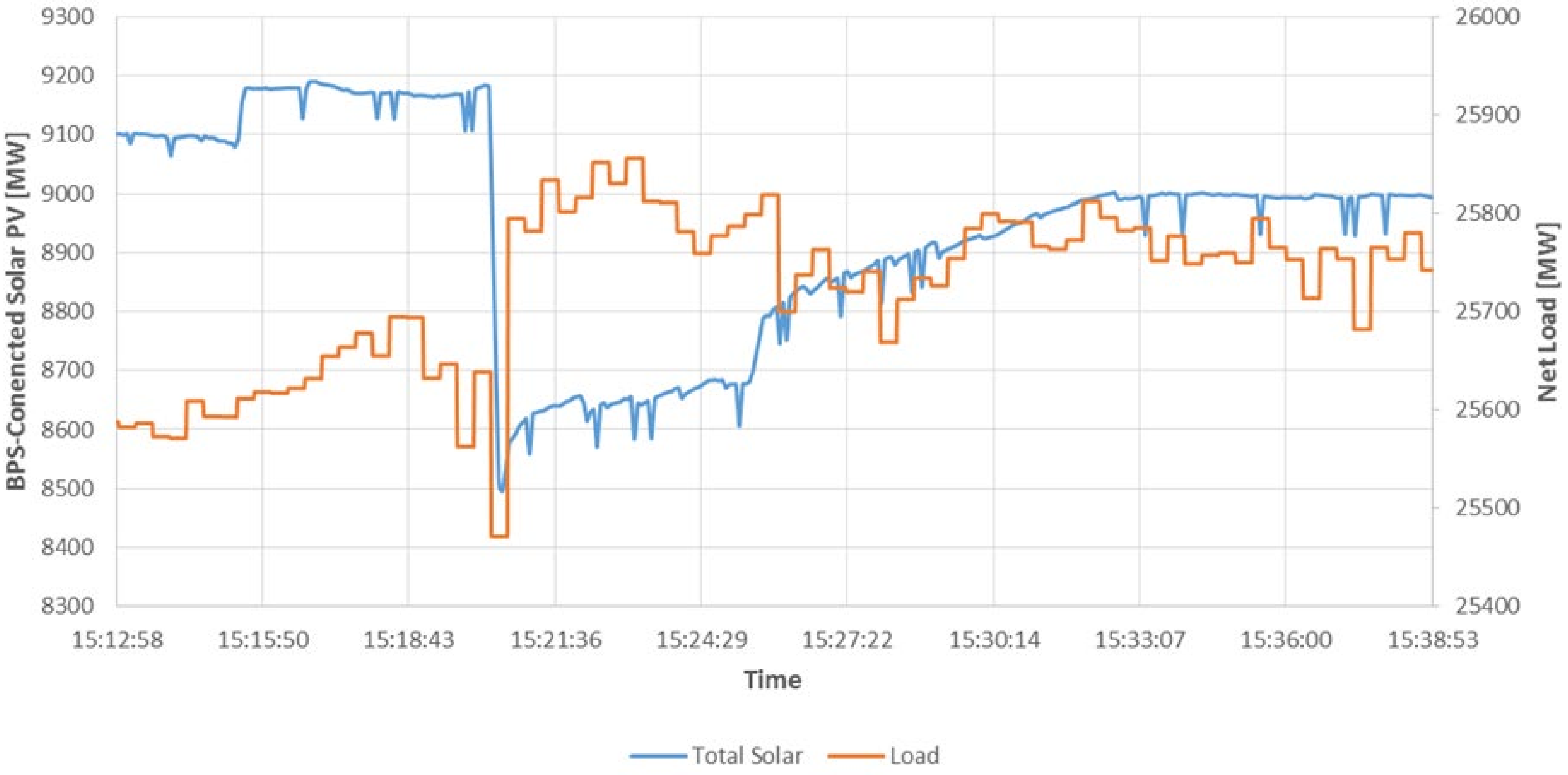
Palmdale Roost Disturbance – CAISO BPS-Connected Solar and Net Load



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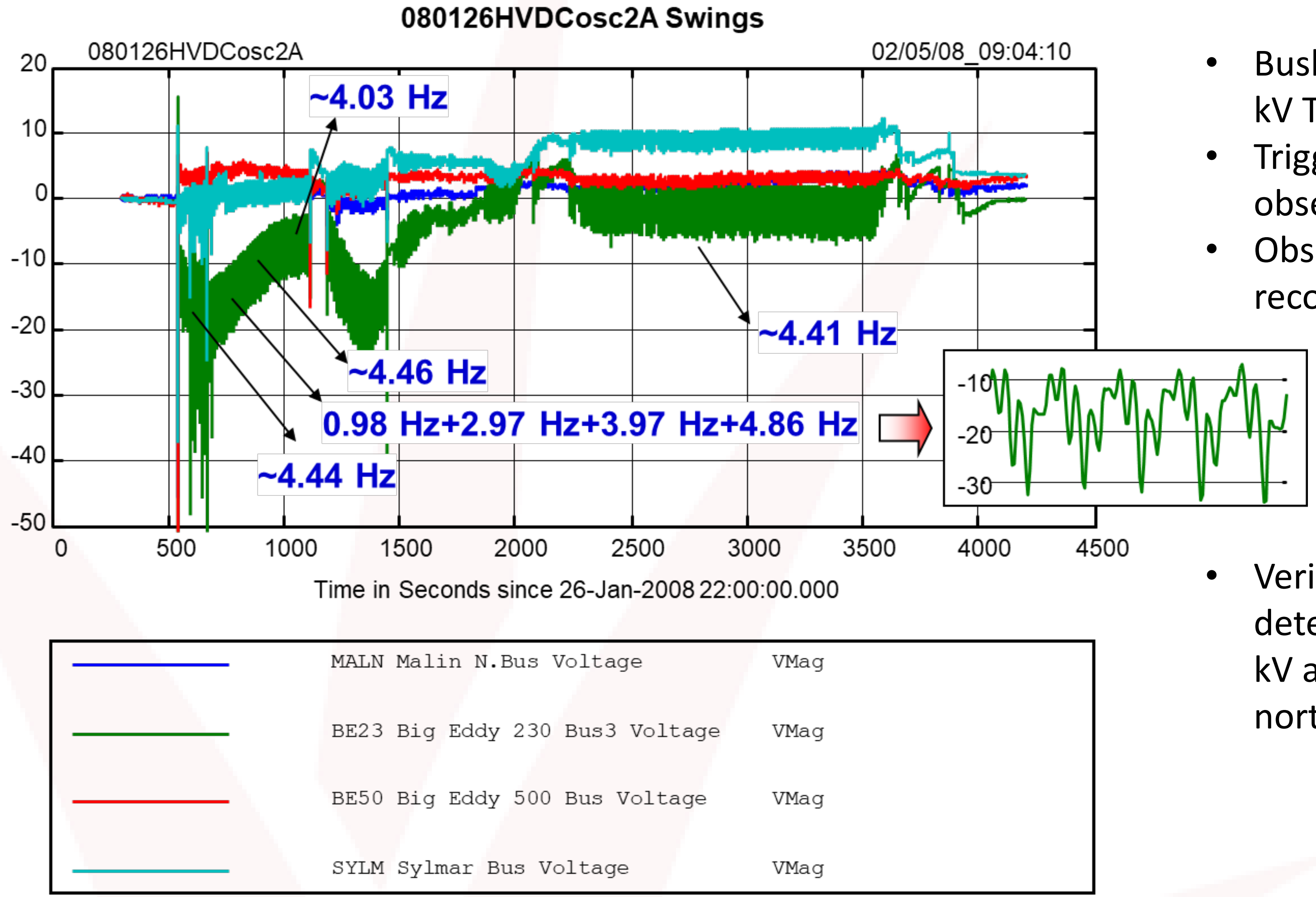
WECC Pacific DC Intertie Forced Oscillations
26 January 2008



- Bushing failure on Big Eddy 500/230 kV Transformer
- Triggered oscillations – not observable on SCADA
- Observed on venerable strip recorder at SCE

- Verified by phasors – PDCI controls determined to be responsible – 500 kV and 230 kV sources separated at northern end

Recommendations on Power Electronic Development

- IEEE Standard 1547 should NOT be used or applied to BPS-connected resources
- Sometimes, fast is too fast! The grid cannot tolerate most things acting in 10 mS or faster!
- There is no such thing as an infinite bus! All devices connected to the grid may interact with the grid and with each other, often across great distances (1,000+ miles). Avoid the use of the term "neighboring system."
- Myopic analysis of a company or RTO system is inadequate…analysis MUST be done on and Interconnection scale!
- We have the computing power to analyze several protection/control schemes (including RAS) together – LET'S USE IT!
- Always think about what the new PE device might be faced with – what will the system throw at the device?

NERC Inverter-Based Resource Analyses and Guidelines

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Questions?

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