Oscillation Damping Control via Inverter Based Resources (IBR)

Evangelos Farantatos
Lin Zhu
Deepak Ramasubramanian
EPRI

Yi Zhao
Yilu Liu
University of Tennessee Knoxville

NASPI Workshop "Monitoring, Analysis and Mitigation of Oscillations and Inverter Based Resource Impacts"

April 11, 2022

Outline

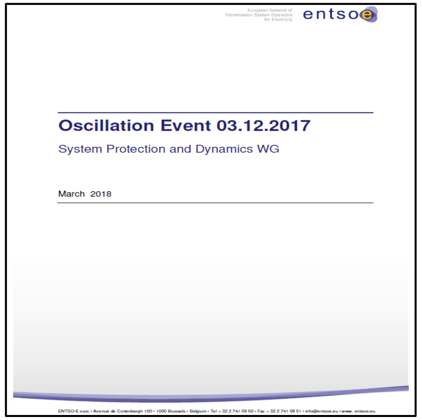
- Background
- Forced Oscillation Control via IBRs
- Damping of Low Frequency and Sub-Synchronous Oscillations Using HVDC
- IBR Power Oscillation Damping

EPRI

Oscillations Events

Low Frequency Oscillations

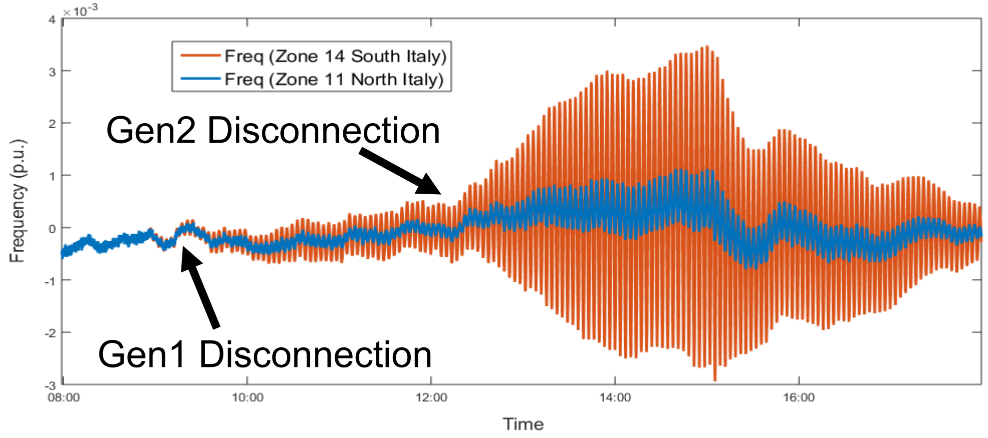
- EU Events
  - Dec 3rd 2017 (0.29 Hz)
  - Dec 1st 2016
  - February 19th & 24th 2011


entsoe

Oscillation Event 03.12.2017

System Protection and Dynamics WG

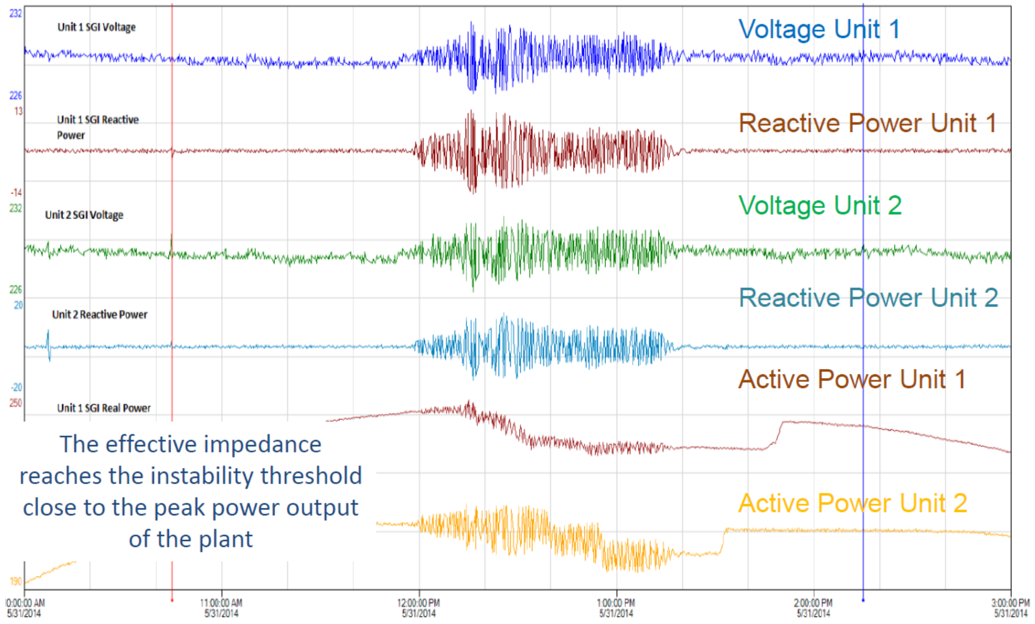
March 2018



Sub-Synchronous Oscillations

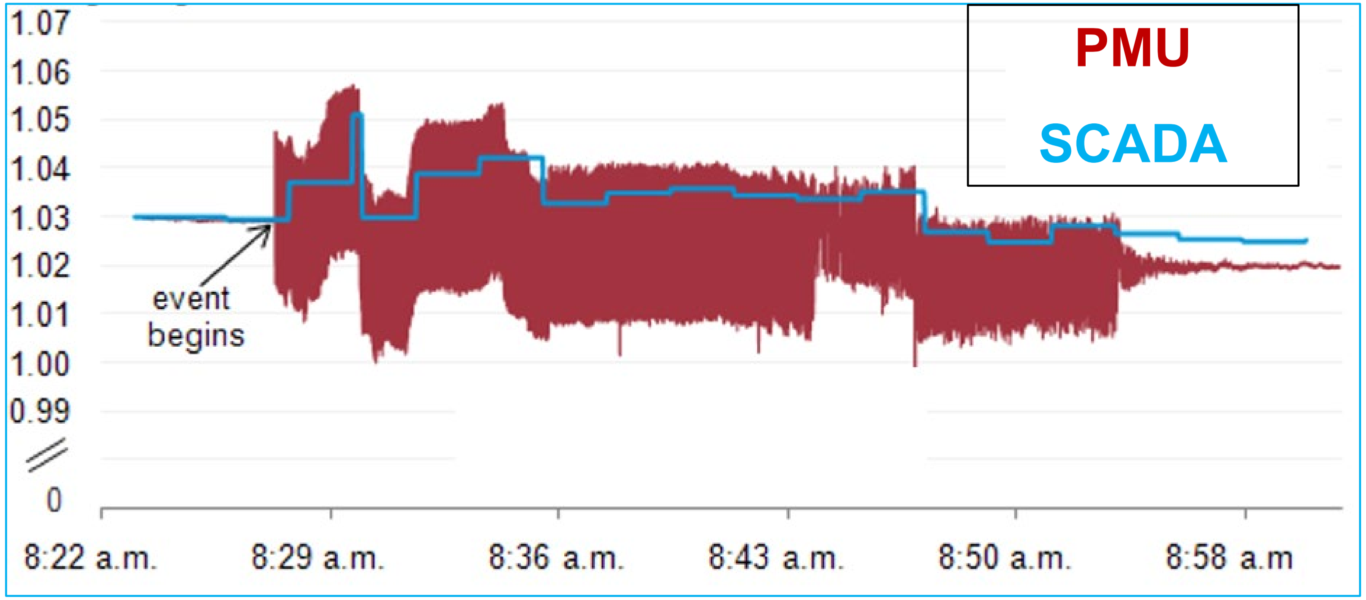
- Inverter controls might create sub-synchronous oscillations (typically 5.0-15.0 Hz) due to control interactions and/or network resonance

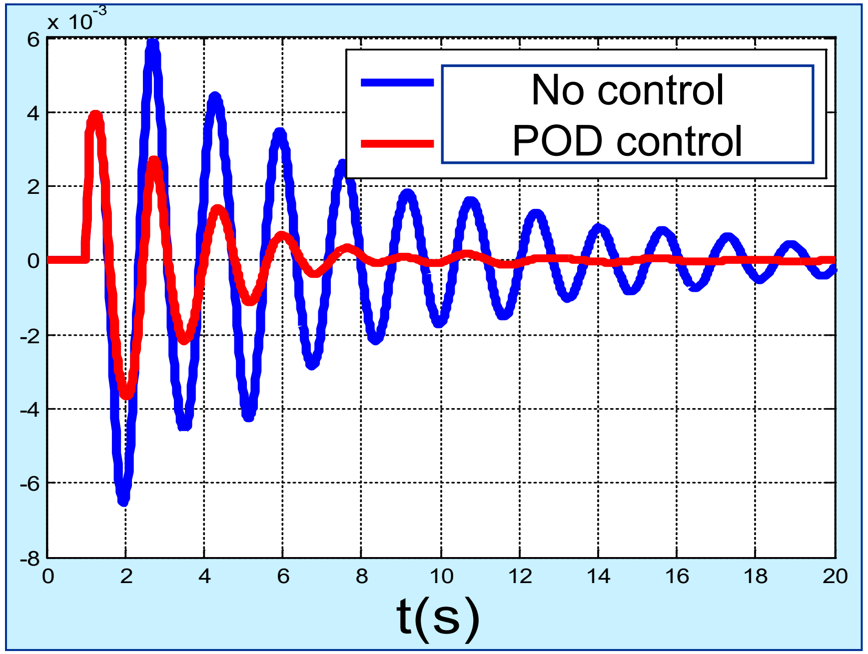
PV Plant – ~7 Hz Oscillation



First Solar Inc., "Deploying utility-scale pv power plants in weak grids," in *2017 IEEE Power & Energy Society General Meeting*, Jul. 2017.

Synchrophasor Technology for Oscillations Monitoring & Control





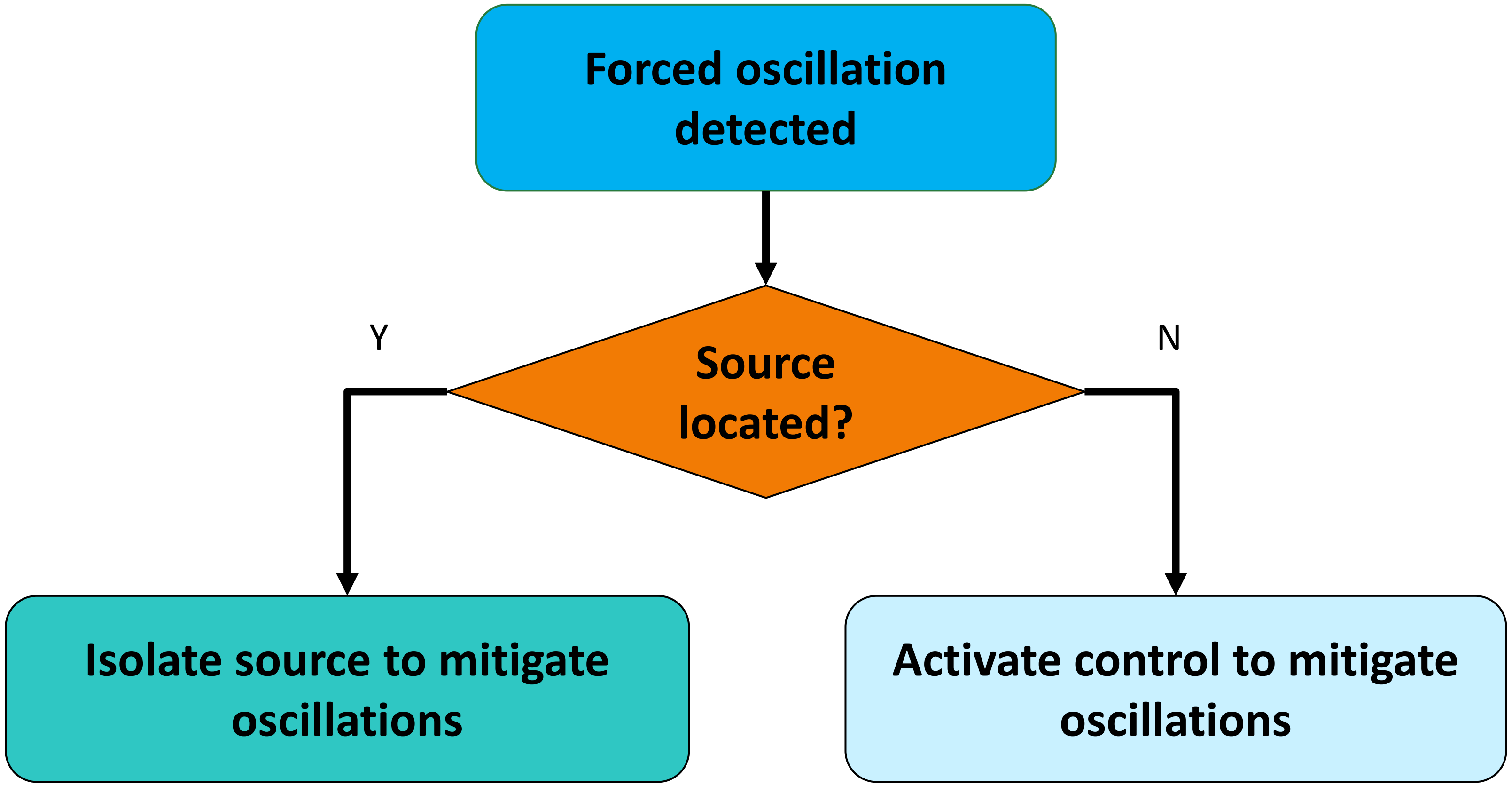
Monitoring → Control

- Use of IBRs as actuators
- Wide Area vs Local Control

Forced Oscillation Control via IBRs

Forced Oscillations Mitigation

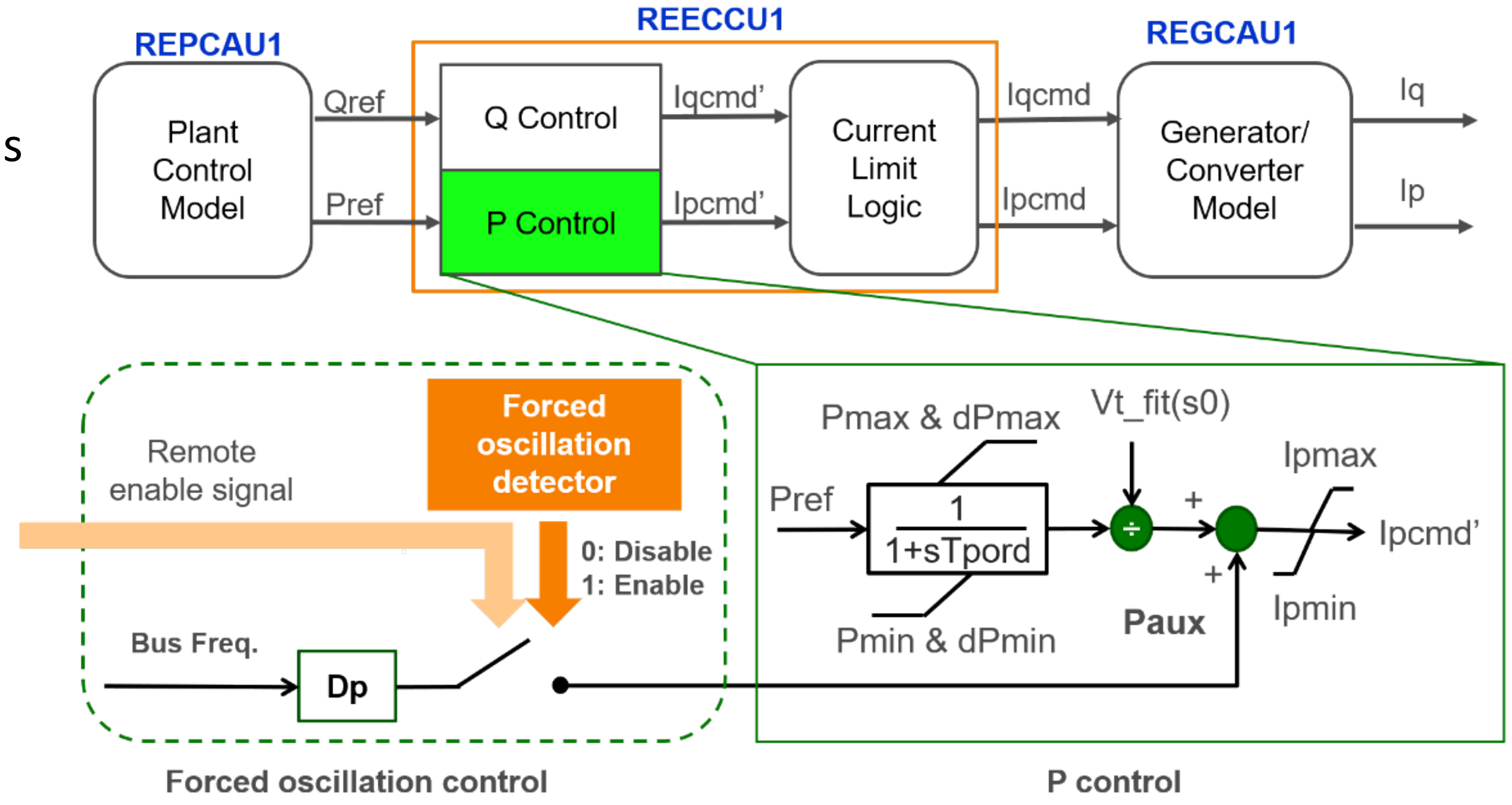
1. Forced oscillation source location
2. Use of Inverter-Based Resources (e.g., Battery Energy Storage Systems) to suppress magnitude of forced oscillations



Forced Oscillation Mitigation Using IBRs

- Controller to reduce energy of oscillations
  - Actuator: IBR
  - Input: Frequency deviation of a HV bus close to the IBR
  - Output: Modulation signal of IBR active current/power
  - Controller:
    - Droop control
    - Forced oscillation detector

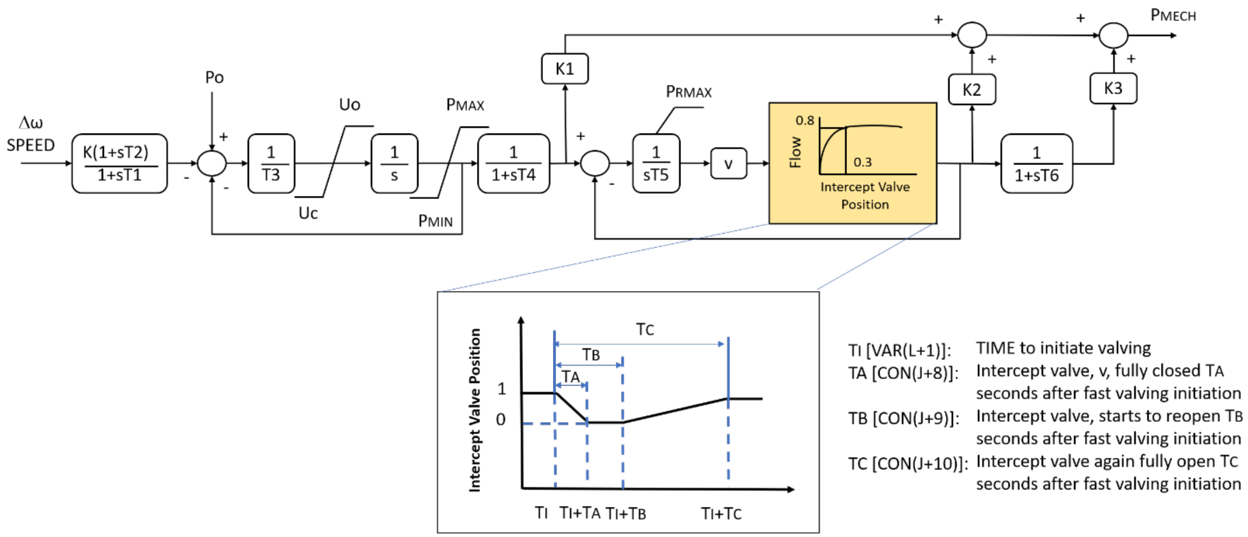
- Simulation implementation using WECC IBR models
- Active power control of the IBR electrical control model (REEC_X)



BESS model with forced oscillation control

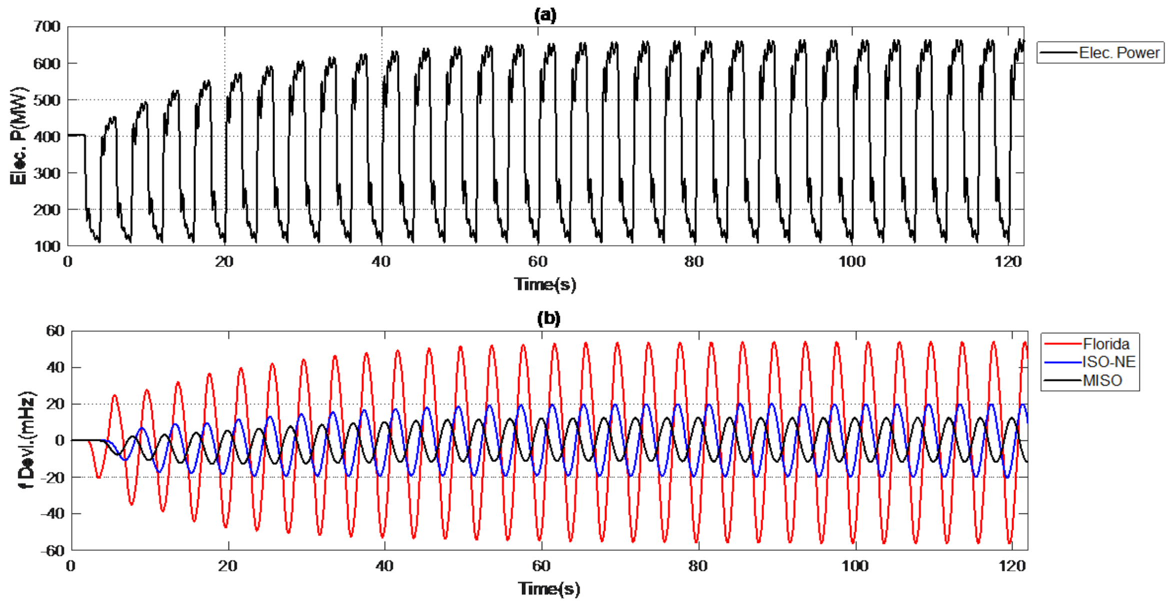
Replication of Jan. 11, 2019 EI Forced Oscillation Event

- 70k-bus EI model was used
  - Fast valving feature of the TGOV3 model used to replicate the event
  - Initiate fast valve every 4 seconds



TGOV3 governor model with fast valving feature

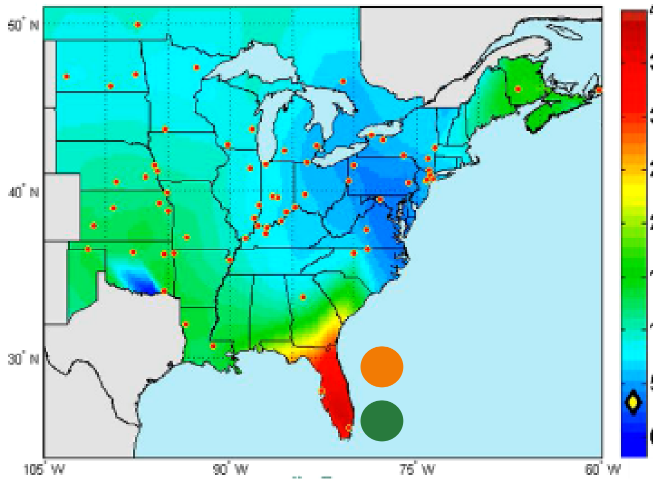
Generator Electrical Power



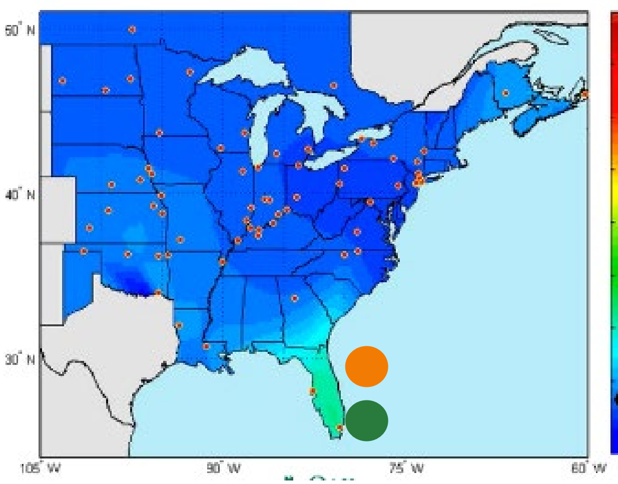
Bus frequency deviation in Florida (red, ~110 mHz peak-to-peak), ISO-NE (blue) and MISO (black)

Simulation Results in EI 70k-Bus Model

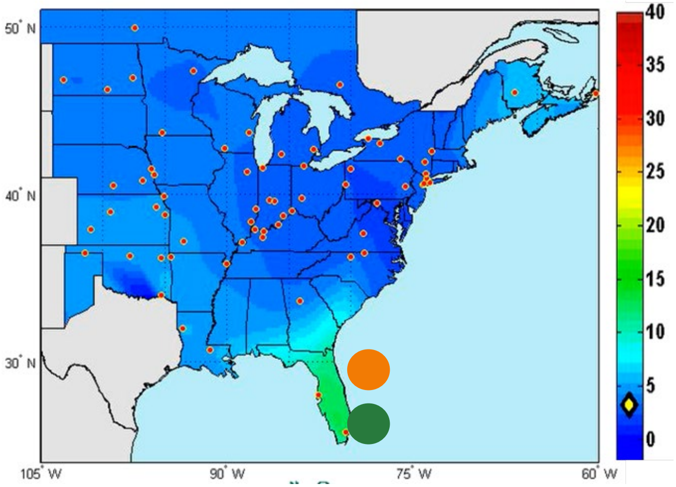
- Forced Oscillation Source: Generator in Florida
- Actuator: BESS in Florida
- Scenarios
  - Case 1: No Control (Jan. 11, 2019 event)
  - Case 2: With Control, one 409 MW BESS
  - Case 3: With Control, 12 distributed 35 MW BESSs



No Control



With Control (1×409 MW BESS in Florida)

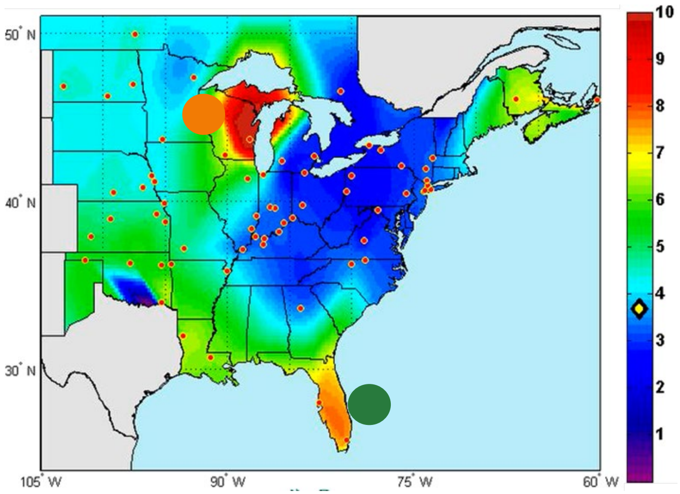


With Control (12 ×35 MW BESS in Florida)

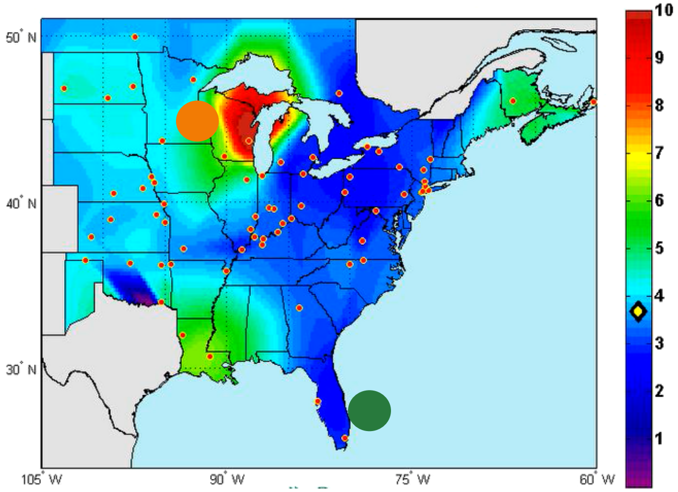
Source: Florida

Battery: Florida

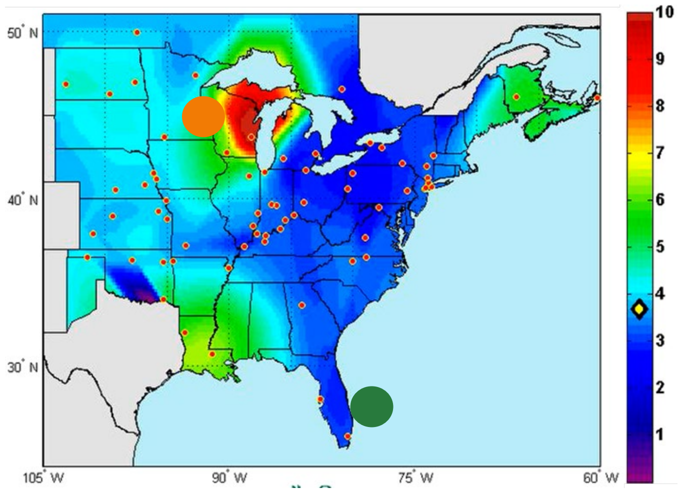
Simulation Results in EI 70k-Bus Model



No Control



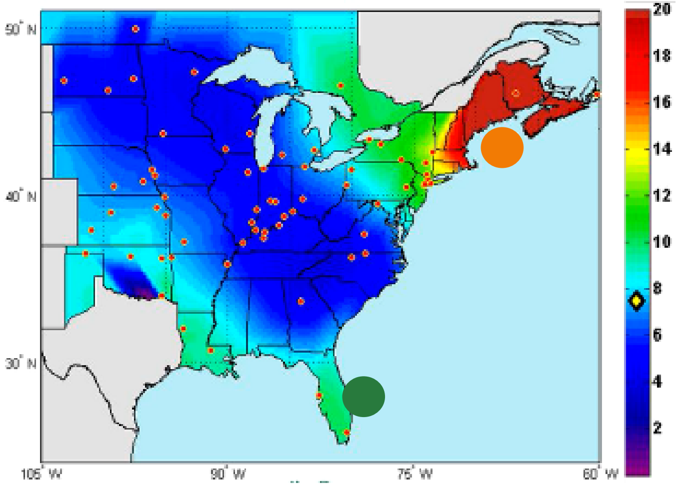
With Control
(1×409 MW BESS in Florida)



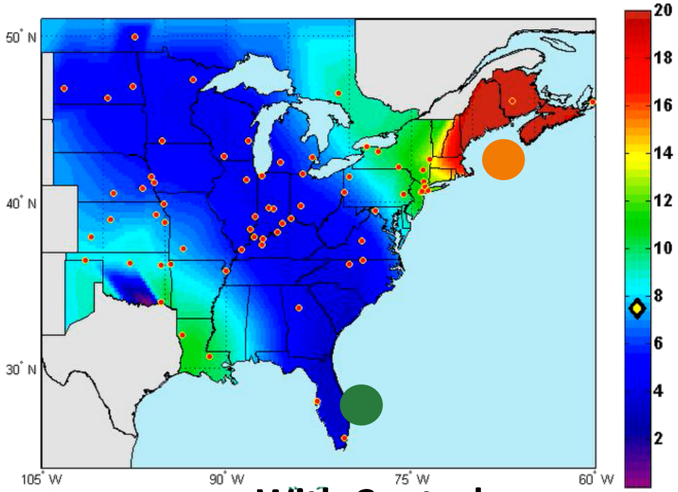
With Control
(12 ×35 MW BESS in Florida)

Source: **MISO**

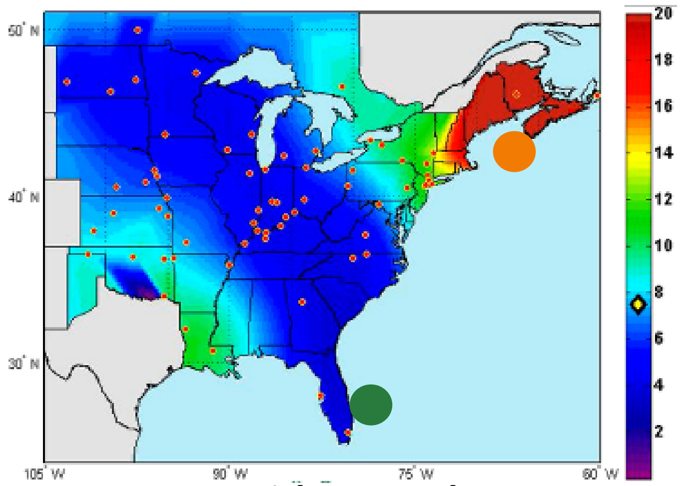
Battery: **Florida**



No Control



With Control
(1×409 MW BESS in Florida)



With Control
(12 ×35 MW BESS in Florida)

Source: **ISO-NE**

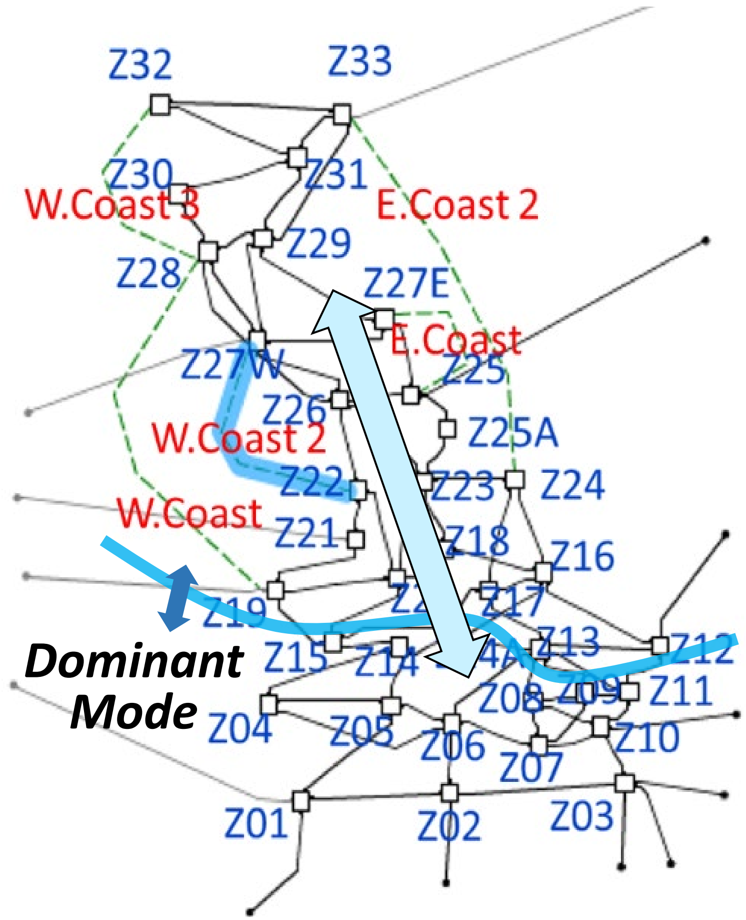
Battery: **Florida**

Damping of Low Frequency and Sub-Synchronous Oscillations Using HVDC

Great Britain Power Grid Model

- Project with the National HVDC Centre, Great Britain
  - Scope: Develop Power Oscillation Damping (POD) controllers to mitigate low frequency inter-area oscillations & local sub-synchronous oscillations
- Reduced 36-zone GB grid model in PowerFactory
  - Representing renewable dominated grid
  - Target oscillation mode: North-South (~0.88Hz, 3.27%)
  - Input signal: Bus frequency between north and south
  - Actuator: VSC-HVDC links

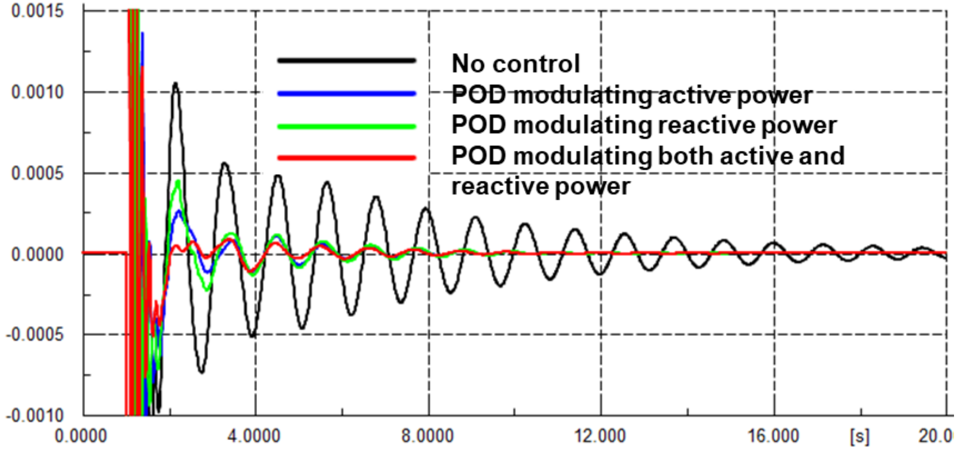
HVDC	Terminal 1	Terminal 2	Type
W.Coast	Z19	Z28	LCC-HVDC
W.Coast 2	Z22	Z27W	VSC-HVDC
W.Coast 3	Z28	Z32	VSC-HVDC
E.Coast	Z25	Z27E	VSC-HVDC
E.Coast 2	Z24	Z33	VSC-HVDC



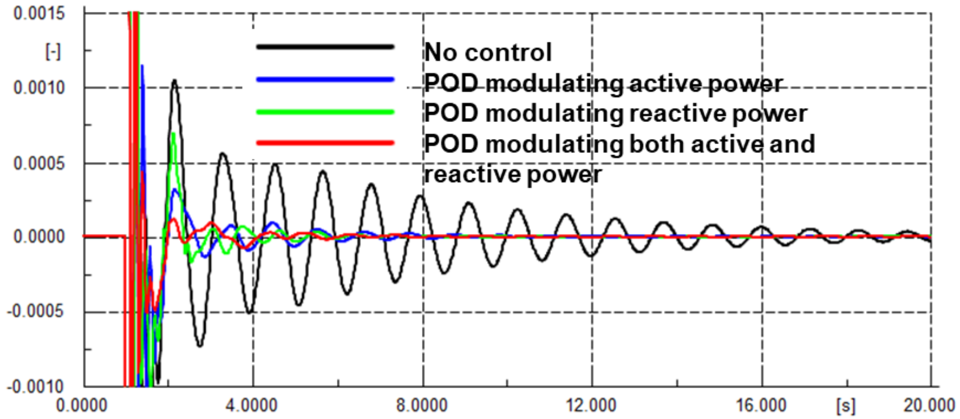
Zone map of GB power grid
Map source: The National HVDC Centre

Low Frequency Oscillations - Demonstrating Results - PowerFactory

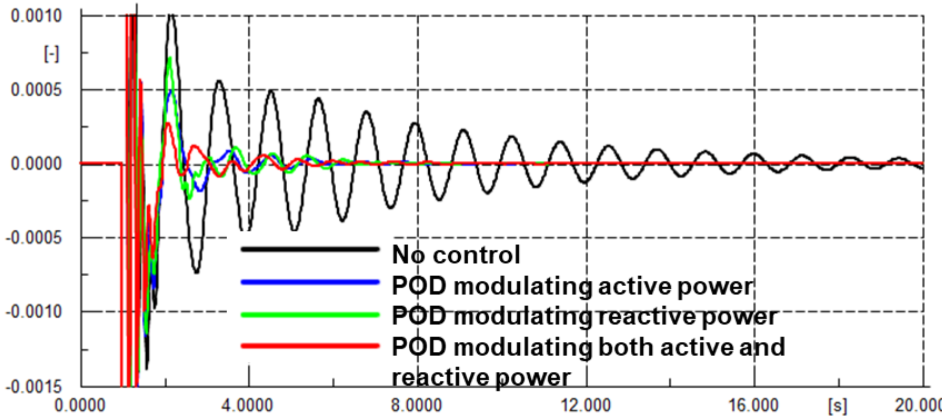
- PODs on VSC-HVDC links by P, Q, and P&Q modulation



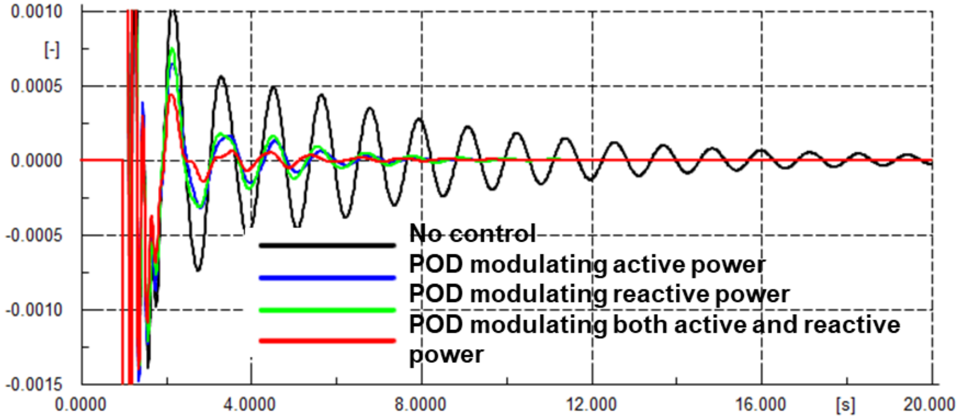
Actuator: W. Coast 3 HVDC



Actuator: E. Coast 2 HVDC



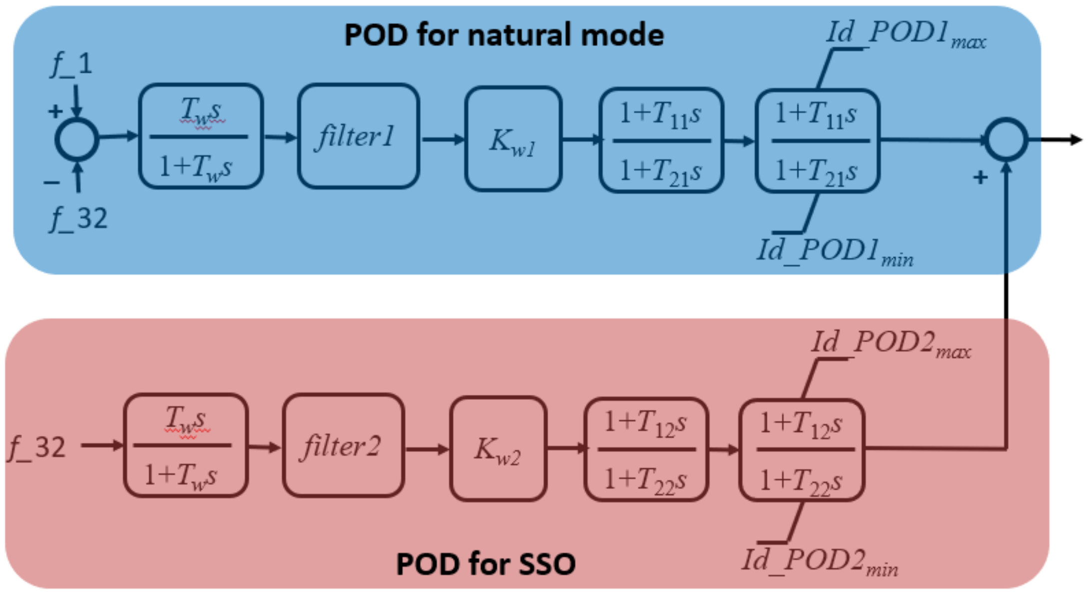
Actuator: W. Coast 2 HVDC

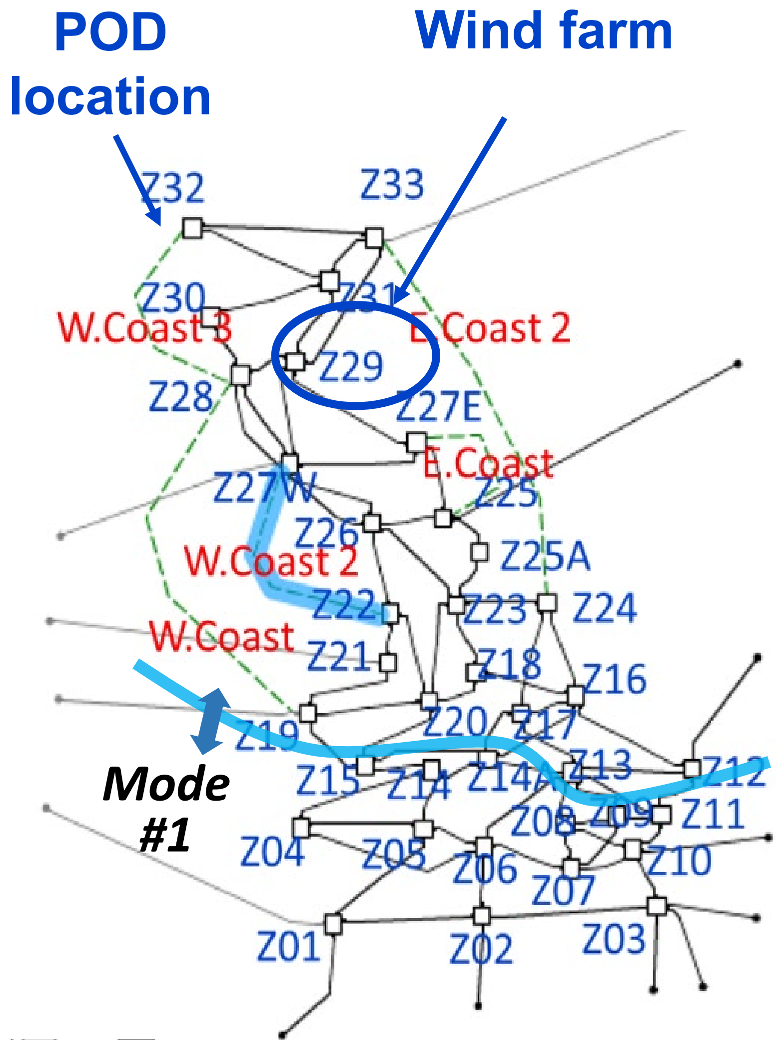


Actuator: E. Coast HVDC

POD for Sub-Synchronous Oscillation

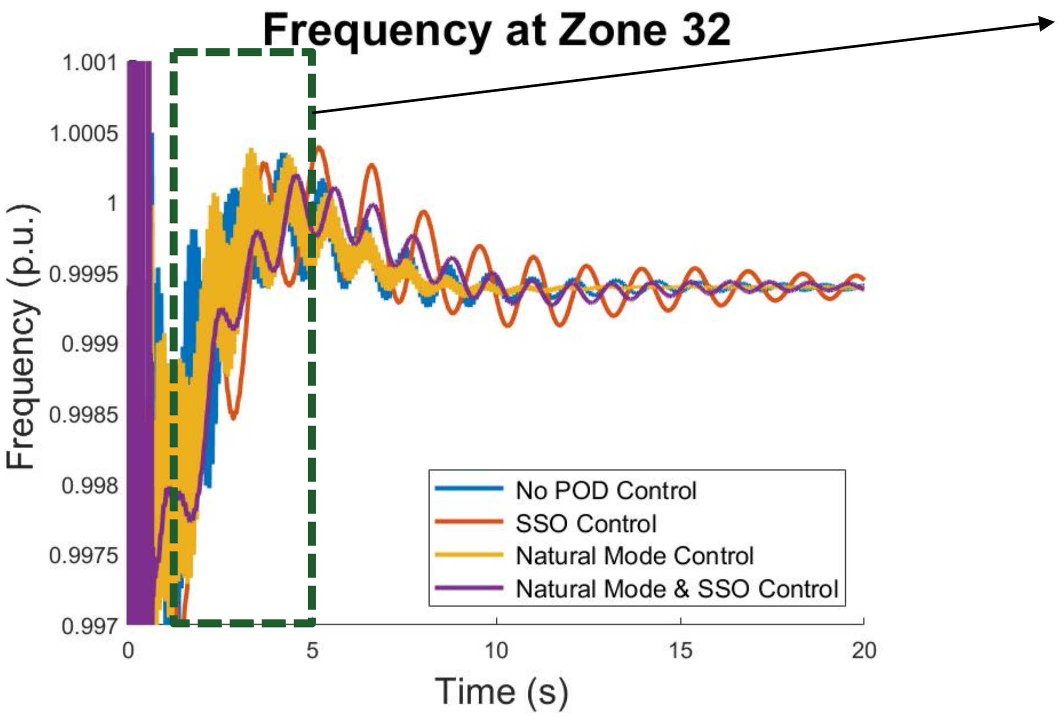
- Wind model with explicit representation of PLL and inner current control loops
- The parameters of the inner current control loop controller, outer voltage controller, and PLL were “mistuned” to produce SSO with frequency around 10Hz
- W.Coast 3 HVDC was used as the actuator to suppress SSO

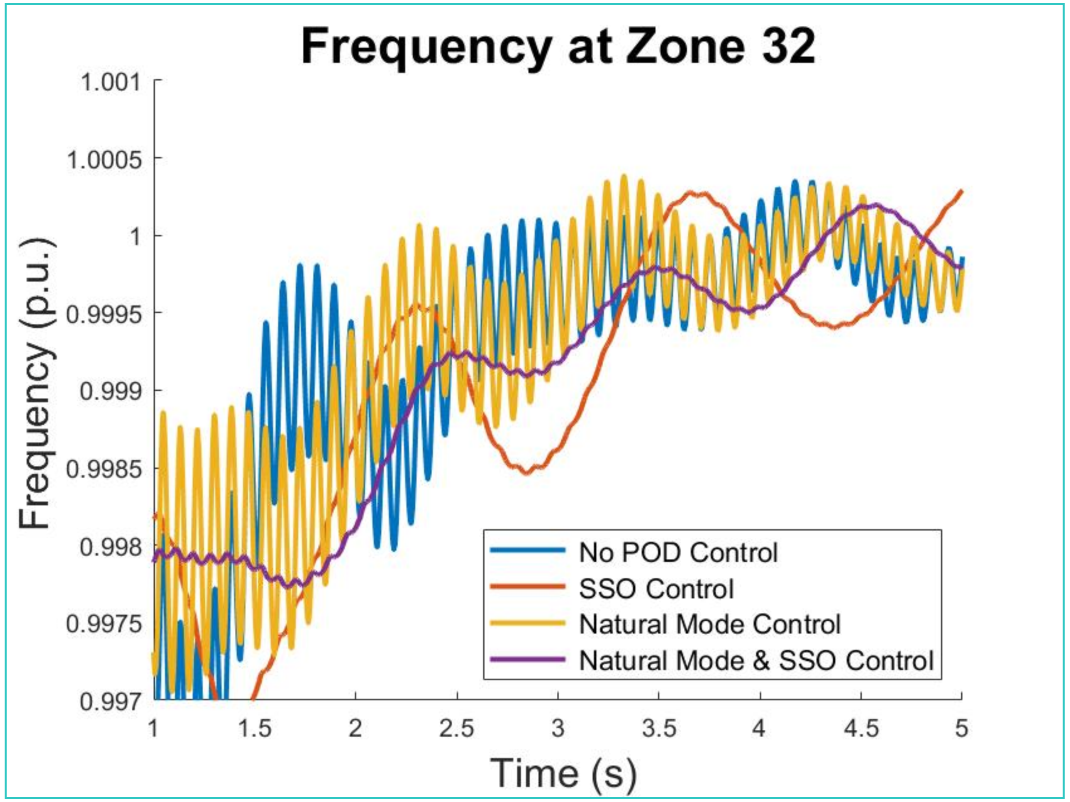




Sub-Synchronous Oscillations - Demonstrating Results - PowerFactory

- Sub-synchronous oscillations (SSO) caused by the interaction between renewable resource control and power network
- POD can suppress both natural oscillations and SSO

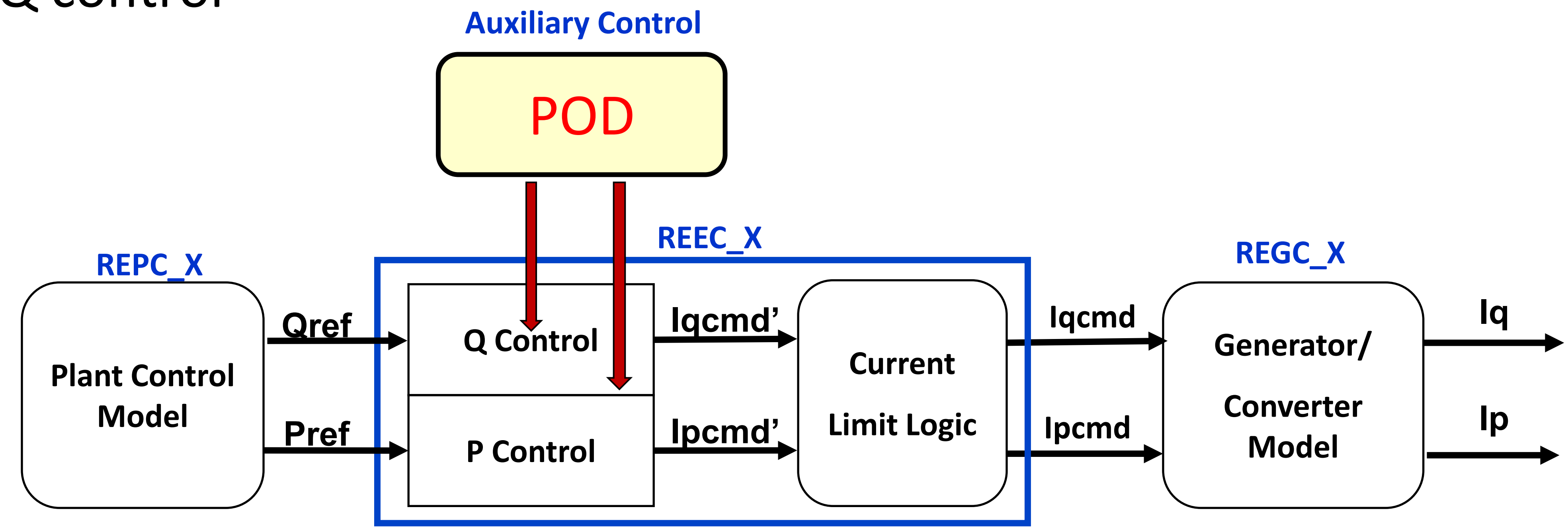




IBR Power Oscillation Damping

IBR Power Oscillations Damper

- Objective: IBRs providing oscillations damping control similar to synchronous generators with PSS
- Local control
- P or Q control

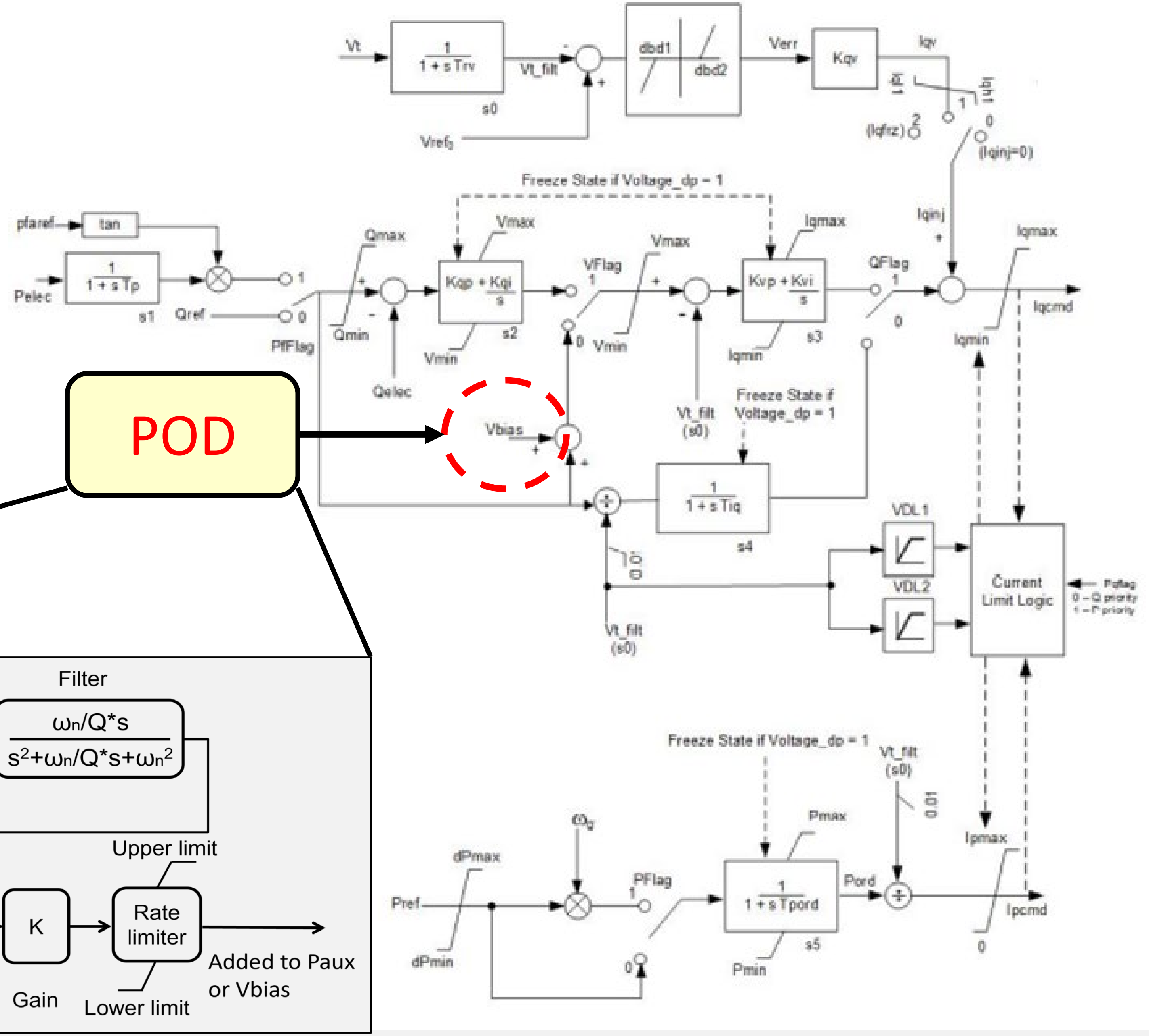


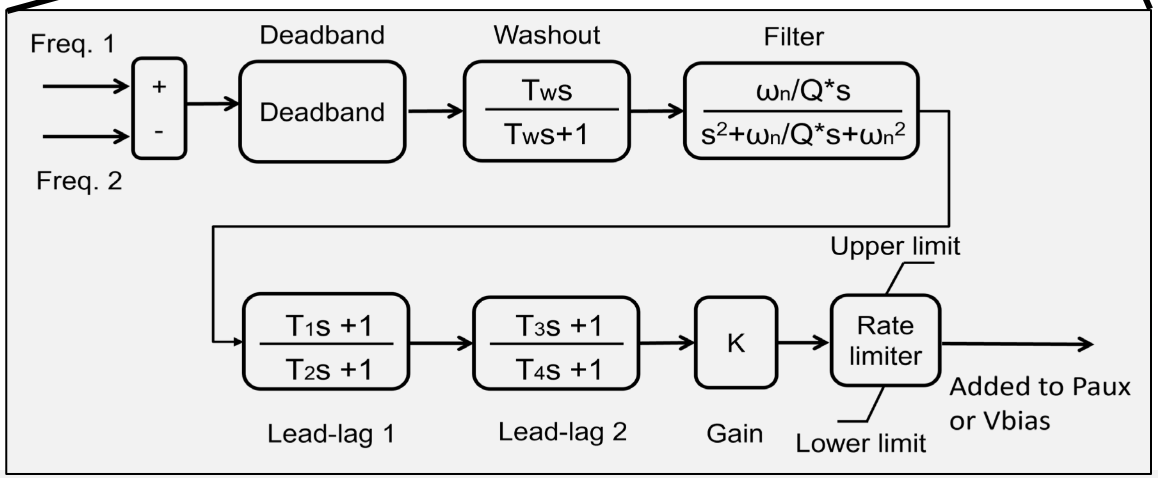
WECC Generic IBR Model

IBR POD Proposed Model

- IBR POD Control Blocks:
  - Washout
  - Filter
  - Two Lead-Lag
  - Gain
- POD output can be added to the Paux signal (e.g., REECCU1) for P modulation or the Vbias signal (e.g., REECA1) for Q modulation

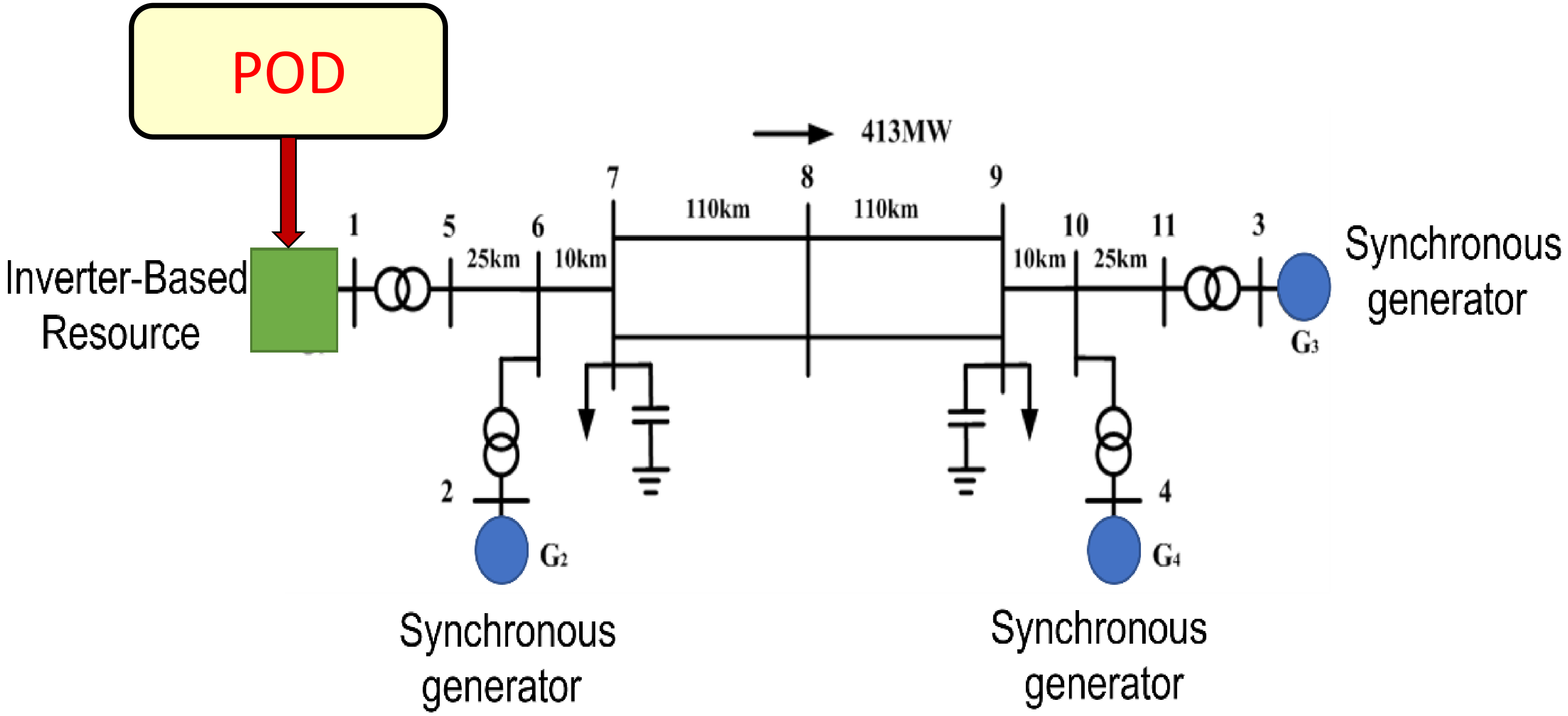
WECC REEC_A Model





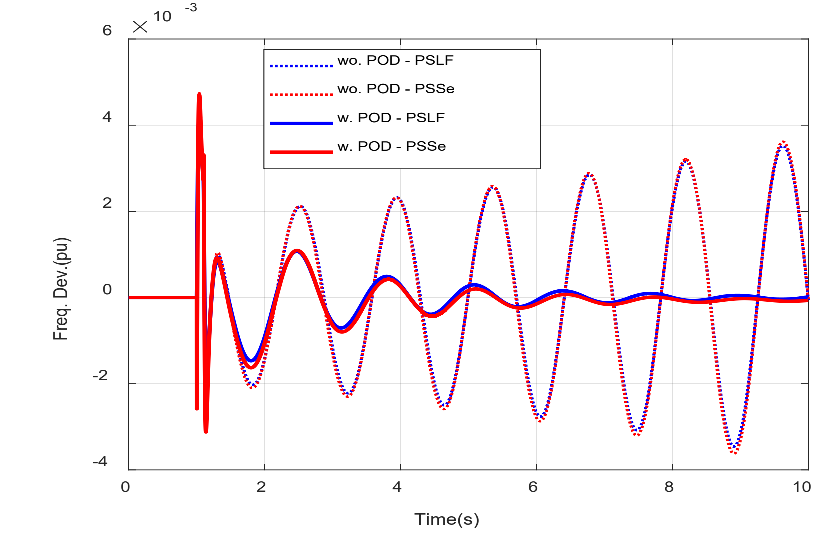
IBR POD – Test System

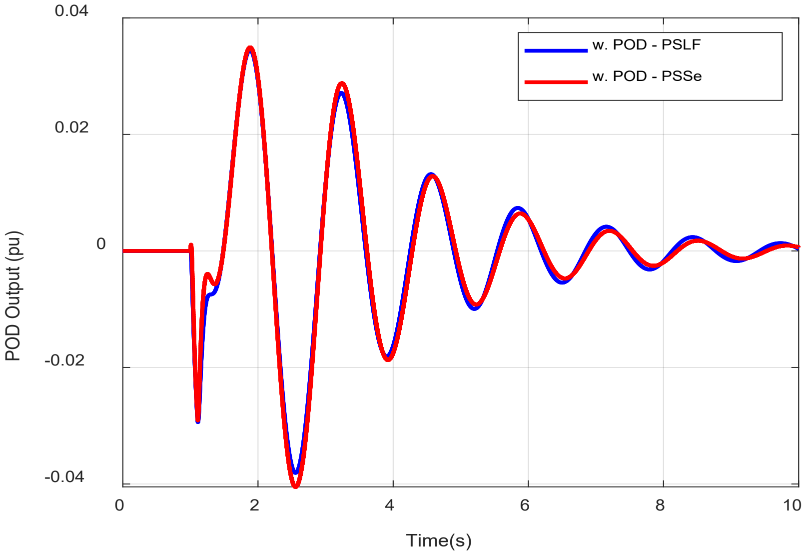
- Kundur 2 area system with one generator replaced by an IBR
- POD model implemented in PSS/E and PSLF



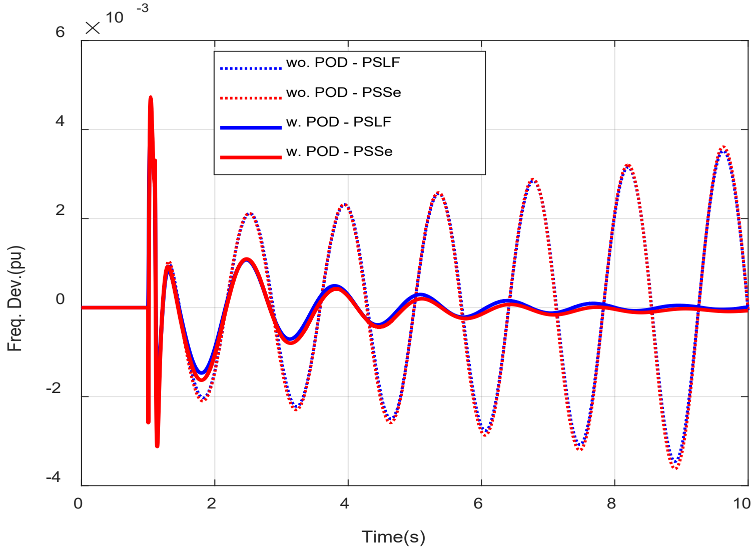
IBR POD – Demonstrating Results

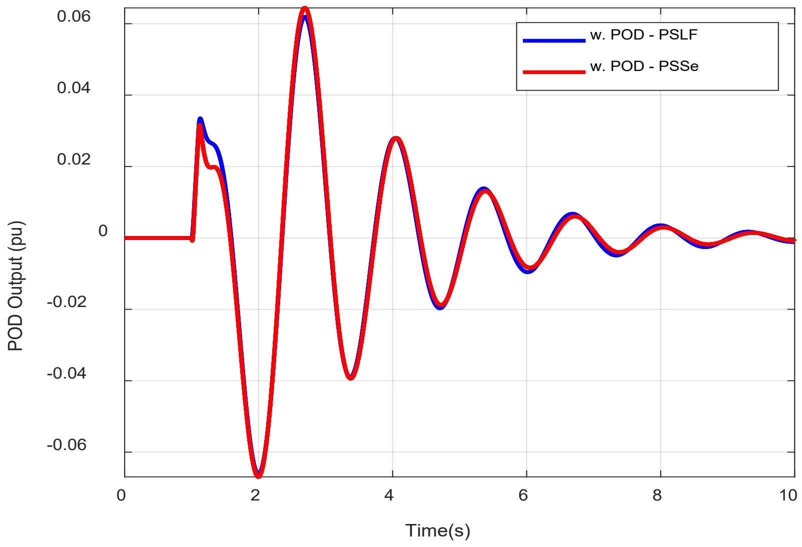
P Modulation





Q Modulation

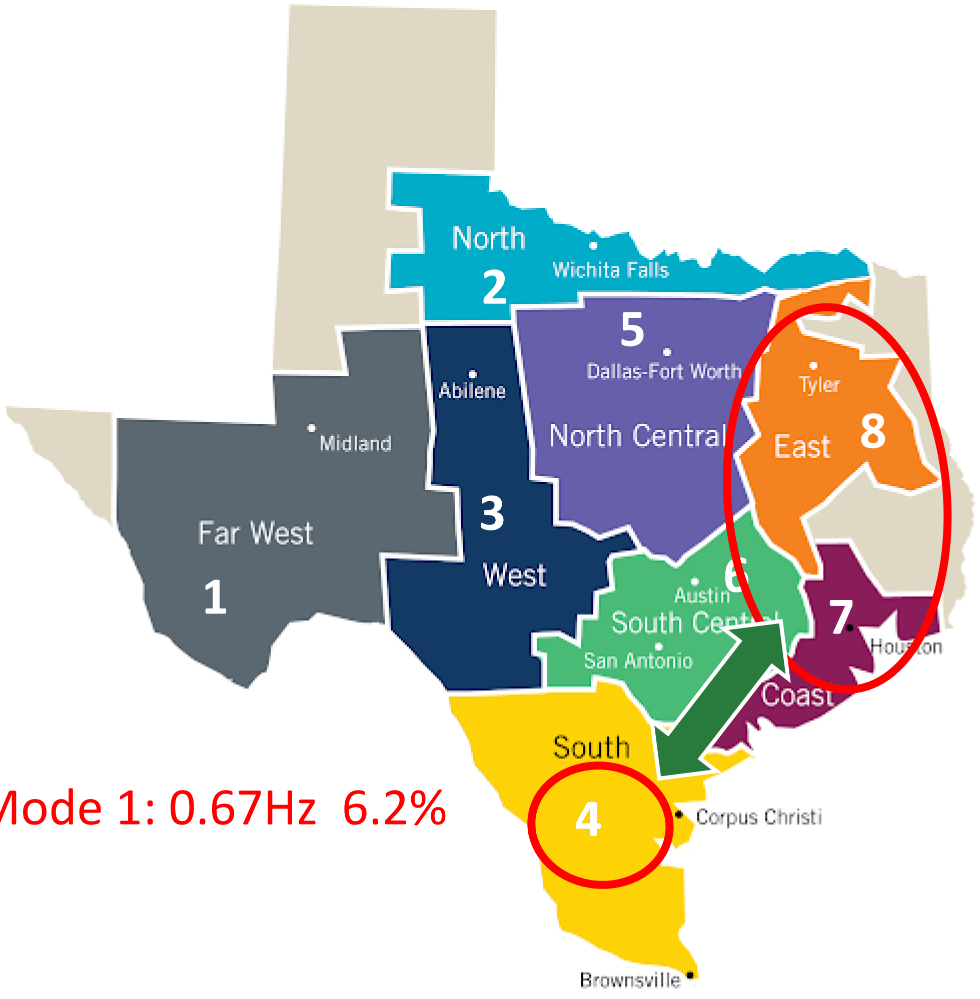




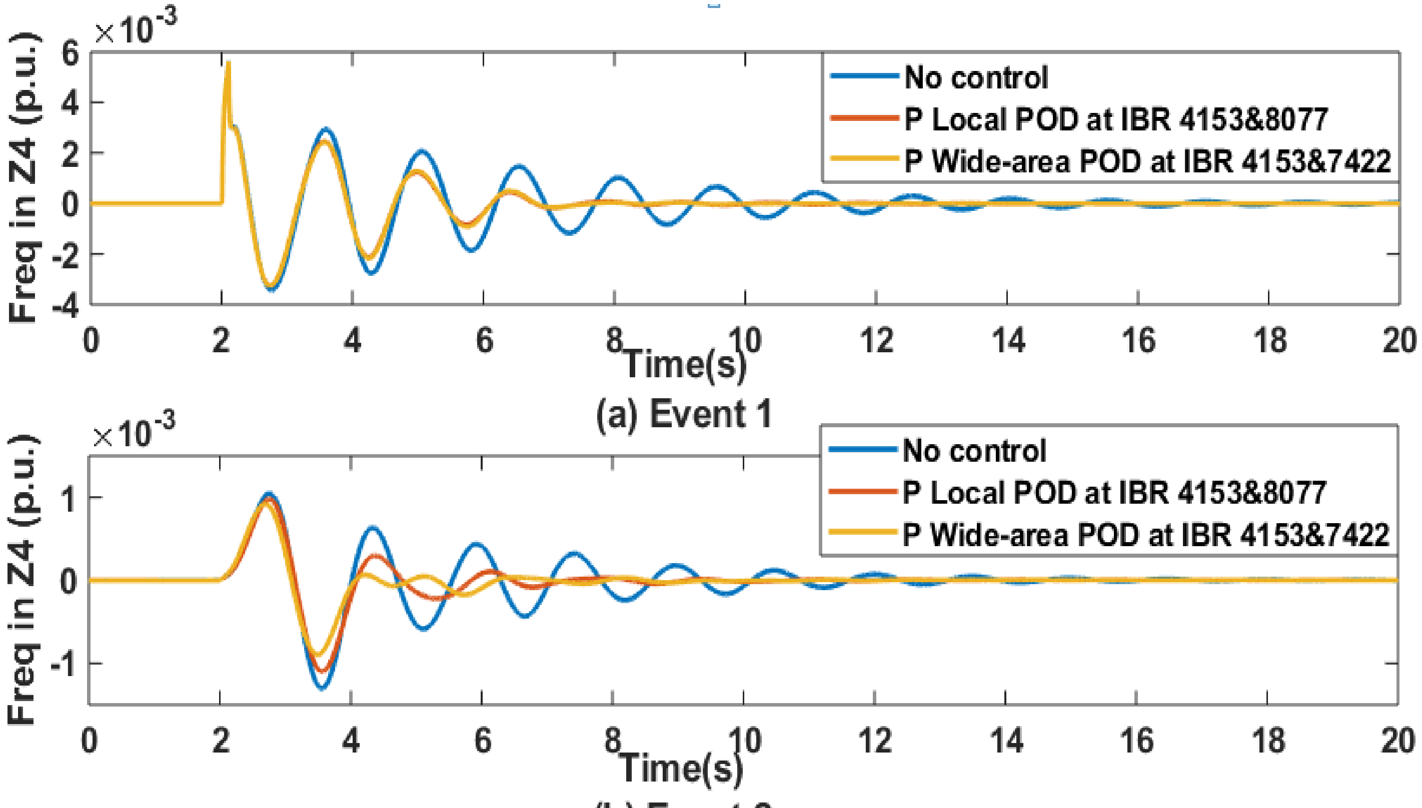
IBR POD stabilizes the system with either P or Q modulation

IBR POD vs WADC - ERCOT 2k Bus Model

- WADC control: feedback signal f_{zone4}-f_{zone7}
- Local POD control: Inverter frequency measurement



Mode 1: 0.67Hz 6.2%



(a) Event 1

(b) Event 2

EPRI

Together...Shaping the Future of Energy™