

# PMU Based Inertia Estimation and Monitoring

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# Motivation - Reducing Inertia

## Increased Penetration of Inverter Based Renewables

Increasing integration of renewable generation displaces synchronous generation → system inertia reduction

### Challenges

#### Rate of Change of Frequency (RoCoF)

Equipment Withstand

Protection Maloperation

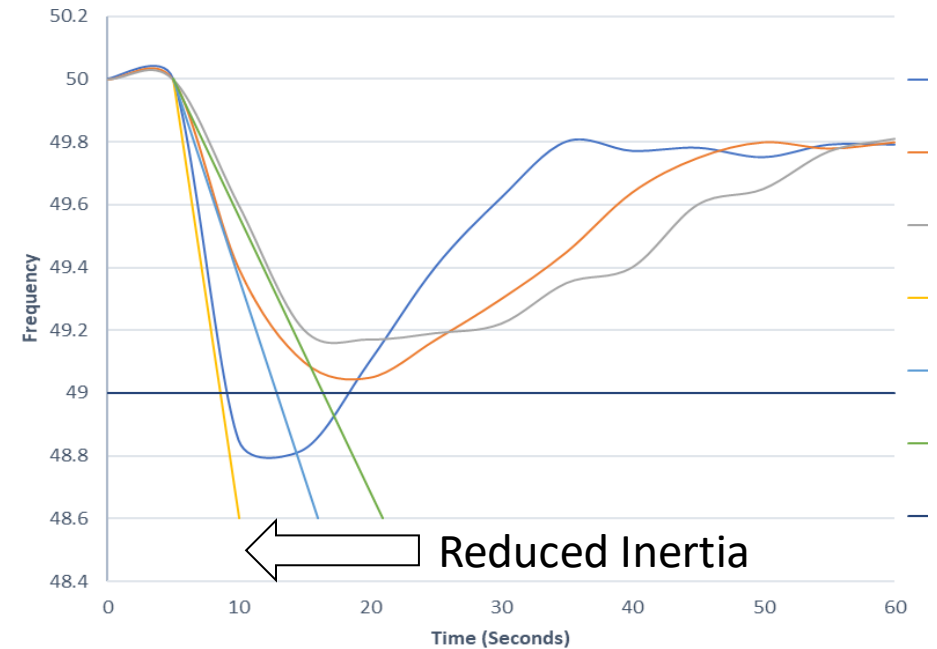
Reserves Response Time

#### Frequency Nadir

Operational Security Standards

Customer Load Shedding

Illustration of System Inertia and ROCOF



Real-time inertia monitoring? Critical inertia floor? RoCoF limit? Faster reserve?

# Inertia Monitoring Methods

## Unit commitment - Monitoring

- Sum of online generation inertia constant (GVAs)

Most utilities/ISOs that estimate inertia use Unit Commitment Monitoring

## Continuous signal - Estimation

- Real time analysis of known stimulation
- Real time analysis of natural small perturbations

At R&D or demonstration status

## Event driven - Estimation

- Post-mortem analysis of large events
- Real time analysis of large events

Most utilities/ISOs perform some form of ad-hoc event-based estimation

Source: EPRI White Paper  
['Online Inertia Estimation & Monitoring: Industry Practices & Research Activities'](#)

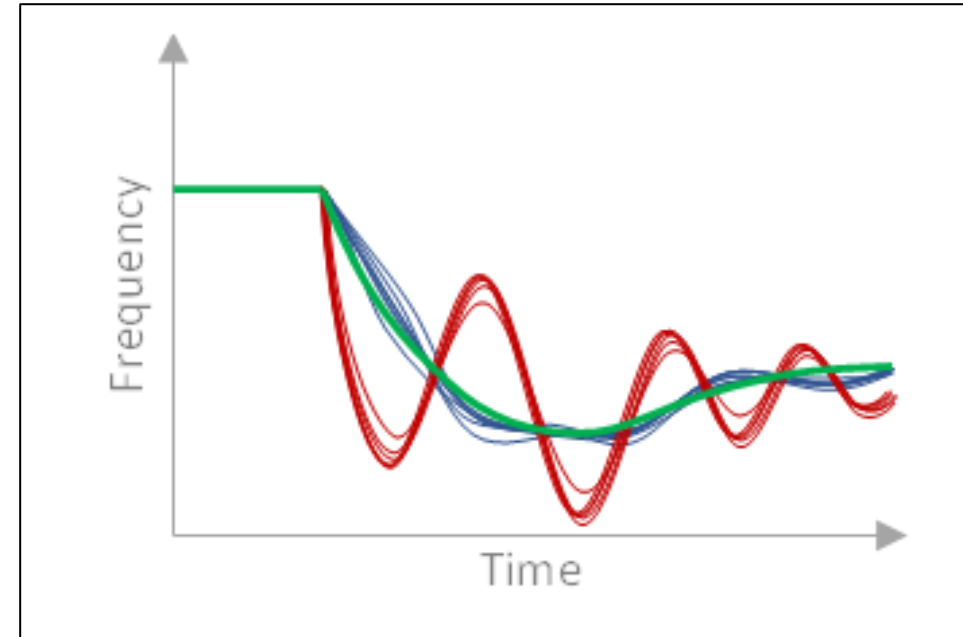
# Regional Inertia

Regions of the system may emerge that have low inertia and are weakly coupled to the rest of the system and its inertia

Reduction in inertia is not spatially uniform, which can result in regions of disproportionately low inertia

If low inertia regions are poorly coupled to the system, they will swing around the center of inertia frequency

Potential severe regional frequency and RoCoF response under local infeed loss

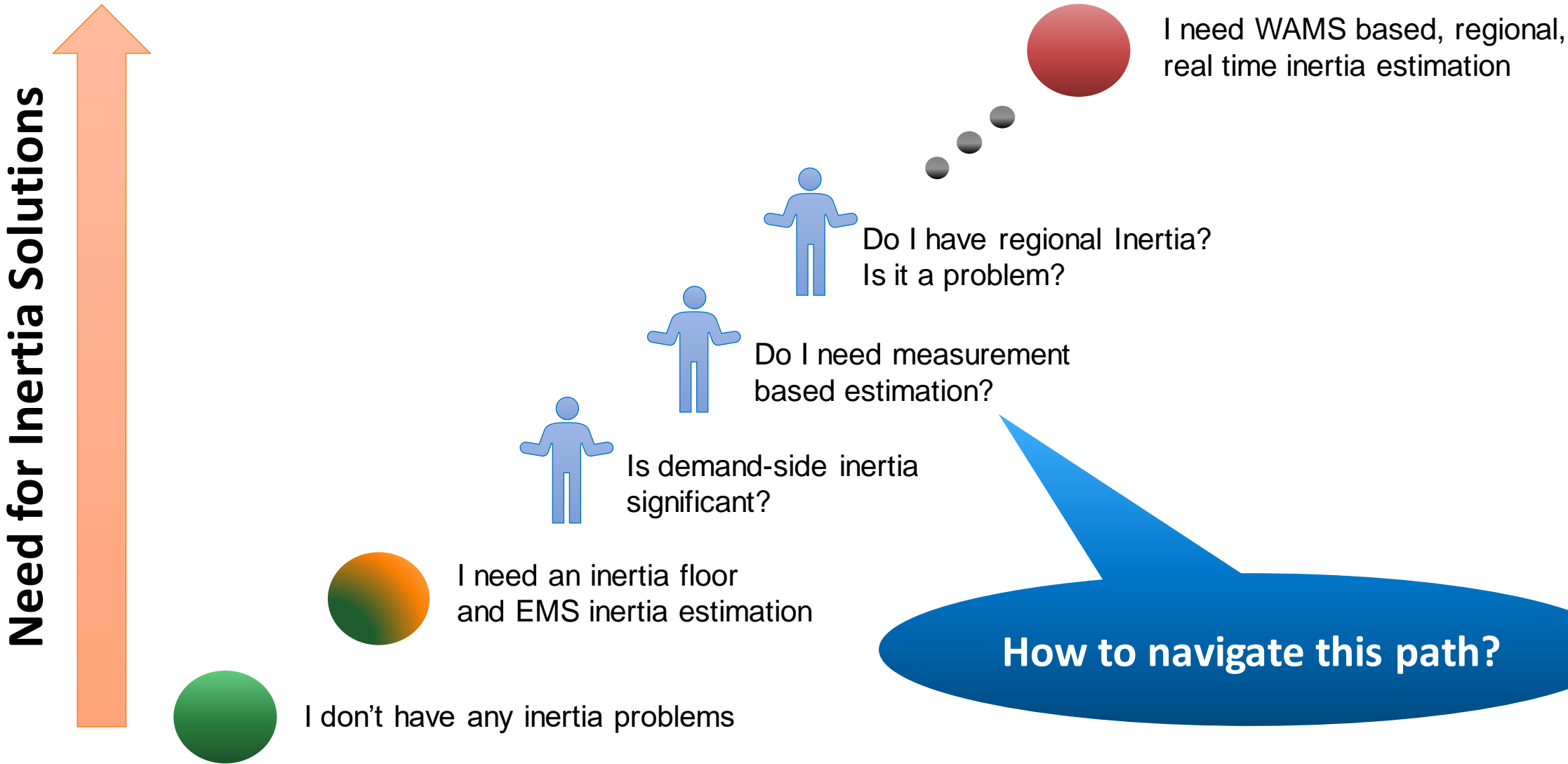


— Centre of Inertia Frequency

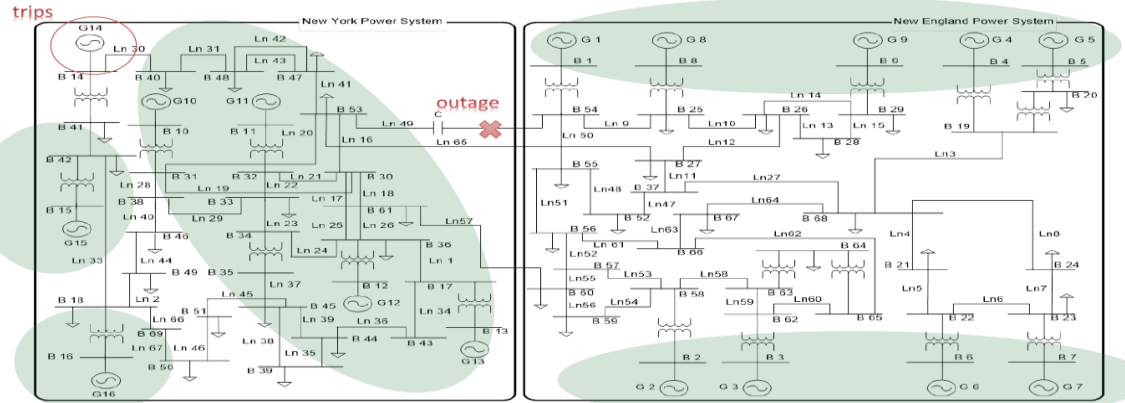
— Cluster Generator Frequencies

— Other Generator Frequencies

# Framework for Assessing Reduced Inertia



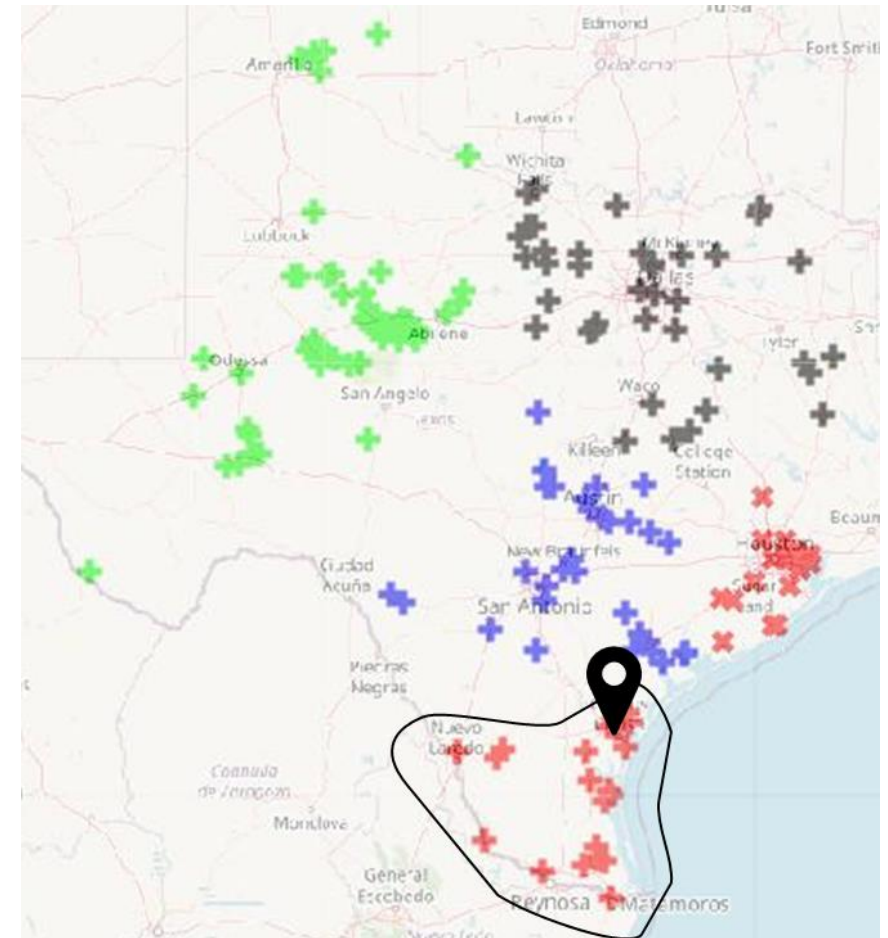
# Region Identification Method



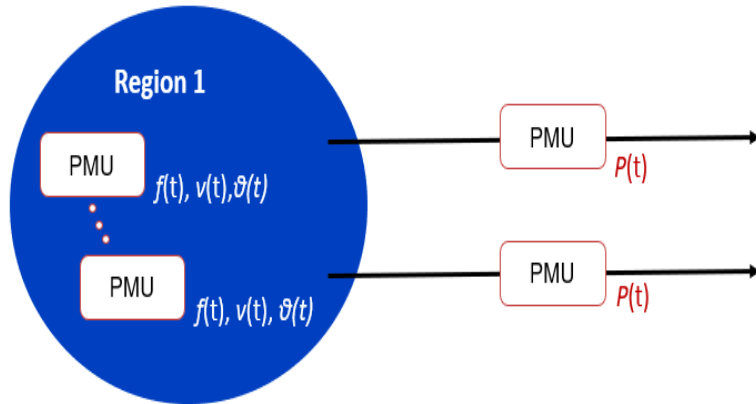
## Regionalization

- Determine whether regions with different inertial response exist in the system
- Identify regions with different inertial response
- Based on online generation status and topology
- Graph theory & spectral clustering
- No time domain simulations

## Synthetic Texas System

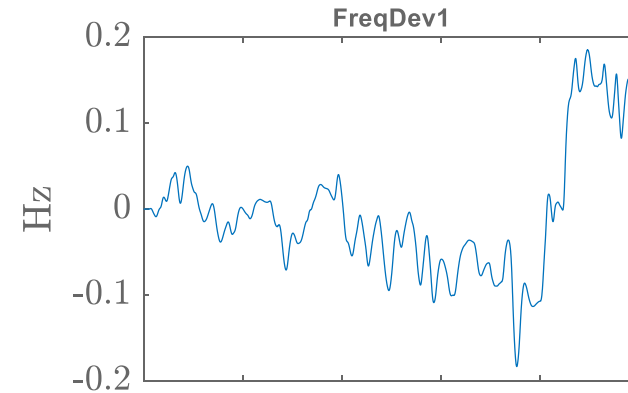


# PMU Measurement Based Inertia Estimation

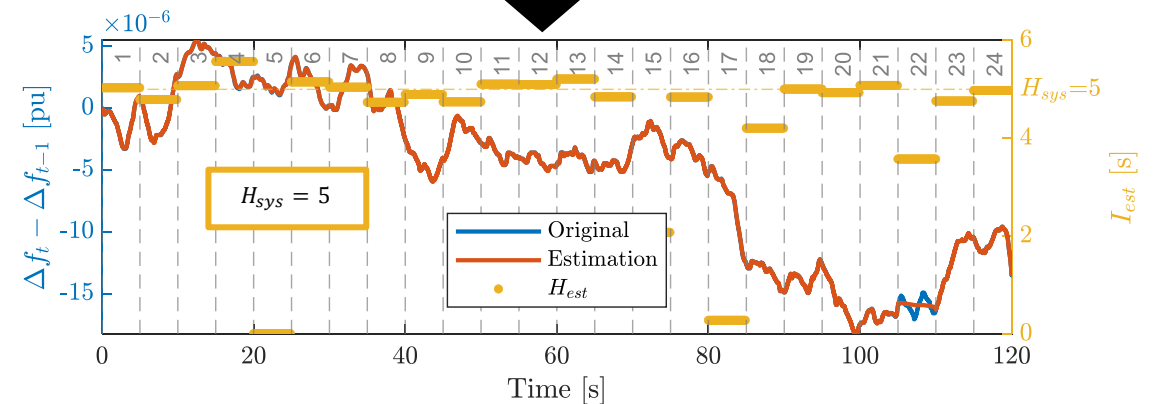


## Regional PMU-Based Inertia Estimation

- PMU Measurement Based
- PMUs within region and at interface lines
- System Identification using ambient data
- Considers region load impact



ARMAX Model



A blue-tinted photograph of four people (three men and one woman) standing together, looking at documents. They are wearing EPRI-branded lab coats or shirts. The woman is wearing a hard hat. The background is a solid blue color.

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