Oscillation Countermeasures Based on Synchro-Waveform Technology and ADMS

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Motivation

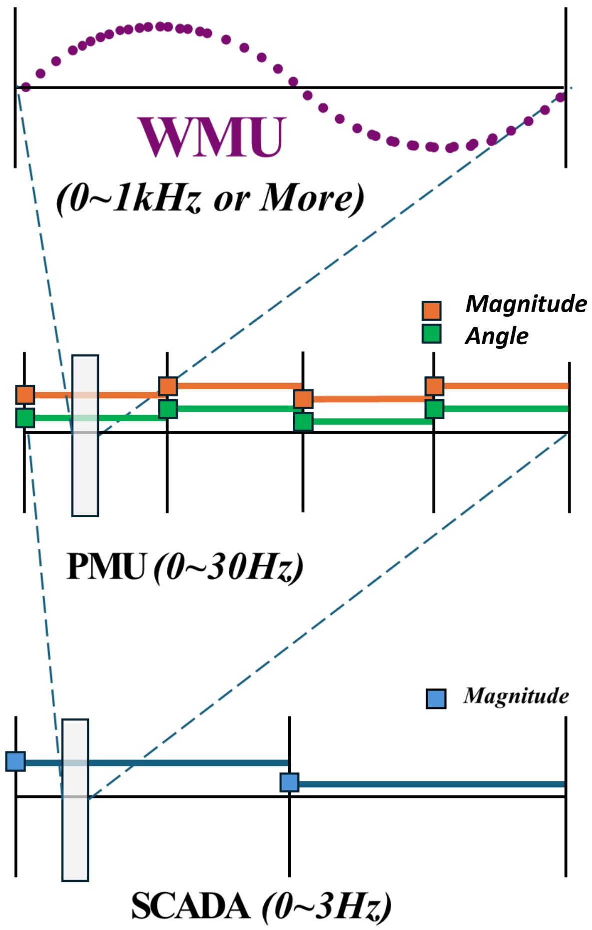
- Sub- and super-synchronous oscillations are becoming increasingly common in modern power systems.
  - 5–80 Hz oscillations are reported in real-world power systems.
- These oscillations involve diverse inverter-based resources (IBRs) and grid conditions.
- Traditional PMUs are insufficient to capture high frequency dynamics—highlighting the need for Synchro-Waveform Technology.

1. Next-level WAMS based on WMU

WMU: waveform measurement unit (synchro-waveform)

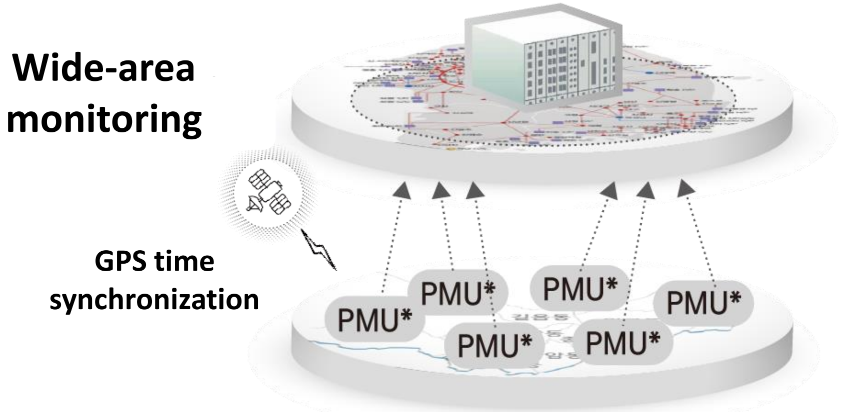
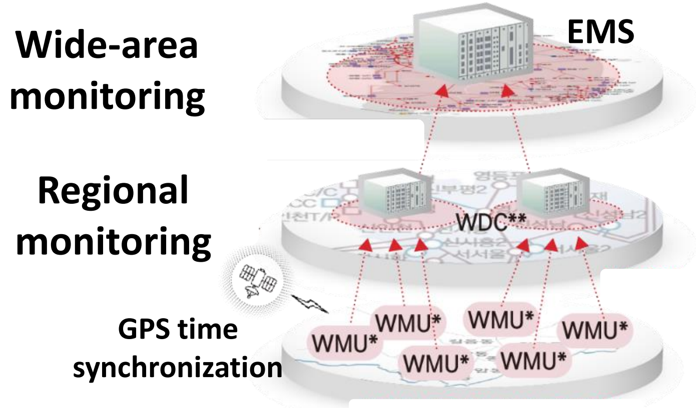
- High-resolution measurement unit based on synchro-waveform technology.
- Enables accurate detection of power system oscillations, including sub- and super-synchronous oscillations.

Device	Measuring data	Reporting rate
WMU	Waveform	Max. 256 samples/cycle (Time synchronized)
PMU	Phasor for nominal frequency	Max. 2 samples/cycle (Time synchronized)
SCADA	Magnitude	1 sample for a few seconds



1. Next-level WAMS based on WMU

Next-level WAMS architecture

As-Is		To-Be
Traditional WAMS		Next-level WAMS based on WMU
• Centralized structure	Monitoring Architecture	• **Hierarchical structure** due to data volume and communication burden.
	Monitoring Structure	
▪ PMU, SCADA	Measuring Device	▪ WMU, PMU SCADA

1. Next-level WAMS based on WMU

Recent Korean Project

- Project title: **Development of Monitoring and Analysis Technologies for DC T&D**
- Management: KETEP (Korea Energy Technology Evaluation and Planning)
- Budget: 22.86 million USD
- Period: 2025 Apr. – 2029 Mar.

Sub-project Topics	Project Leaders
1. Development of WMU-based WAMS	Korea University
2. Advanced Modeling and Analysis of Stability	Korea Electrotechnology Research Institute
3. Field Implementation of WMU-based WAMS	KEPCO KDN

2. WMU-based Oscillation Source Location

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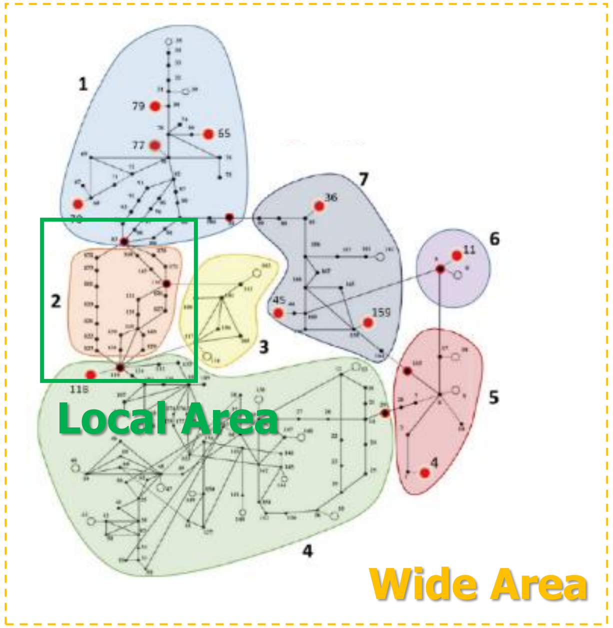
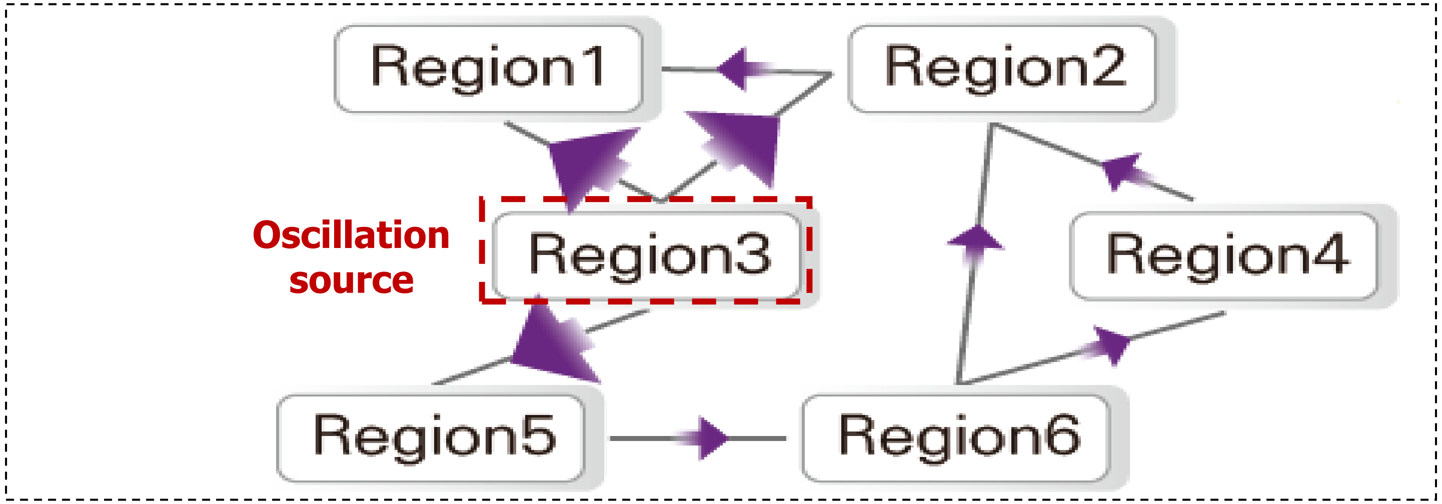
DEF-based oscillation source location

- **Dissipating Energy Flow (DEF)** indicates whether a system component **injects** or **absorbs** oscillatory energy.

Each WMU observes oscillation within a specific grid region.

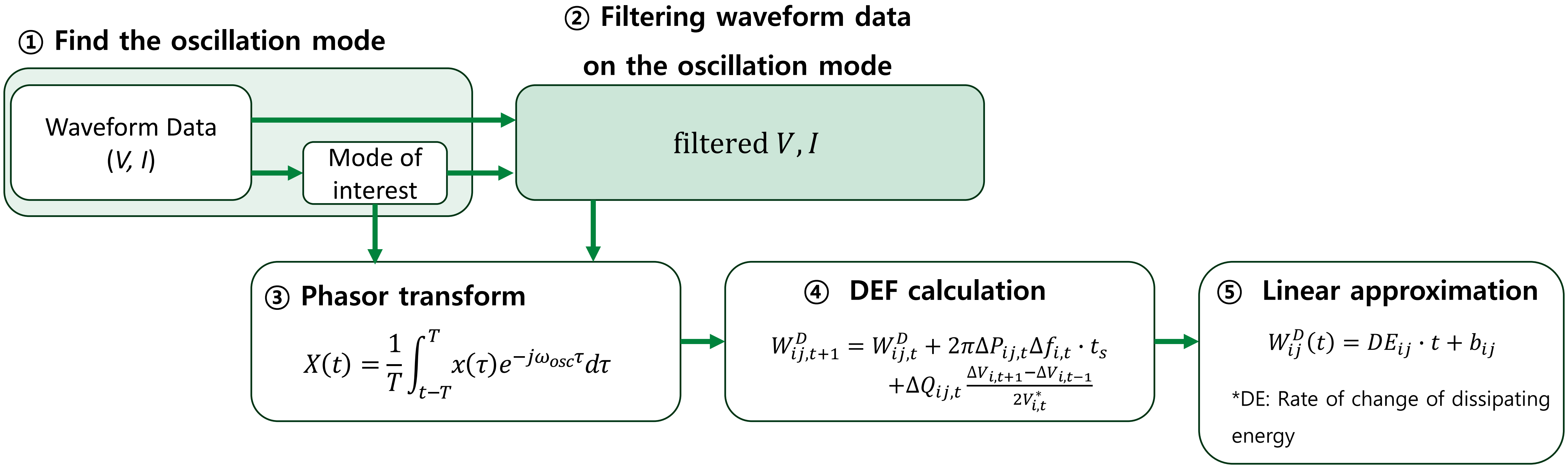


Oscillation energy flow (DEF)



WMU-based DEF

- Calculates extended DEF from synchro-waveform data in an oscillation mode.

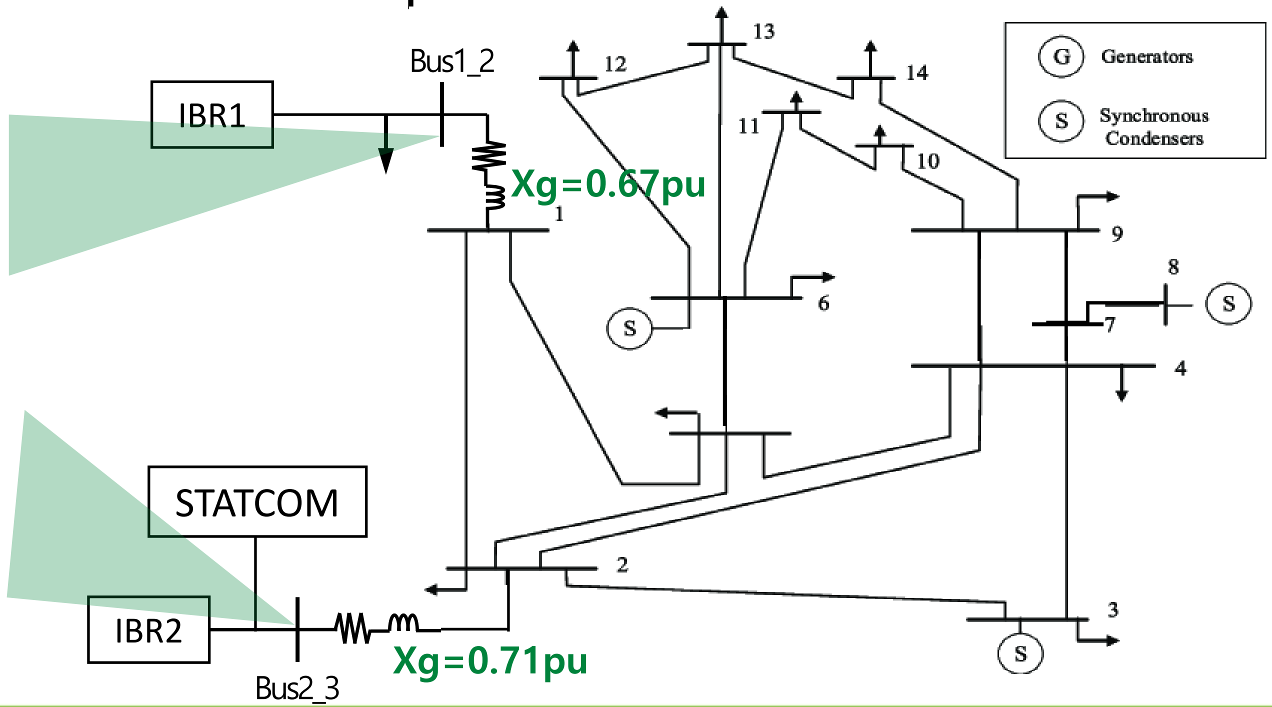


Case study: IBRs with different oscillation modes

- Test system: IEEE 14-bus system with IBRs
- Poorly-tuned IBR controls and weak grid conditions
- Two IBRs causes different oscillation mode.
- Disturbances: Slight increase of IBRs' active power

Modes (IBR1): 44 Hz, 76 Hz

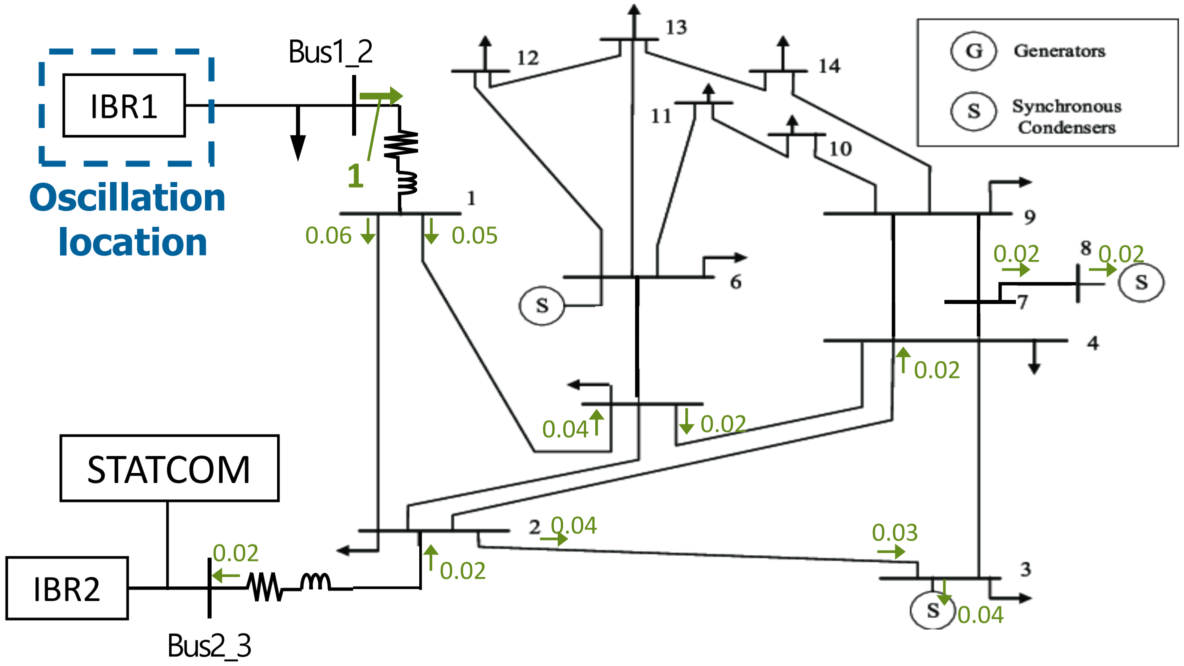
Modes (IBR2): 24.5 Hz, 95.5 Hz



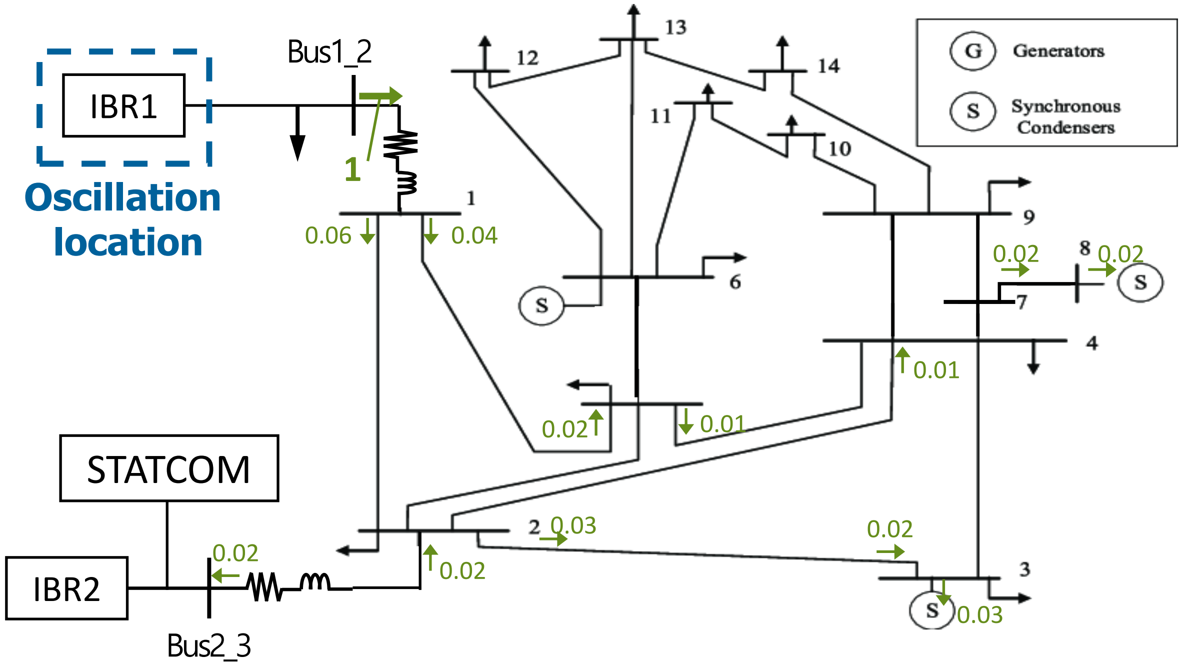
Case study: IBRs with different oscillation modes

- Distinguishes oscillations at different frequencies and identifies their respective sources.
- Identifies IBR1 as the source of 44 Hz and 76 Hz oscillations

44Hz



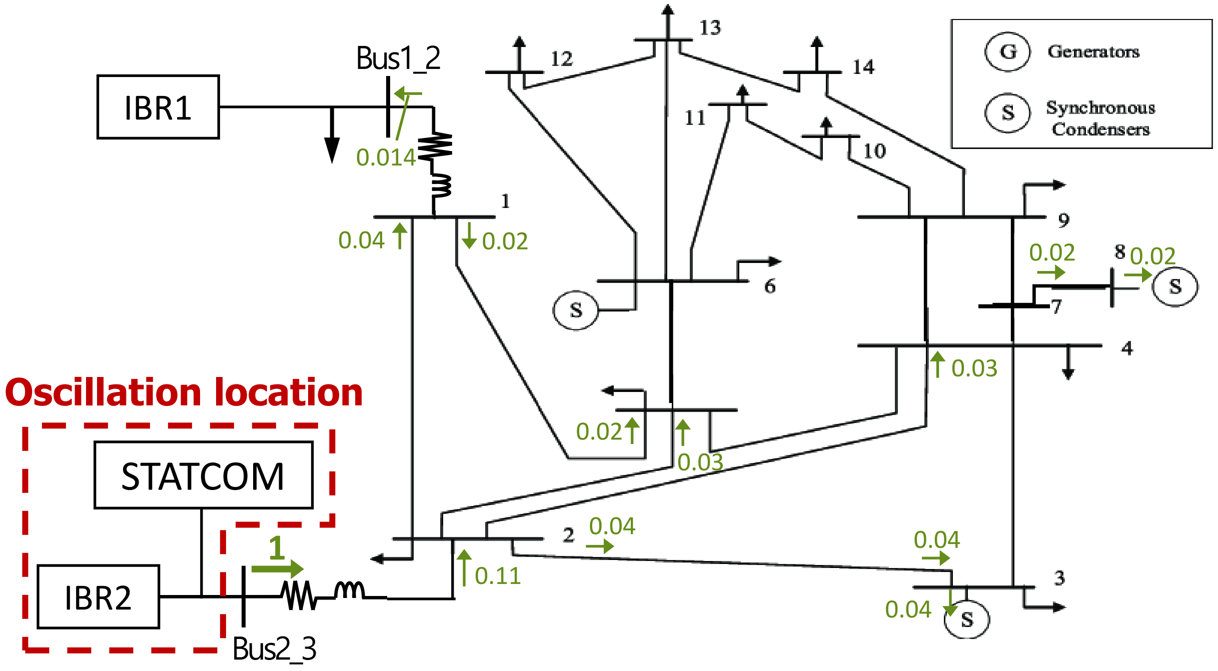
76Hz



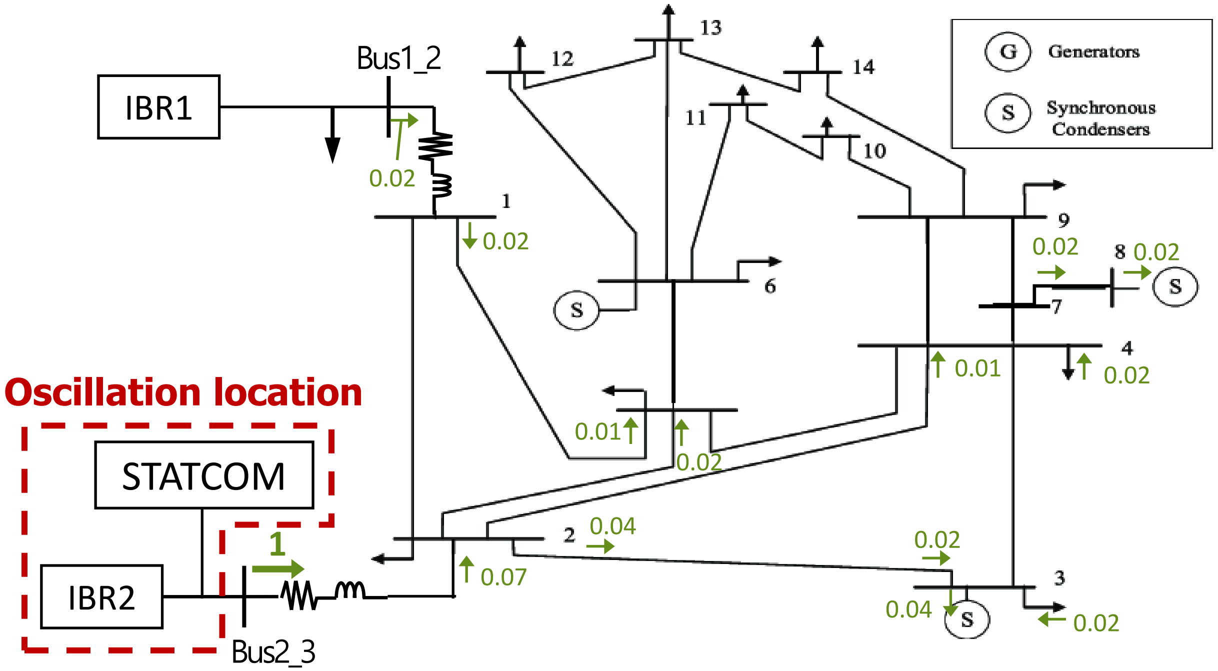
Case study: IBRs with different oscillation modes

- Identifies IBR2 and STATCOM as the source of 24.5 Hz and 95.5 Hz oscillations
- PMU-based DEF method identifies the source correctly within the frequency range that PMUs can capture (< 30 Hz).

24.5Hz



95.5Hz



3. Coordinated WAMS-ADMS Framework

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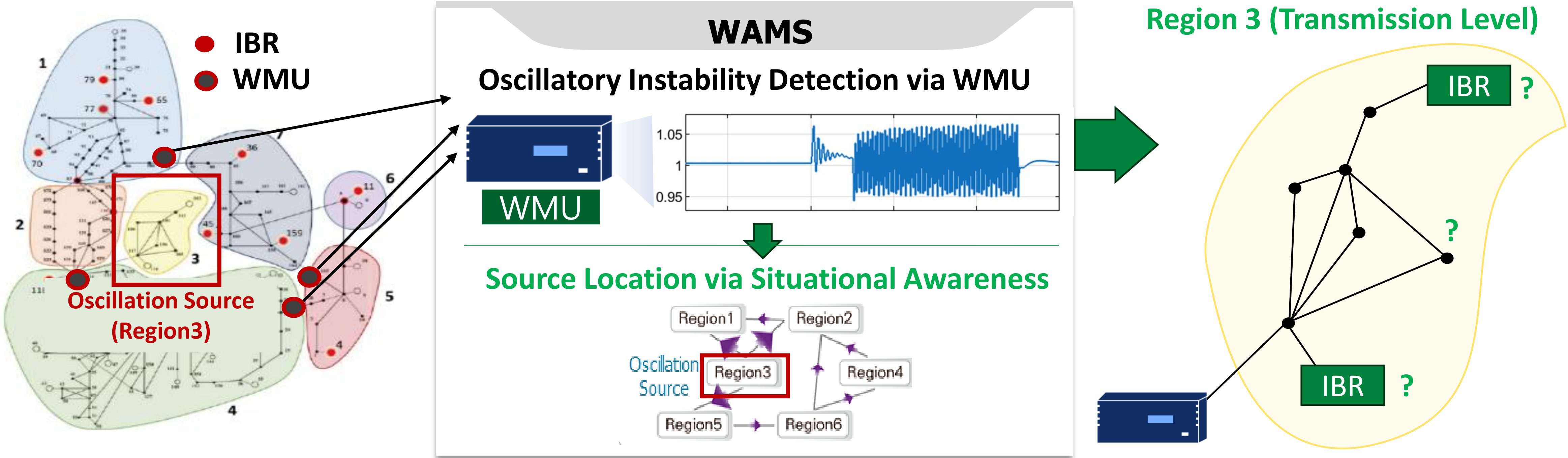
Why Transmission-Level WAMS Alone May Miss the Full Picture

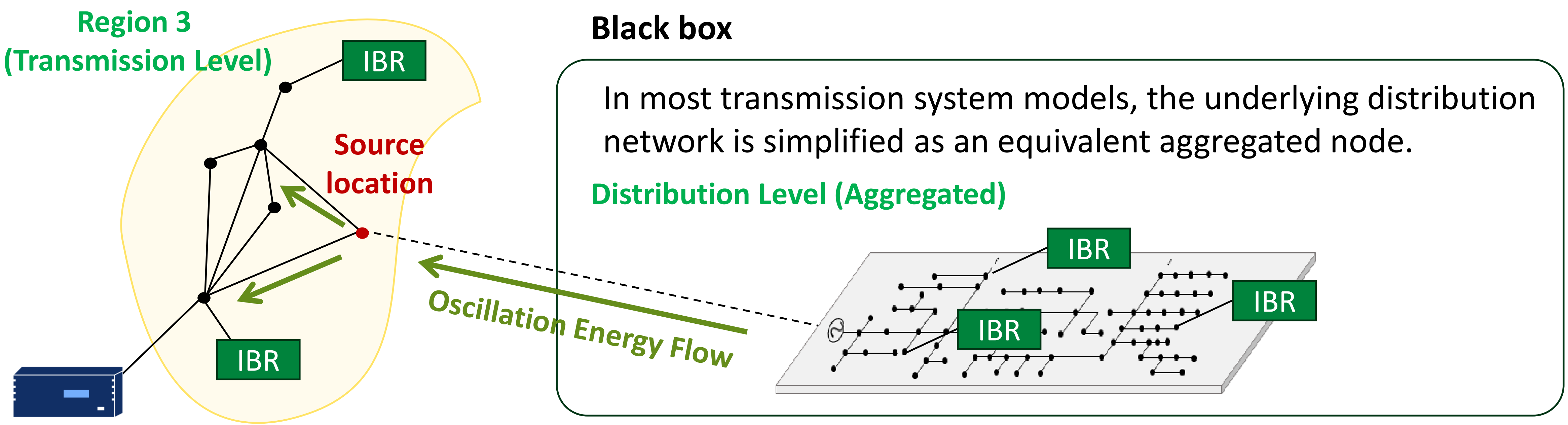
- WMUs are typically installed at transmission-level substations and line terminals, but deployment is often limited to main substations.
- As a result, **WMAS can identify the region of oscillation source** rather than pinpointing the exact node.



3. Coordinated WAMS–ADMS Framework

Why Transmission-Level WAMS Alone May Miss the Full Picture

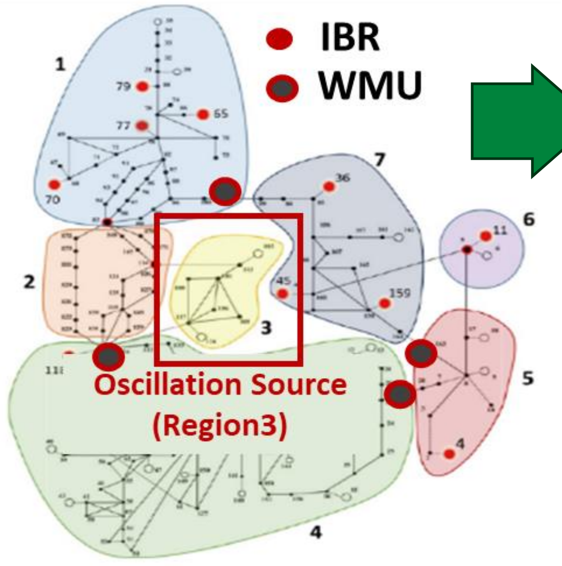
- Oscillation detection at the transmission level may not reveal the true origin if the source lies within an unmodeled distribution substructure.
- As a result, taking effective mitigation actions becomes challenging due to limited visibility and control over the actual source.



3. Coordinated WAMS–ADMS Framework

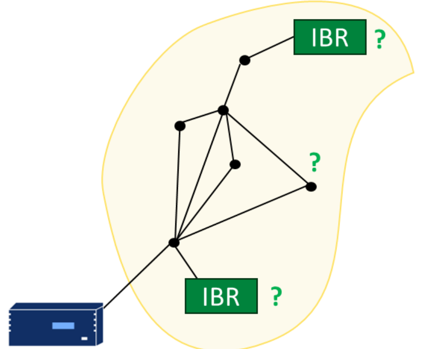
Mutual Enhancement of WAMS and ADMS for Grid Stability

- WAMS detects oscillations at the transmission level and identifies the affected region.
- If the oscillation source is inferred to lie within the distribution networks, WAMS coordinates with ADMS to trigger targeted mitigation action.



WAMS

Oscillation Detection/ Source Identification

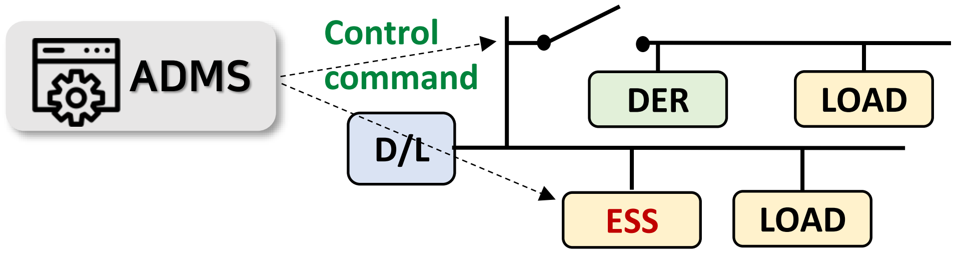


Trigger signal for mitigation

ADMS

- **Triggers targeted mitigation actions (RES/ESS power modulation or Switching)**

➔ **Executes mitigation actions**



3. Coordinated WAMS–ADMS Framework

Mutual Enhancement of WAMS and ADMS for Grid Stability

- Furthermore, ADMS enhances WAMS by supplying real-time topology, switching actions, and DER/ESS control data, enabling more accurate stability monitoring and validation of system stability.

Key Functions of ADMS for WAMS

- Real-time distribution network topology updates
- Switching operation and restoration actions (Control log)
- DER/ESS operational states

WAMS

'More Precise State Estimation'

'Improved Power System Monitoring'

'Enhanced Post-Event Playback Analysis'

4. Conclusion

5. Conclusion

Challenges Facing Modern Power Systems

- The growing integration of IBRs is driving an urgent need for advanced stability monitoring and enhanced stability measures, particularly in distribution networks as well as in transmission systems.

- WAMS, including WMUs at the transmission system, and ADMS at the distribution system can coordinate to improve overall system stability, including oscillation suppression.

- WAMS detects system instabilities and identifies their sources, enabling ADMS to collaborate in targeted actions that mitigate instability and support grid resilience.