# How can a PMU WAM system support a TSO in grid operations and planning?

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For power system expertise

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   - In operations
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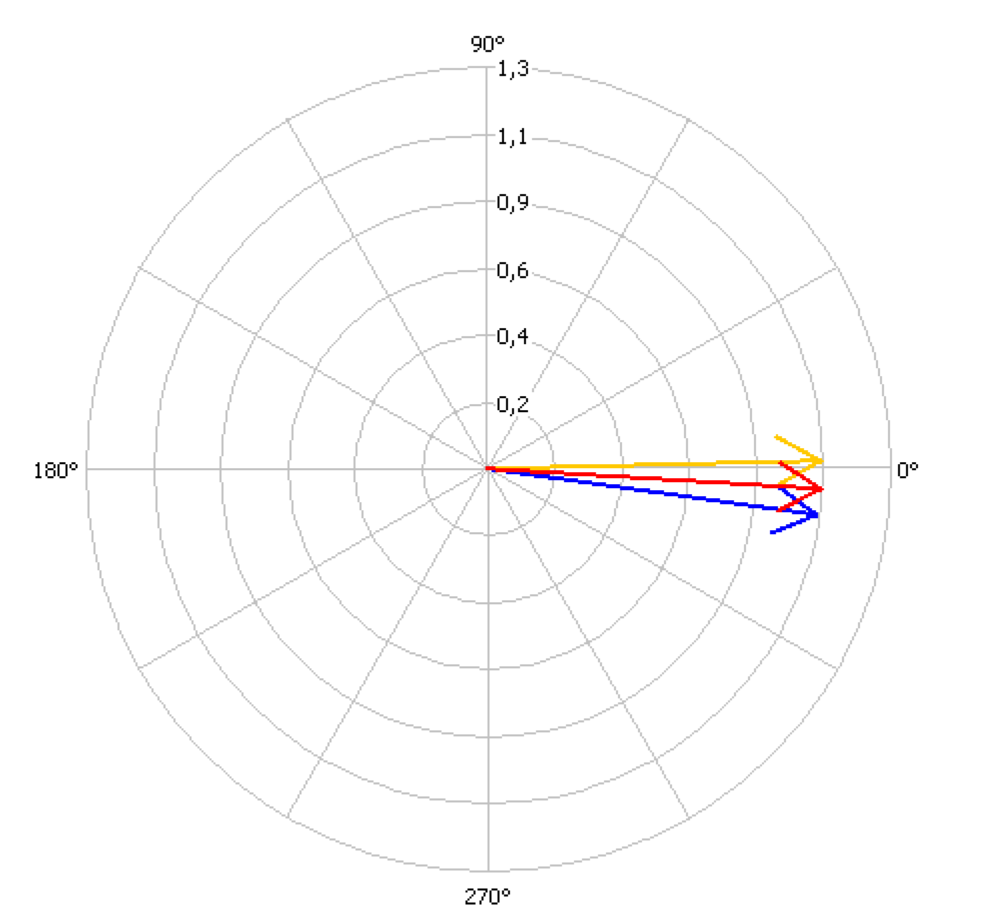
# Theoretical background – PMU

- PMU - Phasor Measurement Unit
- Time synchronised via GPS clock (or PTP)
- Measures:
  - Voltage (and angle)
  - Current (and angle)
  - Frequency
  - Rate-of-change of Frequency (RoCoF)
- In general connected to M-class CT

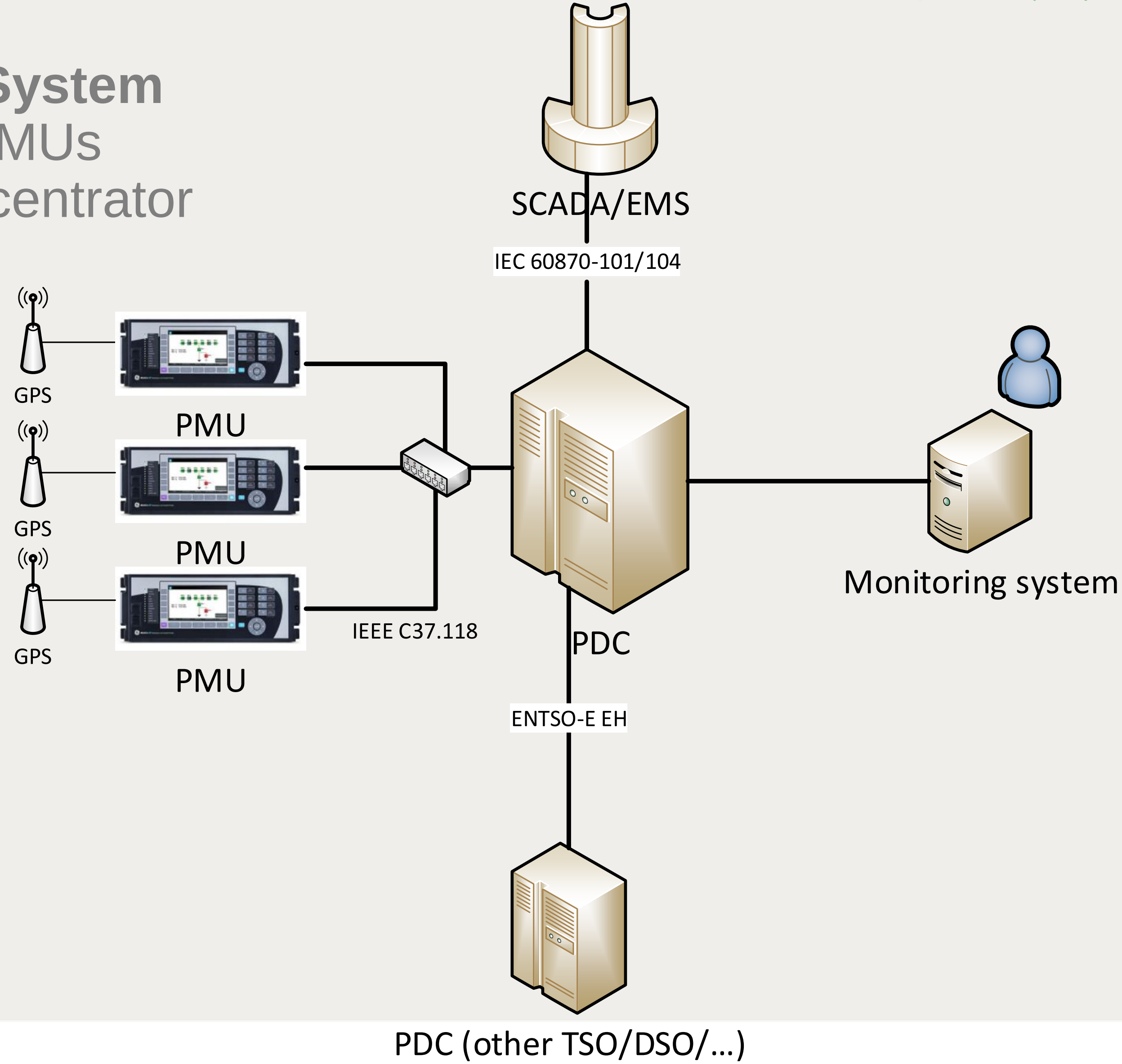


# PMU vs. SCADA measurement

| Attribute | SCADA/EMS | PMU |
|---|---|---|
| **resolution** | 1 sample every 2 - 10 s | 10 - **250** samples/s |
| **observability** | quasi-static, typically up to 0.125 Hz (every 4 sec.) | limited dynamic, typically up to **15 Hz** (50 fps) |
| **measurements** | V & I (RMS magnitude), frequency, analogue values, Boolean status | V & I (RMS magnitude and **relative angle**), frequency, **RoCoF**, analogue values, Boolean status |
| **time synchronisation** | no | **yes** |
| **measurement timestamp** | at substation's RTU or central MTU | at the **source** |
| **relative phase angle** | no | **yes** |

# Theoretical background – WAMS

- **WAMS – Wide Area Monitoring System**
  Multiple (geographically spread) PMUs connected via a Phasor Data Concentrator (PDC)



# Theoretical background - Location of PMUs

- For angle dynamics/ power oscillations:
  - At each or near (inside the influencing area) relevant power plants. Monitoring stress of a line corridor
- For frequency:
  - Close to the power plant with the largest inertia
  - Near heavily loaded tie-lines (e.g. tie-lines presenting higher sensitivity to generation variation)
- For voltage stability:
  - Near critical load areas (busbar with lower loadability margin)
  - Near generation (if reaching reactive injection or absorption limit)
  - Nodes equipped with FACTS (e.g. SVCs)

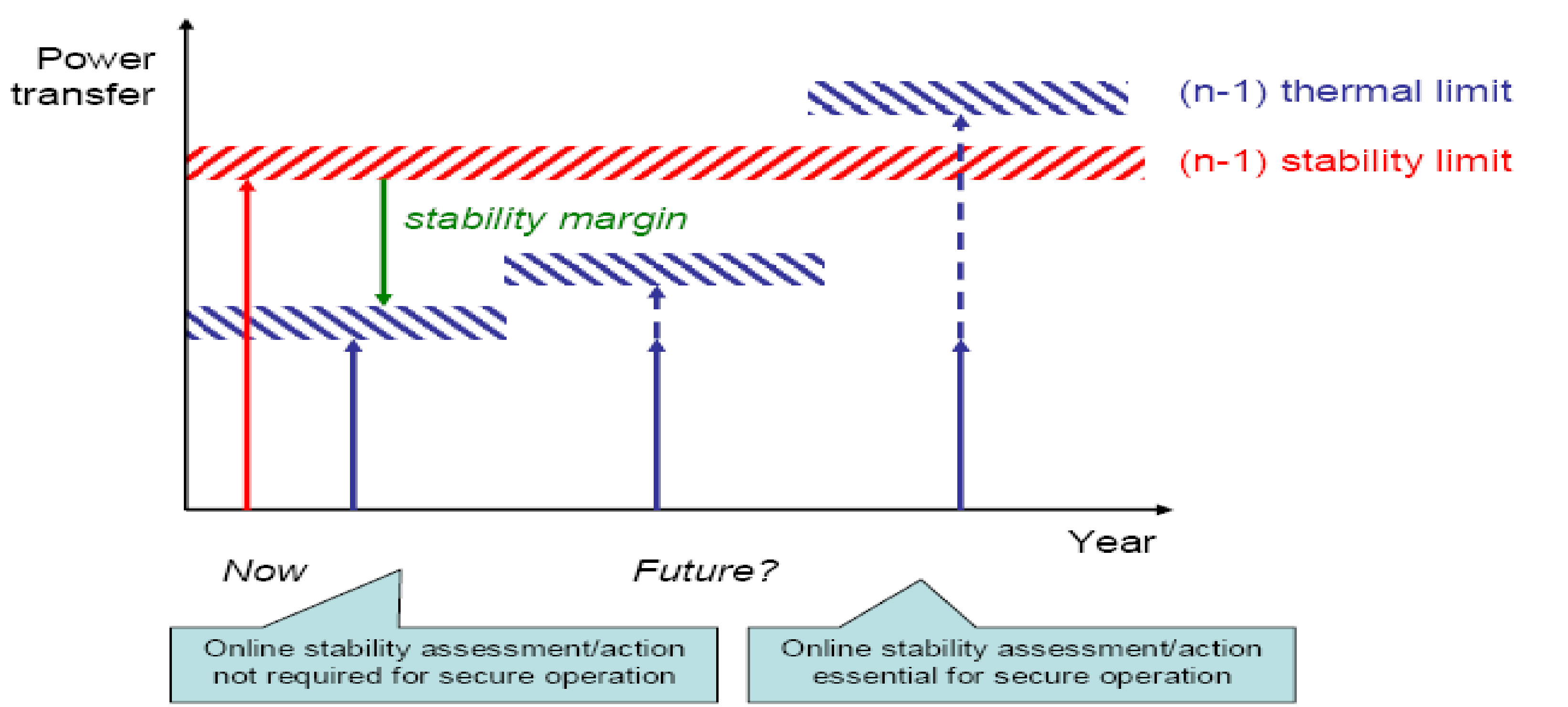
# WAMS - example


| | |
|---|---|
| Frequency set point | 50 Hz |
| Current Frequency | 50.029 Hz |
| Current Frequency Deviation | 0.029 Hz |
| Current grid time deviation | 11.262 s |

https://www.swissgrid.ch/en/home/operation/grid-data/current-data.html#wide-area-monitoring

# PMU/WAMS applications in System Operations

- Complement SCADA measurements and Improve State Estimator accuracy
- Online dynamic security assessment
  - Evaluate system stability and margin
  - Islanding detection (frequency, phase)
- Capacity management
  - Monitor corridor loa
  - Dynamic line rating
- Disturbance support
  - Support re-synchror
  - Post-mortem disturb
- Evaluate system streng
  - Online short-circuit
  - Online inertia measu

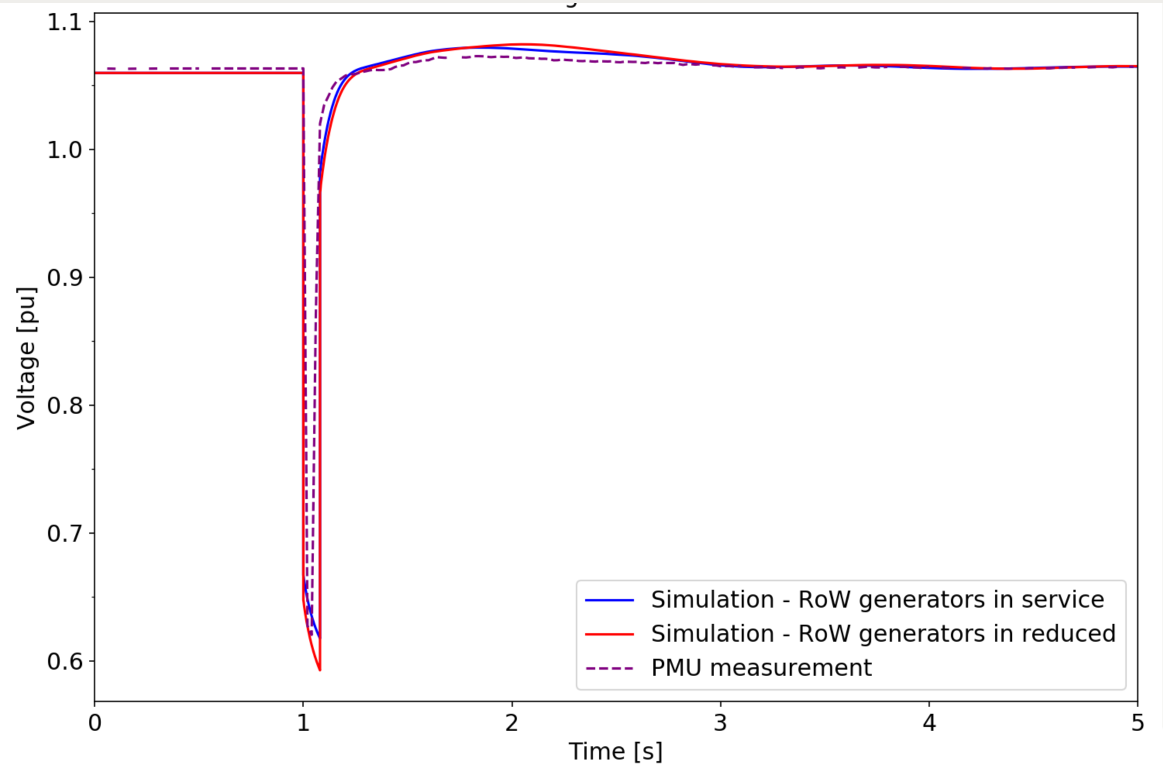


# PMU/WAMS applications in System Planning

- Modelling and controllers:
  - Validation and calibration of dynamic models
  - Compliance monitoring of generators
  - Validation short circuit-calculation
  - Validation inertia calculation
- Mitigation of oscillations:
  - Perform statistic analysis on the recorded oscillating modes
  - Identification of sources of damping and low frequency oscillation modes
  - Perform statistic analysis on the recorded oscillating modes
  - Tune PSS controllers in generation units
- Other applications:
  - Asymmetry analysis
  - …

# Example - Dynamic model validation

- Short-circuit in Belgium near NL border
- Resulted in 3 phase voltage dip in 380 kV-Borssele, measured by PMU
- Repeated in simulation
- Results (i.e. voltage rise-time and post-fault voltage) match quite well



# POLL – PMU/WAMS

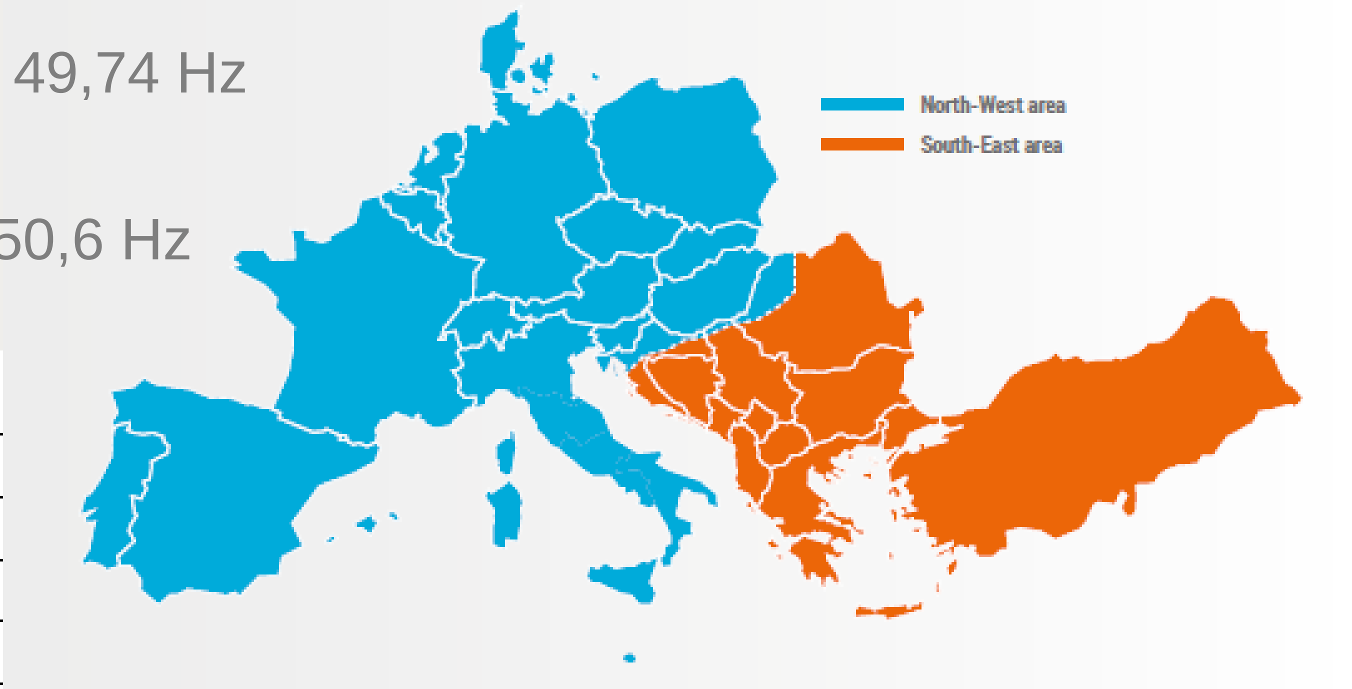
Image from ENTSO-E

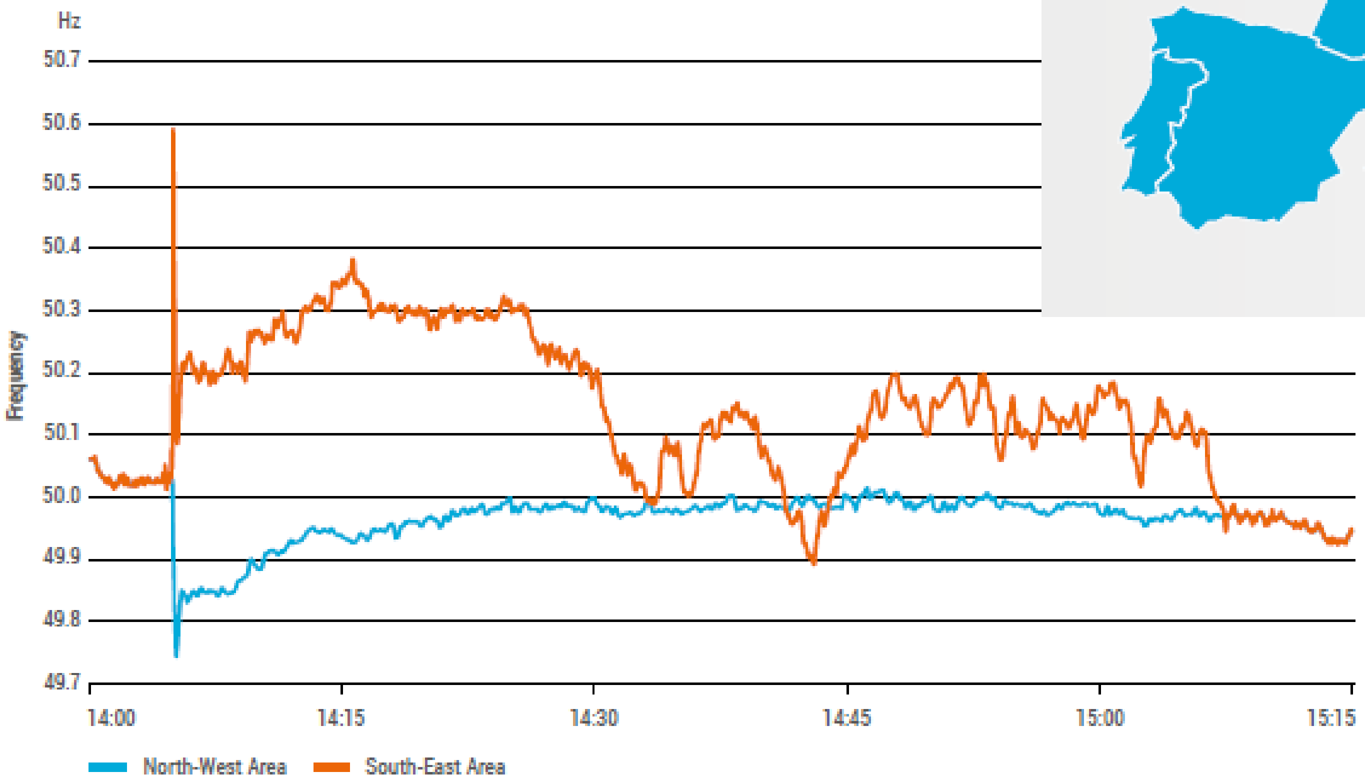
# System Split - 8 January 2021

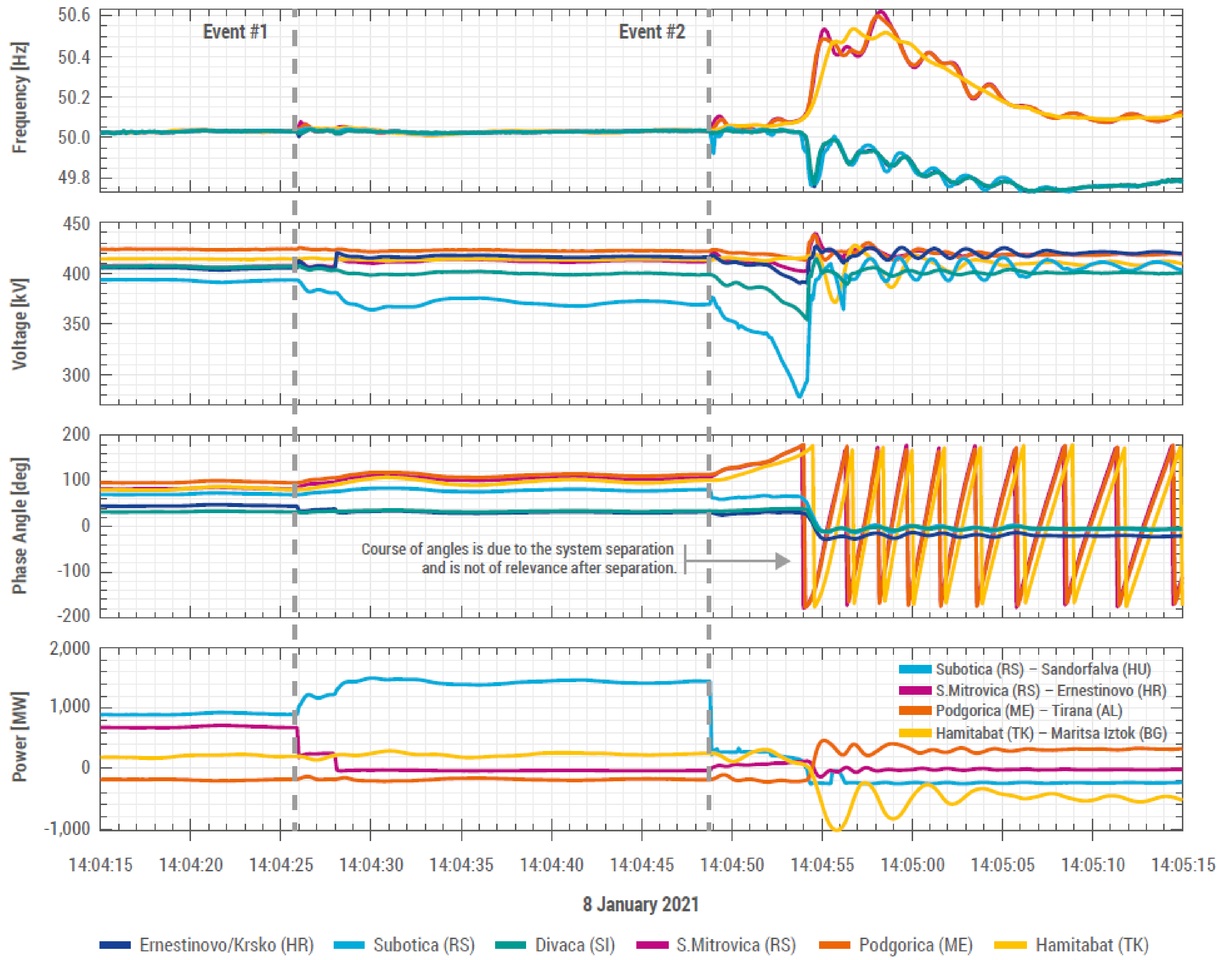
- Ernestinovo 380 kV substation (Croatia) busbar coupler failure
- Overload protections tripped within 43 seconds
  - First connection in Serbia tripped after 23 seconds
- South of Croatia, Serbia, Romania separated
- Power deficit/surplus: 6,3 GW

# System Split - 8 January 2021 (2)

- North-west area frequency drop to 49,74 Hz
  - RoCoF: 60 mHz/sec
- South-east area frequency rise to 50,6 Hz
  - RoCoF: 300 mHz/sec






Source: ENTSO-E Continental Europe Synchronous Area Separation on 8 January 2021 (Interim Report)

# Conclusion

**PMUs and WAMS**

**Unmissable tools for TSOs to prevent blackouts in the changing energy landscape**

# Thank you for your attention!

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