6.11.2024

Lasse Linnamaa

Subsynchronous oscillations in Finnish power system

Energiforsk seminar on vibrations in nuclear applications

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Agenda

- About subsynchronous oscillations in power systems
- Phenomena seen in Finnish grid – examples of observations
  - Interarea oscillations
  - Converter driven oscillations
  - SSR event

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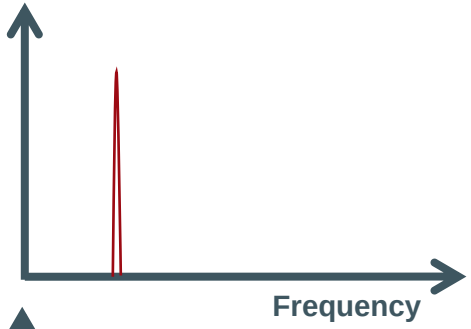
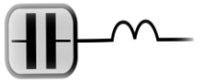
SSO Background

Torsional Modes

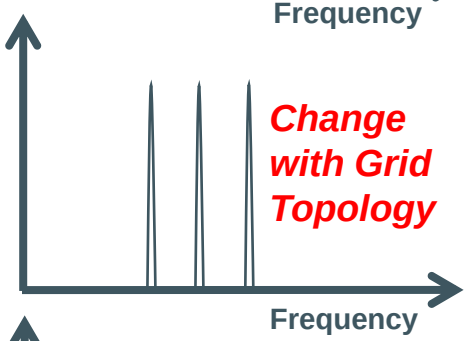
Generator Shaft



RLC Modes

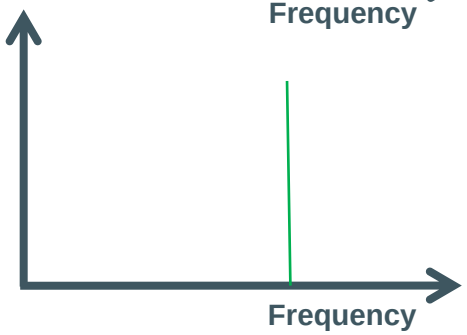


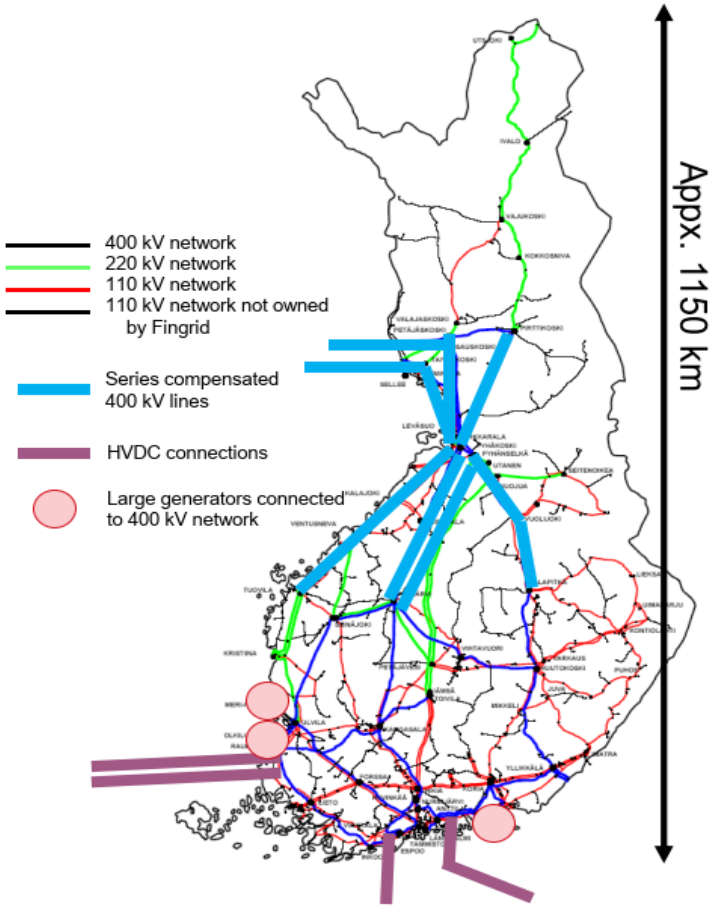
Network RLC Circuit



Control Modes

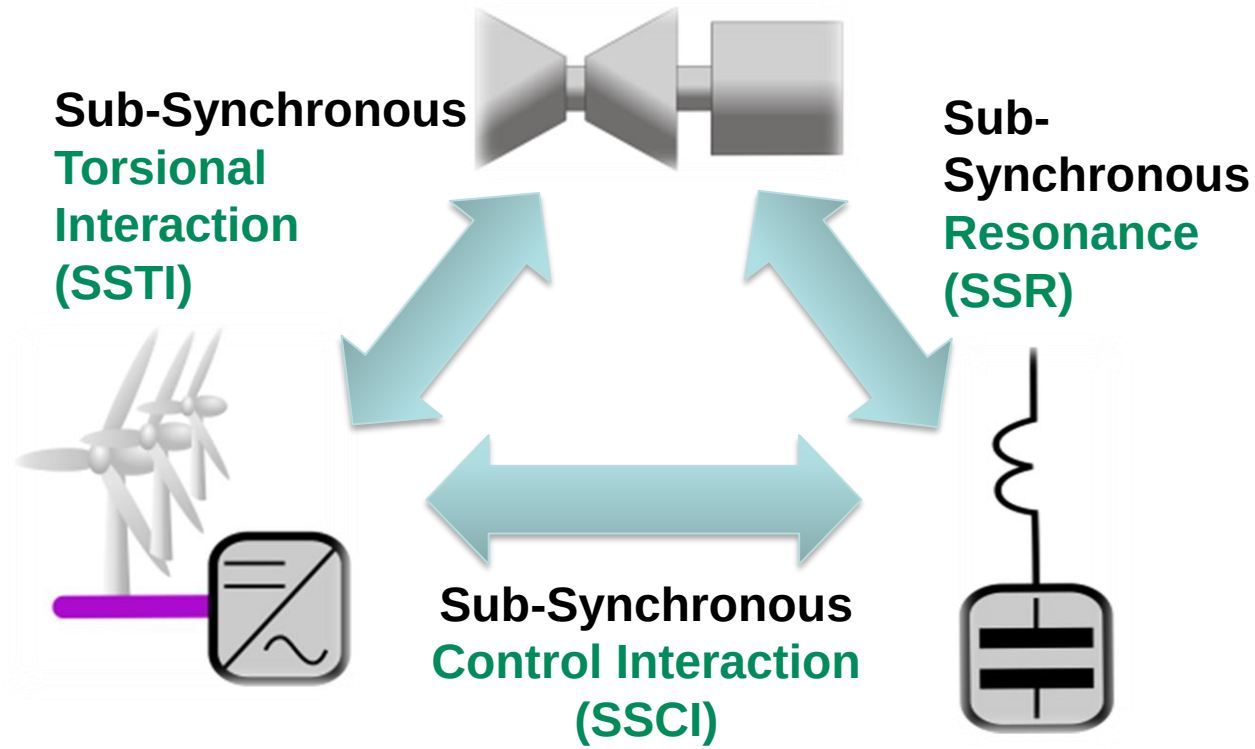
Power Electronic Converters

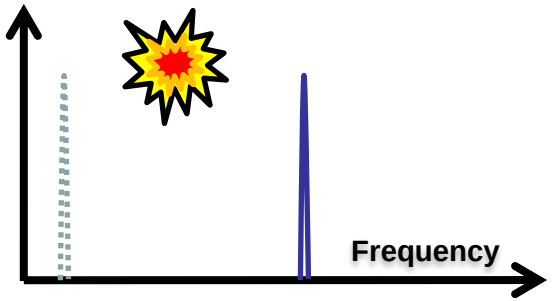




SSO Background – SSO Interaction

When oscillatory modes interact…



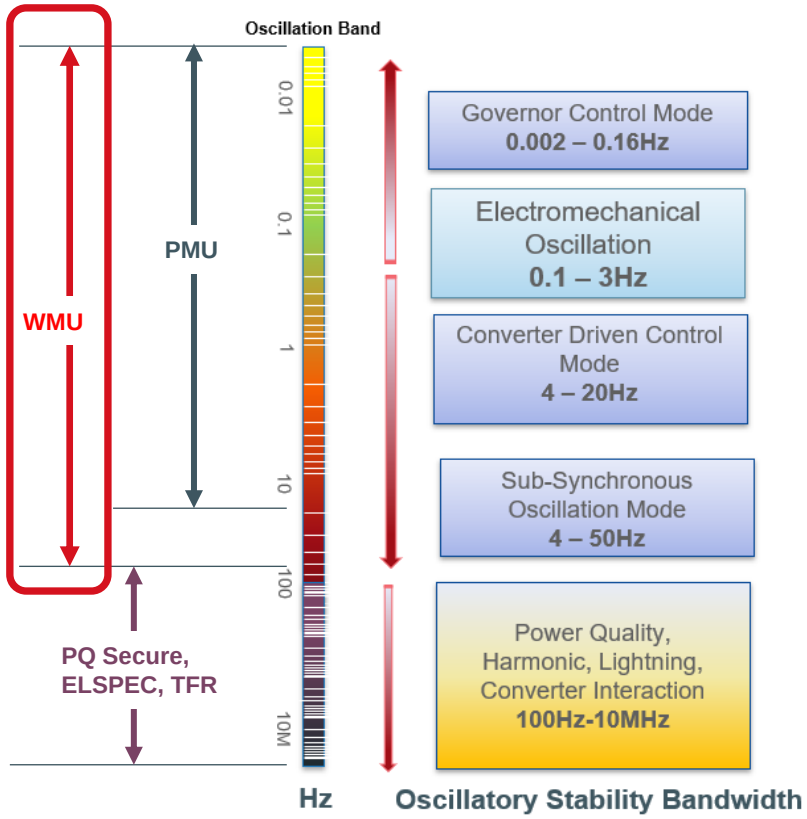


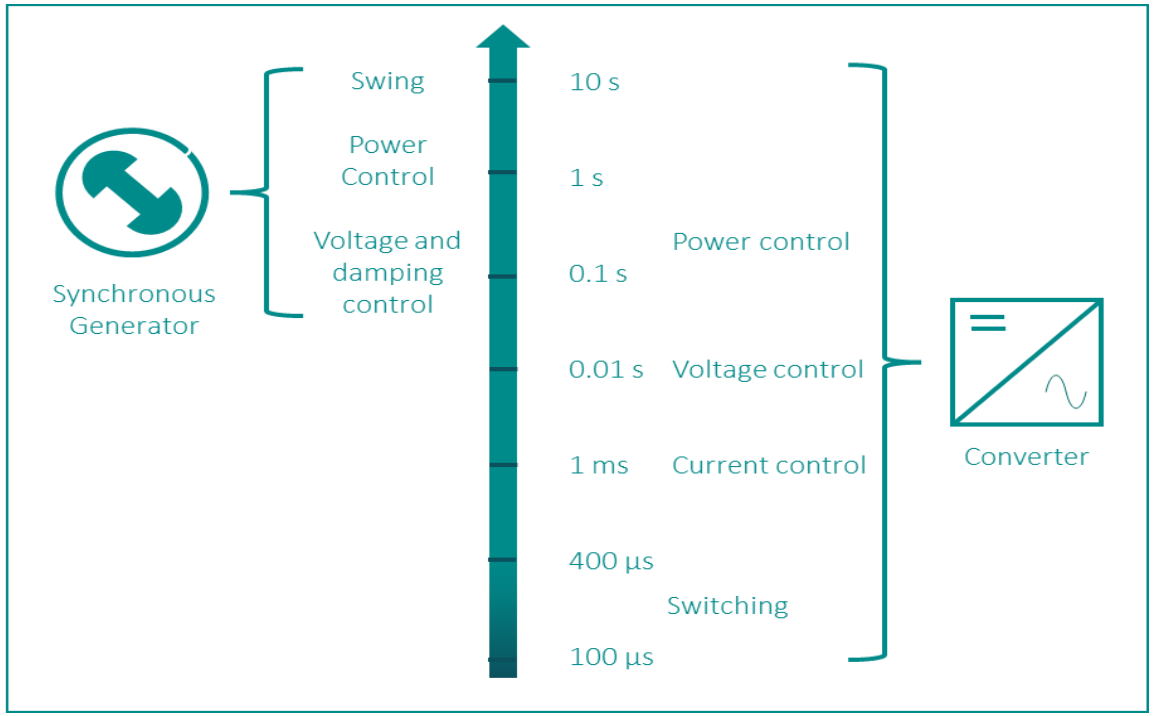
- **Plant wear & stress**
- **Network disruption**
- **Generator damage**

Bruce English, "Reactive Power Solutions, Subsynchronous Oscillations (SSO): Risk Analysis, Protection, and Mitigation Techniques", GE Digital Energy. Available: http://www.slideshare.net/GEEnergyConsulting/v5-ssr-ssciwebinar

Hole burnt in shaft after SSR event:
Mojave desert, USA 1970

Oscillation phenomena





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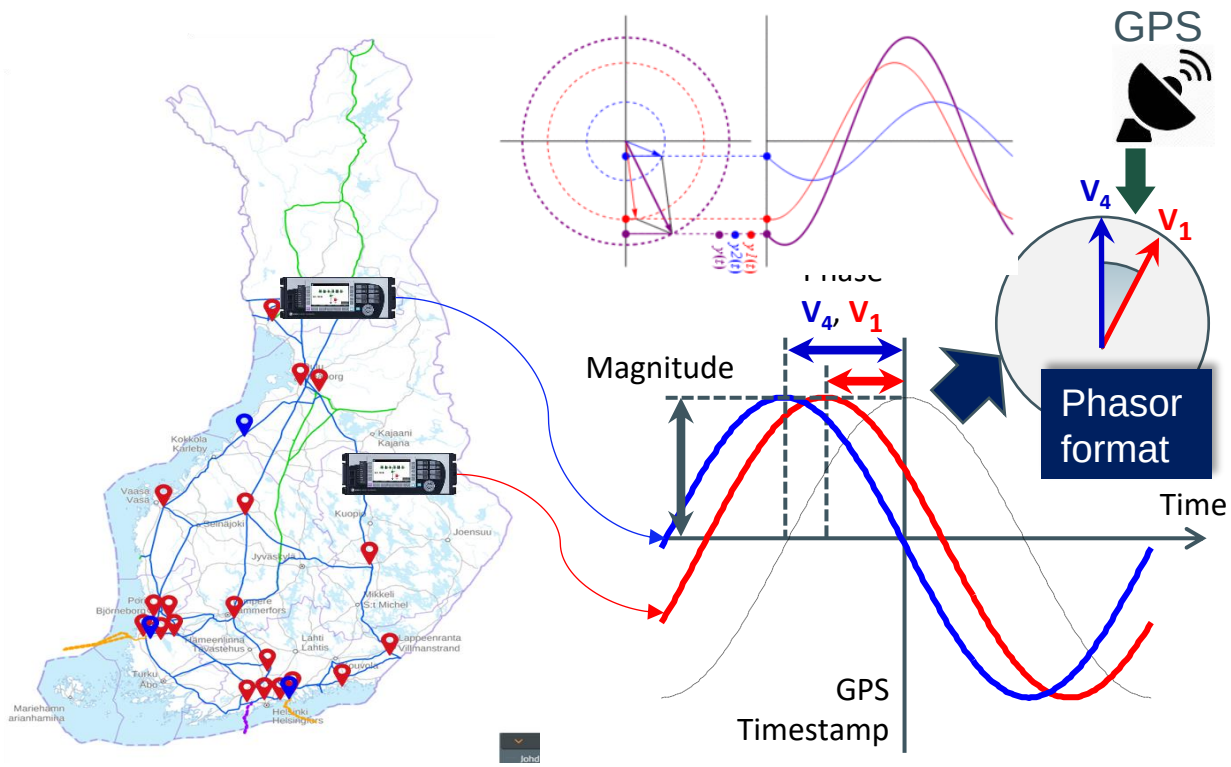
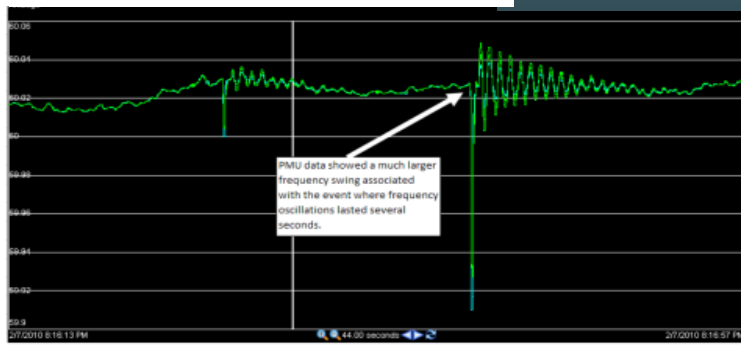
Synchrophasor basics



Data streaming over IP network

PMU data (60 Samples per second) showed a much larger frequency swing

WAMS



Angle Change means: Sudden MW Change in a **SPECIFIC** location of the grid.

SCADA

SCADA data (1 sample every 1-2 seconds) showed a small change in the system frequency

Frequency Change means : Sudden Gen-Load MW imbalance **SOMEWHERE** in the grid

PMUs acquire V & I waveforms and convert to phasor format at per-cycle resolution. Data is streamed from all measured locations to monitoring applications & controlling locations.

- High resolution showing **system dynamics**
- **Accurate timing** for real-time and post-event disturbance capture
- Summary measure of **system stress** for various stability issues

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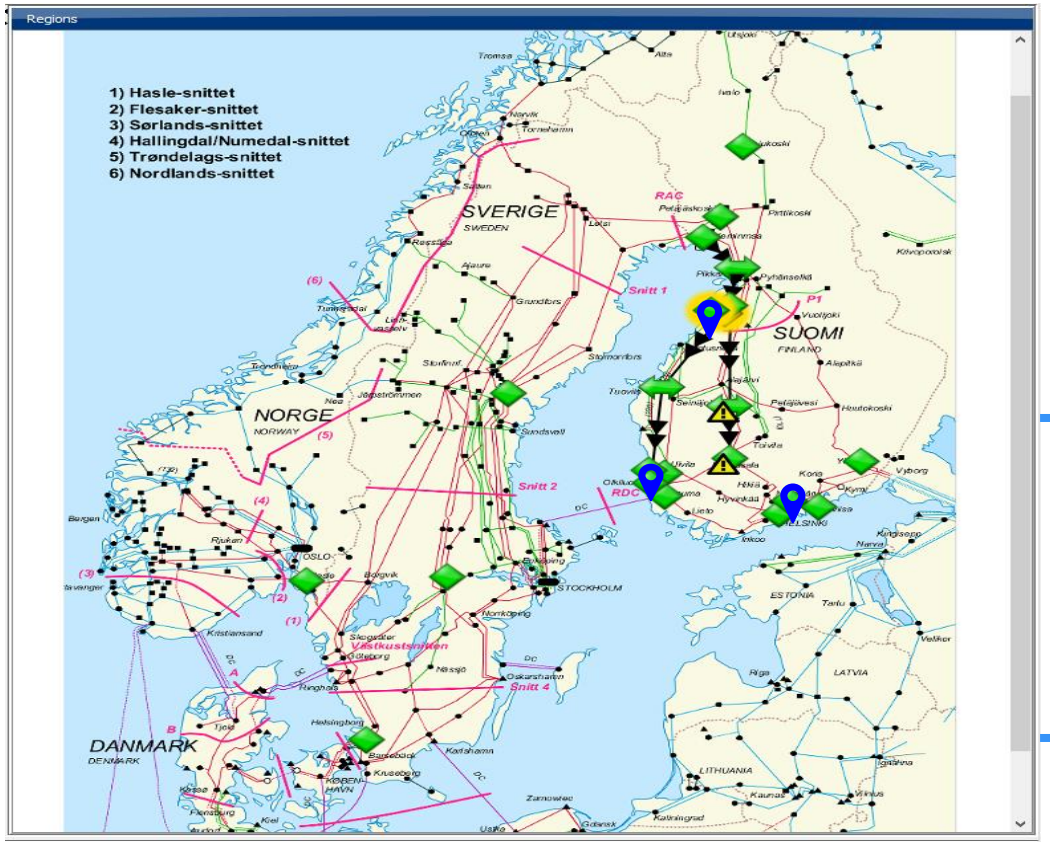
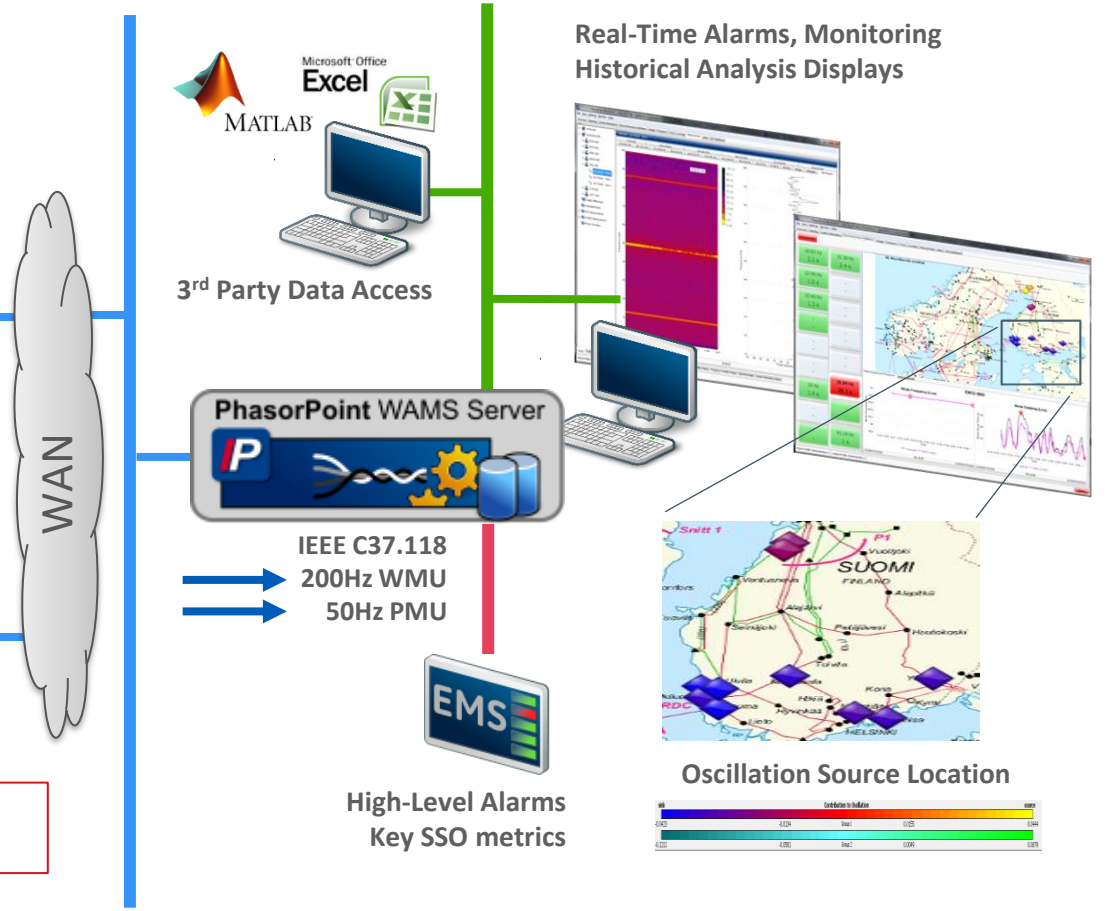
WAMS – Wide Area Measurement System



- 30+ PMUs (Phasor Measurement Unit) → to be extended!
- 3+ WMUs (Waveform Measurement Unit) → to be extended!

WMU Locations

Analysis, Alarming, Visualisation & Historian
e-terraphasorpoint



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Observations from Finnish grid

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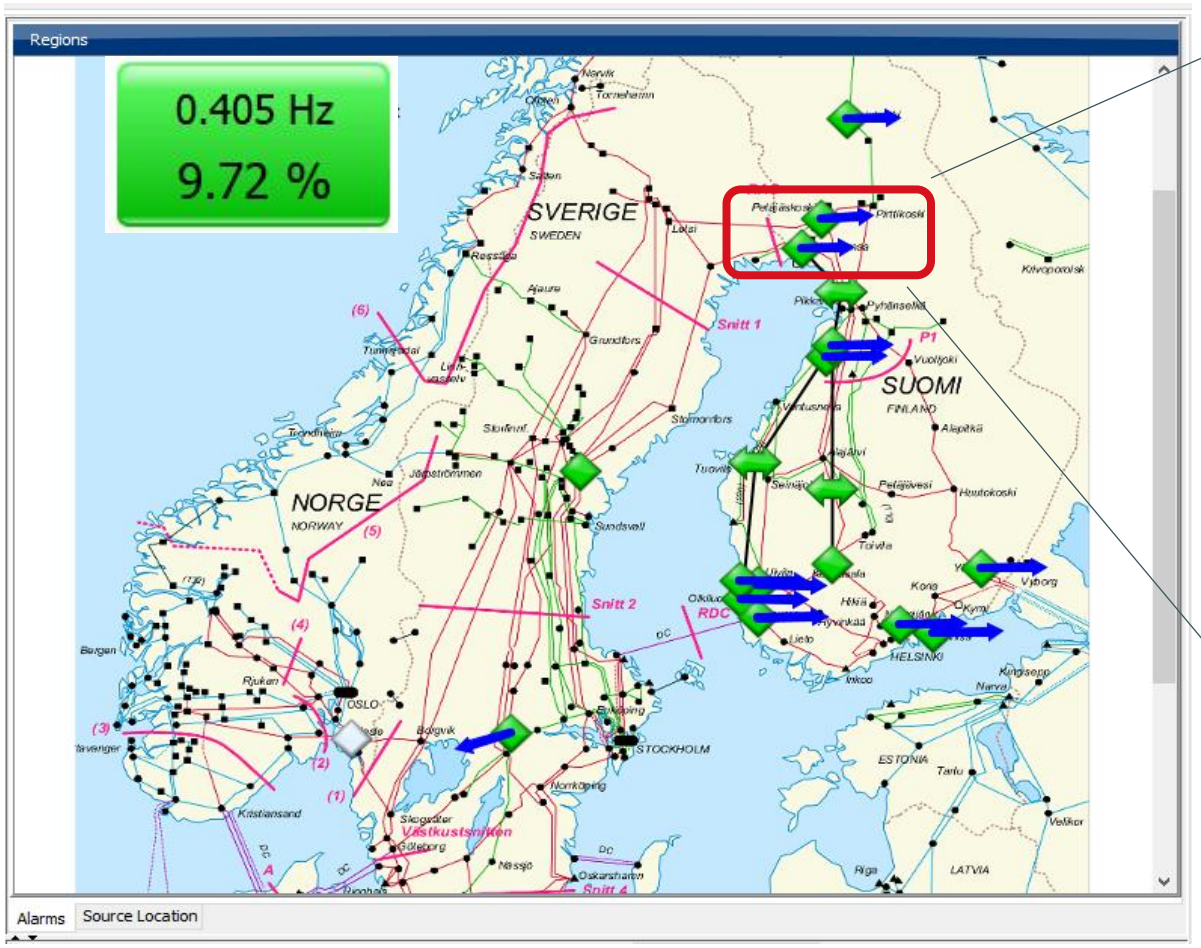
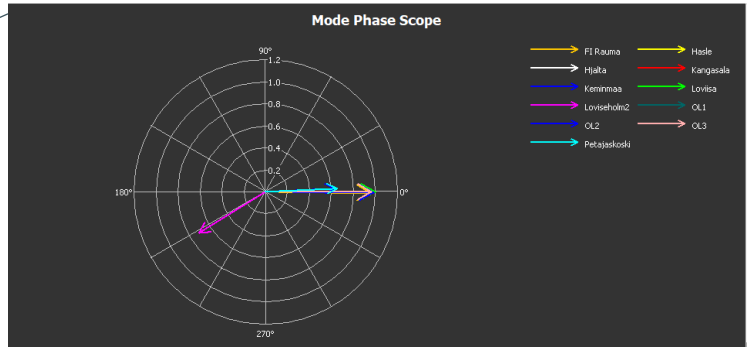
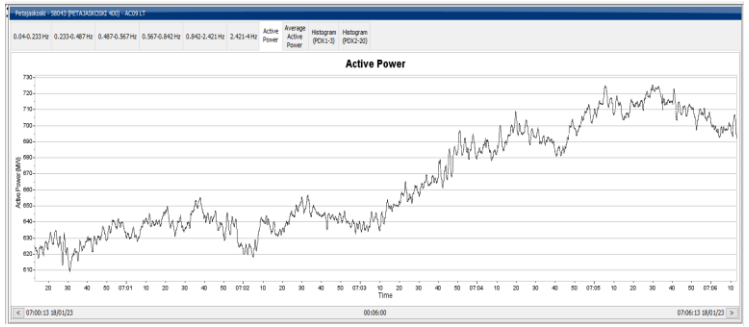
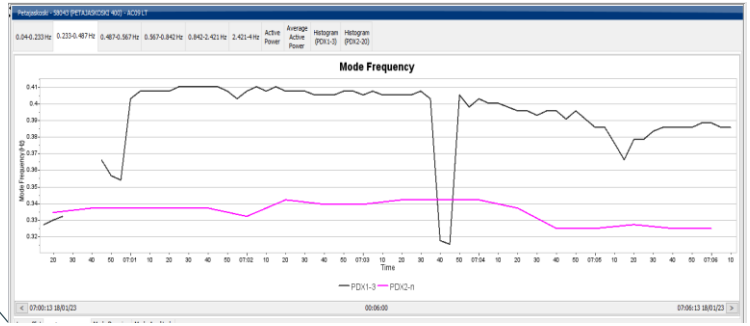
Electromechanical Oscillation – Dominant Inter-Area Mode 0.3-0.4 Hz

GE Phasorpoint:



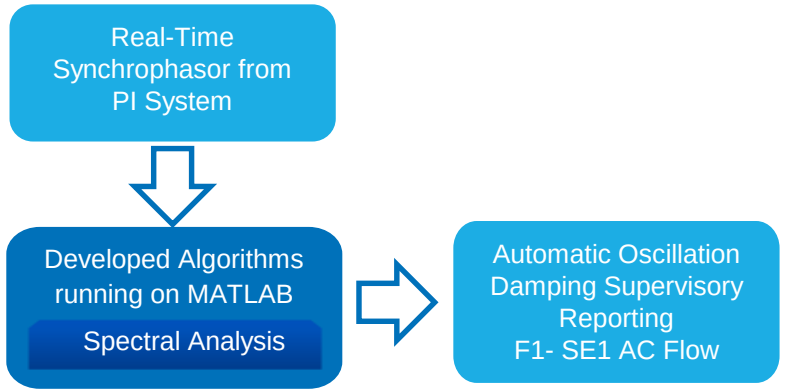




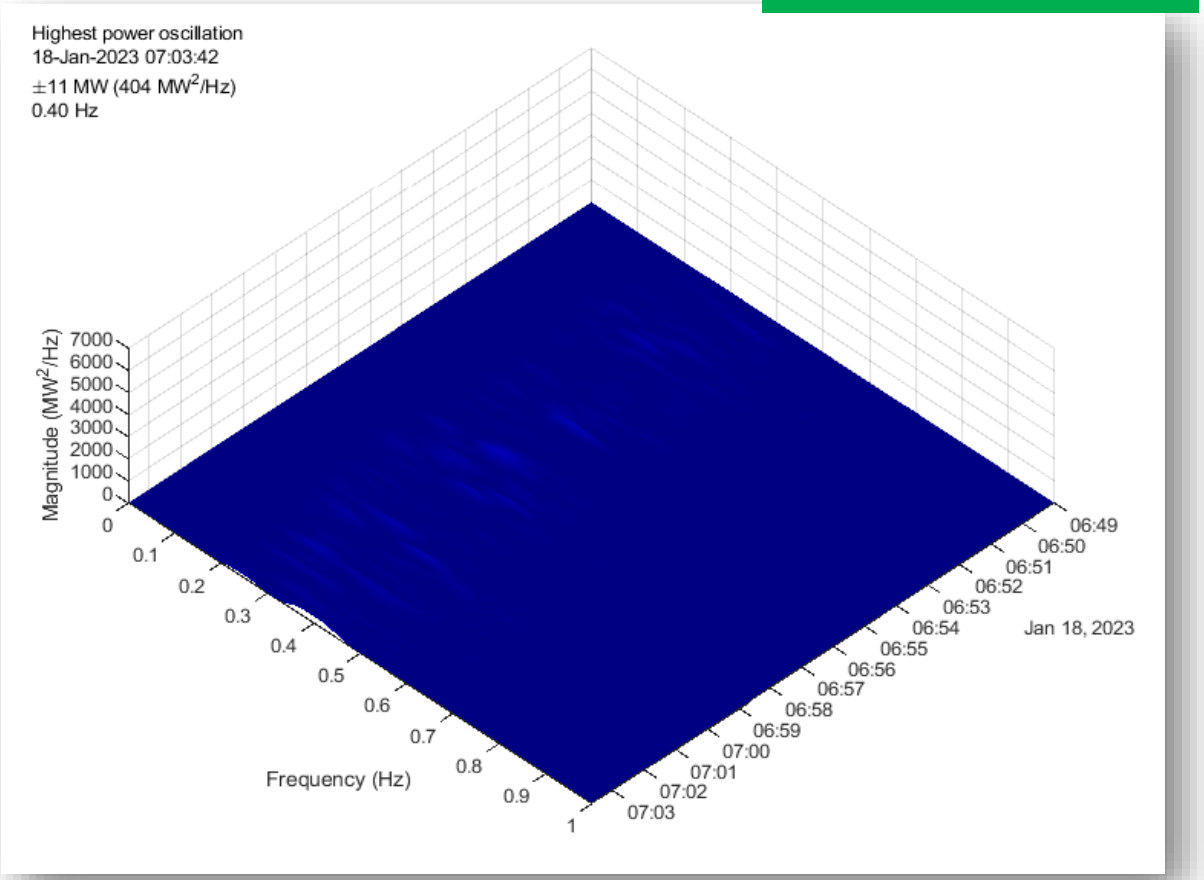


Electromechanical Oscillation – Dominant Inter-Area Mode 0.3-0.4 Hz

Fingrid Real-Time Oscillation Supervisory:

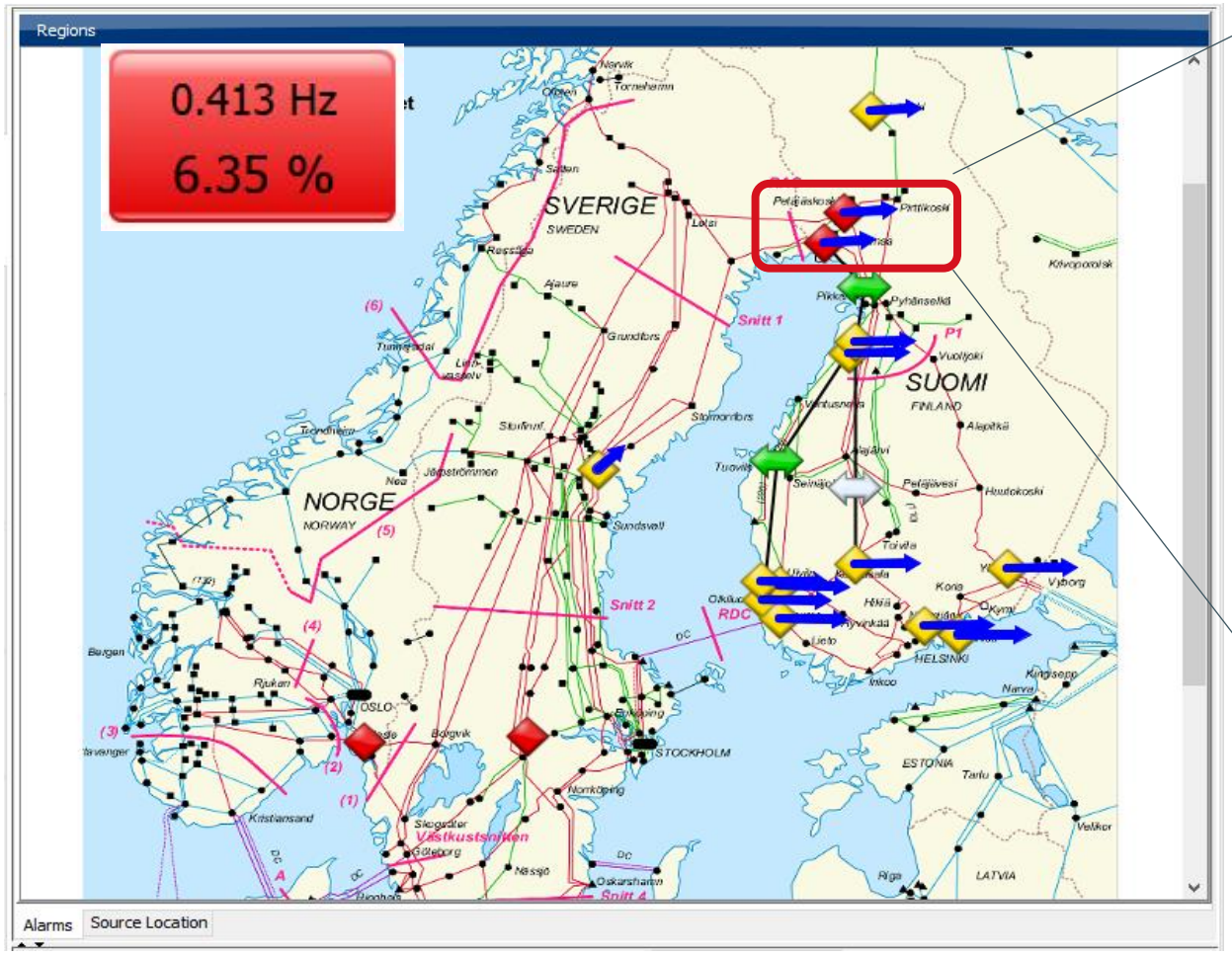


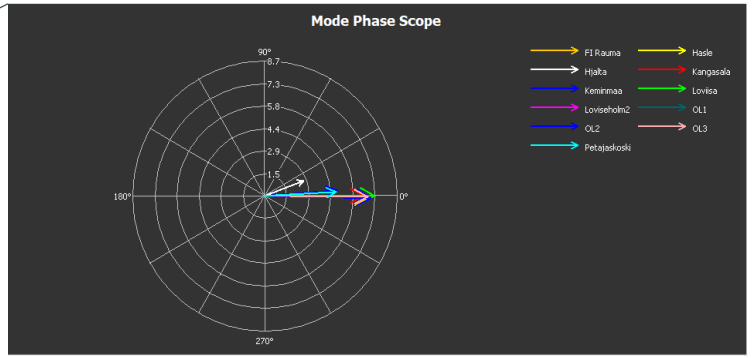
Normal Situation

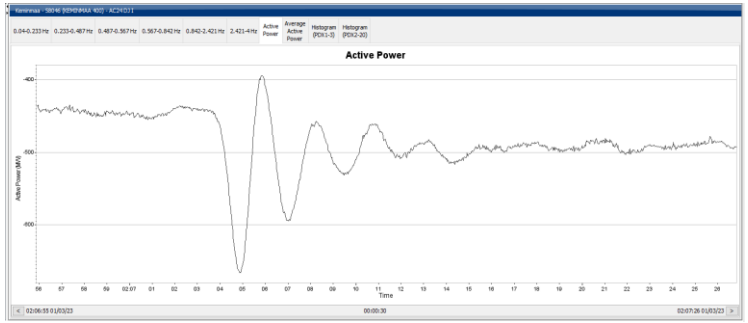


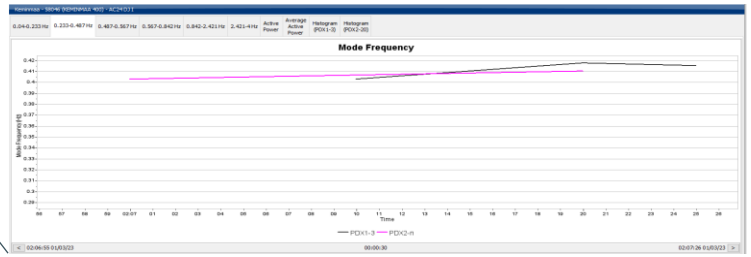
Electromechanical Oscillation – Dominant Inter-Area Mode 0.3-0.4 Hz

GE Phasorpoint:



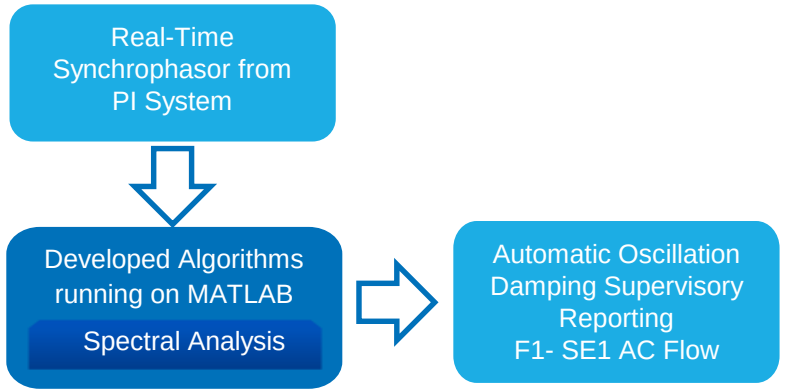




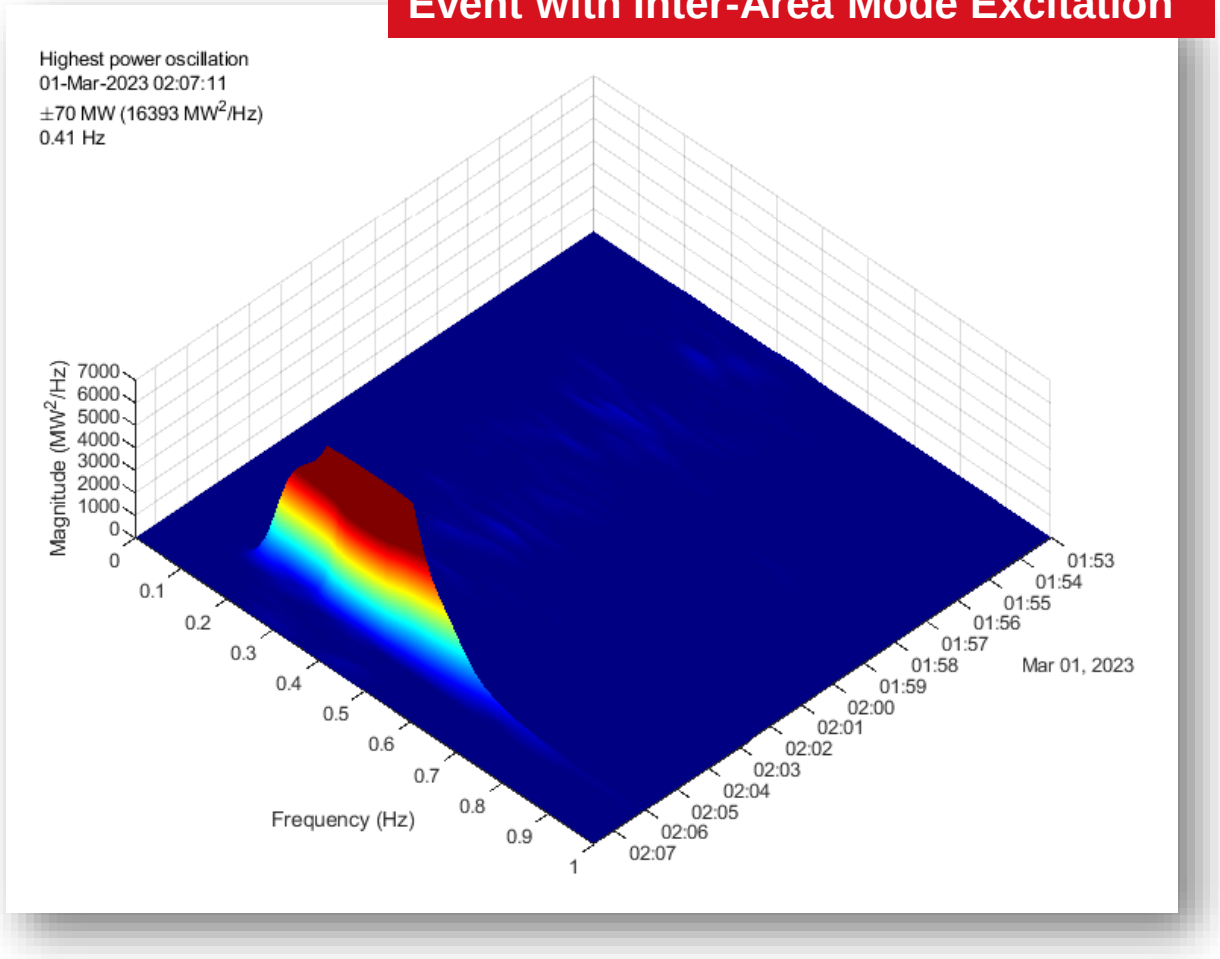


Electromechanical Oscillation – Dominant Inter-Area Mode 0.3-0.4 Hz

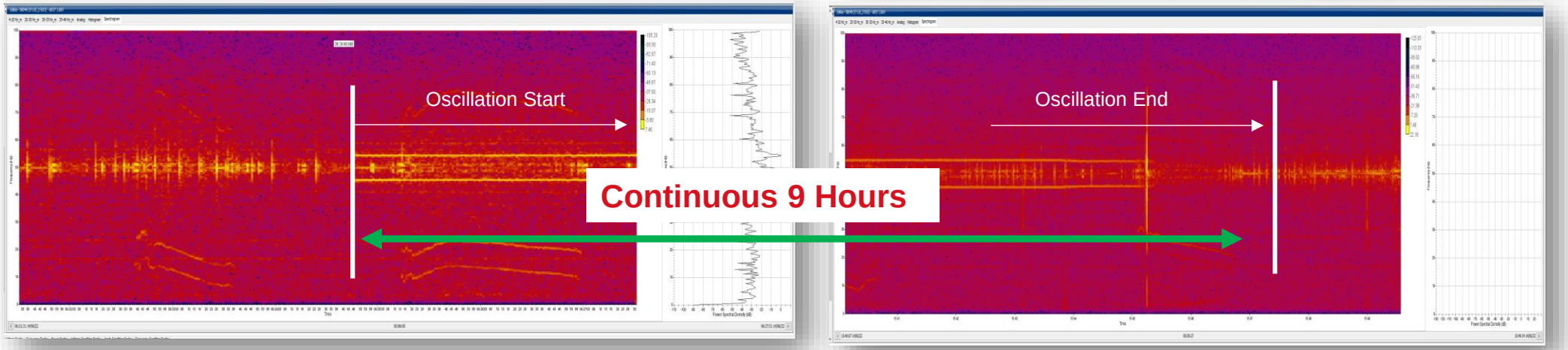
Fingrid Real-Time Oscillation Supervisory:



Event with Inter-Area Mode Excitation



Type-4 Full Converter Wind Turbine Driven Control Mode – 5-6 Hz (SSCI)



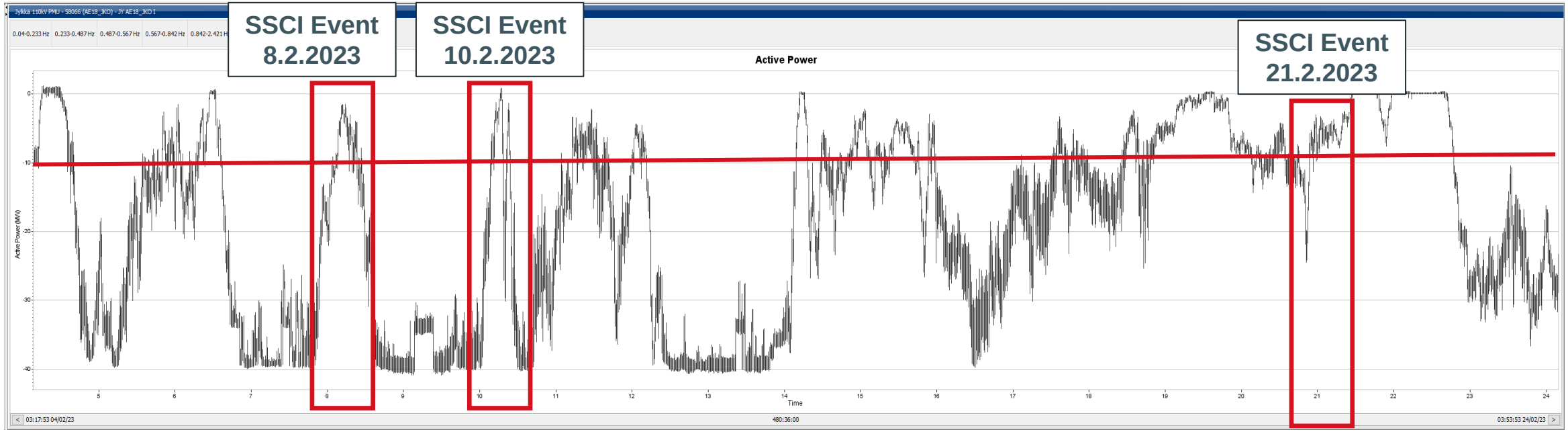
110kV WMU Measurement

Observation :

- 5Hz mode detected on 110kV WMU Measurement
- Probable cause: Common mode interaction of wind farms voltage controllers

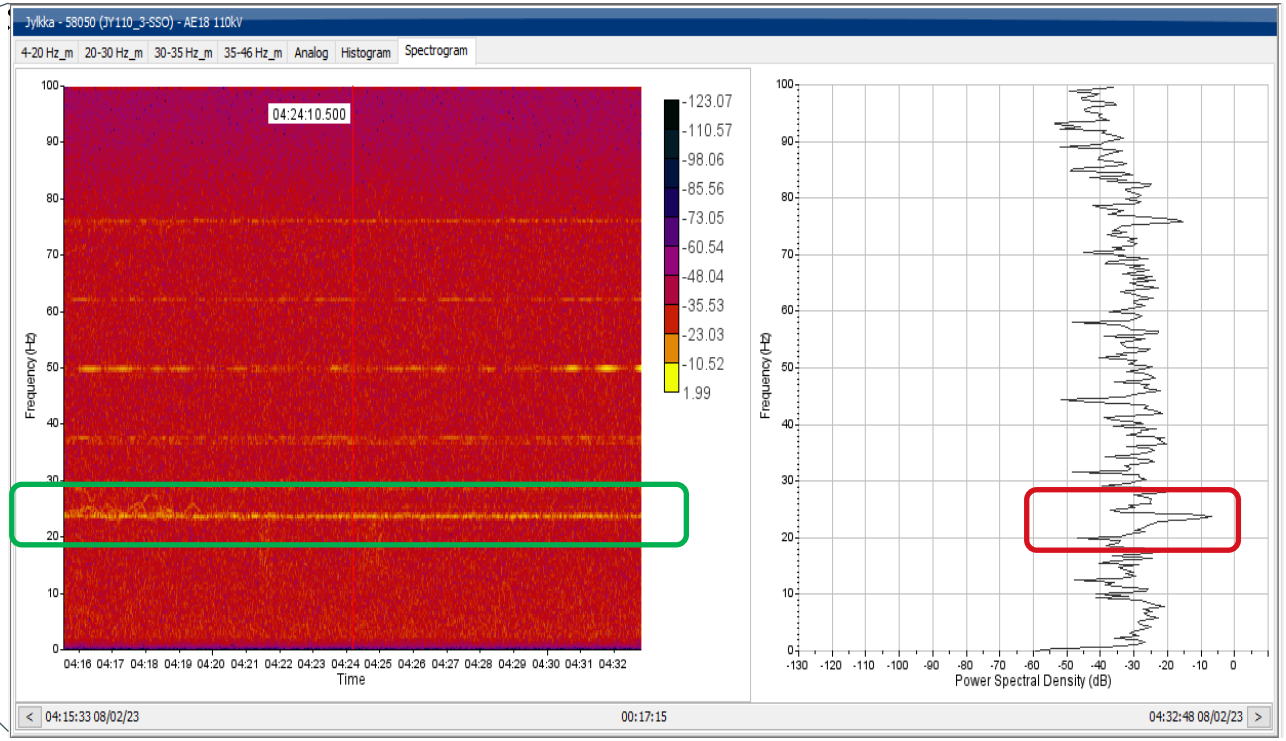
400kV PMU Measurement

Type-3 DFIG Wind Turbine Driven SSO Event (SSCI)



- Consistent SSO mode of 26-28Hz observed in Wind Farm Feeder during low power output
- Believe to be related to DFIG and Series compensated line i.e SSCI phenomena

SSCI Event 8.2.2023 (example)



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Thanks! Questions?

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