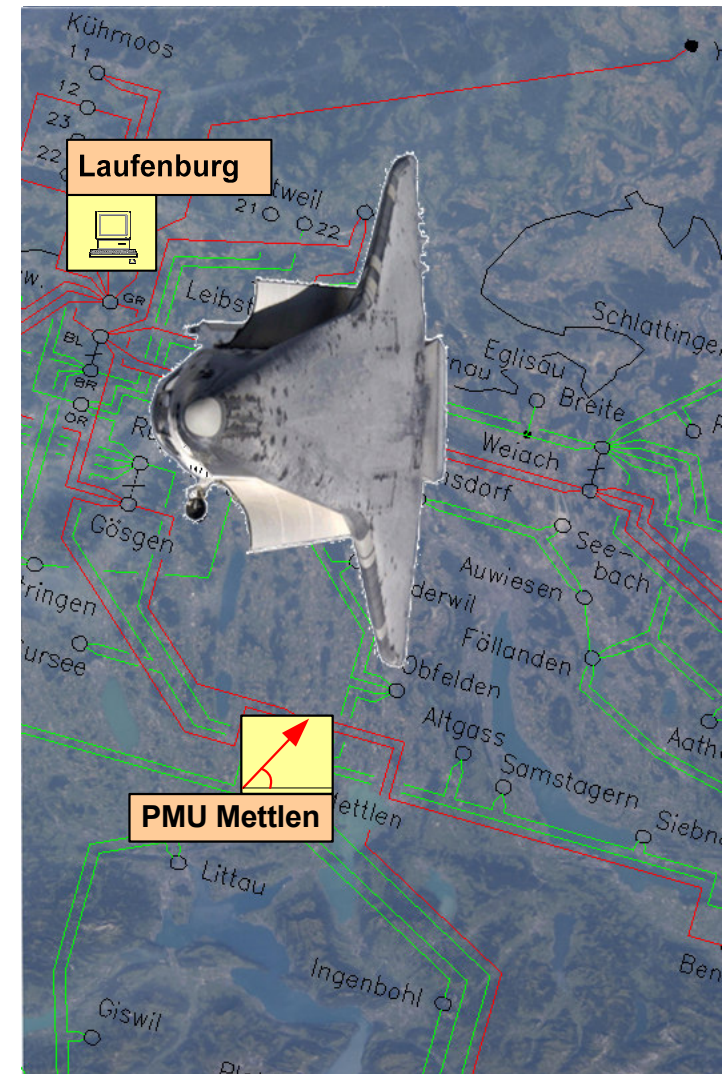




# Wide Area Monitoring in the Middle of the Central European System

Four Years of Practical Experience

Walter Sattinger  
swissgrid, Laufenburg, Switzerland  
NASPI Meeting, Montreal, 2007 Sept. 5-7





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1. Central European System – Short Overview
2. Why PMU Measurement Technique?
3. Milestones and Applications
4. Conclusions and Outlook

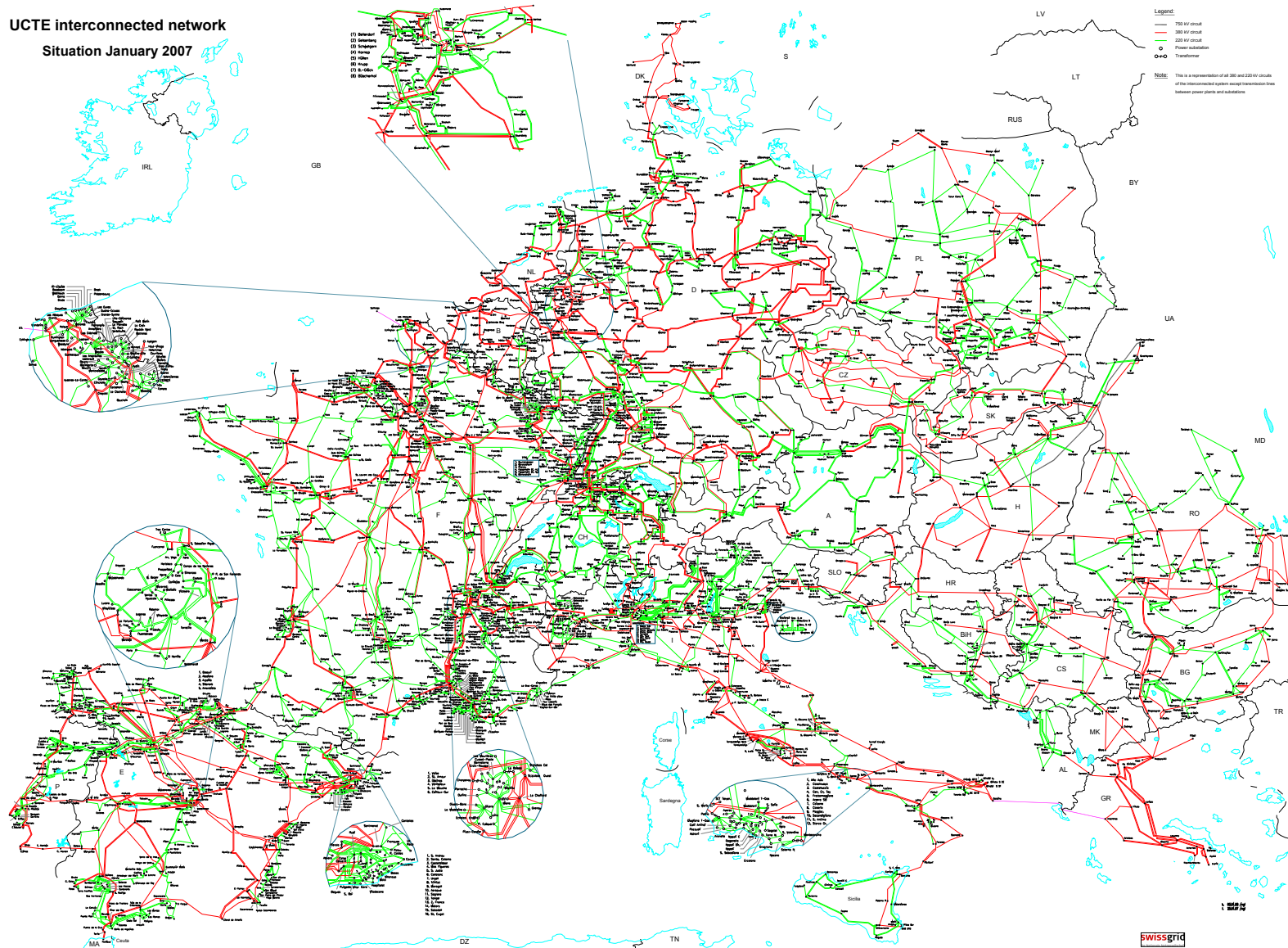


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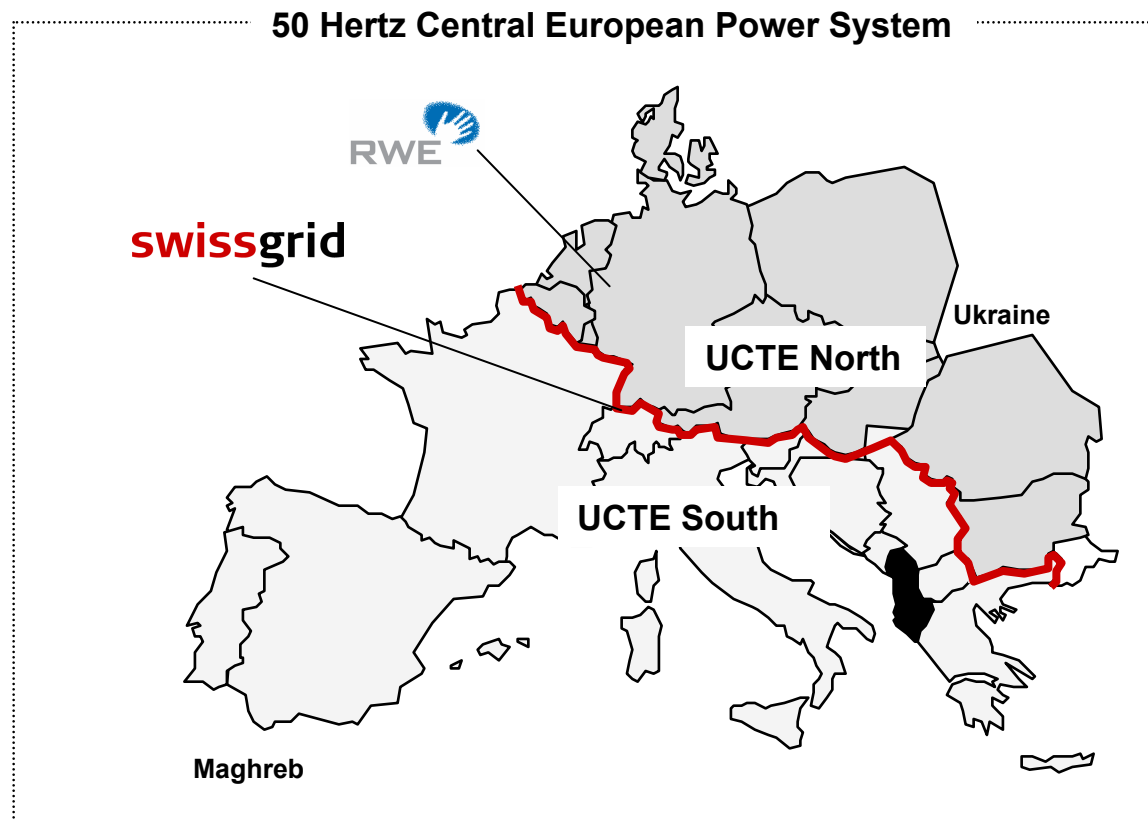
## Central European Transmission System Structure

UCTE interconnected network  
Situation January 2007





# swissgrid UCTE\*-Coordination Centre South



**UCTE Key Figures (2006):**  
450 million inhabitants  
Peak load: 300 - 390 GW  
El. energy cons./year: 2530 TWh

**Switzerland Key Figures:**  
7.3 million inhabitants  
Peak load: 10.2 GW  
El. energy cons./year : 62 TWh  
**2.5% of UCTE energy consumption**  
**10% of UCTE cross-border power exchange**

\*Union for the Coordination of Transmission of Electricity



# Central European Power System - UCTE

- Highly-Meshed System
- 24 Countries
- 29 TSOs
- Decentralized System Operation
- Coordination on the Level of:
  - System Operation Standards
  - Operation Planning
  - Scheduling and Accounting





1. Central European System – Short Overview
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# Benefit of WAM-PMU Measurements



time

- Dynamic model calibration

- Timely high resolution wide area measurements

- Generate "smart alarms"
- Activate Special Protection Schemes

- Direct measurement of voltage phase angle
- Combine fast dynamic with steady-state information
- SCADA & protection link

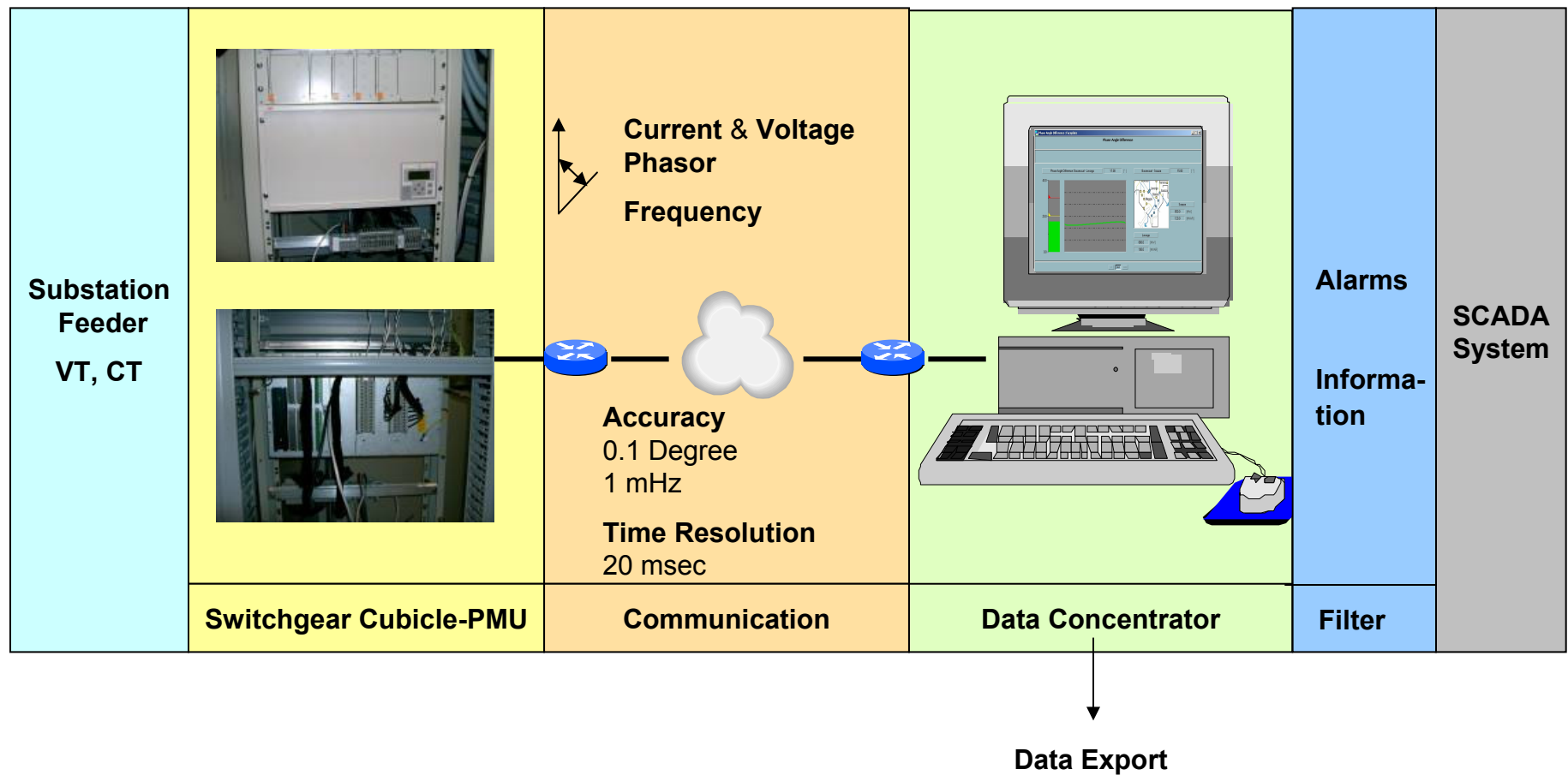
- Qualified analysis

- Each measurement point with own precise time stamp

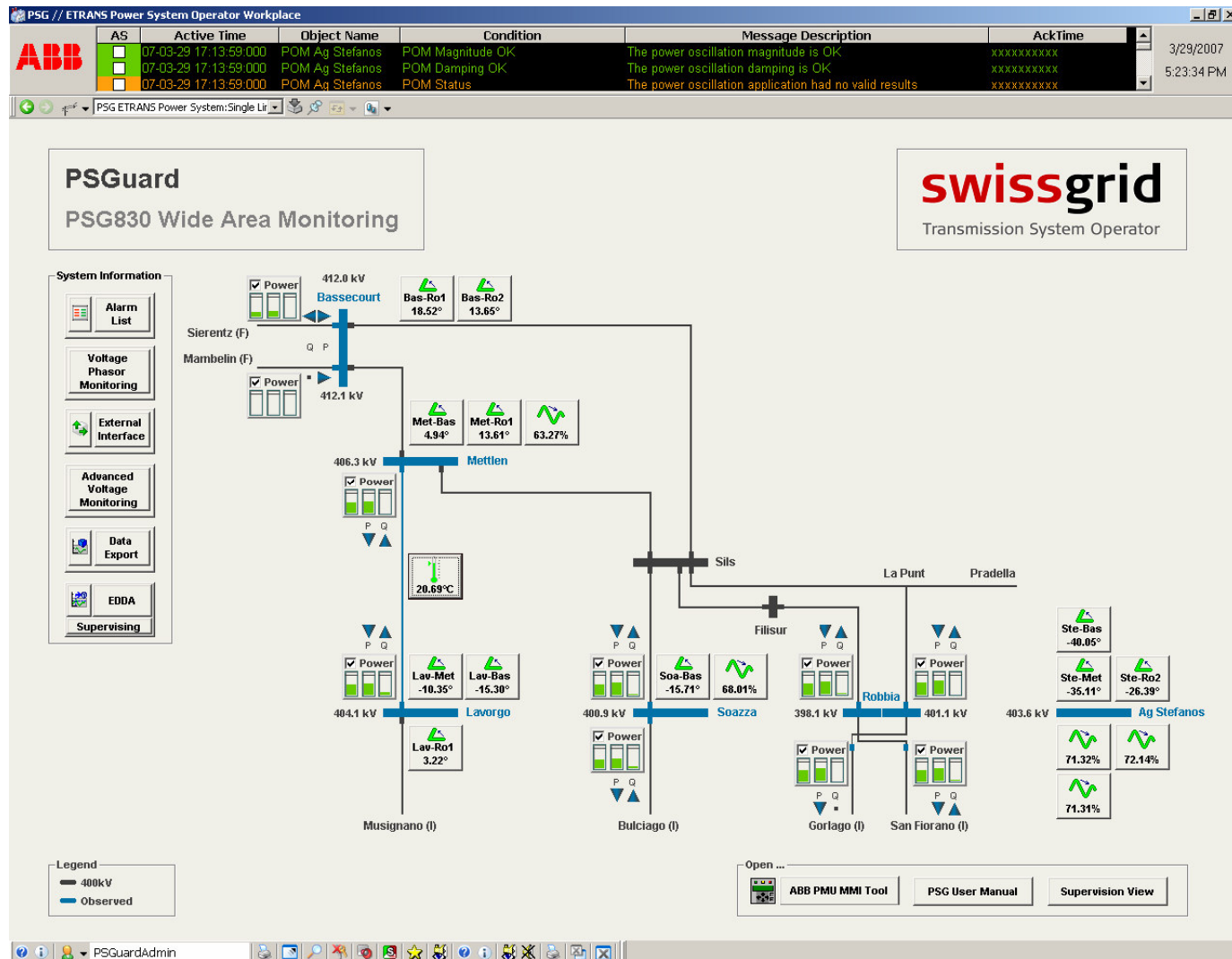




# System Structure



# User Interface & System Functions





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- On-line dynamic monitoring during UCTE resynchronization Oct. 2004
- Monitoring of UCTE system damping with respect to inter-area oscillations
- Analysis of Nov. 4th 2006 UCTE-wide disturbance



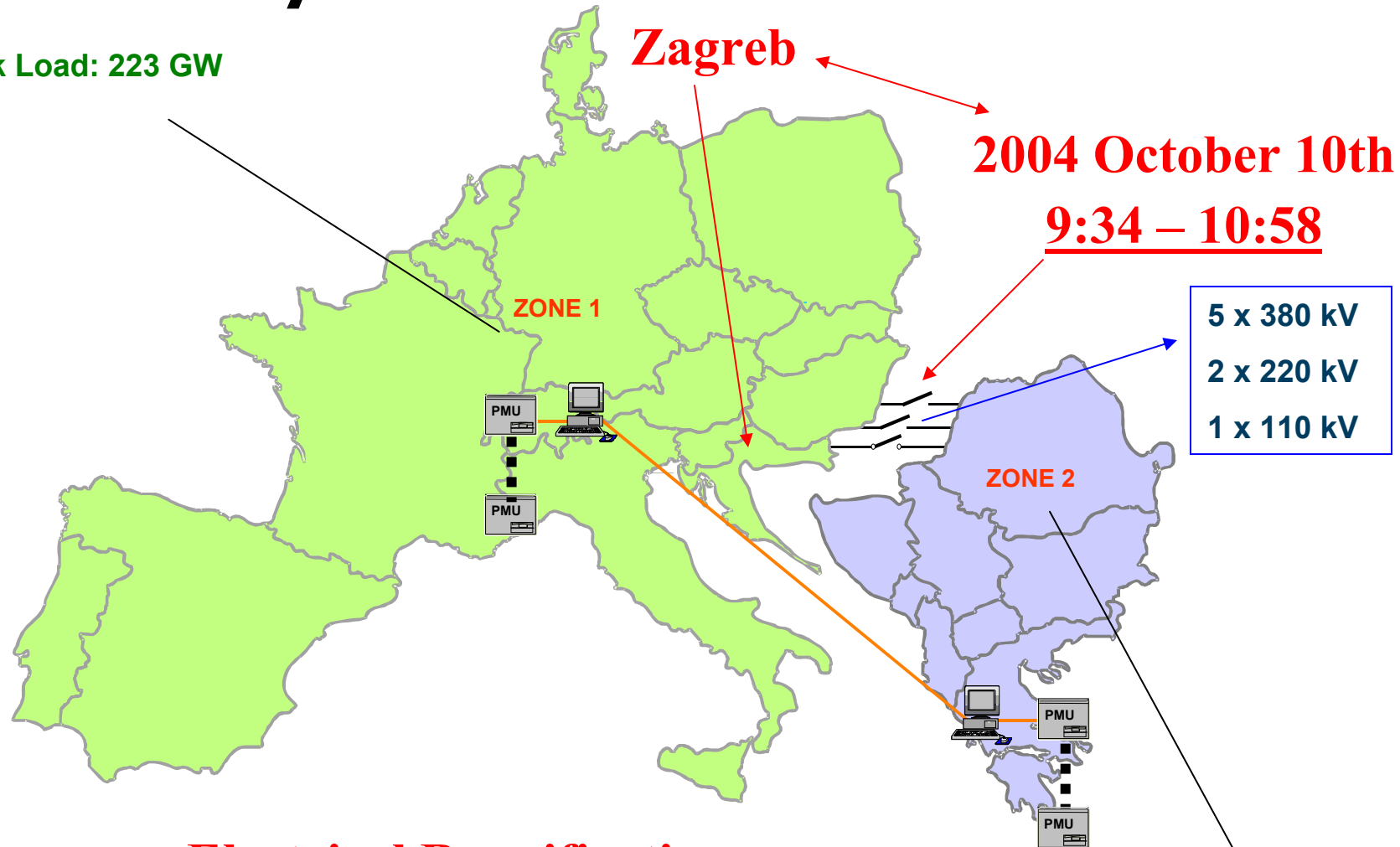
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# UCTE Resynchronisation

Peak Load: 223 GW

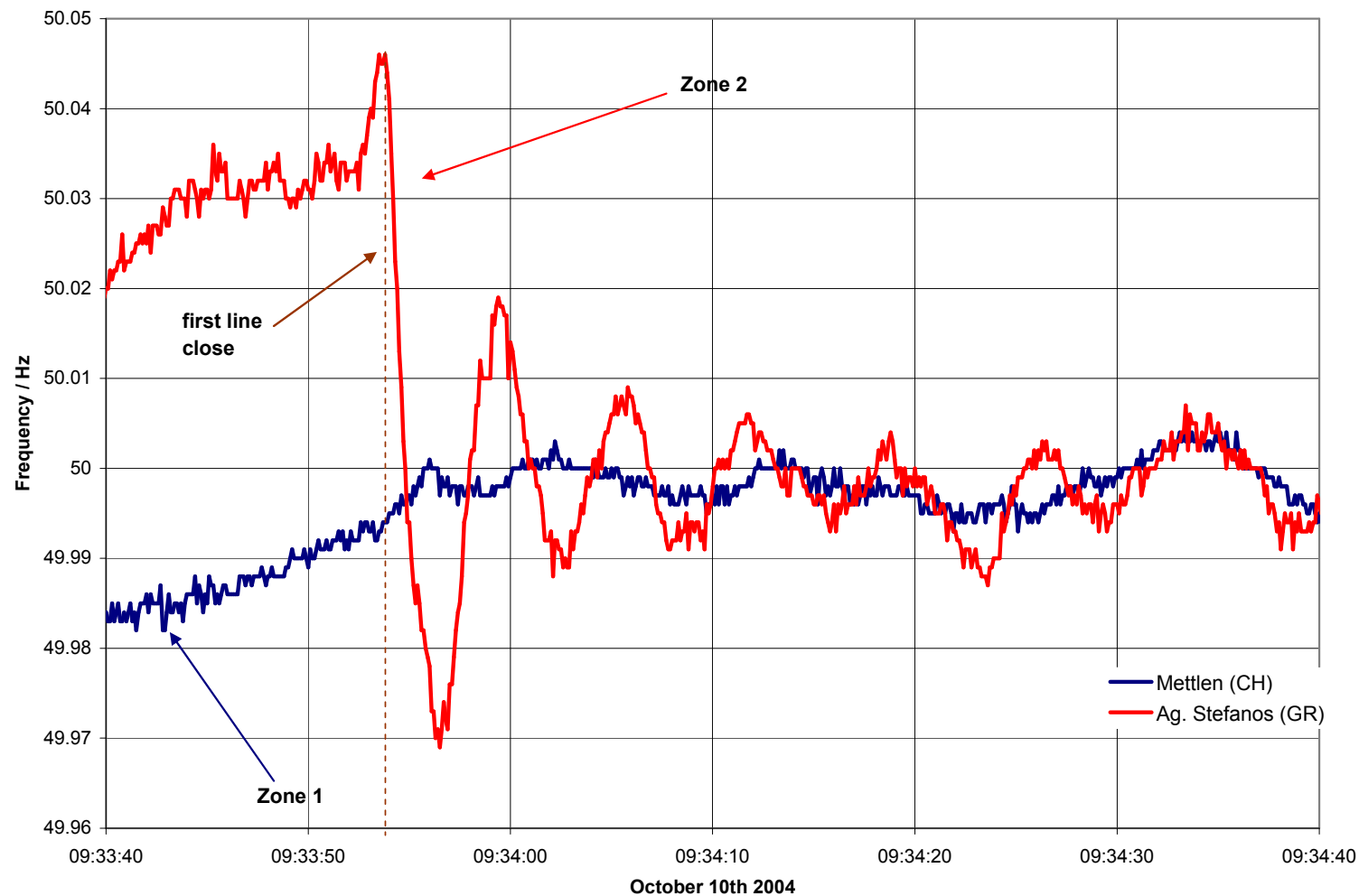


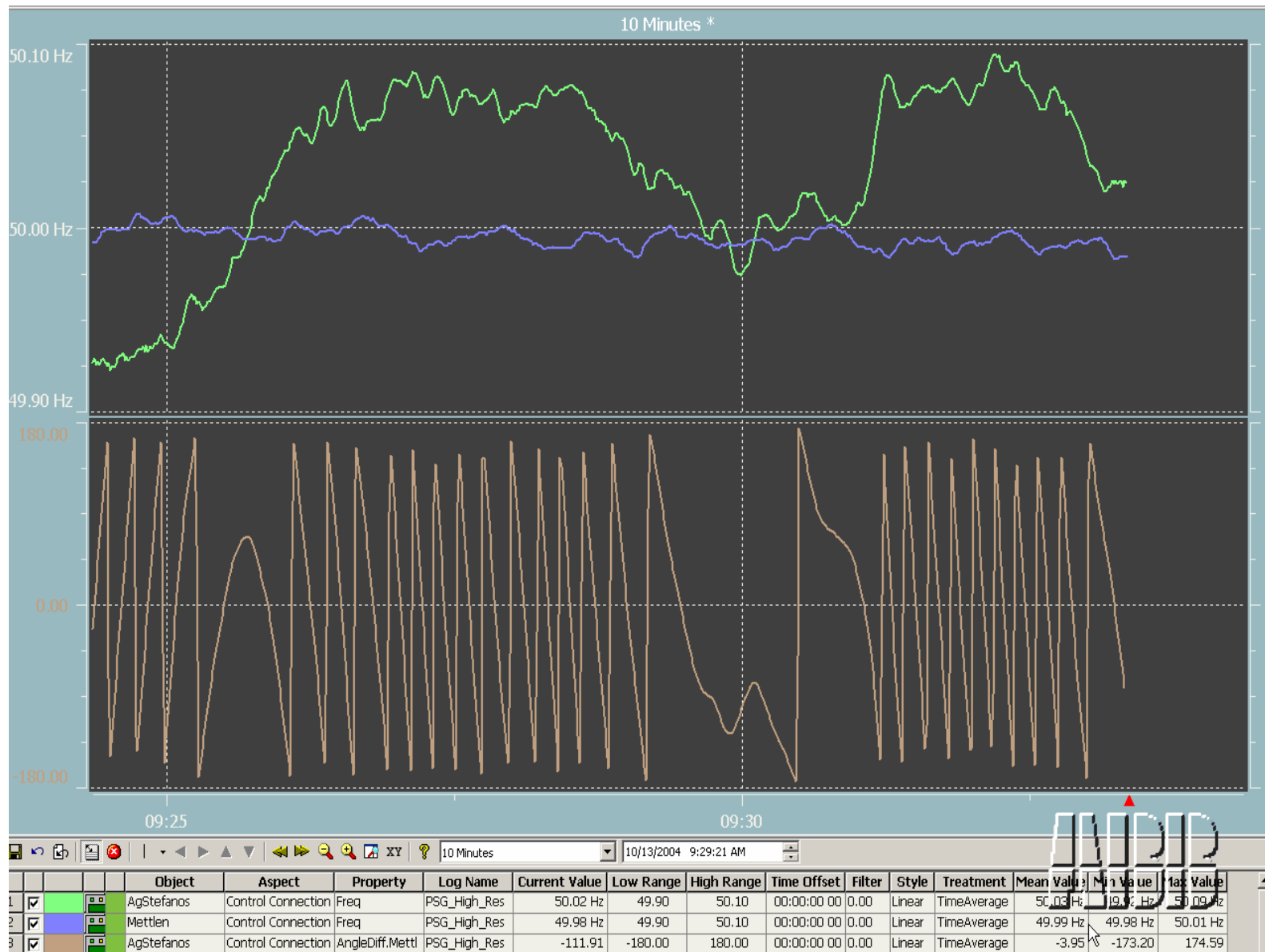
**European Electrical Reunification**

Peak Load : 21 GW



# Frequency – System Stability Index





## Reconnection Video

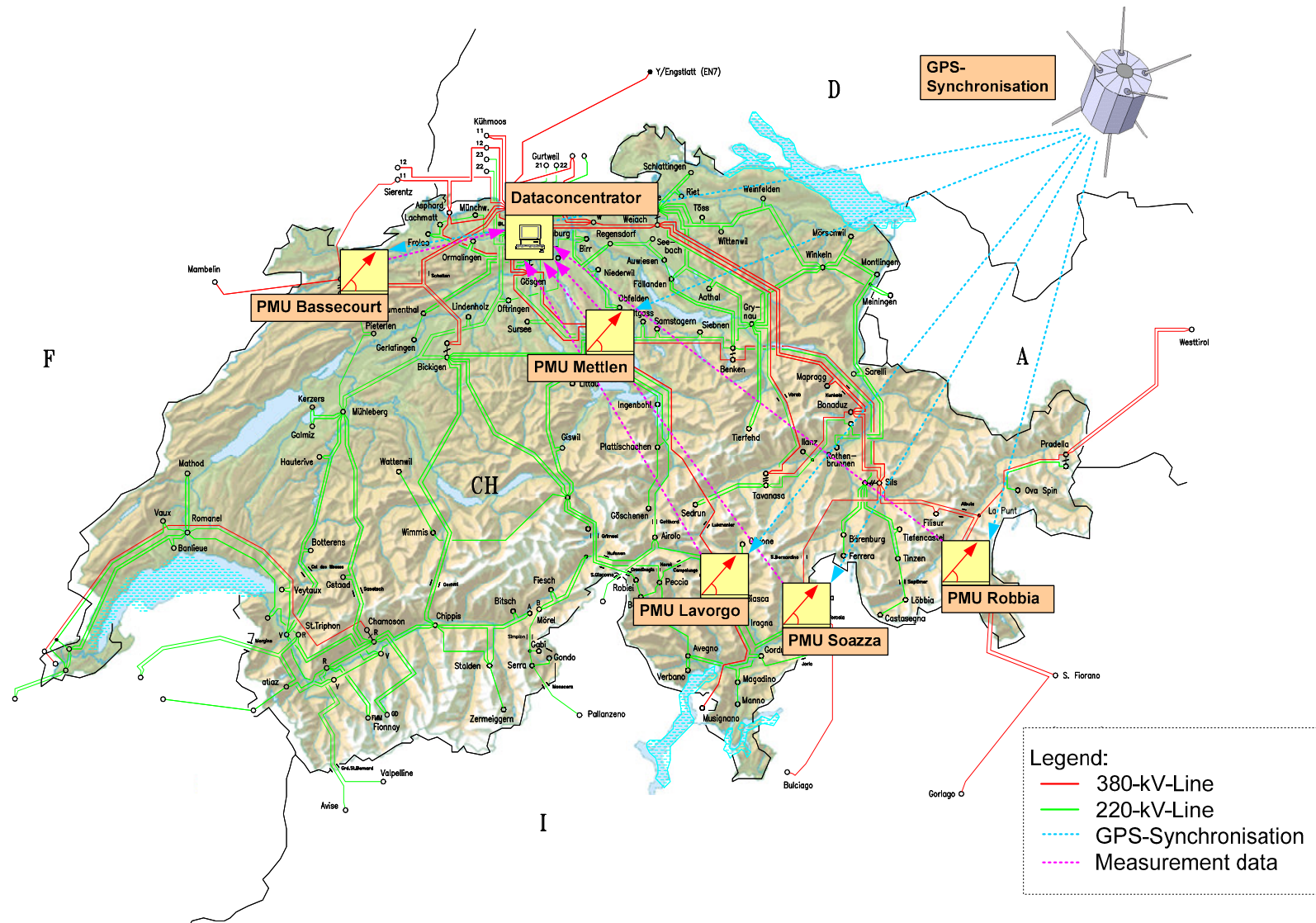




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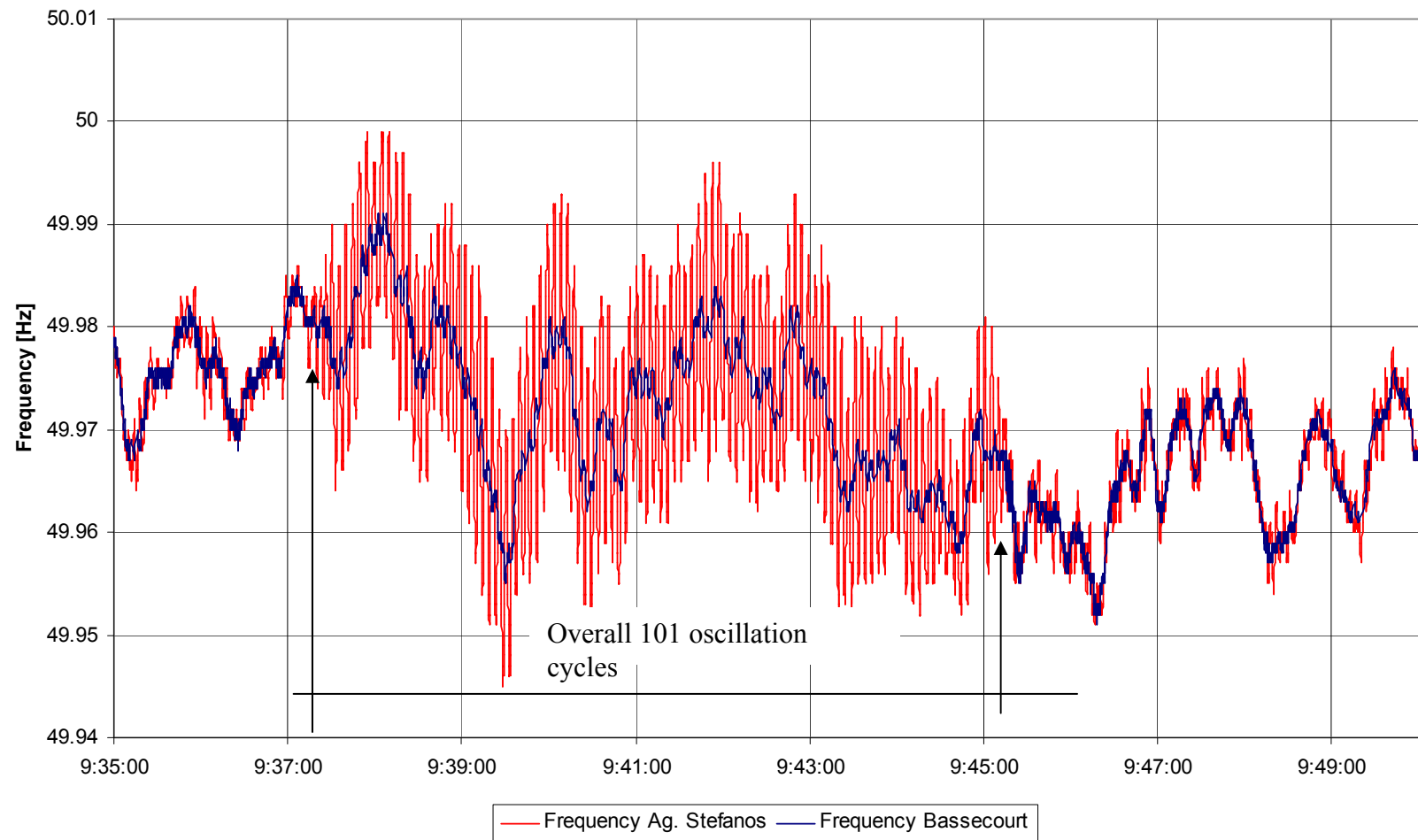
# Wide Area Monitoring – Early Warning System





# UCTE East-West Inter-Area Oscillations

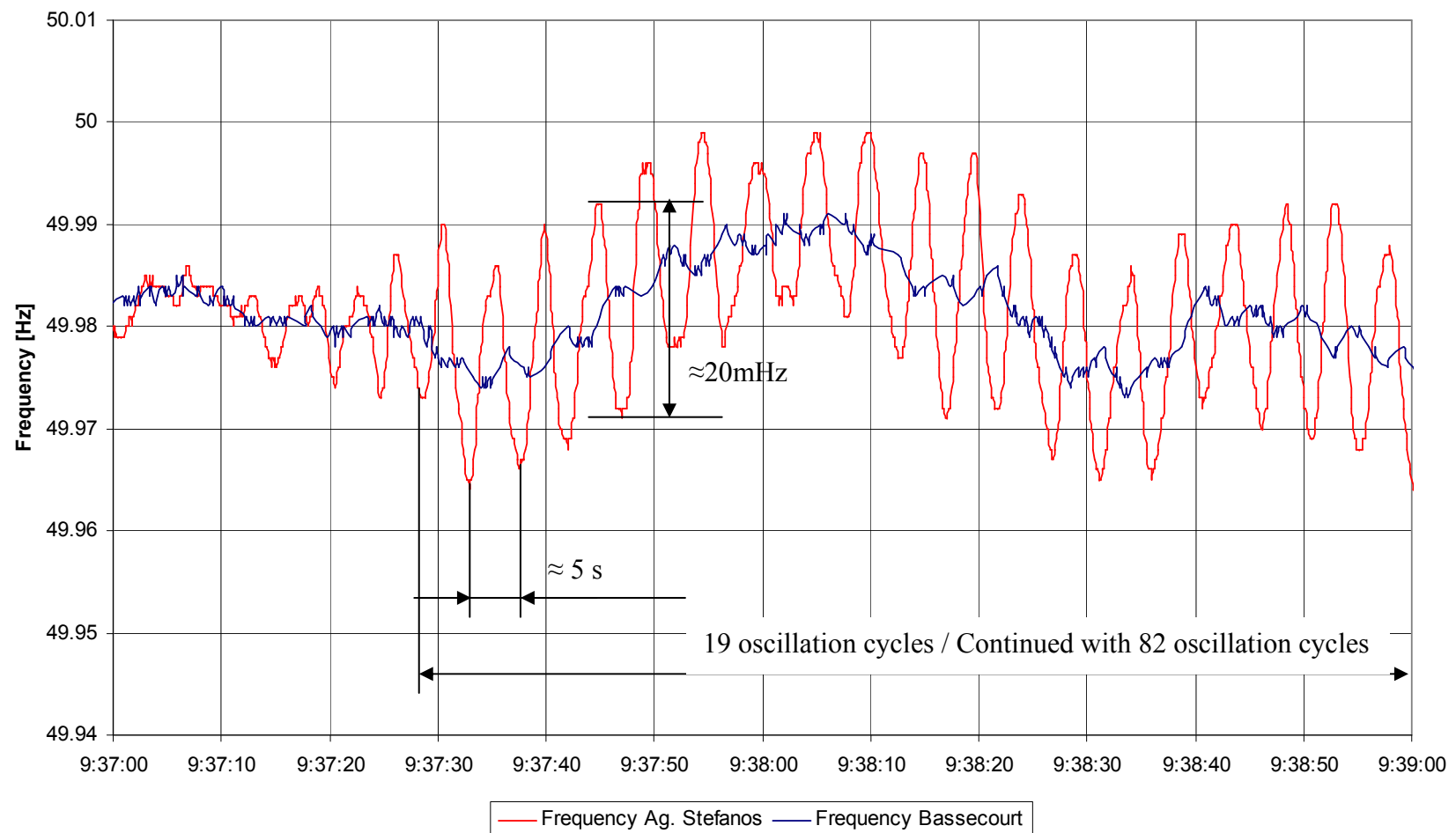
01.05.2005 09:35:00 UCTE inter-area oscillation





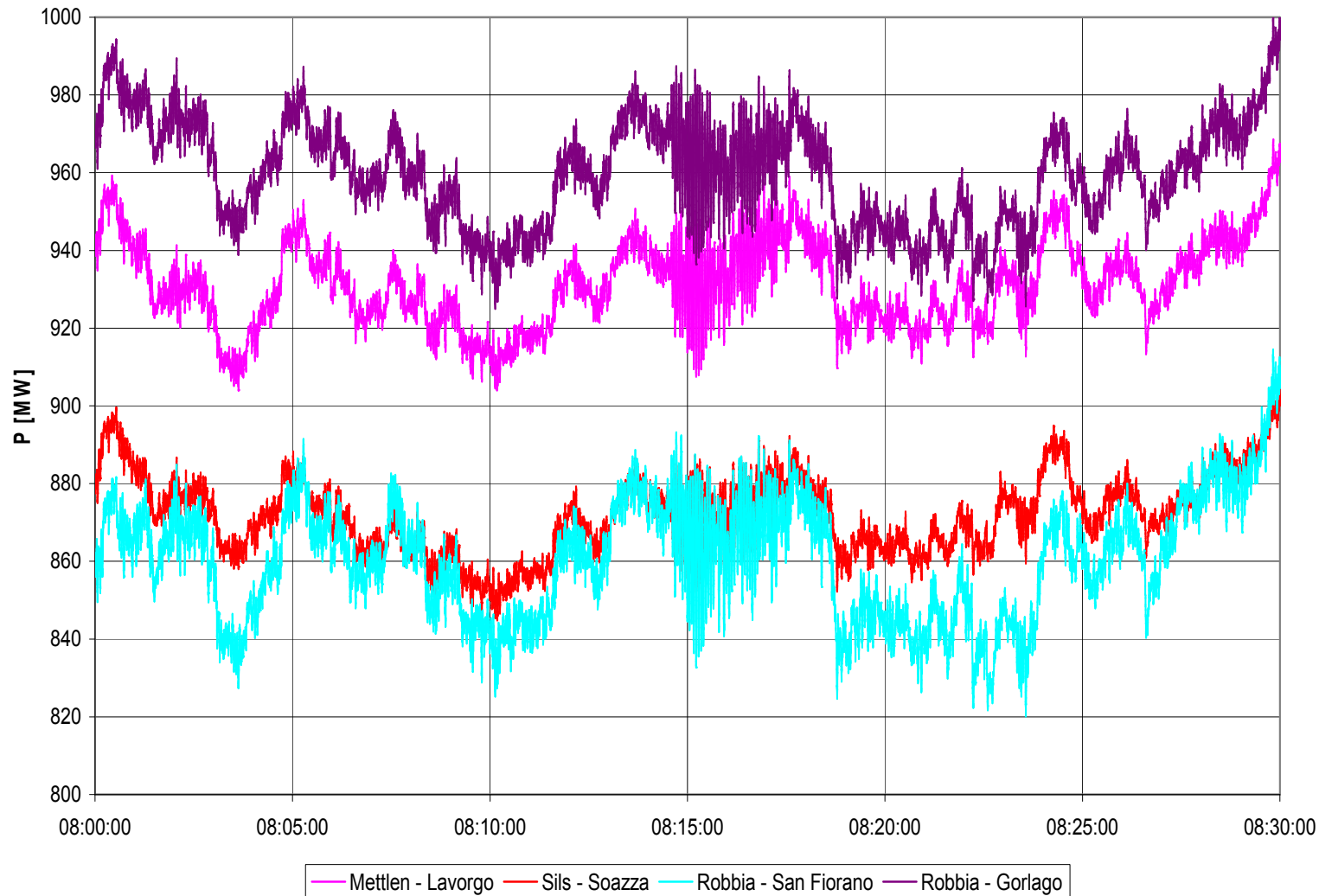
# Details East-West Inter-Area Oscillation

01.05.2005 09:35:00 UCTE inter-area oscillation





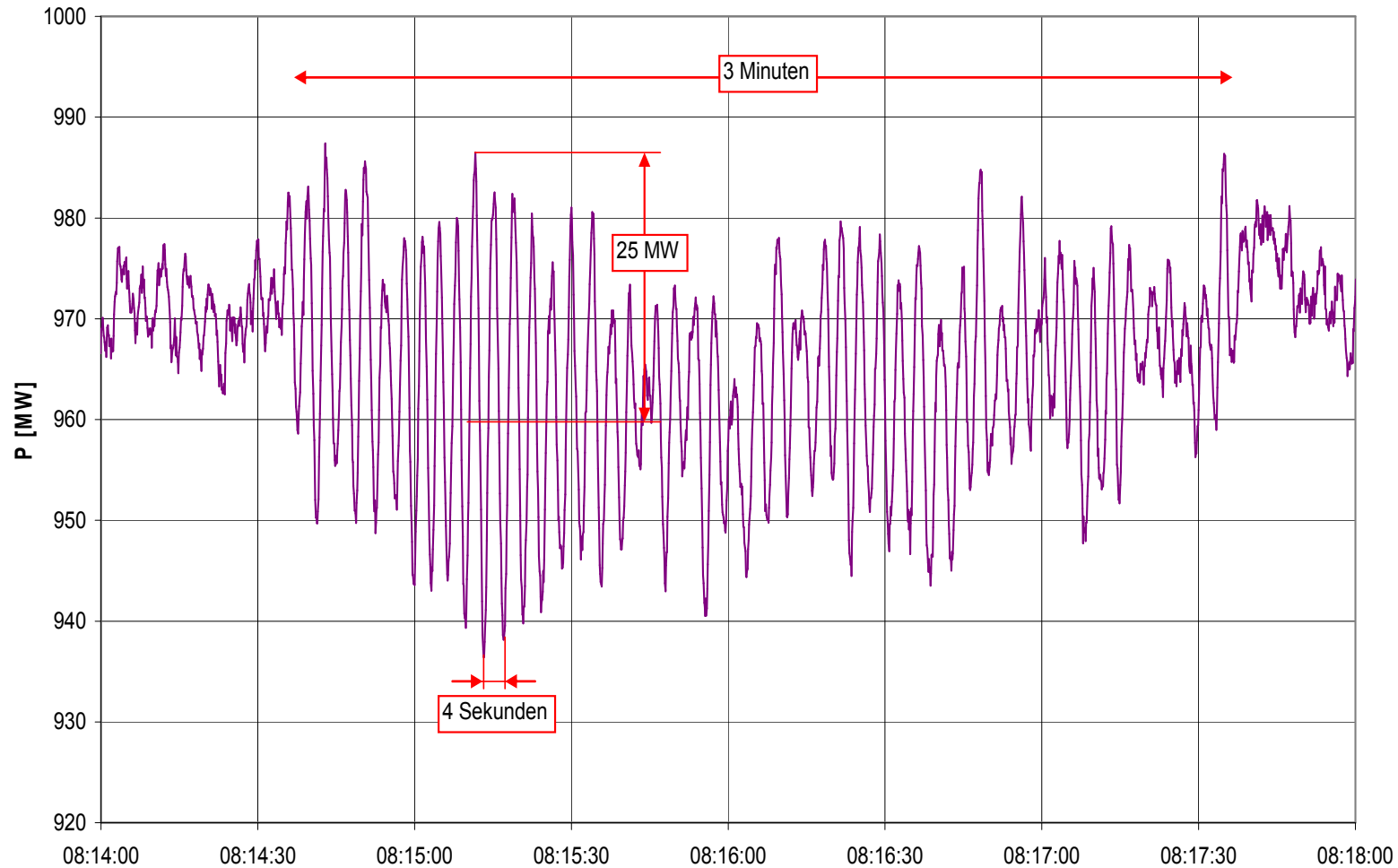
# UCTE North-South Inter-Area Oscillation



2007, April 1st



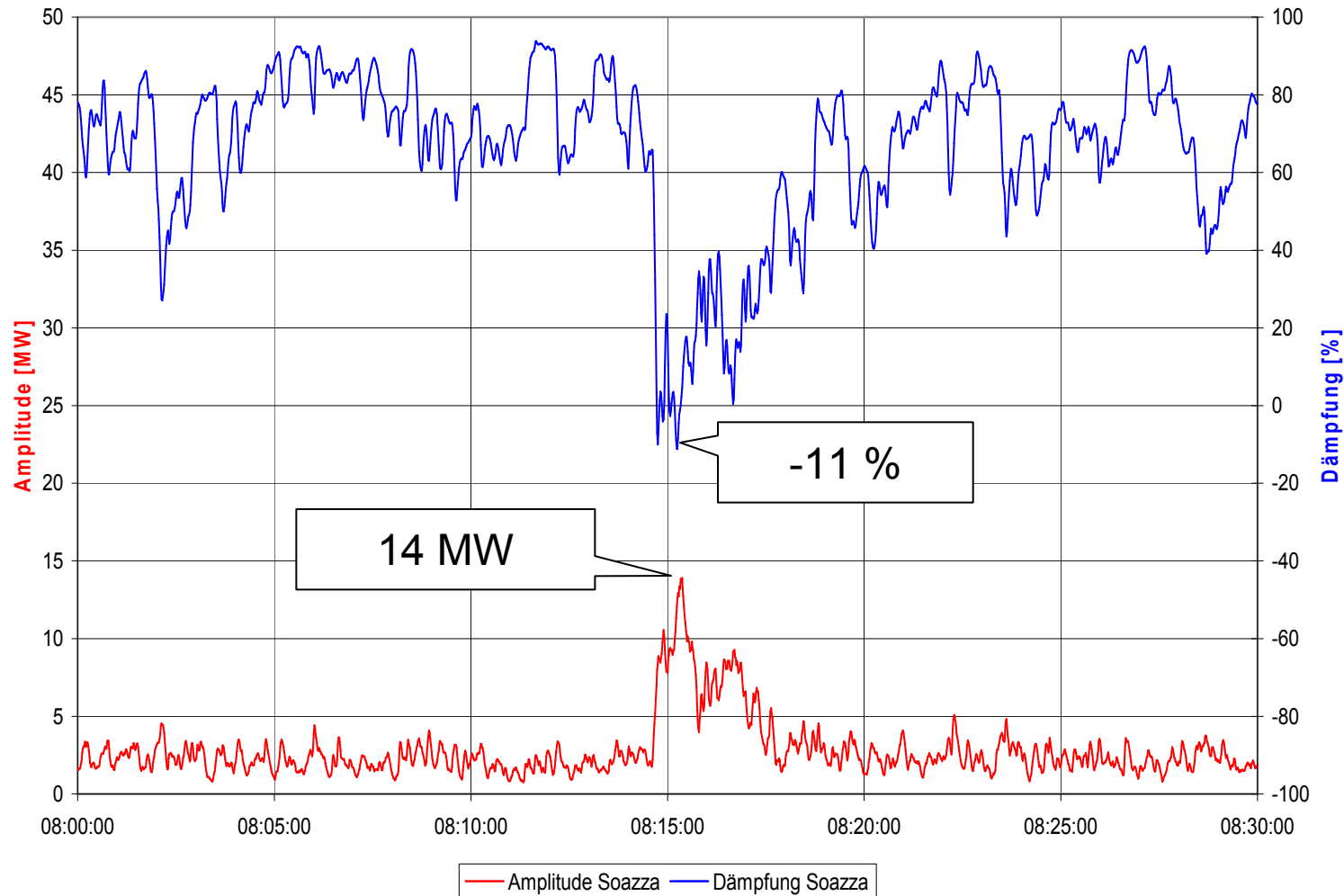
# Robbia-Gorlago Line Active Power Flow



2007, April 1st



# Power System Oscillation Detection



2007, April 1st





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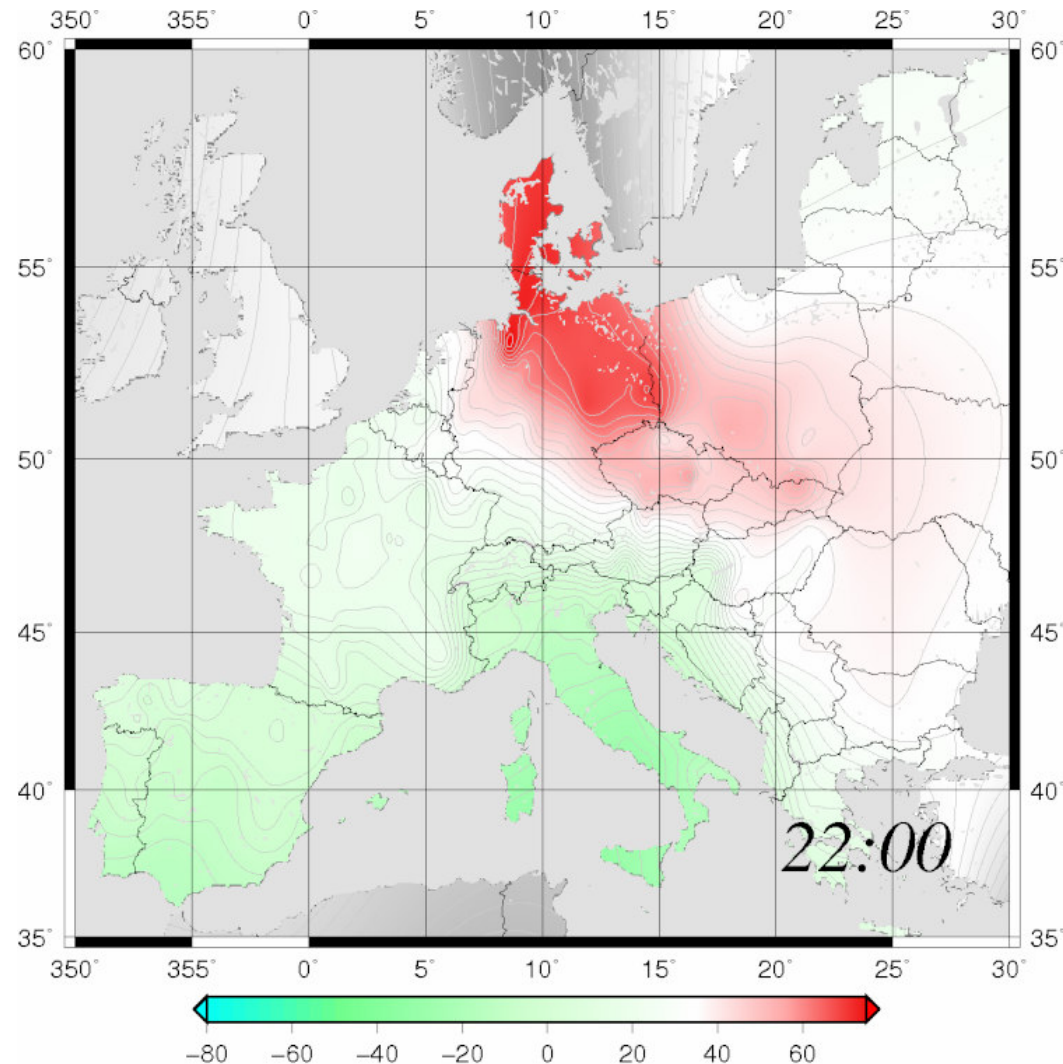
- On-line dynamic monitoring during UCTE resynchronization Oct. 2004
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- **Analysis of Nov. 4th 2006 UCTE-wide disturbance**



# Snapshot Visualisation Nov. 4th 2006

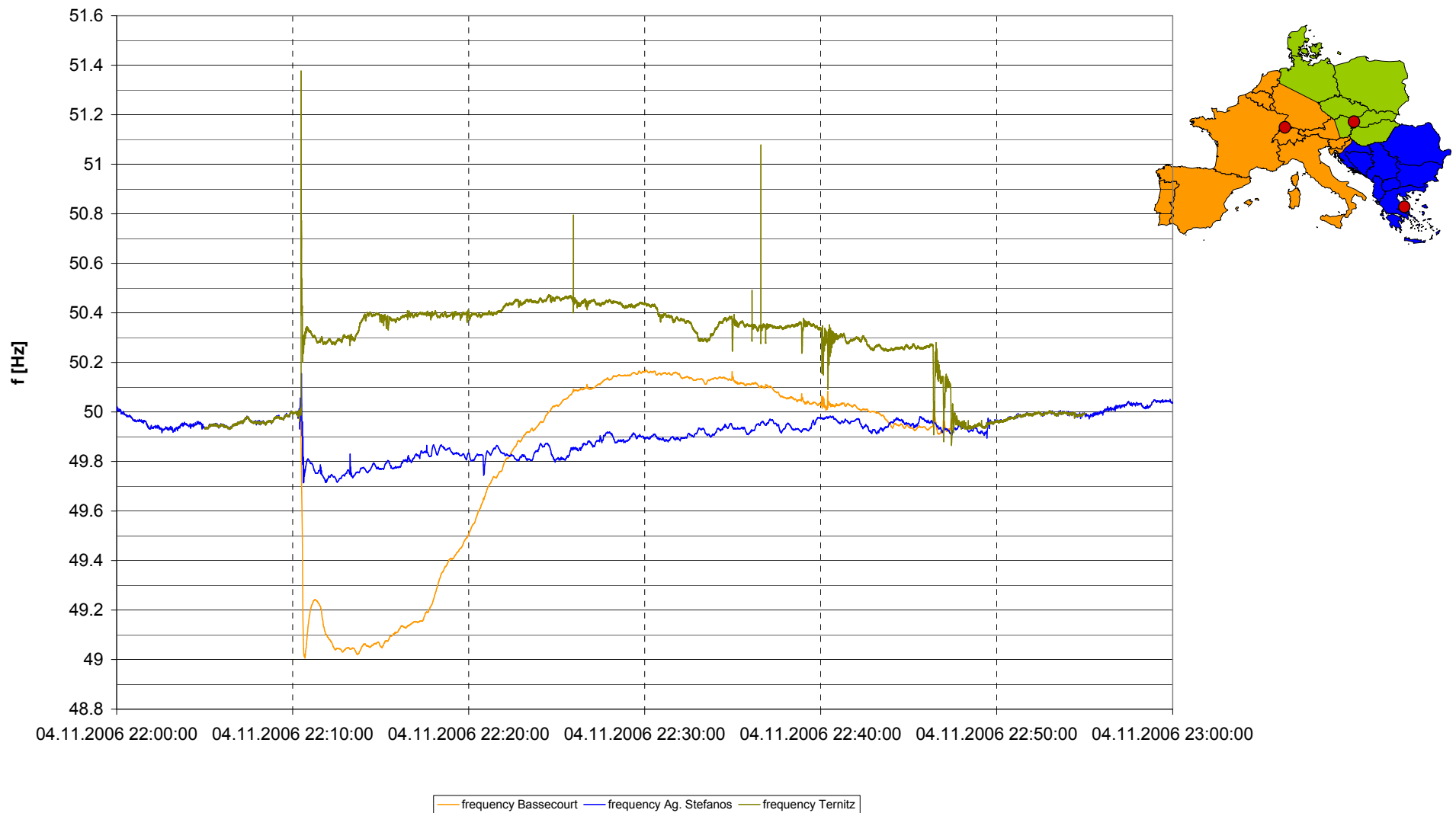
**Phase Angle (°)**

**Fig. D1a: Voltage phase angle differences in the UCTE system at 22:00 /ELES/**



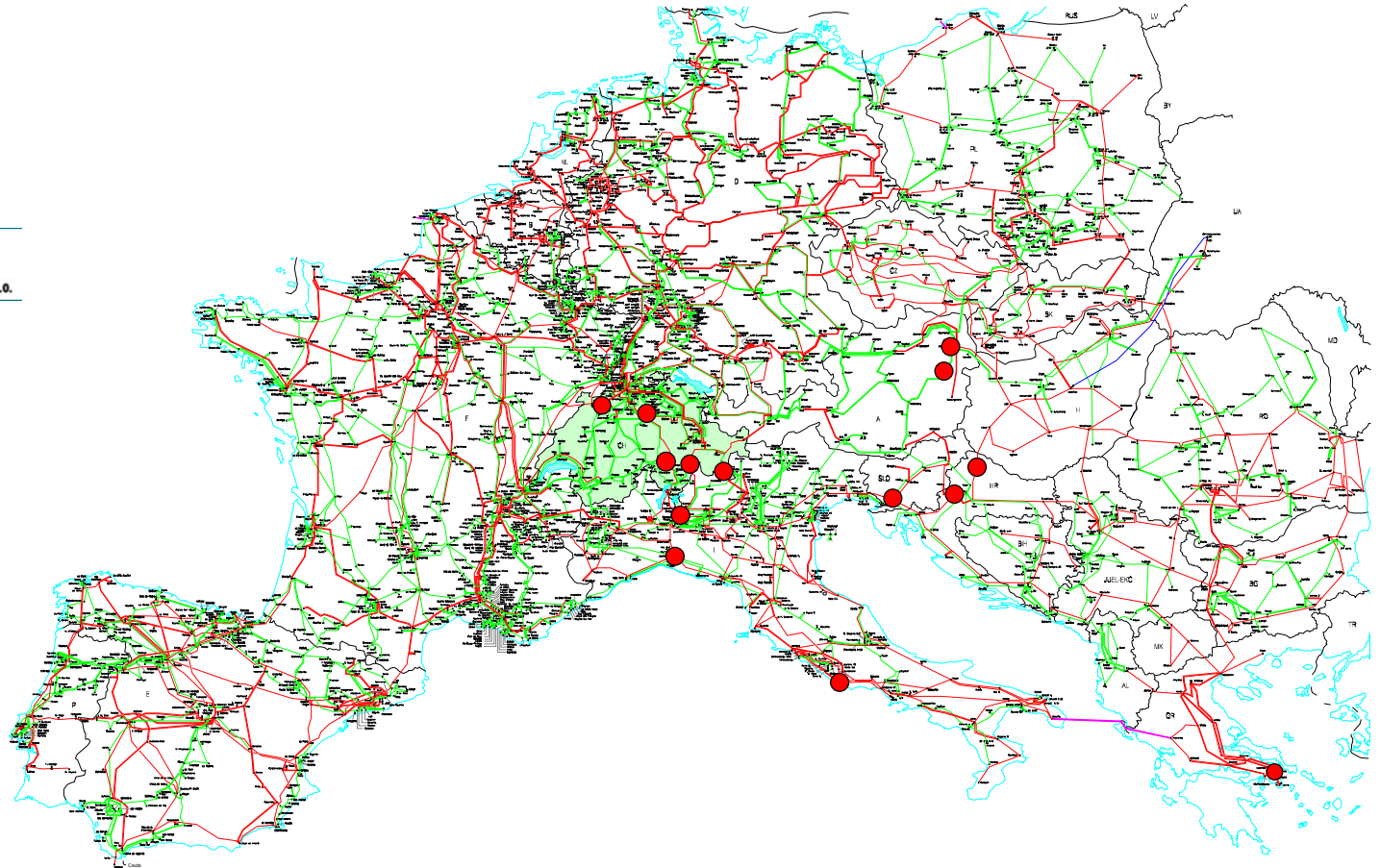
Source: UCTE Final Report

# Three islands system operation



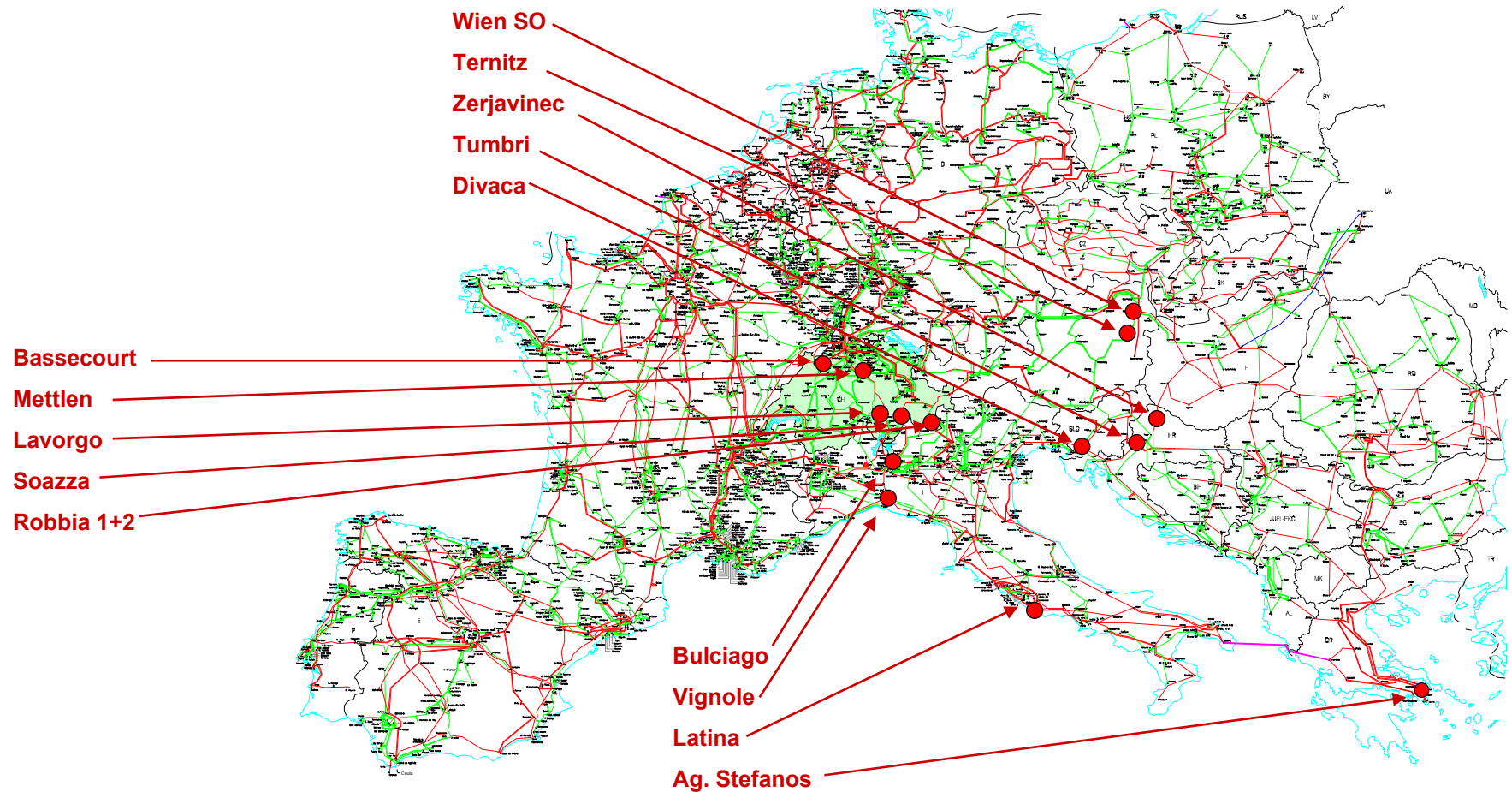


# Merged WAM Recordings





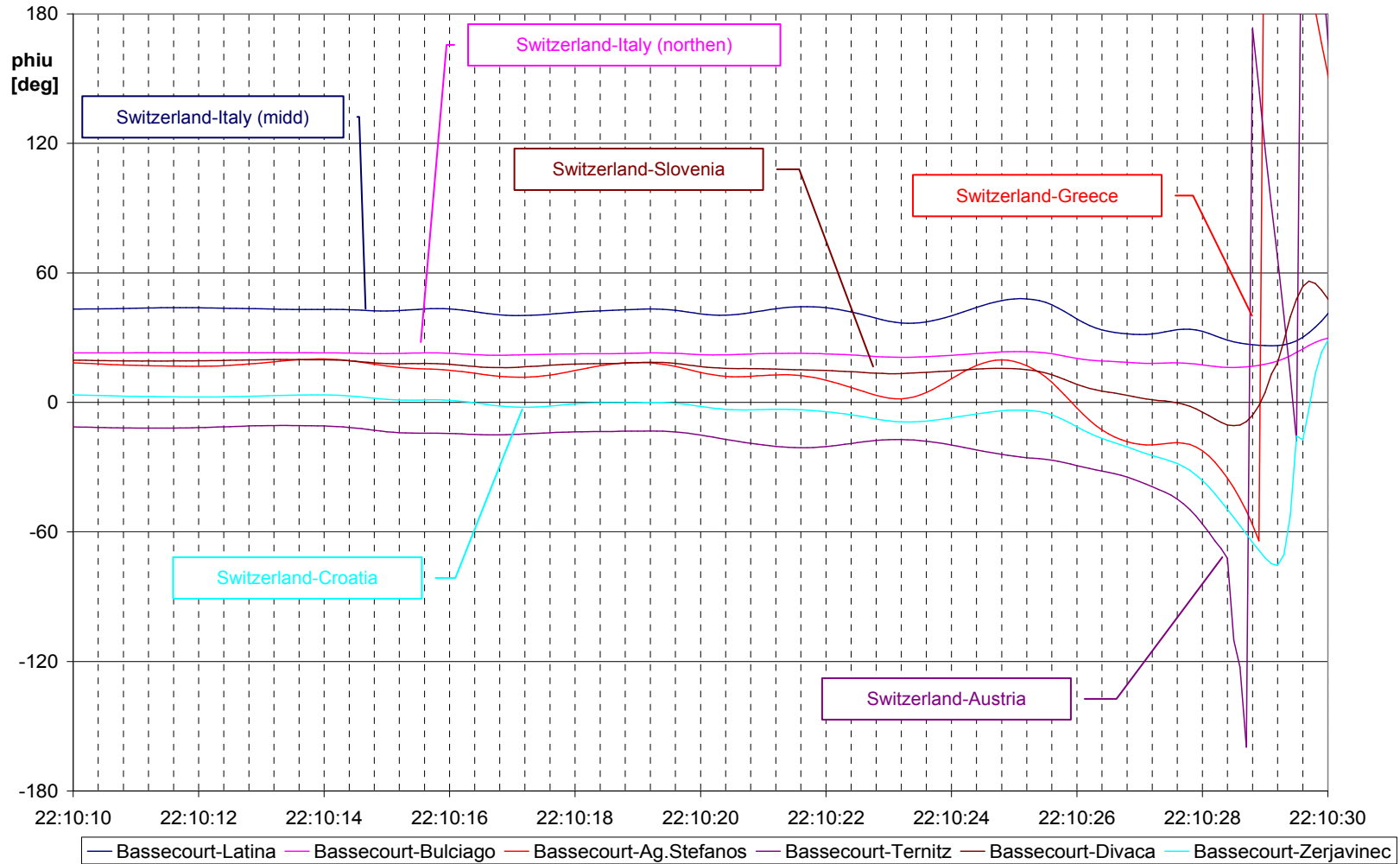
# Locations of collected PMU data





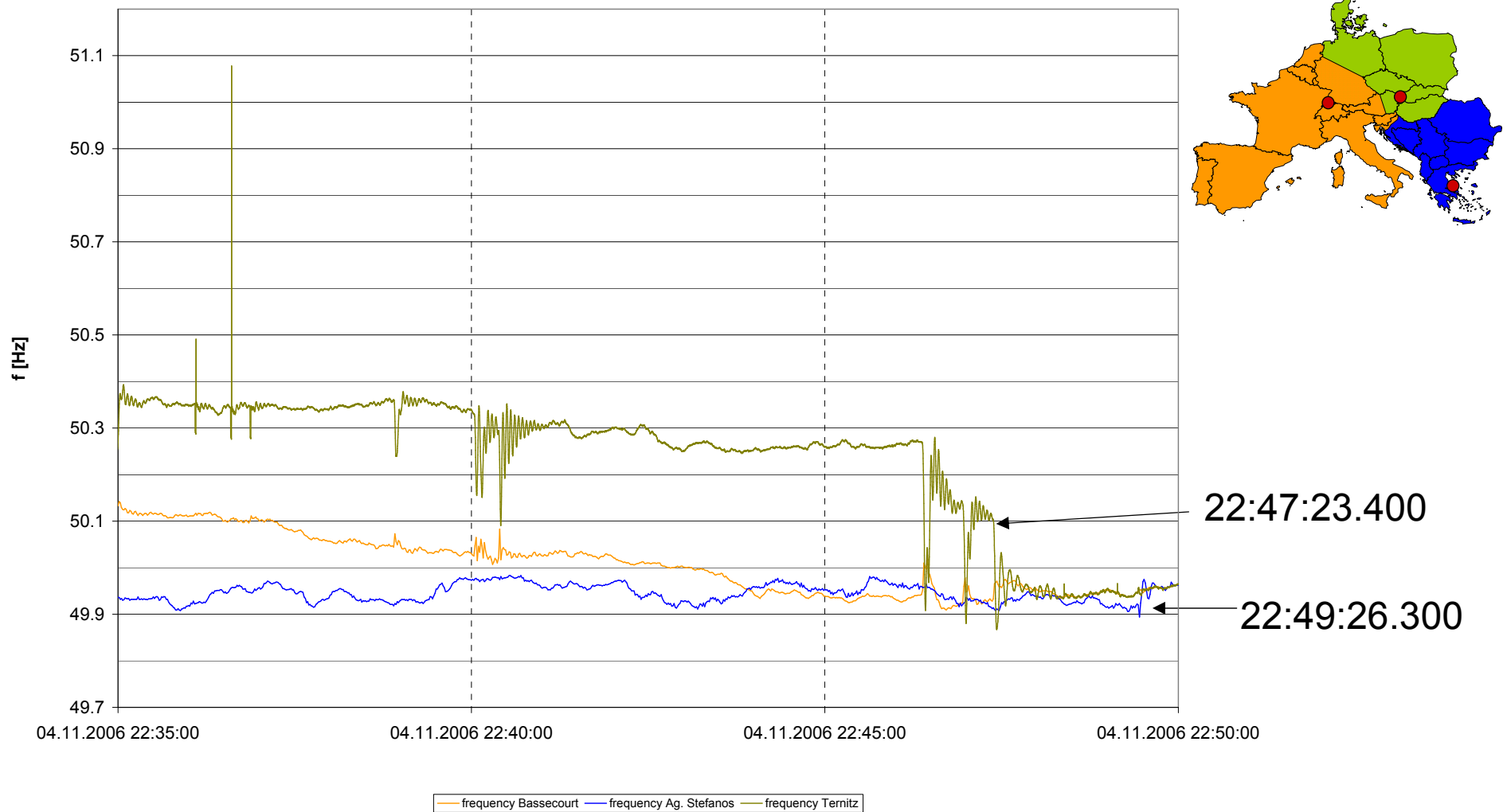


# Voltage Phase Angle Differences





# Resynchronisation of islands







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# Conclusions and Outlook

- Successful Implementation of WAM Technology
  - Comprehensive System Information based on few measurements
  - Link between on-line dynamic system monitoring and steady-state SCADA overview
- Key Points
  - Reliable communication infrastructure
  - GPS satellite visibility
  - Intelligent data computation and storage
- Next Steps
  - Increase number of functions delivered to the control room
  - Exchange of PMU and Data Concentrator information within UCTE



**Thank you for your attention**