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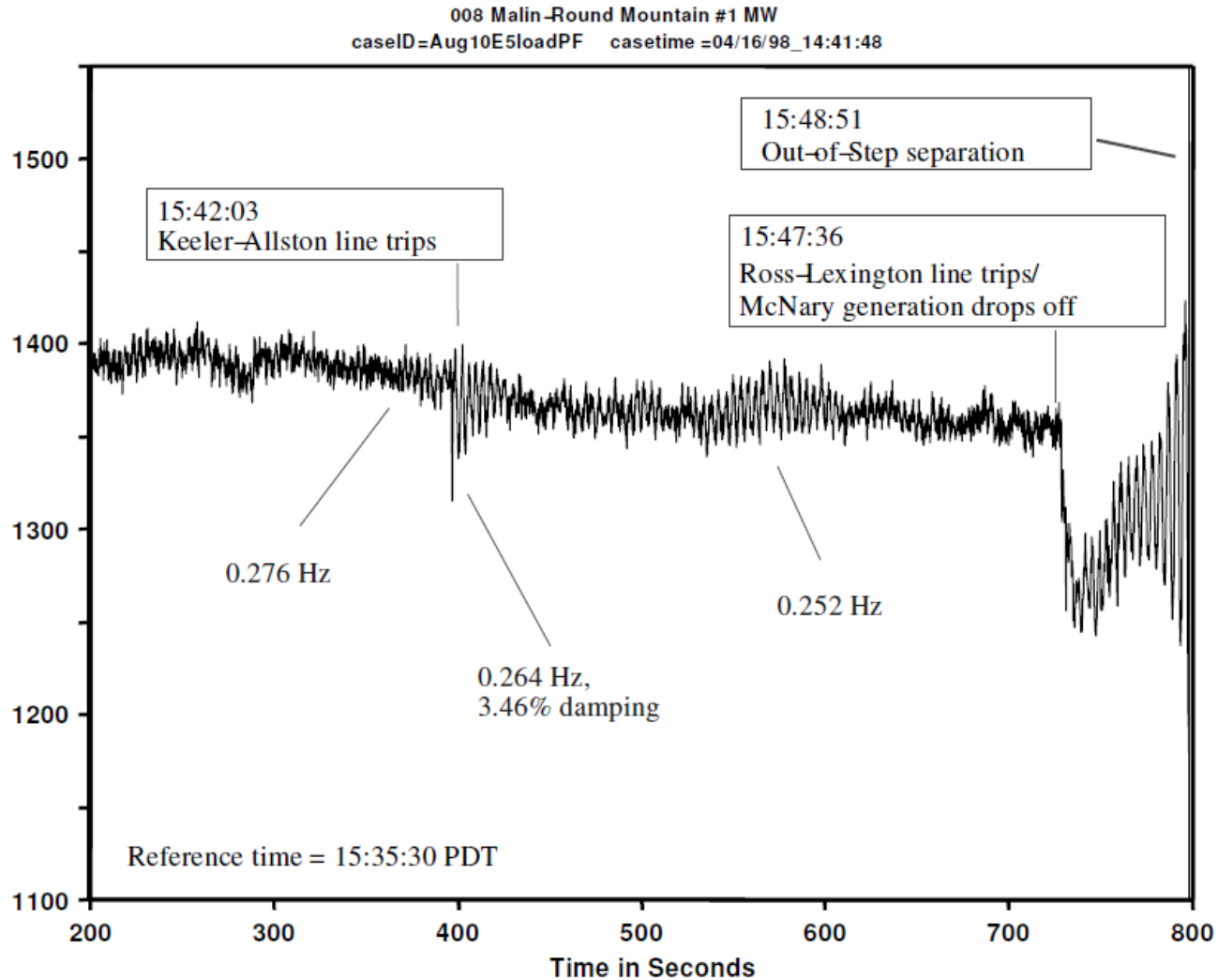
Walter Sattinger, Roland Notter – Swissgrid ag.

Monitoring of Power Oscillations in Continental European Transmission Grid

Outline

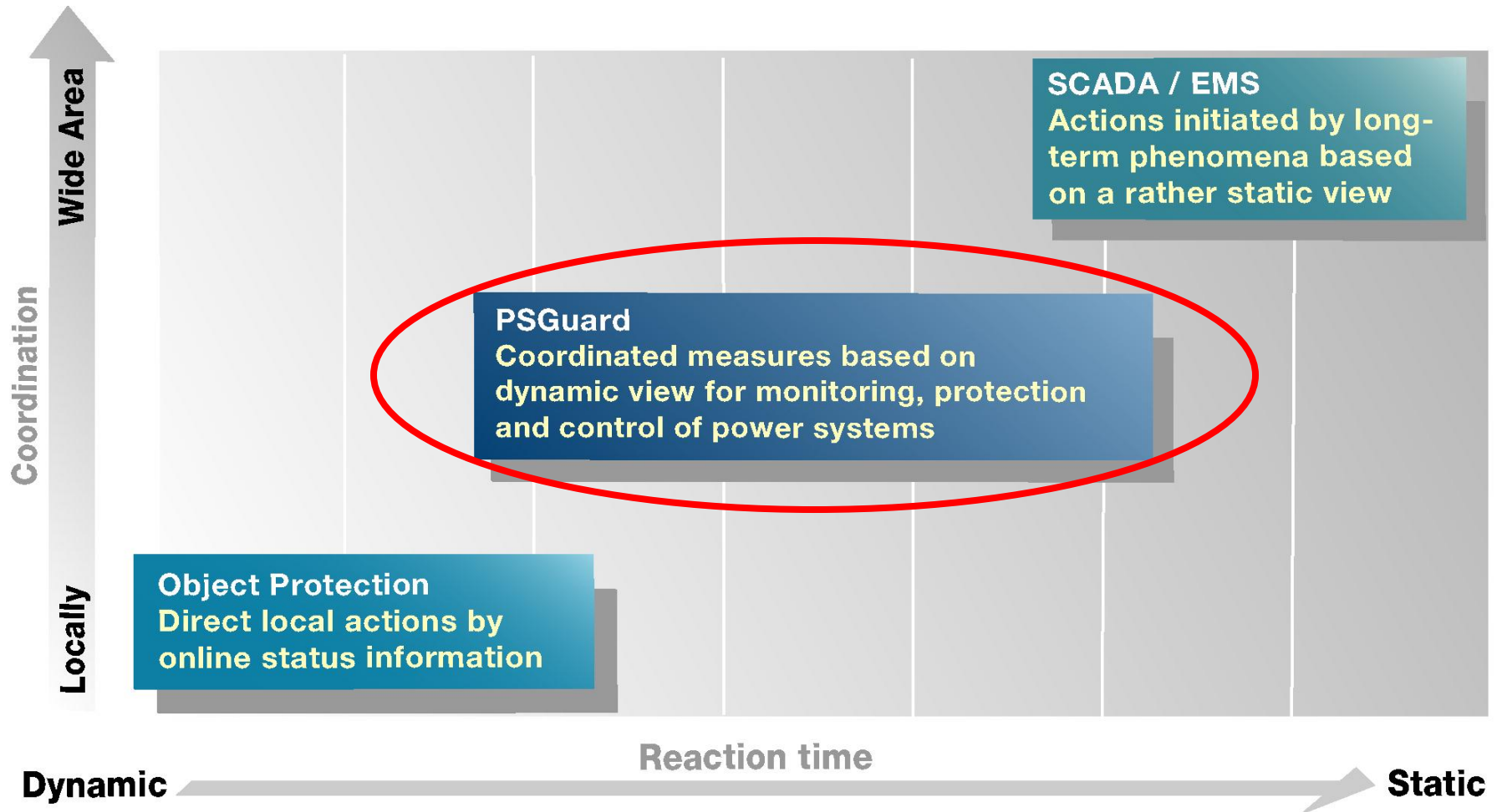
- Power Oscillations
- Wide-area Monitoring Systems
- Real-time analytics for power oscillation monitoring
- Example event and monitoring analytics response
- Conclusion

Power Oscillations - WSCC Blackout, USA August 10, 1996

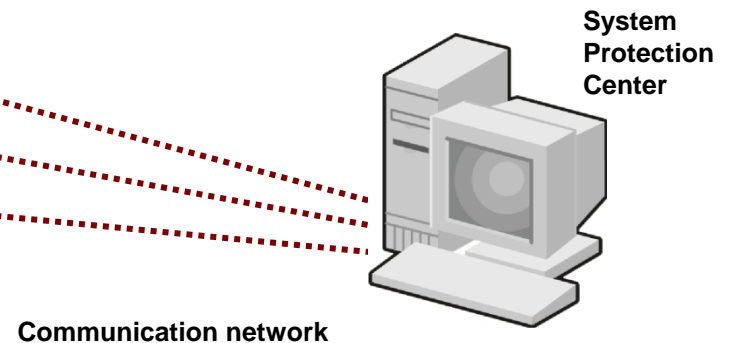
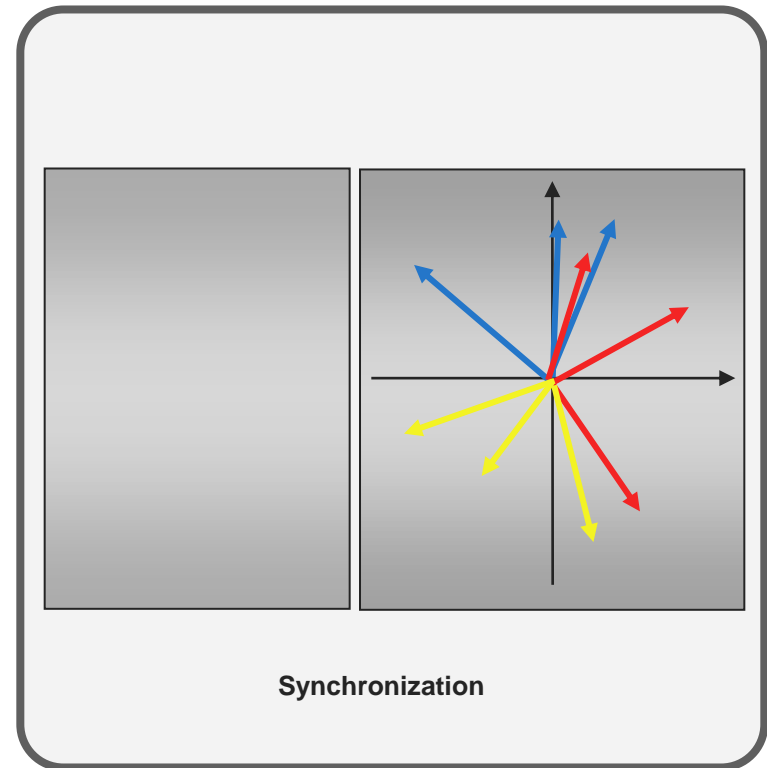
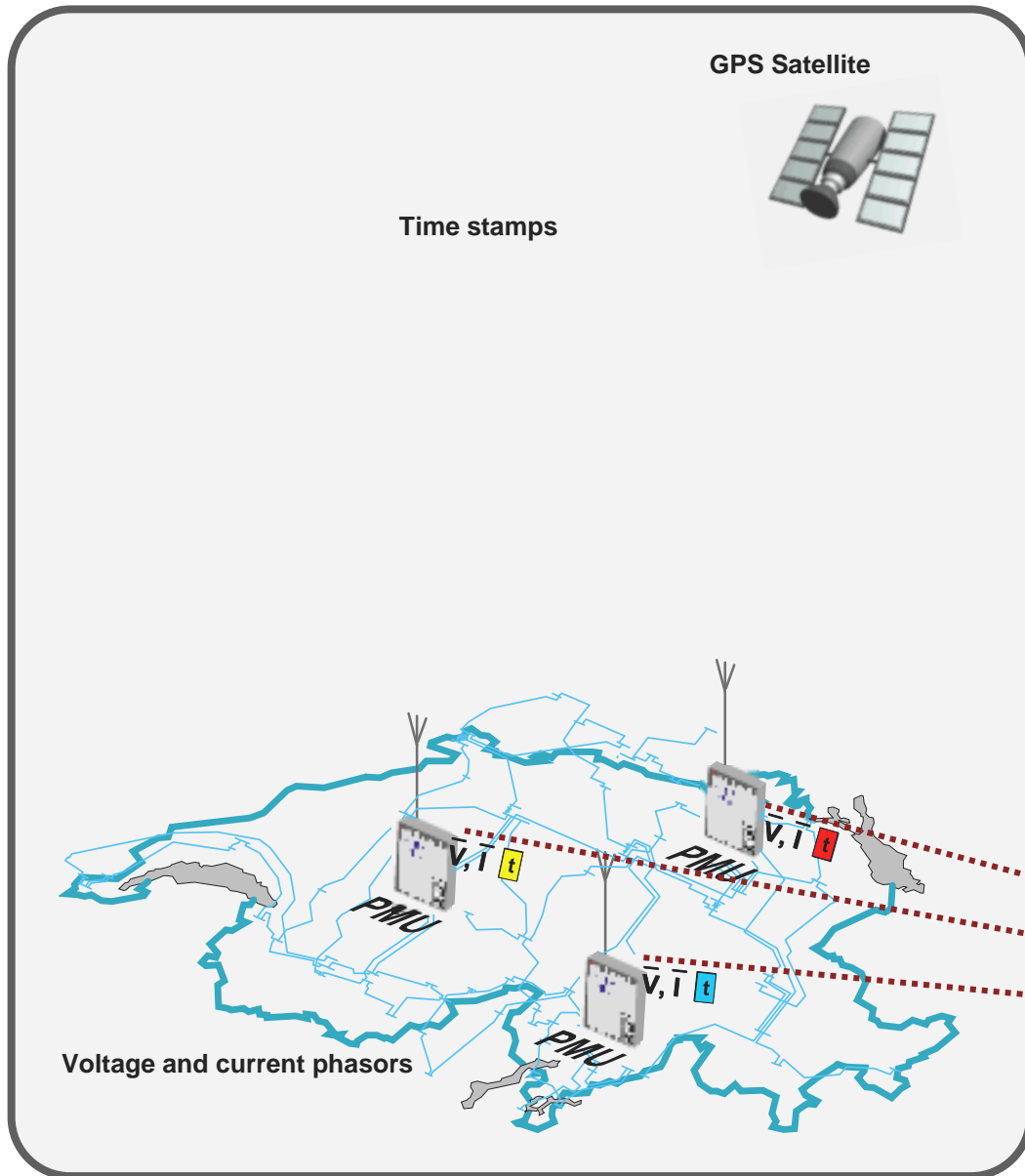


Wide-area Monitoring and Control

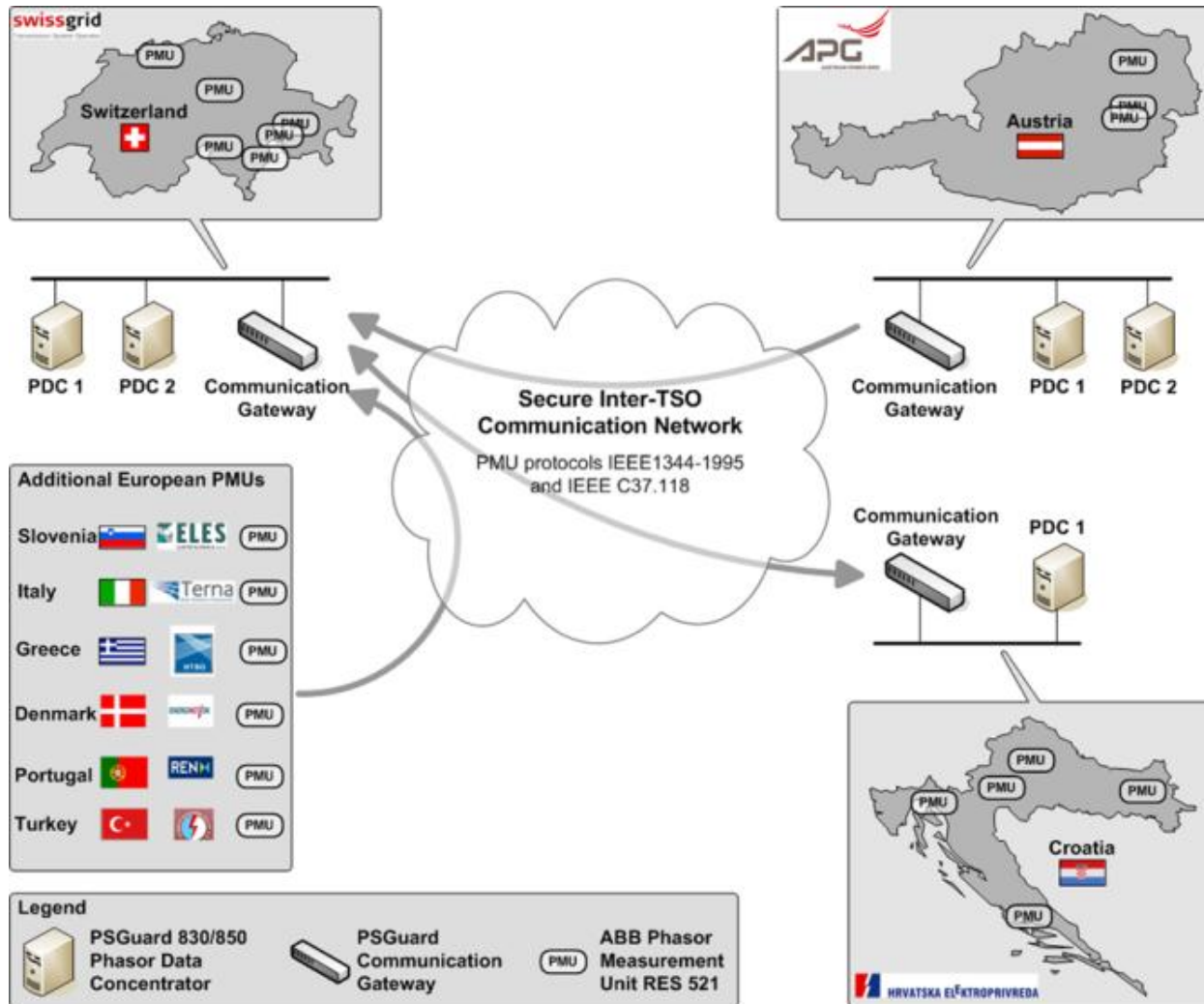
Positioning towards SCADA & local protection



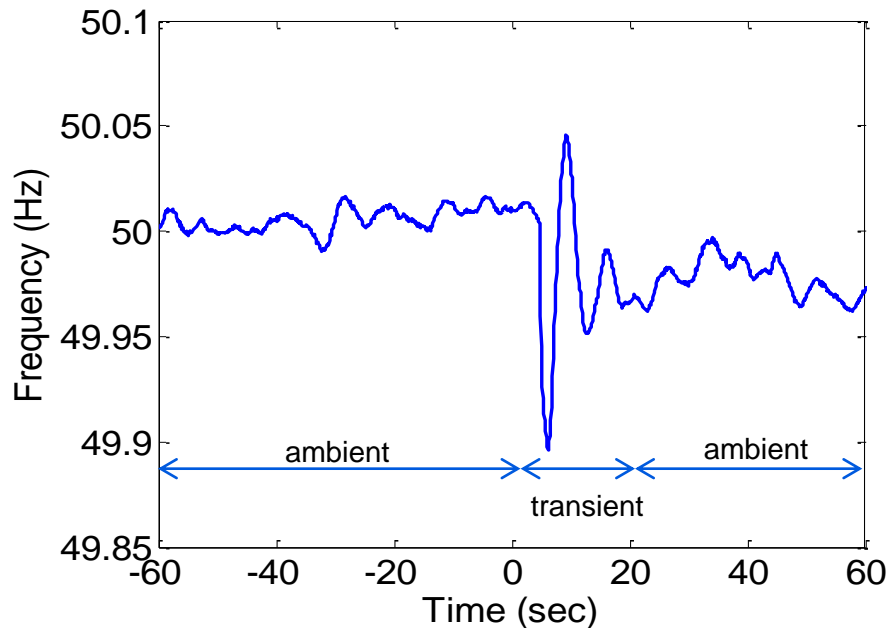
Wide-area Monitoring System (WAMS)



Europe wide WAMS at Swissgrid

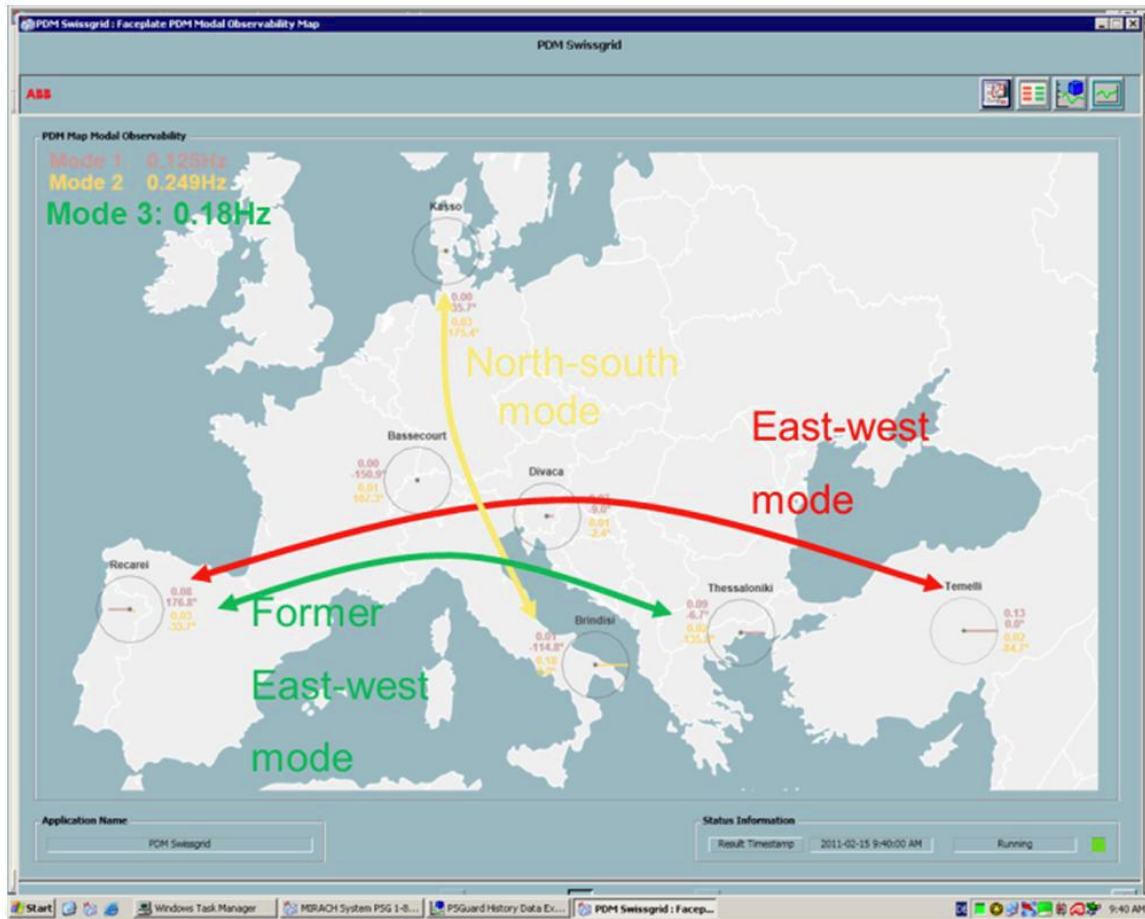


Monitoring Tools used at Swissgrid



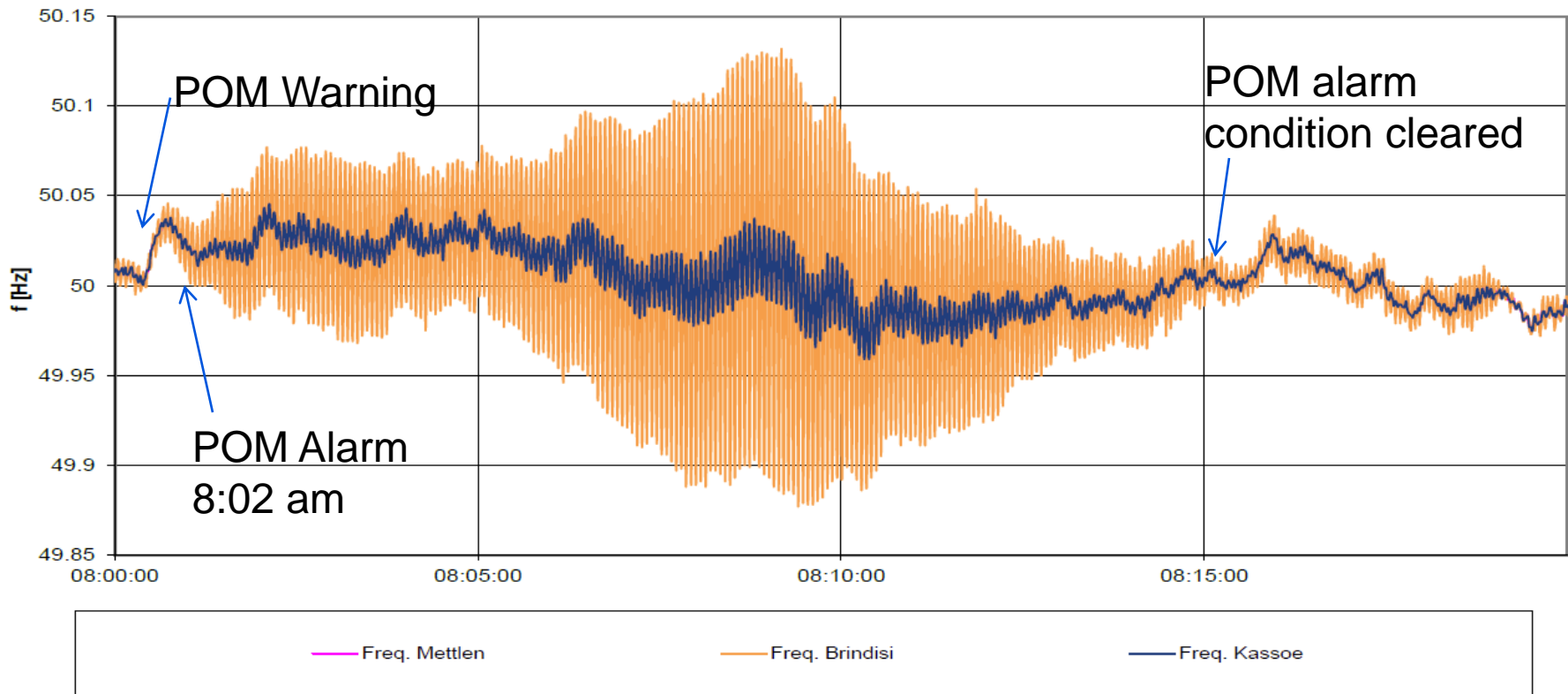
- Power Oscillation Monitor
 - Transient oscillations
 - In ABB PSGuard since 2003
 - Utilizing single measurements
 - Aggressively tuned for fast response and alarming
- Power Damping Monitor
 - Ambient oscillations
 - In ABB PSGuard since 2011
 - Utilizing multiple and system wide measurements
 - Tuned for stability and accuracy of damping and mode shape estimates
 - Long time window

Real-time Modal Analysis Ambient Conditions



- Mode discovery independently of off-line model
- Basis for:
 - Validation of PSS tuning
 - System stability early-warning system

Detection of Large Oscillations Case of 2011-02-19

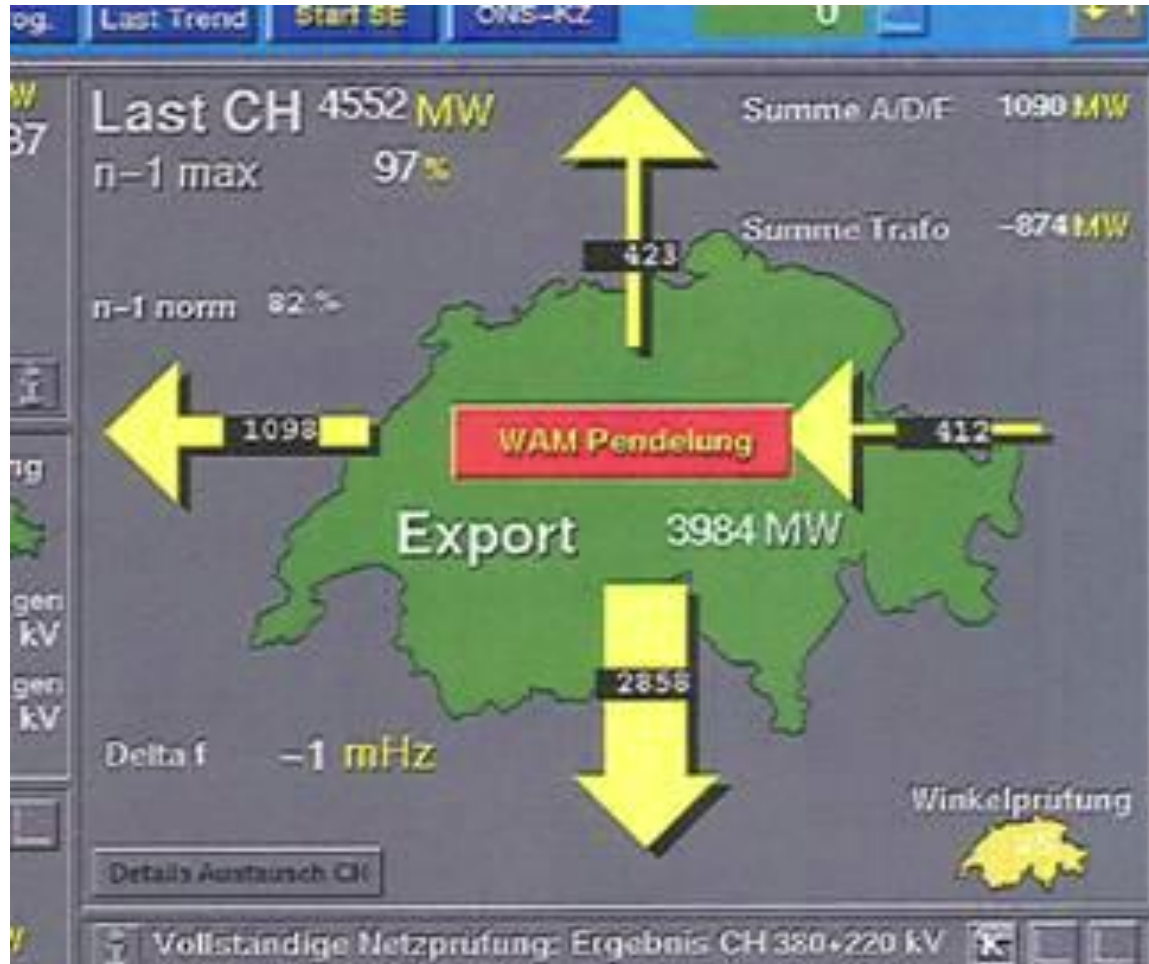


Reference:

https://www.entsoe.eu/fileadmin/user_upload/_library/publications/entsoe/RG_SOC_CE/Top7_110_913_CE_inter-area-oscil_feb_19th_24th_final.pdf

Detection of Large Oscillations

Swissgrid SCADA/EMS Wall Display



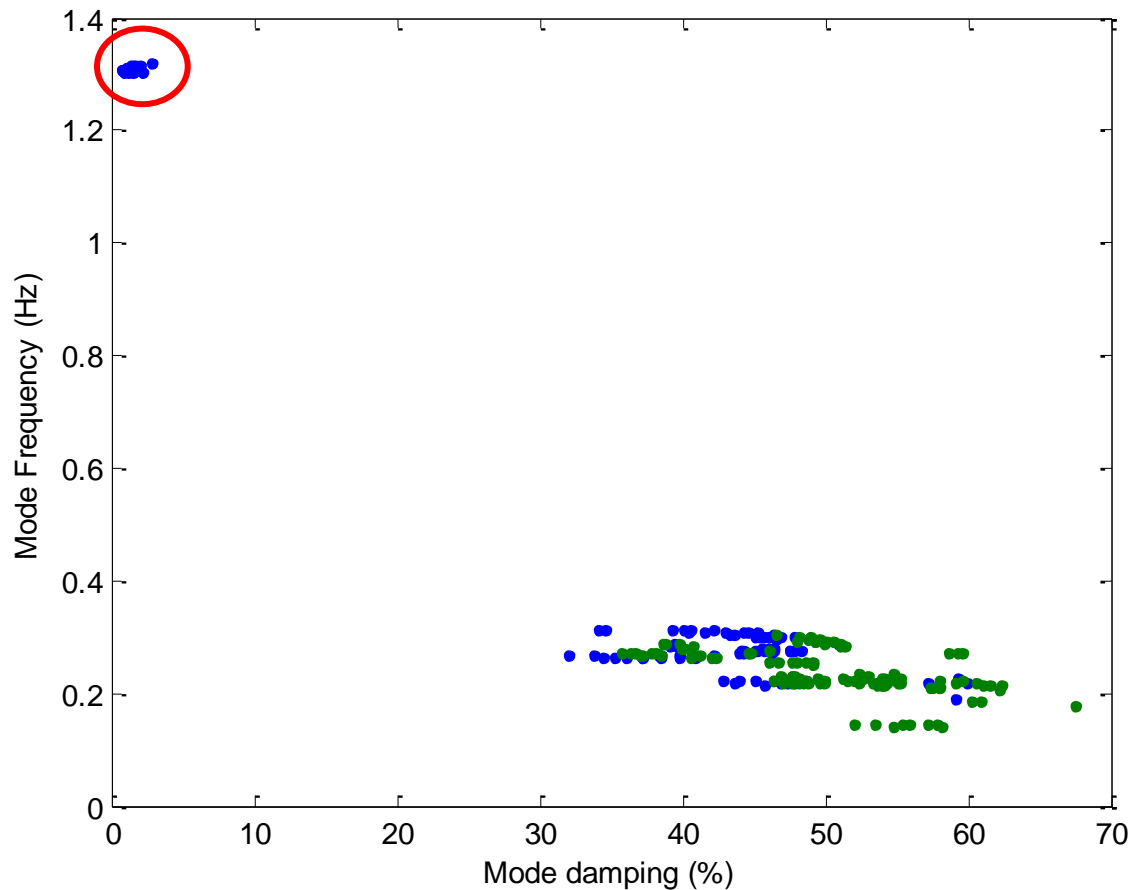
Conclusion

- Swissgrid and ABB have 10 years of joint experience of Modal Estimation tools in practice
- WAMS and Power Oscillation Monitoring Tools offer
 - Inter-area modes:
 - Early warning and alarming in the control room in case of oscillation events
 - Adequacy assessment and advice for improving stabilizer damping control
 - Local modes
 - Detection of poor dynamic behaviour of power plants
- Improved operator awareness of dynamic events

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for a better world™



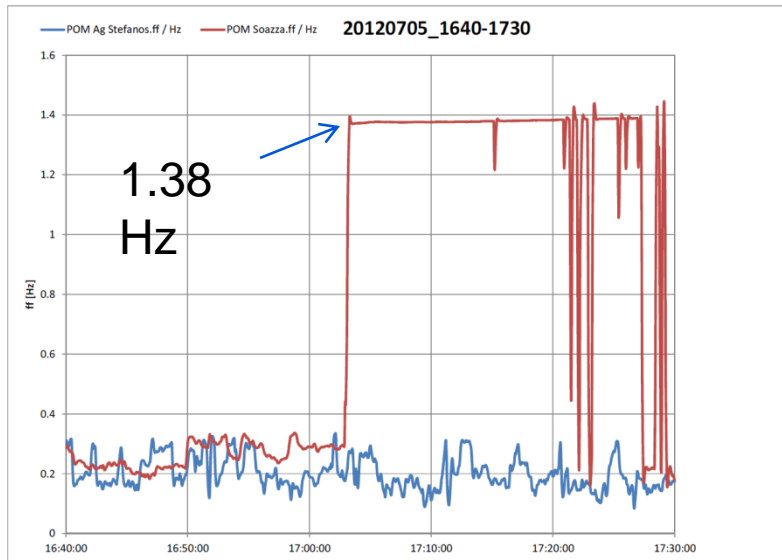
Power Damping Monitoring Response Case of 2012-07-05



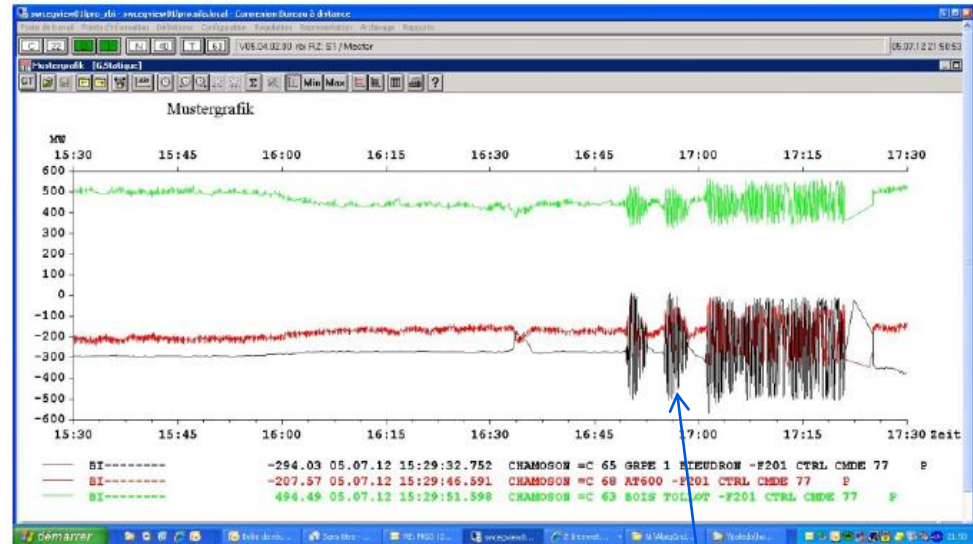
- Data for entire time window (16.30-17.30)

Use of POM for Discovery of New Modes

Case of 2012-07-05



WAM : POM Warning

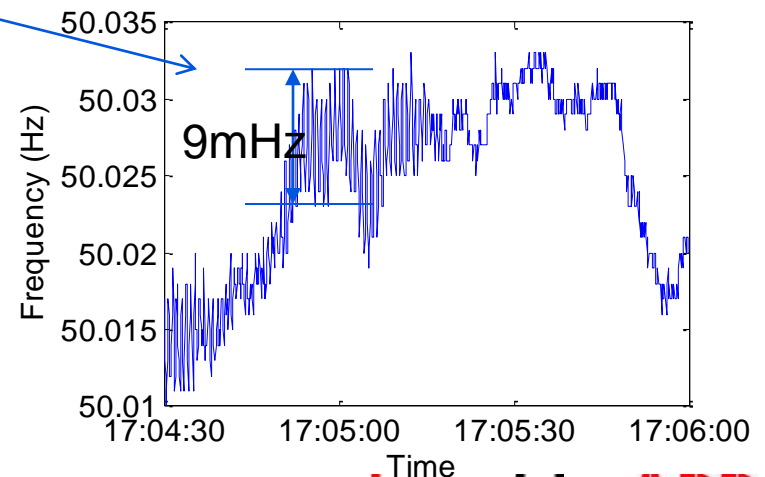
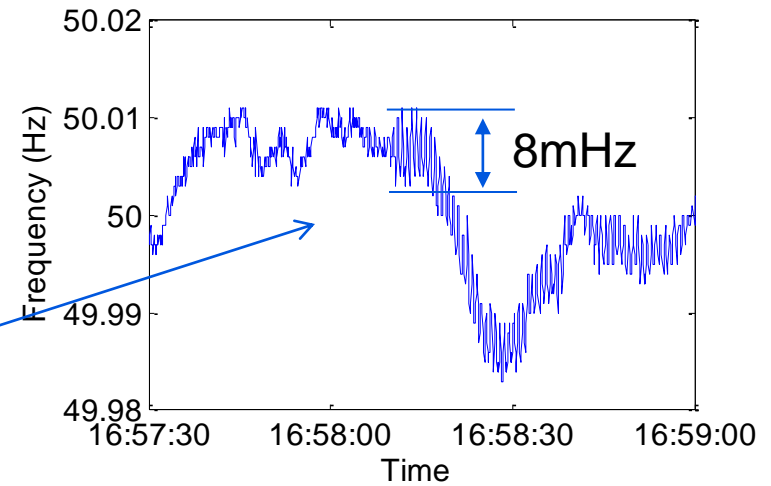
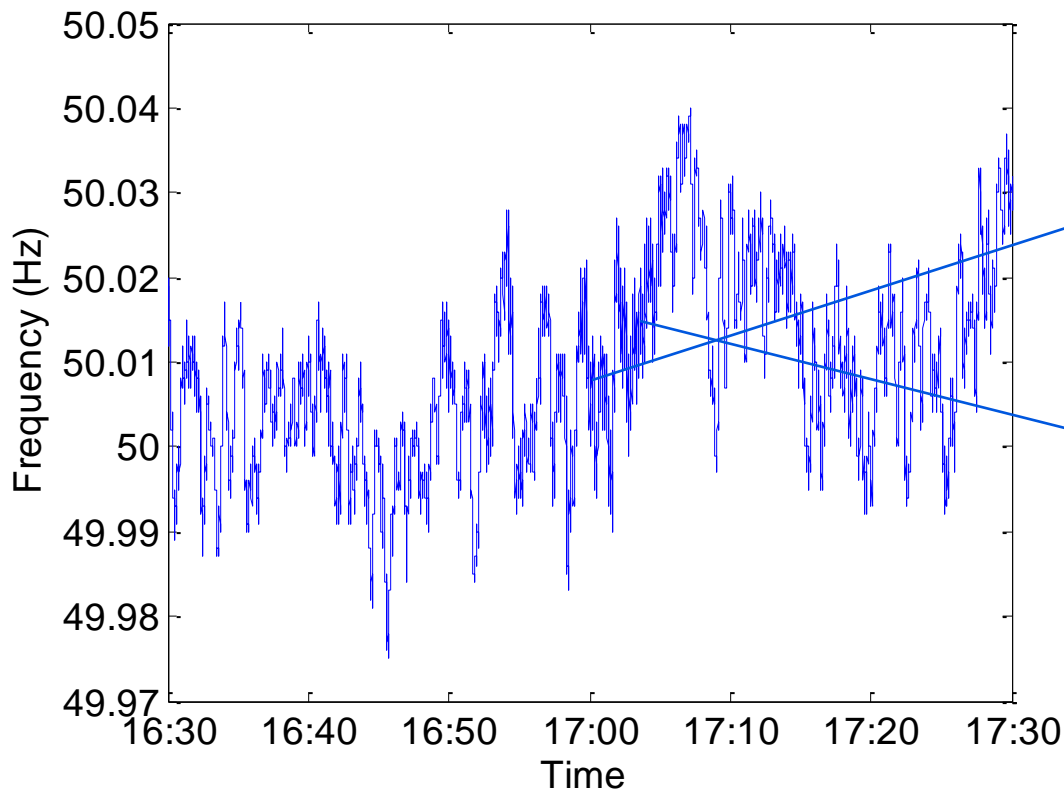


PP C M1: +/- 150 MW
Time: ca. 30 Minutes

Local plant mode 1.31 Hz

Raw Frequency Data

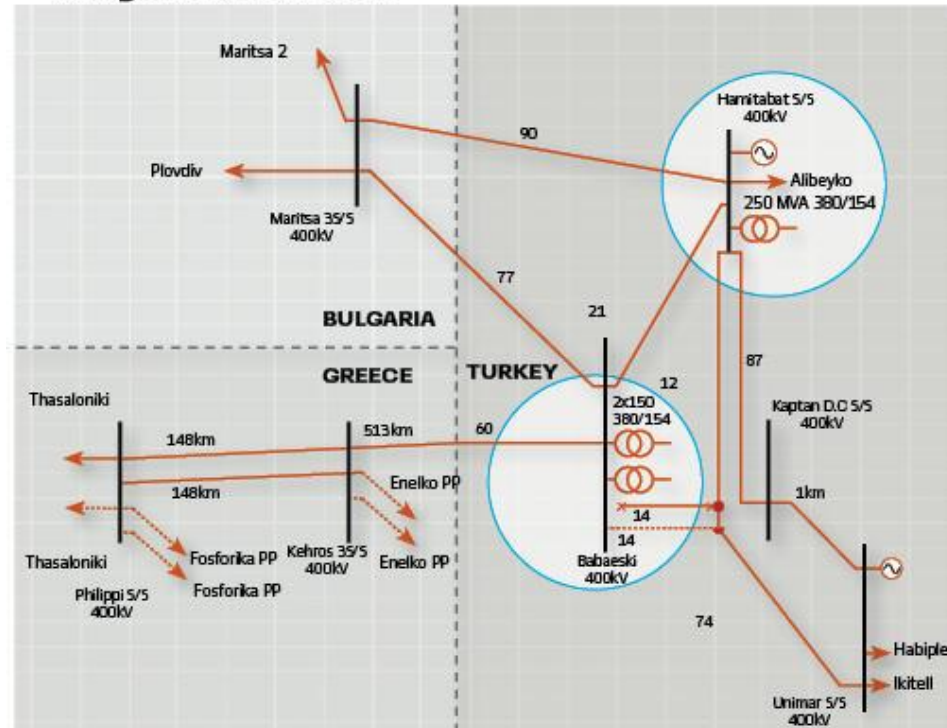
Case of 2012-07-05



Huge Generator Trip in Turkey

Case of 2011-10-25

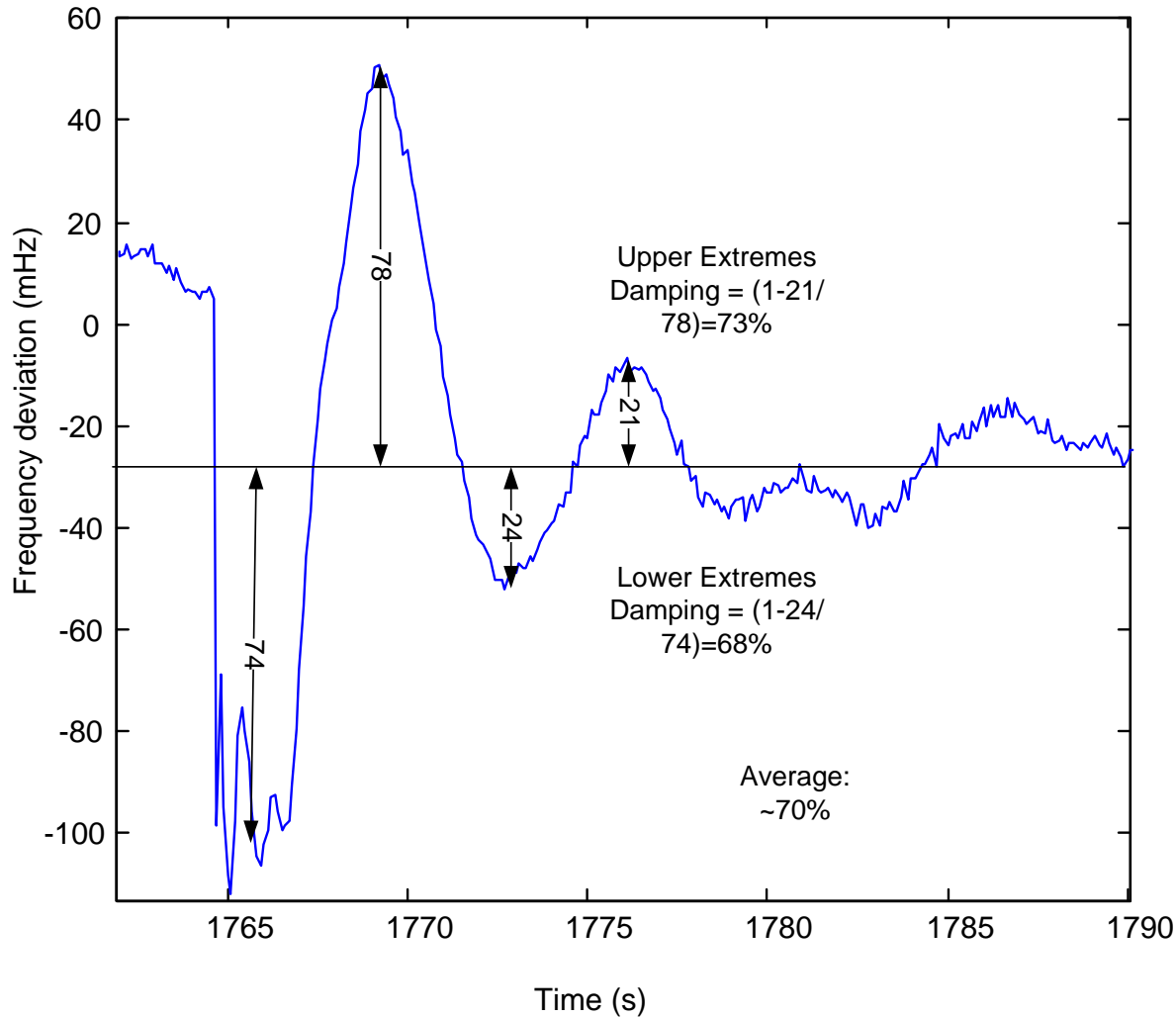
1 Interconnection lines with the 400kV grids of Bulgaria & Greece



- At 14.59, A busbar fault causes a power plant in Turkey to trip off the grid
- 1300 MW generation loss
- 270 MW of load is tripped nearby the plant by system protection scheme
- A well damped oscillation in the east-west direction follows
- Prior to the event PDM reported a damping of 60 %

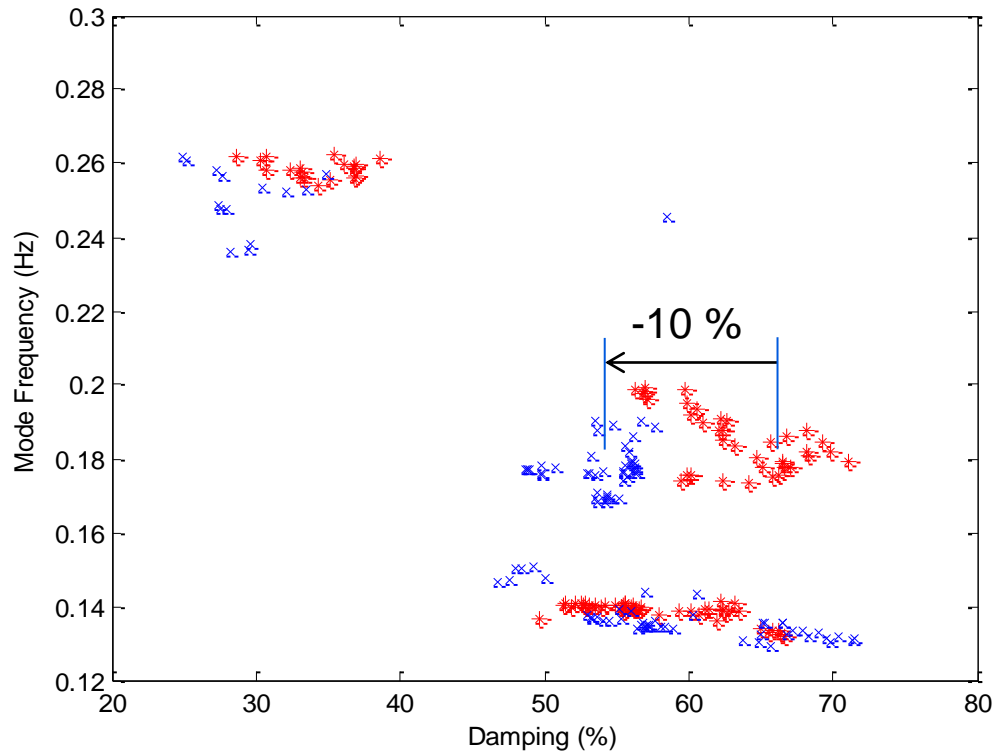
Source: PACWorld Magazine

Raw Data and Validation of Oscillation Damping Case of 2011-10-25



- Actual damping approximately 70 %

Power Damping Monitor (PDM) Output Case of 2011-10-25



- Before event (red) and After Event (blue)
- Trip of plant appears to have reduced damping of the old east-west mode with around 10%
- PDM reported around 60% damping of new east-west mode before disturbance