

A satellite view of Europe at night, showing city lights and the dark landmasses against the blue glow of the atmosphere and the starry night sky.

Stakeholders Workshop on System Operation Emergency – Defence Plan

Eckhard Grebe
Brussels 19 March 2012

Content

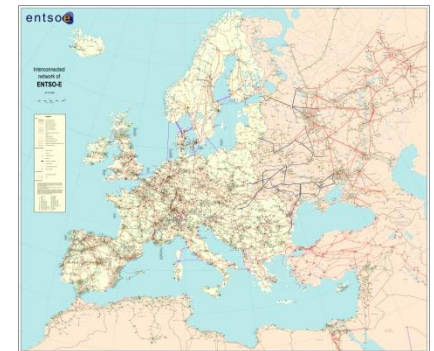
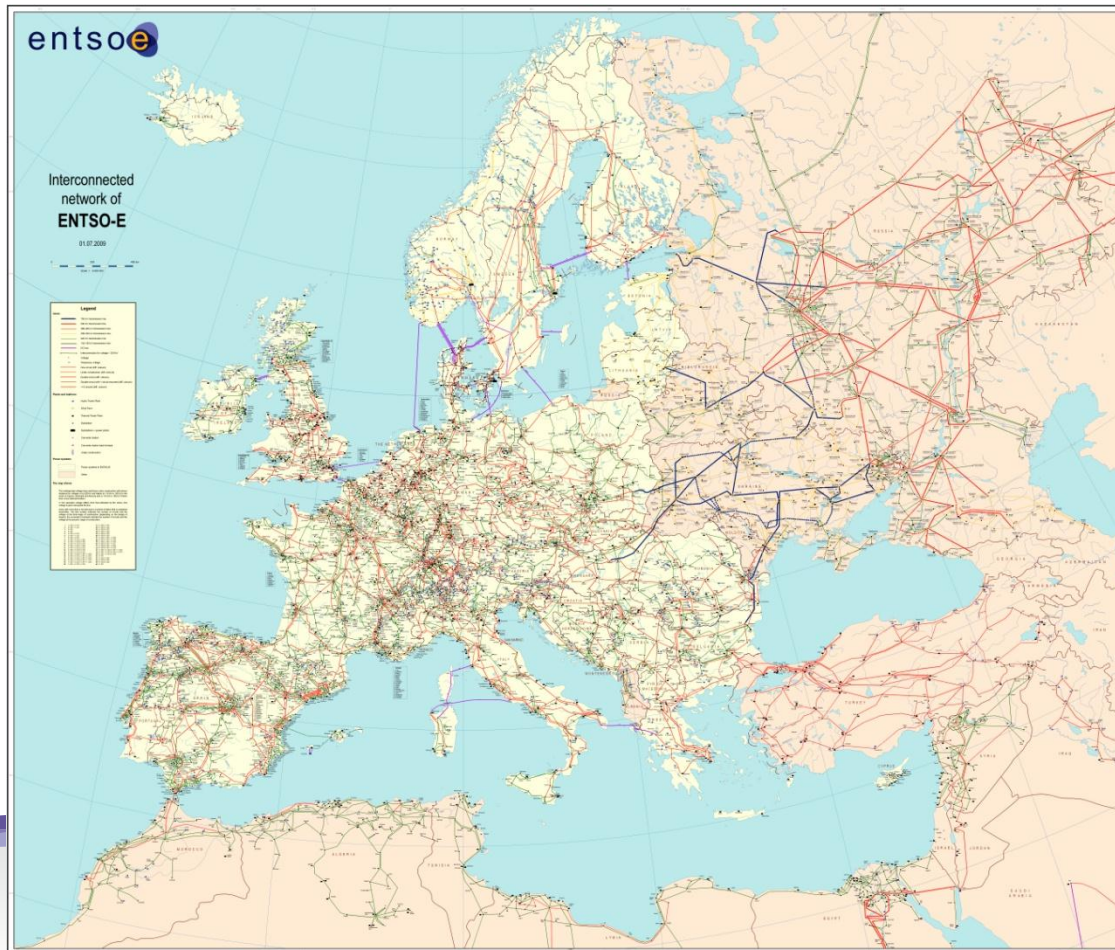


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- 3 Classification of stability problems and demonstration by incidents
- 4 Key functions of Defence plans and measures against the different classes of instability
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The Power System...

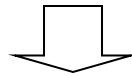


- **Forms a physical unit (power plants, grid, consumers)**



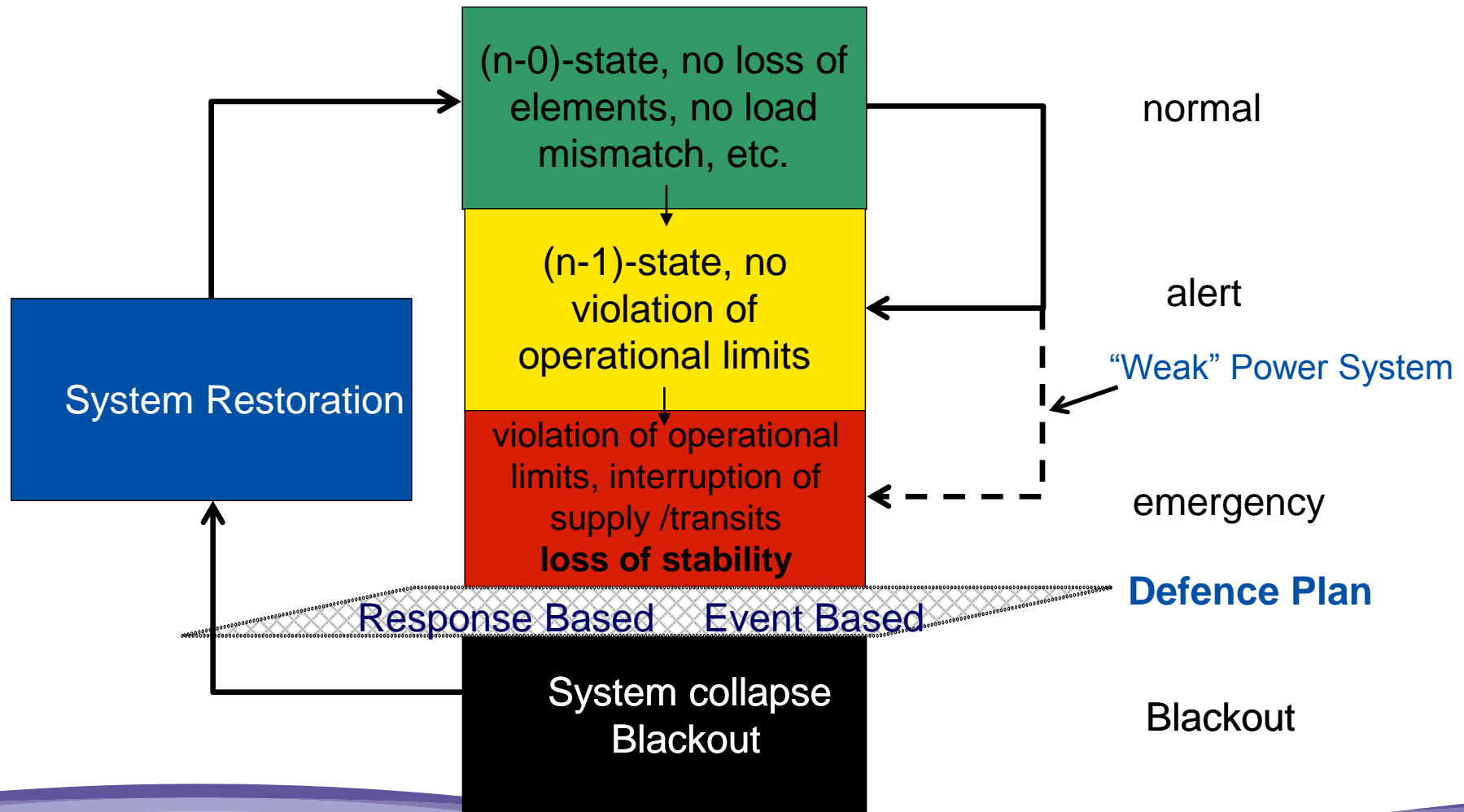
The Power System...

- Forms the backbone of the electrical energy supply
- Blackouts (could) have enormous economical and socio-political consequences
 - *Production downtimes*
 - *Failure of critical infrastructure*
 - *Threat to social welfare*
 - ...

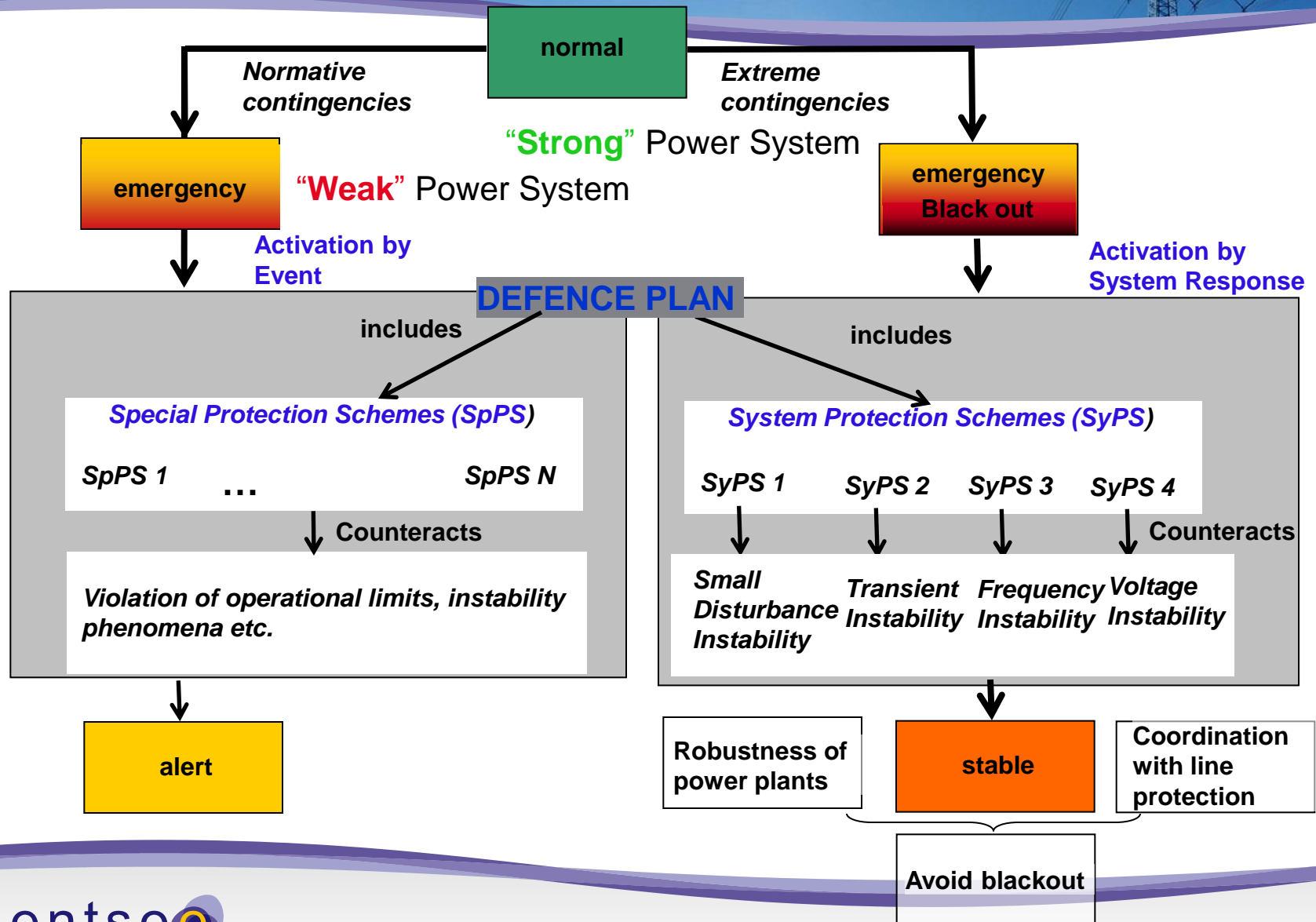


Justification for Defence Plans and
Emergency Procedures

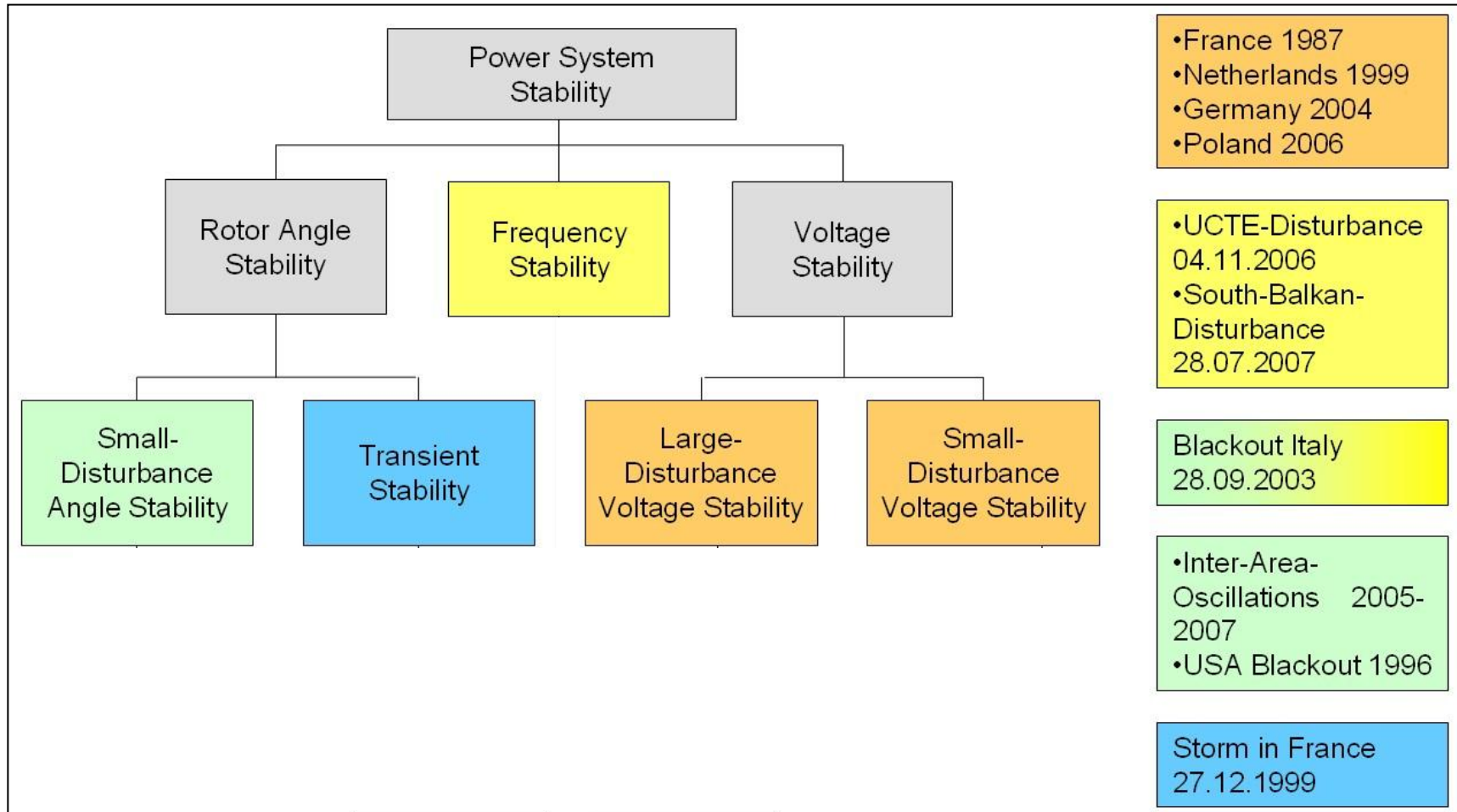
Defence plans in the context of system states



Classification of Terminology

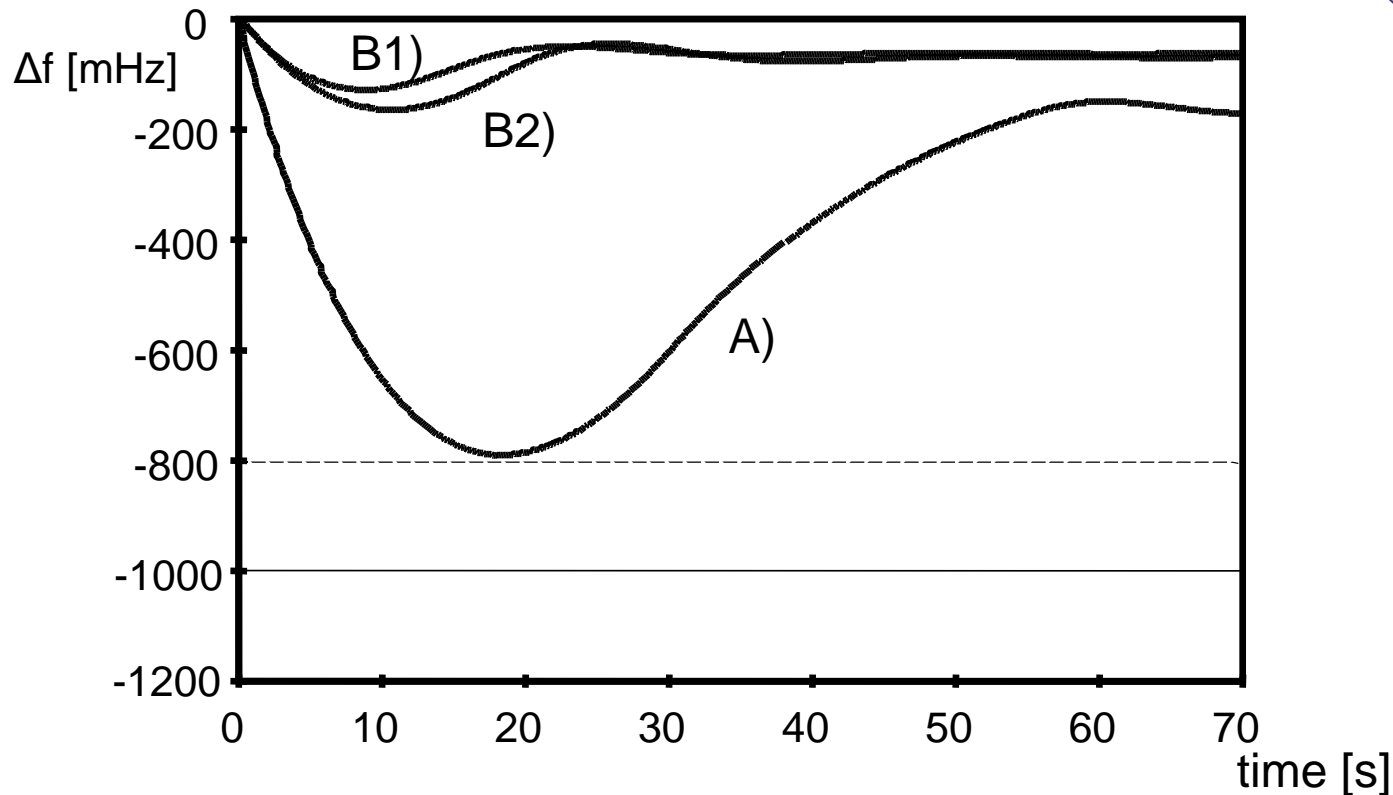


Loss of Power System Stability causes Blackouts...



Primary Control Behaviour

Region
Continental Europe



A) Base case: $\Delta P = 3000$ MW, $P_{\text{SYS}} = 150$ GW

Load characteristic: 1% / Hz

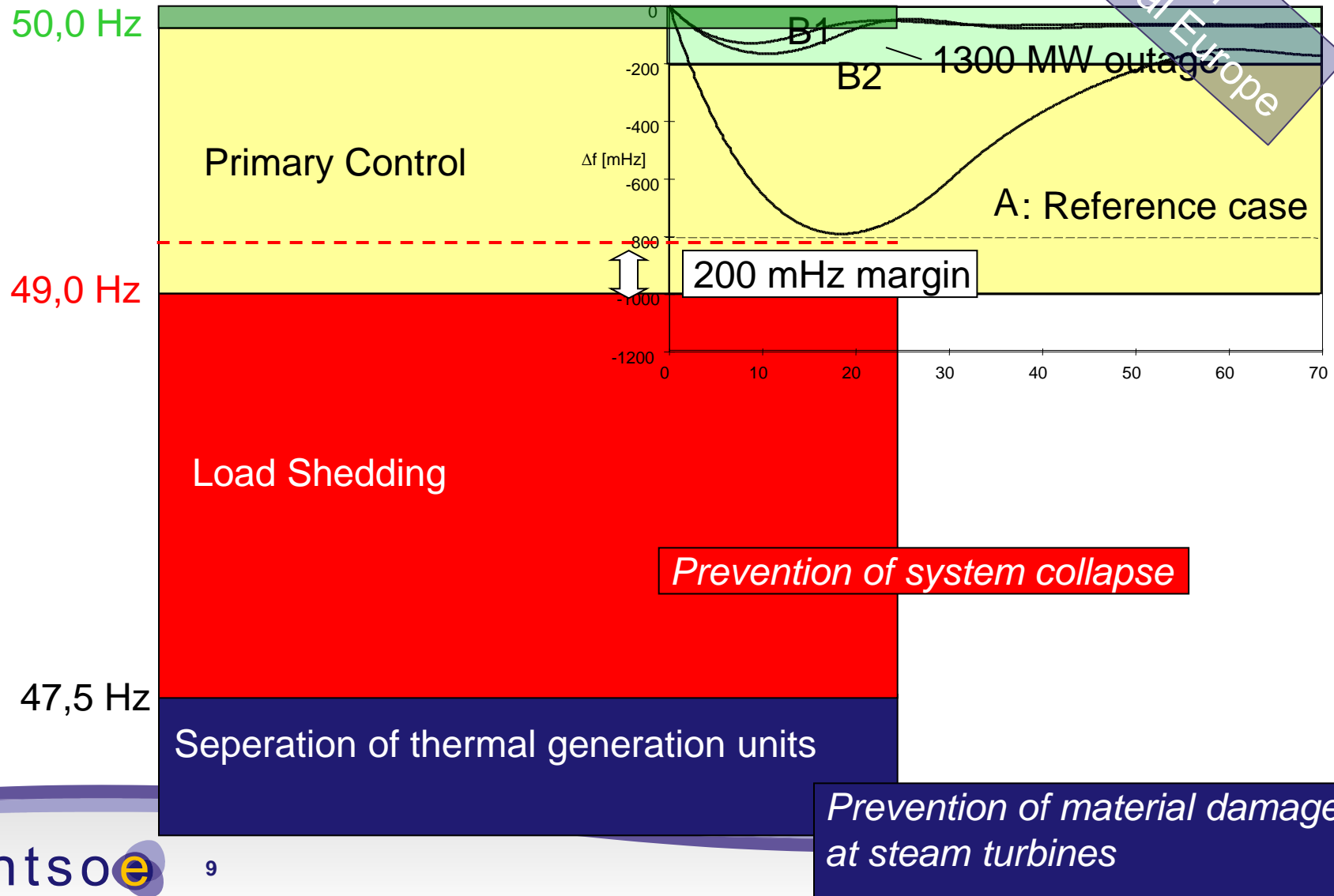
B) Typical generation loss: $\Delta P = 1300$ MW, $P_{\text{sys}} = 200$ GW

B1) Load characteristic: 2% / Hz

B2) Load characteristic : 1% / Hz

Operating ranges of the frequency

Region
Continental Europe



Operating ranges of the frequency

Region
Continental Europe

50,0 Hz

49,5 Hz

49,0 Hz

47,5 Hz

Primary Control

Load Shedding

Seperation of thermal generation units

option: disconnection of
pumps

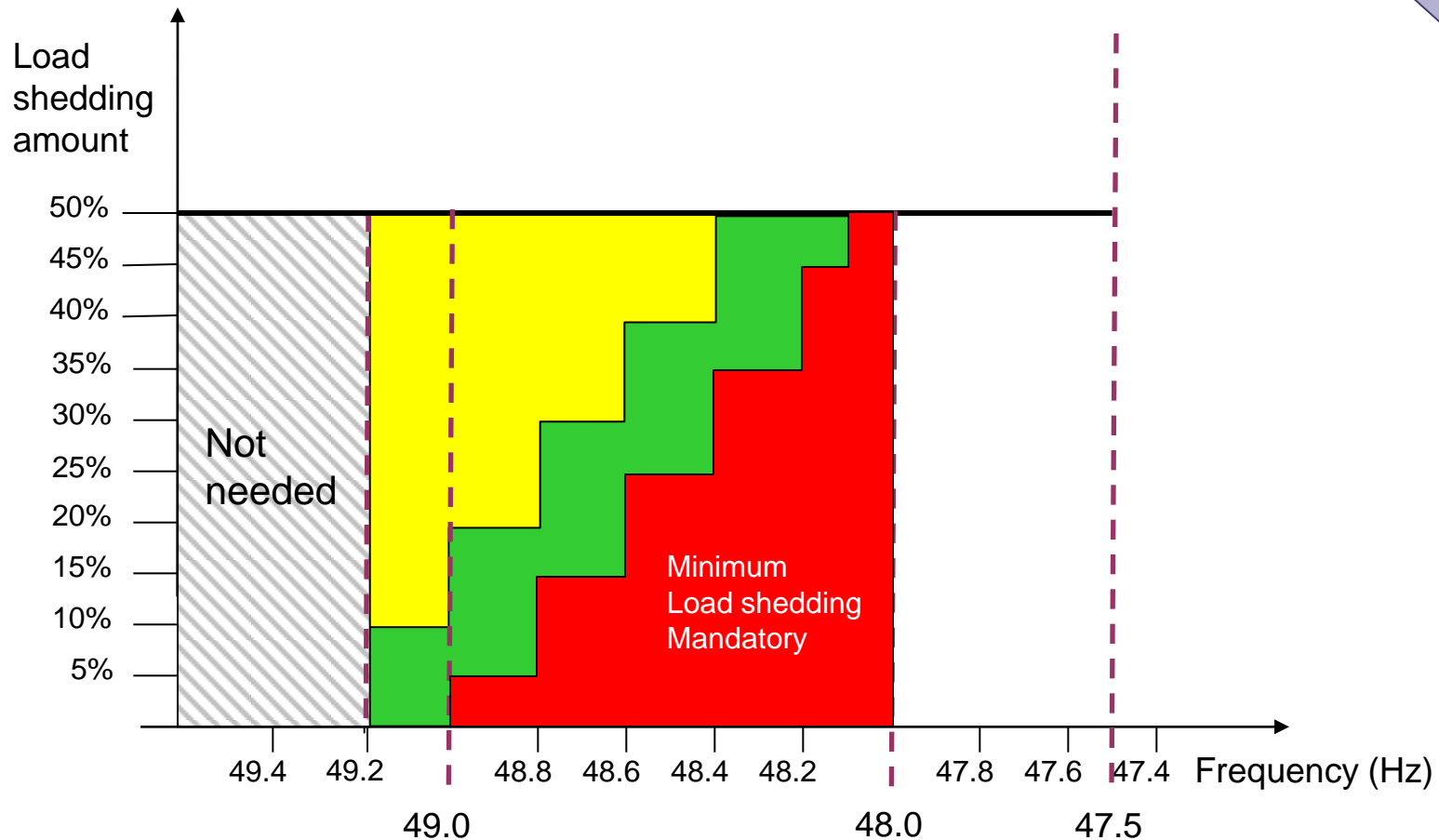
load shedding acceptable

Prevention of system collapse

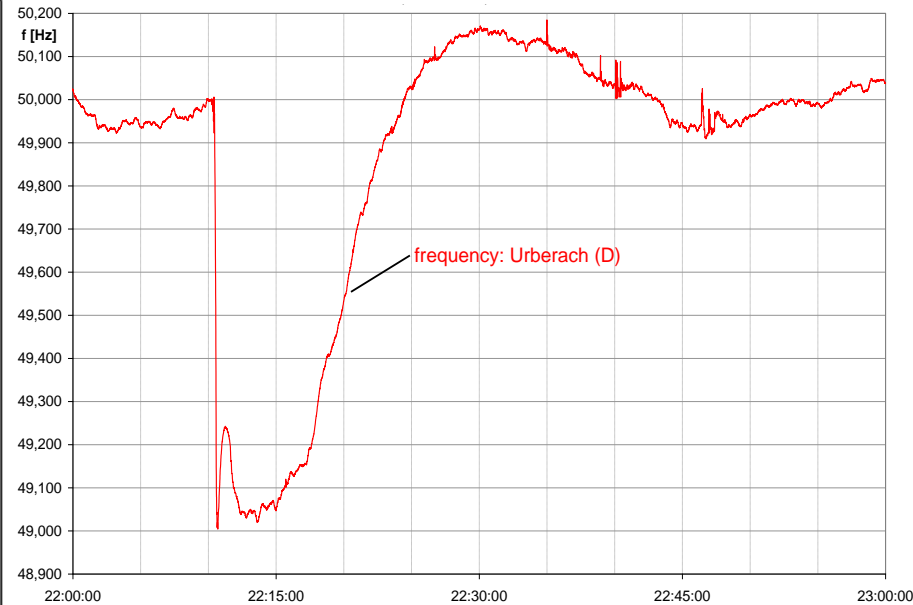
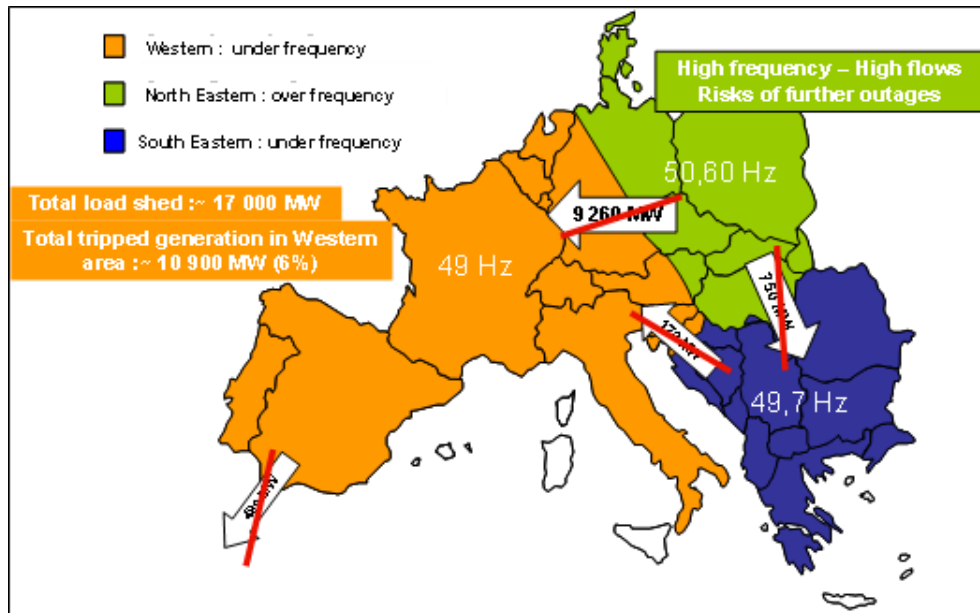
*Prevention of material damage
at steam turbines*

Recommendations for load shedding schemes to be implemented on DSO level

Region
Continental Europe

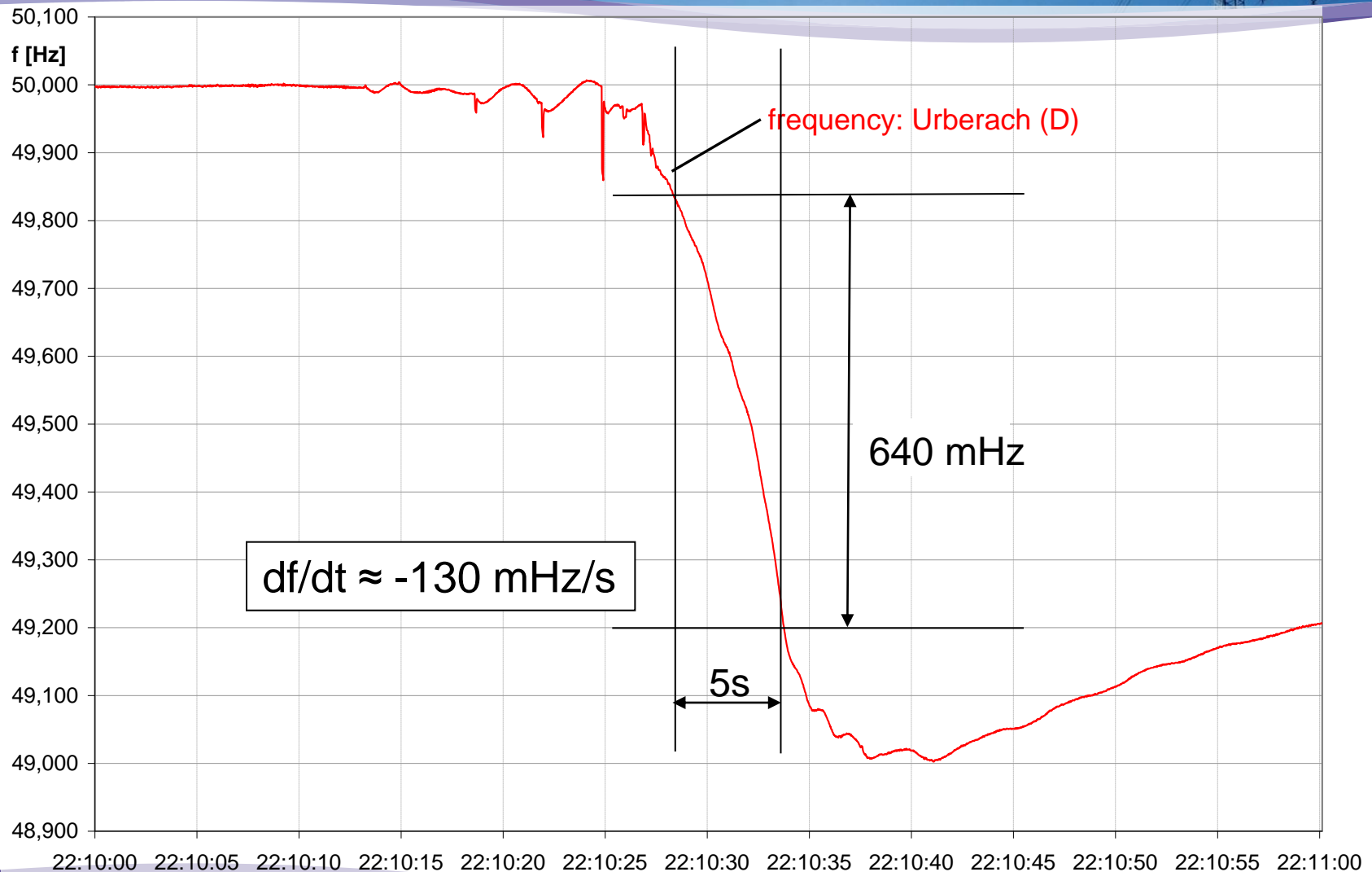


UCTE – Disturbance on 4 November 2006



System Collapse and Blackout were prevented by Under-Frequency Load Shedding (UFLS)

UCTE – Disturbance on 4 November 2006

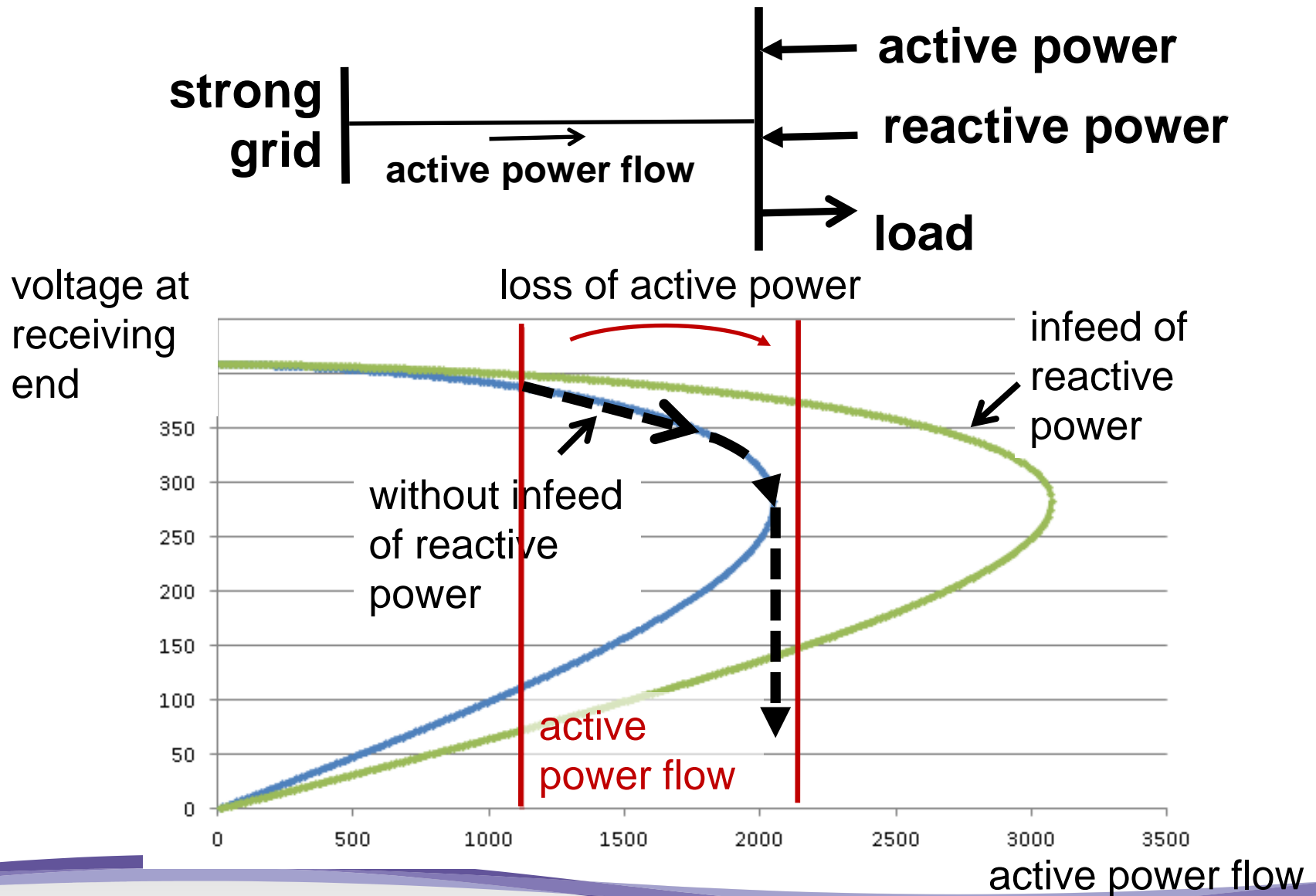


Loss of Voltage Stability

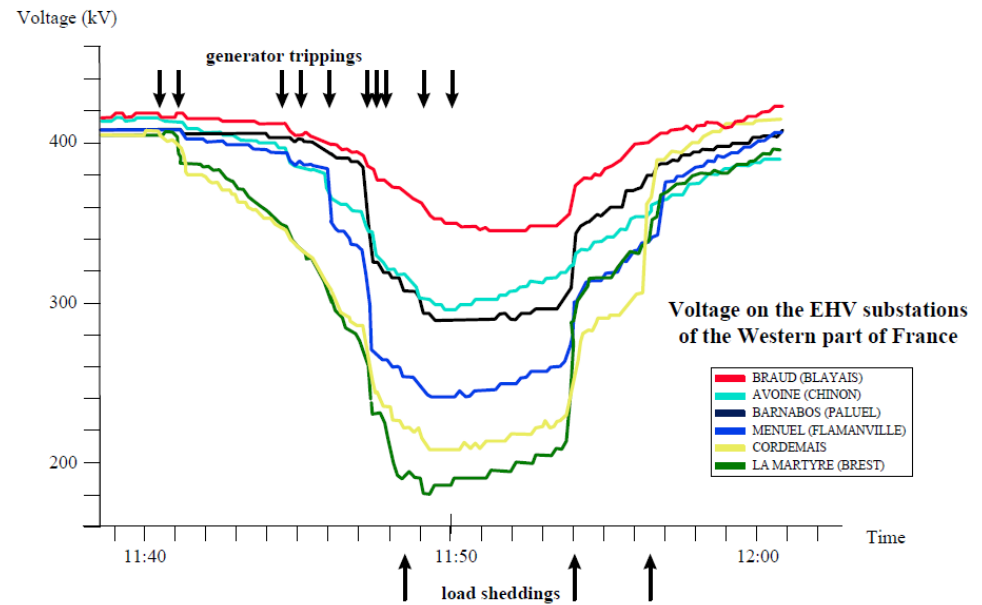
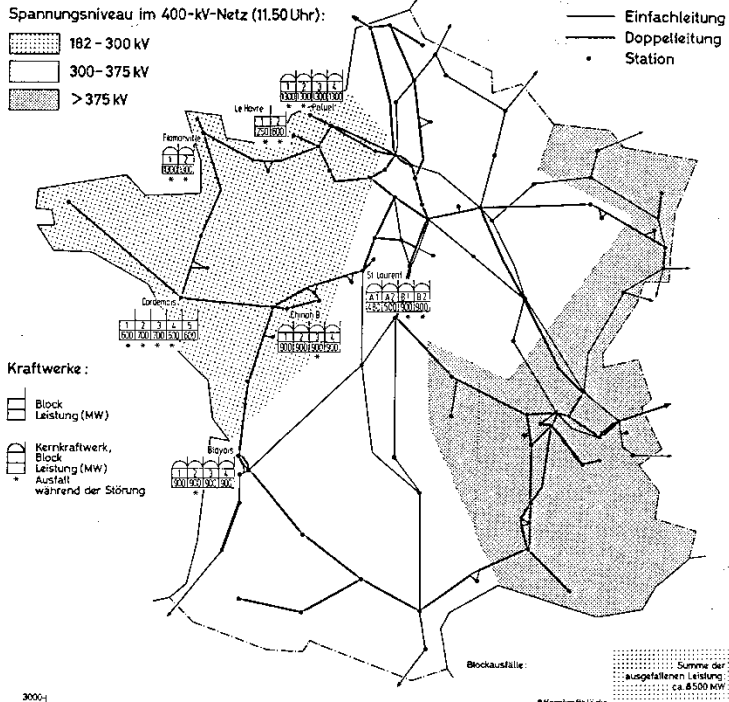


Attempt of load dynamics to restore power consumption beyond the capability of the combined transmission and generation system

The Nose Curve of Transmission Corridor



Voltage Collapse, France , 12th January 1987



Voltage vs. Time for some French EHV substations during the collapse

Defence Plan against Loss of Voltage Stability

- **Blocking of On Load Tap Changing (OLTC)**
 - **Under-Voltage Load Shedding (UVLS)**
- **To be implemented on DSO Level**

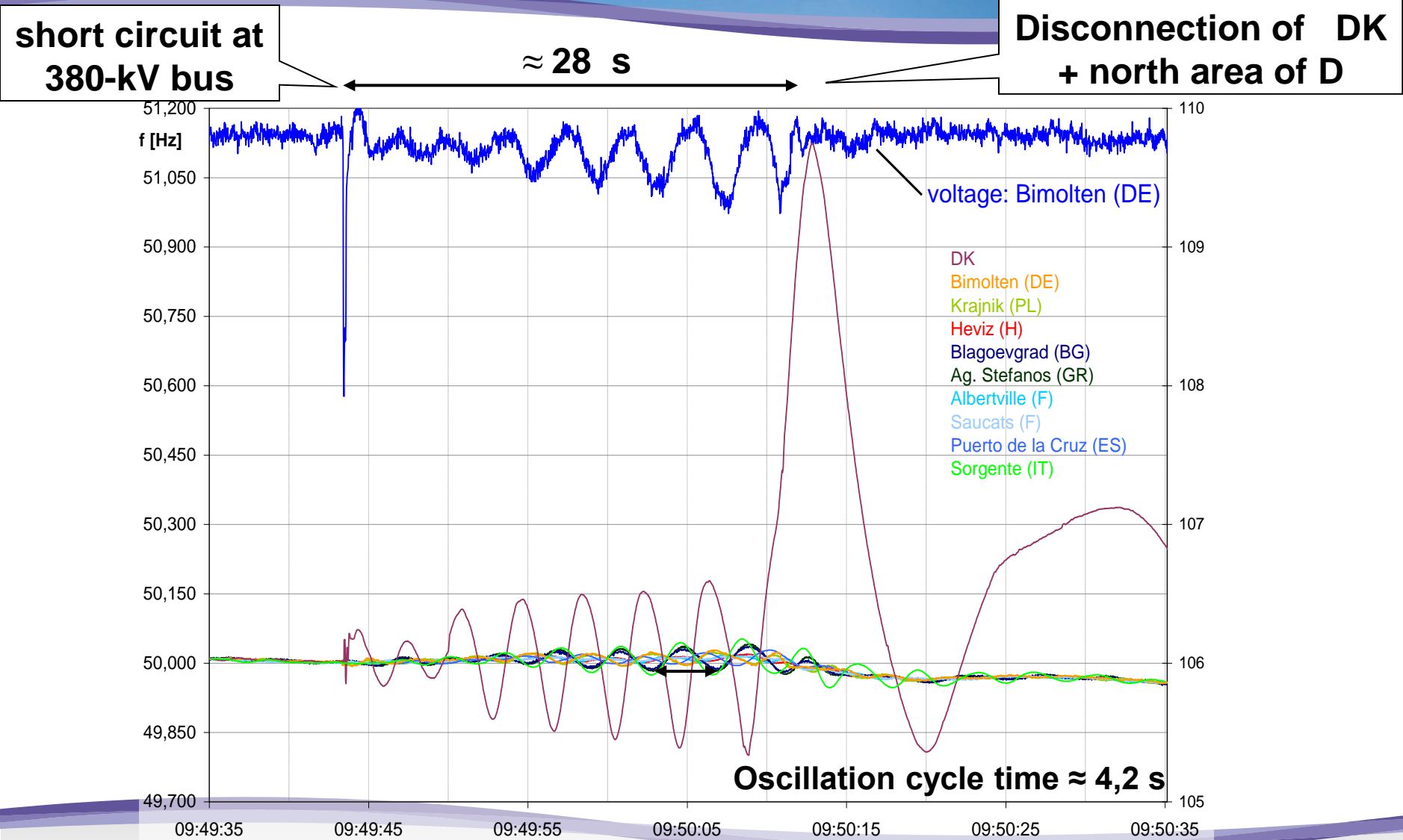
Loss of Oscillatory Stability 2007-05-29; 09:49

sequence of events:

1. double busbar failure in 380 kV substation Wilster at 09:49:43 h
2. disconnection of all 380 kV lines in substation Wilster
 - DK + area north of Hamburg connected by remaining two 220-kV-lines
3. +28 sec.:
 - tripping of remaining two 220kV-lines
 - loss of power import (≈1500MW)
4. +59 sec:
 - Baltic cable tripped by emergency protection control
5. + 5 min.:
 - resynchronisation via 380 kV lines



The islanding of Denmark prevented cascading effects



Defence Plan against Loss of Angle Stability

- **Natural function of line protection
(distance relay – depending on settings)**
 - **Out of Step Protection**
- **To be implemented on TSO level**

Conclusion

- The function of the Power System is of enormous importance for the economy and social welfare.
- TSOs are responsible for the system security and have to manage also rare and extreme contingencies which involve loss of stability.
- Defence Plans include last resort measures to contain extreme contingencies and to avoid uncontrolled propagation of disturbances.
- In a “robust” power system the course of events leading to the loss of stability is not/hardly predictable. Therefore Defence Plans should preferably be decentralized and response based.
- Avoiding blackouts needs
 - Defence Plans mainly to be implemented at DSO level and
 - generation units, which are able to
 - control voltage and frequency
 - withstand unusual voltage and frequency variations

Reference

“Technical Background and Recommendations for Defence Plans in the Continental Europe Synchronous Area”, Sub Group “System Protection and Dynamic”, Regional Group Continental Europe, 31.01.2011.

<https://www.entsoe.eu/resources/publications/system-operations/>

Thank you for your attention!



Reliable Sustainable Connected



Back up

Frequency behaviour after large power deficit

$$\frac{df}{dt} = \frac{f_n \Delta P / P_n}{2 H}$$

System Inertia $H = 5 s$

$\Delta P = 20 \%$

$$\frac{df}{dt} = \frac{50 \text{ Hz} \cdot 0,2}{10 s} = 1 \text{ Hz} / s$$

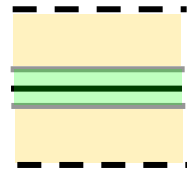
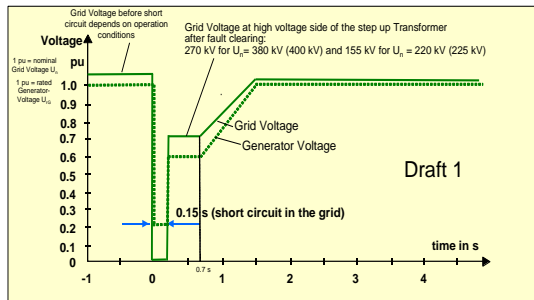
- the frequency decreases
49 Hz after 1 s
48 Hz after 2 s (without load shedding)

Incidents in Region Continental Europe

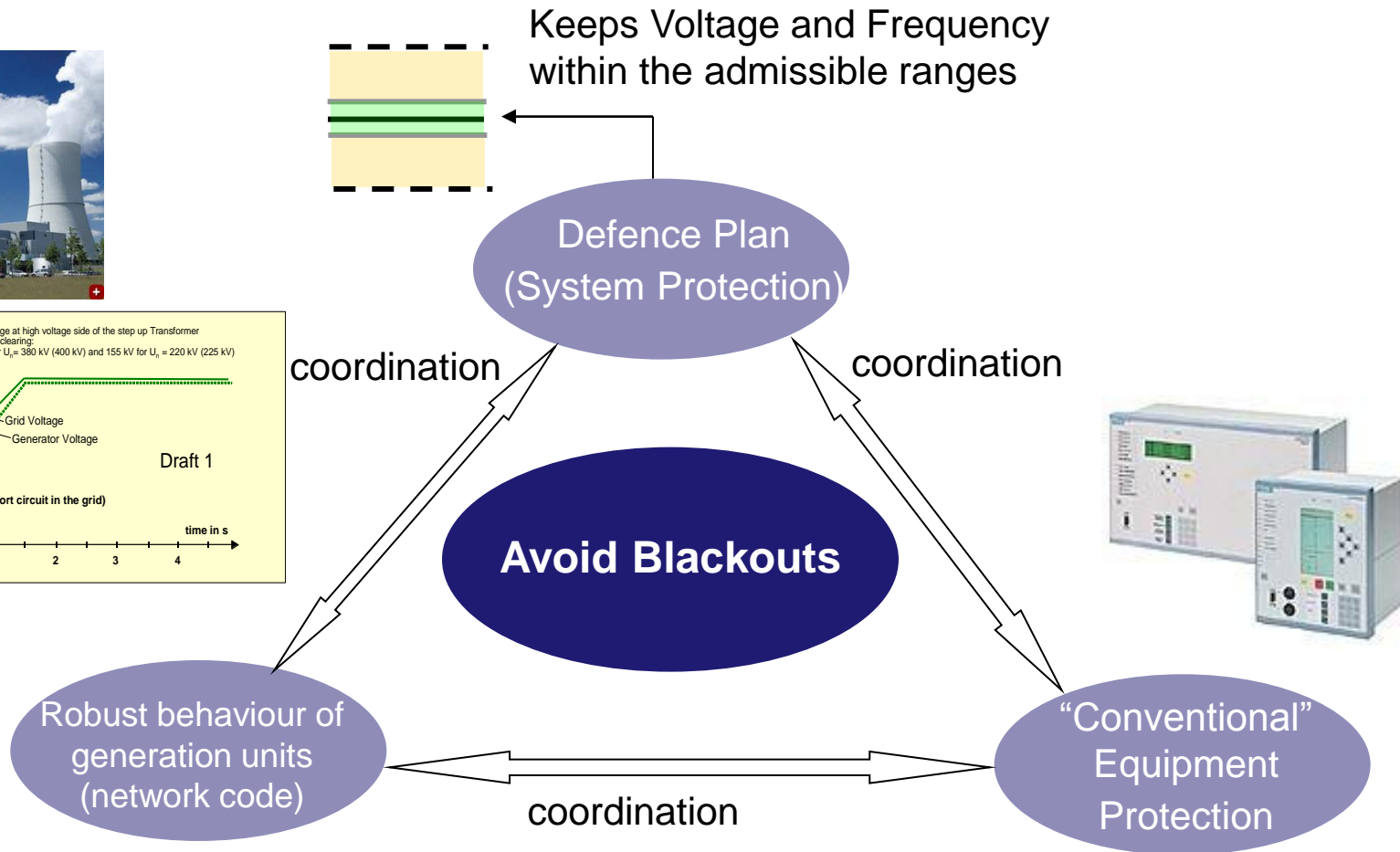
Successful prevention of system collapse by load shedding

- 4N event 2006 -> 130 mHz/s
- Kosovo, 24th July 2007 -> 300 mHz/s

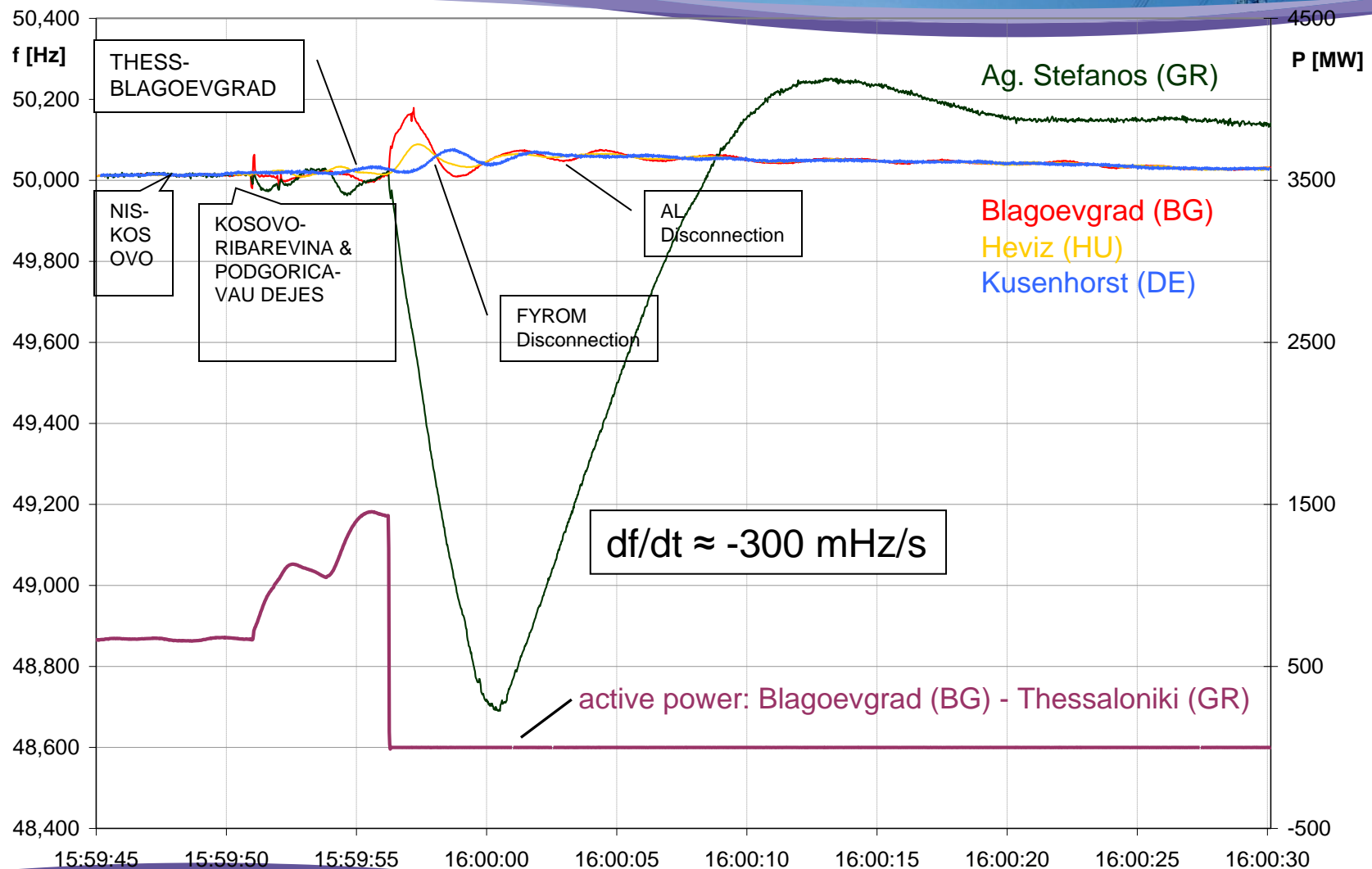
The implementation of Defence Plans needs coordination...



Keeps Voltage and Frequency within the admissible ranges



Kosovo disturbance on 24 July 2007



Loss of Angle Stability: Blackout Italy 2003

