Why has it happened again?
UCTE blackout of 4 November 2006

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Outline

- It happened before: reminder of US/Canada and Italy blackouts of 2003 and lessons learned (or not)
- Overview of UCTE blackout of 4/11/06
- Comparison with the blackouts of 2003 (US/Canada, Italy)
- Common underlying causes
- Conclusions

I’ve told you so!

Fragment of CMI presentation in December 2003

Recent blackouts in US/Canada, UK and Europe: Is liberalisation to blame?

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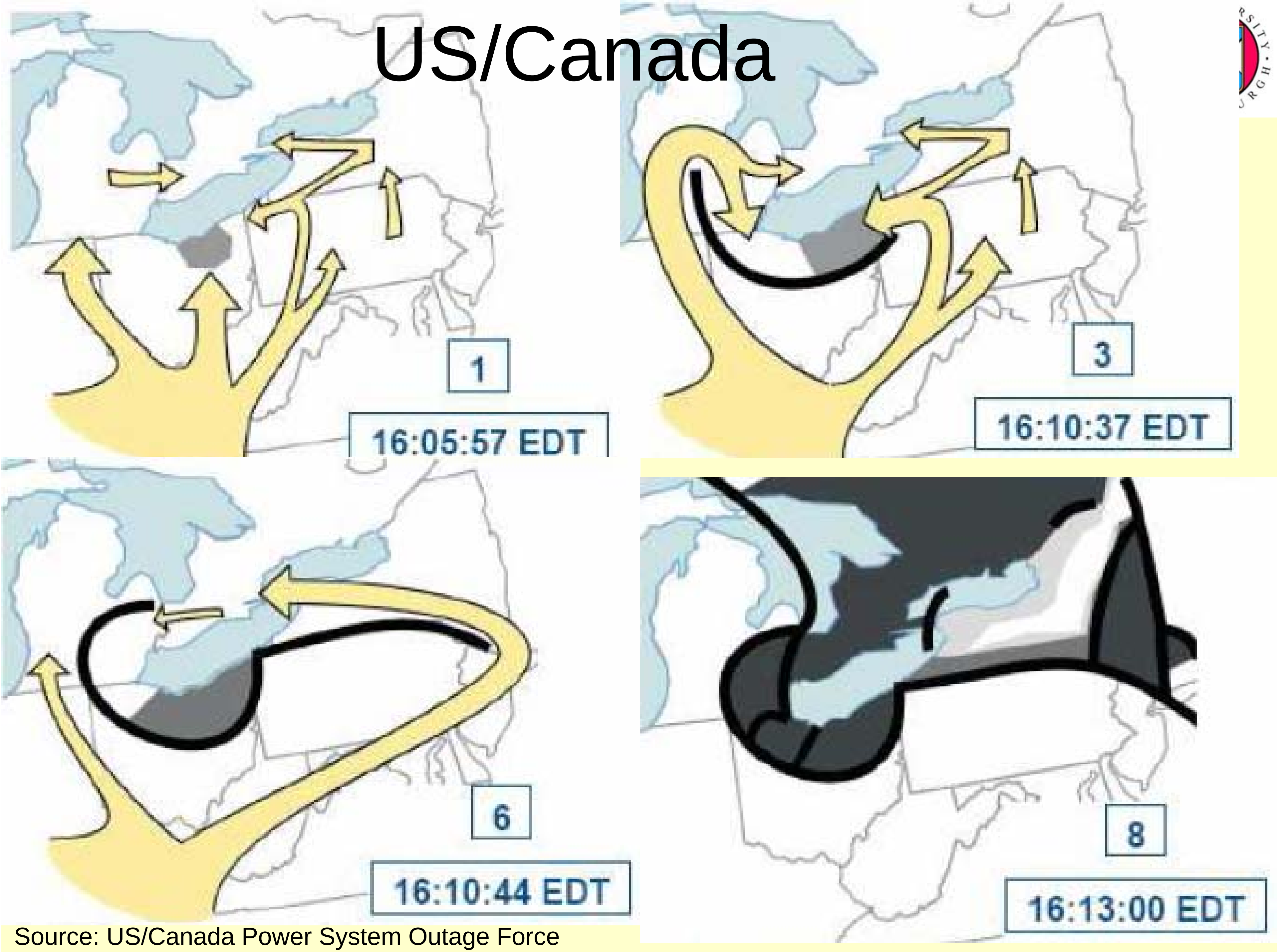
Major transmission failures in late summer/autumn 2003

- 7 blackouts affecting 112 million people in 5 countries
- **14 August 2003, USA/Canada**
- 23 August 2003, Helsinki
- 28 August 2003, south London
- 5 September 2003, east Birmingham
- 23 September 2003, Sweden and Denmark
- **28 September 2003, whole Italy except Sardinia**
- 22 October 2003, Cheltenham and Gloucester

2003 blackouts

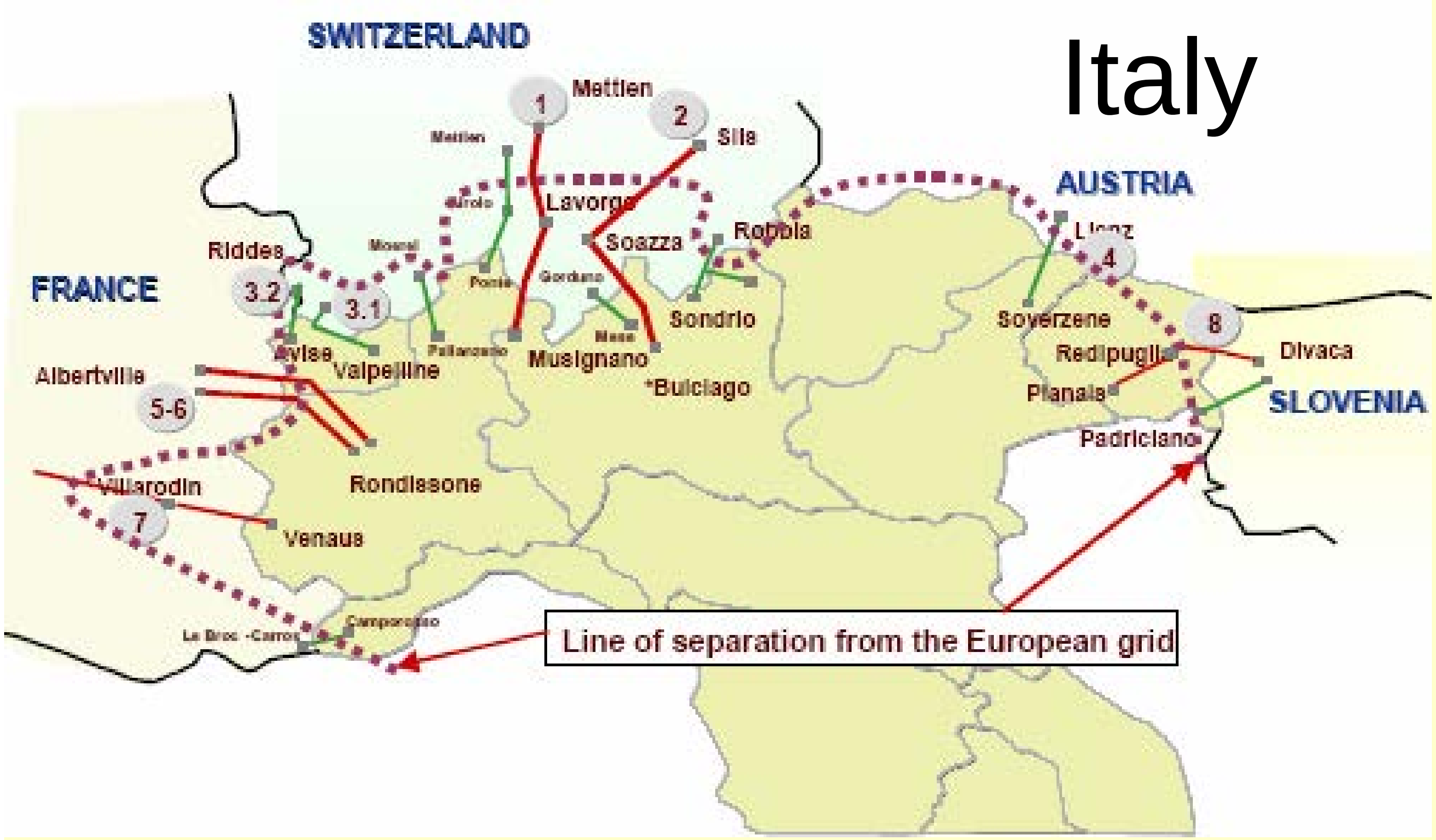
- All blackouts were transmission-based
- No problem with generation adequacy
- Systems were not stressed prior to blackouts
- Disturbances may always happen but why a local disturbance was not contained and blacked out a large area?

US/Canada



Source: US/Canada Power System Outage Force

Italy



- 3 am
- A line outage in Switzerland caused a cascade that blacked out whole Italy
- TSOs blaming each other

Source: UCTE

Common patterns in US and Europe

- Historically: self-sufficient utilities serving native load
- Reasons to develop interconnections:
  - share generation reserves
  - Better frequency control
  - Also limited **coordinated** exchanges while maintaining conservative security margins

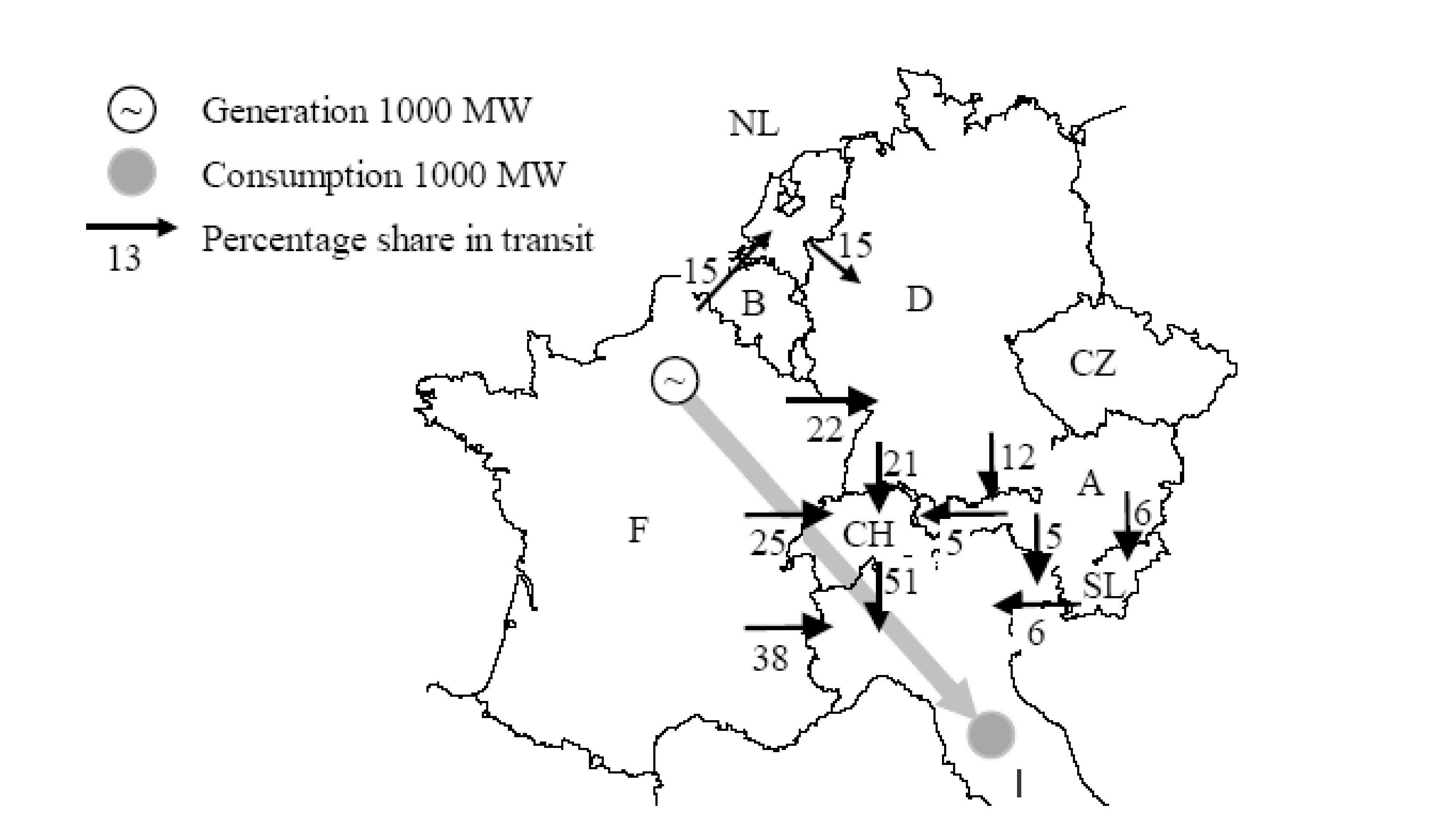
Liberalisation since 1991

- **Uncoordinated** cross-border trades (12% of load in Europe, 4 times increase since 1998 in USA)
- Interconnection used for the purpose (i.e. wide-area trading) it was not designed for
- Increased transmission distances
- Transmission systems run closer to their limits due to commercial pressure

Main generic reason for cascading blackouts

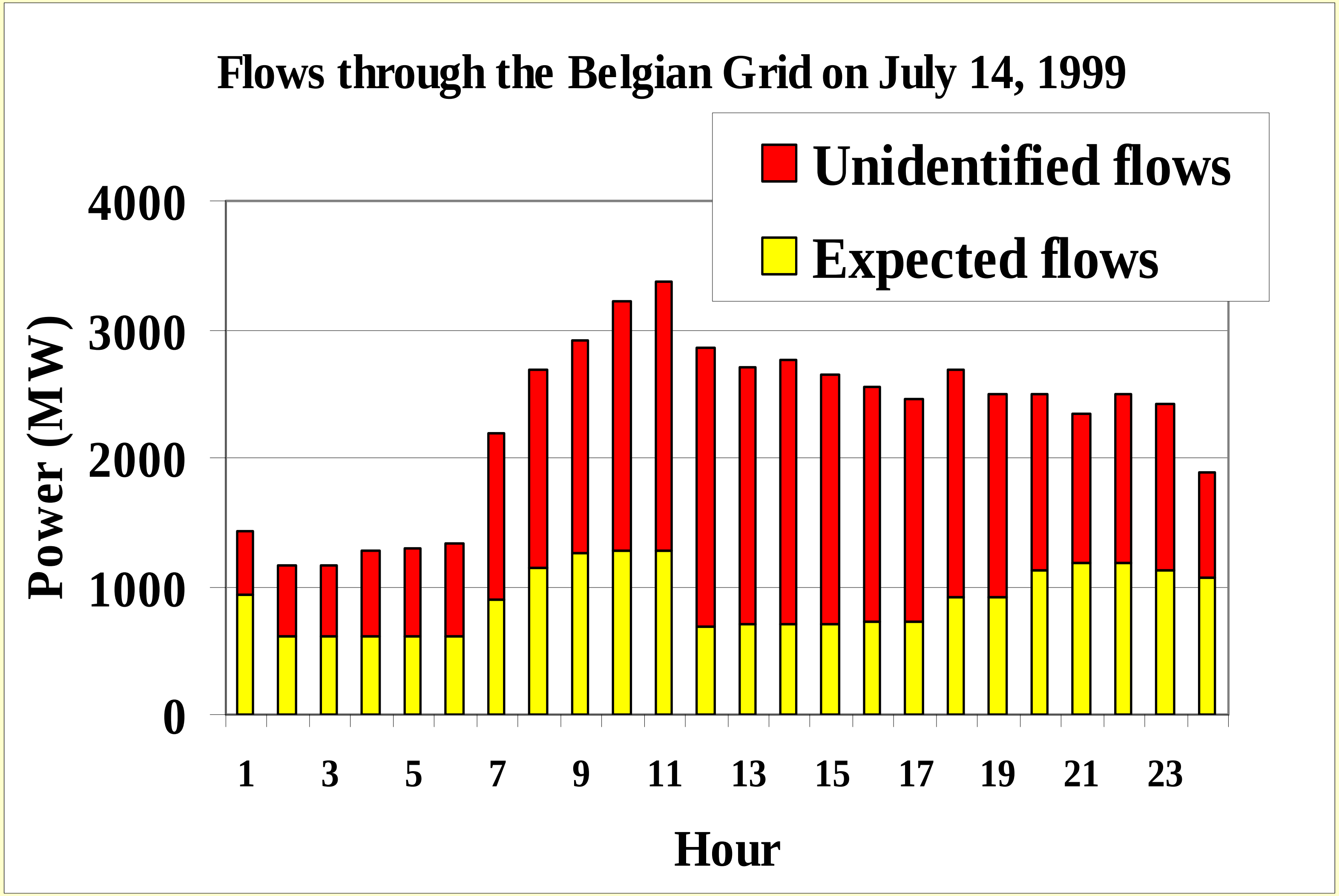
- Operational procedures for running an interconnected system were developed in the world of monopolistic, vertically integrated utilities
- They cannot deal effectively with liberalisation, open access and cross-border trades
- Each utility looks after its own area
- Lack of coordination, lack of exchange of real-time information, none sees the big picture, reliance on manual procedures

Parallel flows: trade from northern France to Italy



Source: H-J Haubrich, W. Fritz

Unexpected flows in bottlenecks



Source: P. Bonnard, 2003 IEEE Trans. Distr. Conf

The future

- Still decentralised but coordinated operation of TSOs
  - Operators must be able to see “the big picture”
  - Exchange of real-time data is a must
  - Automated response to disturbances
- Technical problems are many but they can be solved
- Political, institutional and legal challenge to make it happen

Year 2005

- US/Canada: *Energy Act* transforms NERC into Electric Reliability Organisation which can enforce standards
- Europe: UCTE Multilateral Agreement (MLA) making the technical standards of the Operation Handbook binding among TSOs
- Far more needed

Is my analysis made in 2003 still valid?

UCTE blackout

- UCTE: Union for the Co-ordination of Transmission of Electricity – association of TSOs
- 450M people, 23 European countries
- The worst blackout in 50 years of UCTE as far as the number of TSOs affected and frequency deviations involved
- 15M households affected
- It happened at night – relatively light load (similarly as in 2003 in Italy)
- Prodi called for a central pan-European TSO to be formed
- Knee-jerk reaction: more transmission investment needed

Country/TSO	Load shed
Austria/APG	1500 MW
Belgium/Elia	800 MW
France/RTE	5200 MW
Germany/E.ON Netz	400 MW
Germany/RWE TSO	2000 MW
Italy/TERNA	1500 MW
Netherlands/TenneT	400 MW
Portugal/REN	500 MW
Spain/REE	1050 MW

Source: UCTE

- 274 GW including 15 GW of wind (5.5%)

Source: UCTE

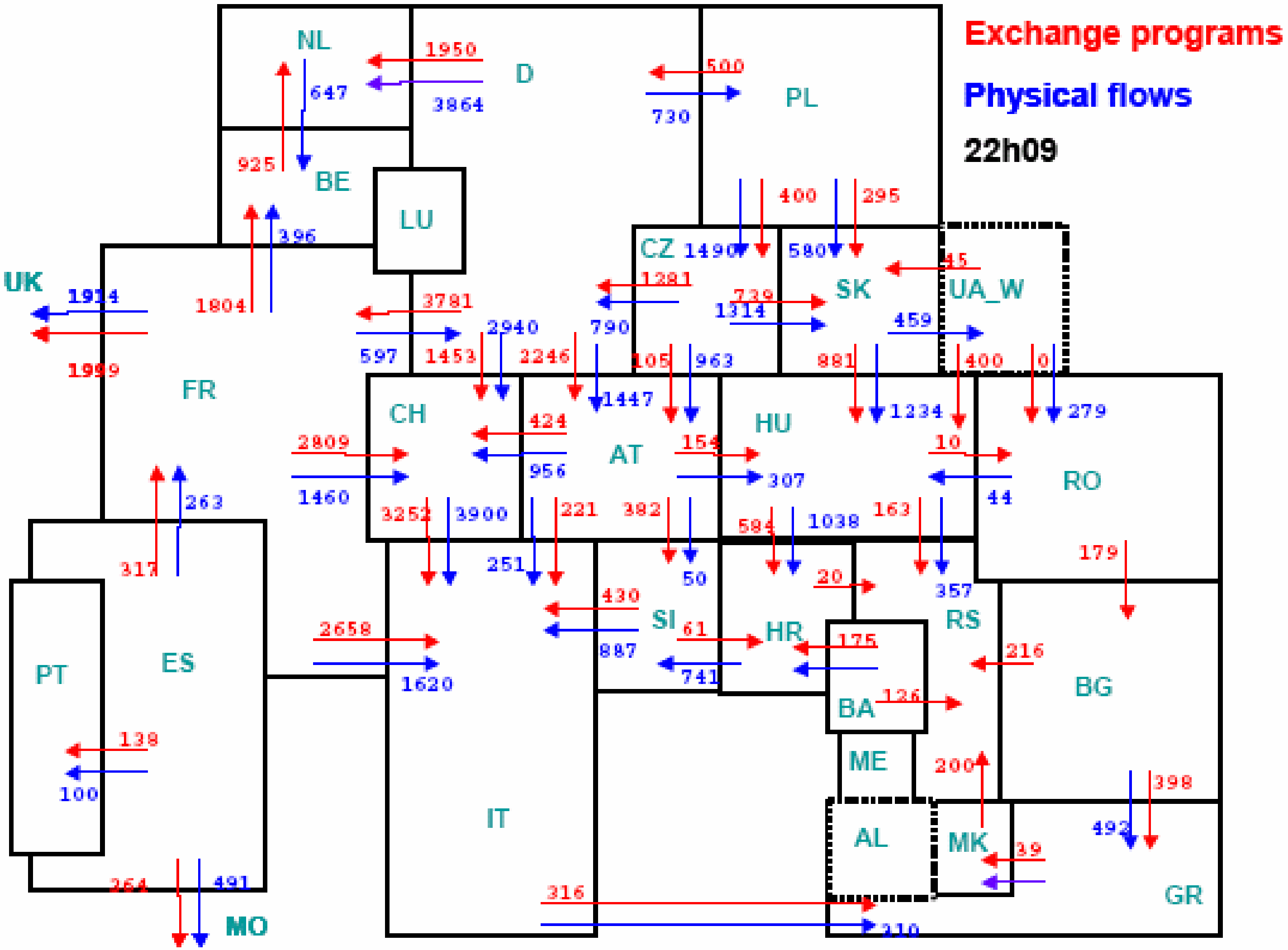


Figure 2: Exchange programs (red) and physical flows (blue) on 4 November at 22:09

- Note the difference between scheduled and actual flows (e.g. FR-D, FR-BE)
- Especially important D-NL, D-PL due to high wind

Source: UCTE

Timeline

- 18 Sept: a shipyard request EON for a routine disconnection of double circuit 380 kV line Diele-Conneferde on 5 Nov
- EON, RWE TSO and TenneT approve provisionally
- (N-1) criterion security rule: a single incident (unexpected tripping of a line, transformer or a plant) should not jeopardise security
- 3 Nov: the shipyard request to bring forward the disconnection by 3 hours. Late announcement could not change exchange programs
- EON agrees provisionally but does not modify Day Ahead Congestion Forecast (DACF) distributed to all TSOs

- 7 pm: EON informs RWE and TenneT about new time for the line outage
- 9.30 pm: EON concludes empirically, without doing (N-1) analysis, that the outage would be secure. Post-mortem analysis showed that the system would not be (N-1) secure
- RWE does (N-1) analysis of its area which indicates high but secure loading
- 9.38: EON switches off of the line
- 9.39-41: warnings of high flows
- Protection settings on EON-RWE line were different but EON dispatchers did not know about it

	E.ON Netz (Landesbergen)	RWE TSO (Wehrendorf)
Steady state value (thermal capacity of the line)	2 000 A	2000 A
Warning value (alarm)	1000 A and 2 000 A	1 795 A (90 % of the max. limit value)
Maximal accepted value	2 550 A (85% of Tripping current) for a max. time 1 hour.	1995 A (95 % of the tripping current
Tripping current	3 000 A	2 100 A

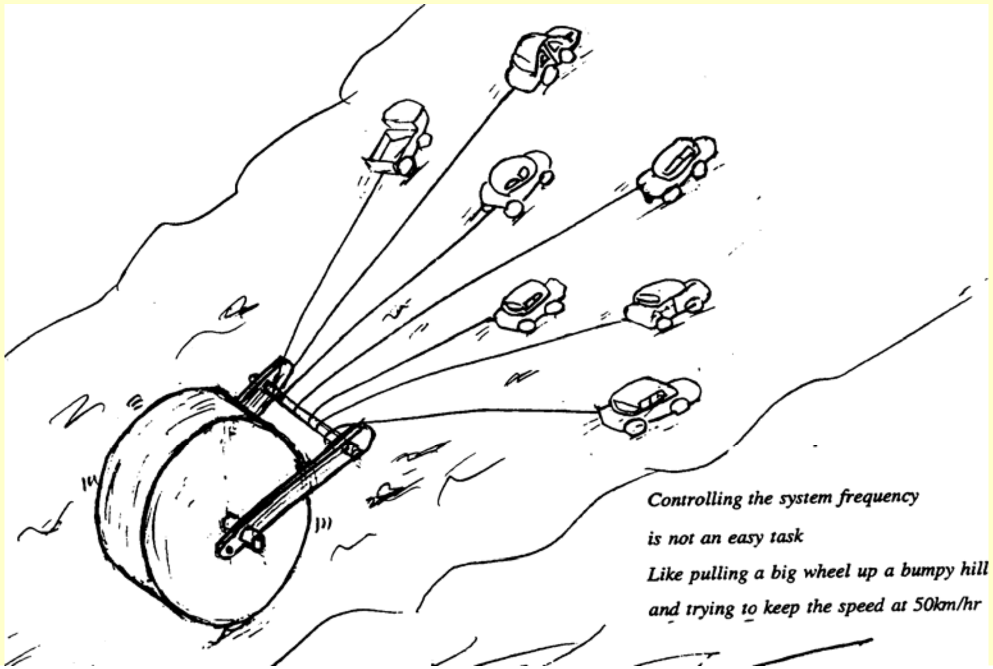
Table 1: Current limit values on the line Landesbergen-Wehrendorf

Source: UCTE

- 10.07: increased load on the line triggers alarm in RWE who ring EON requesting action
- EON assess the situation empirically, without simulations, and decides to couple a busbar to reduce the current by 80 A
- Result: the current increases by 67 A and the line trips
- Cascading line tripping all over UCTE and separation into 3 regions with different frequencies

Why different frequencies?

- Power generated must be equal to power consumed
- Frequency is the same at any part of interconnected network
- If there's a sudden loss of generation, energy imbalance is made up from kinetic energy of all rotating generators
- The speed (frequency) drops triggering all turbine governors to increase generation
- If frequency drops too much, automatic load shedding is activated
- generation deficit => frequency drops, generation surplus => frequency increases



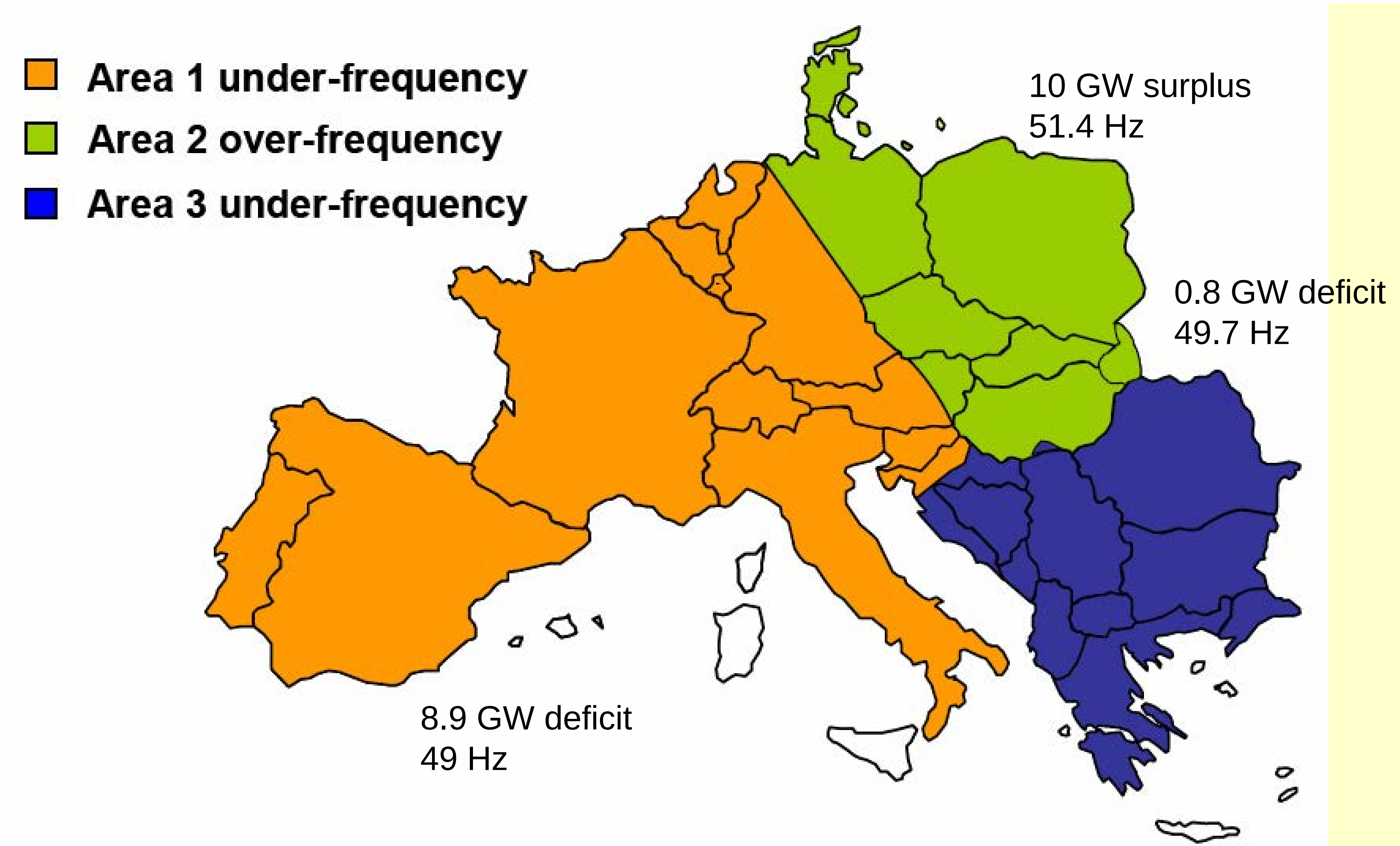
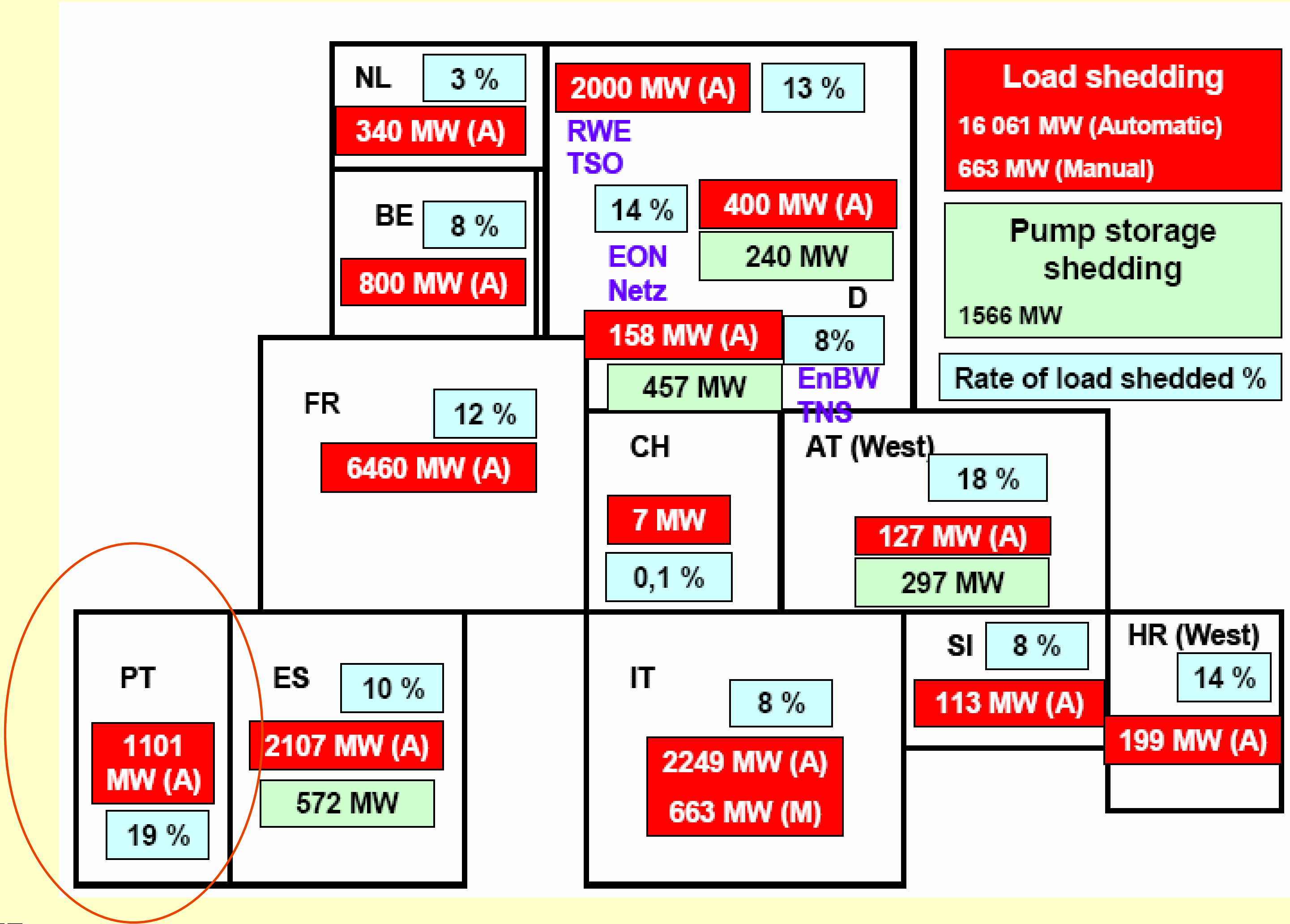


Figure 4: Schematic map of UCTE area split into three areas

Source: UCTE

Automatic under-frequency load and pump shedding in Western Europe

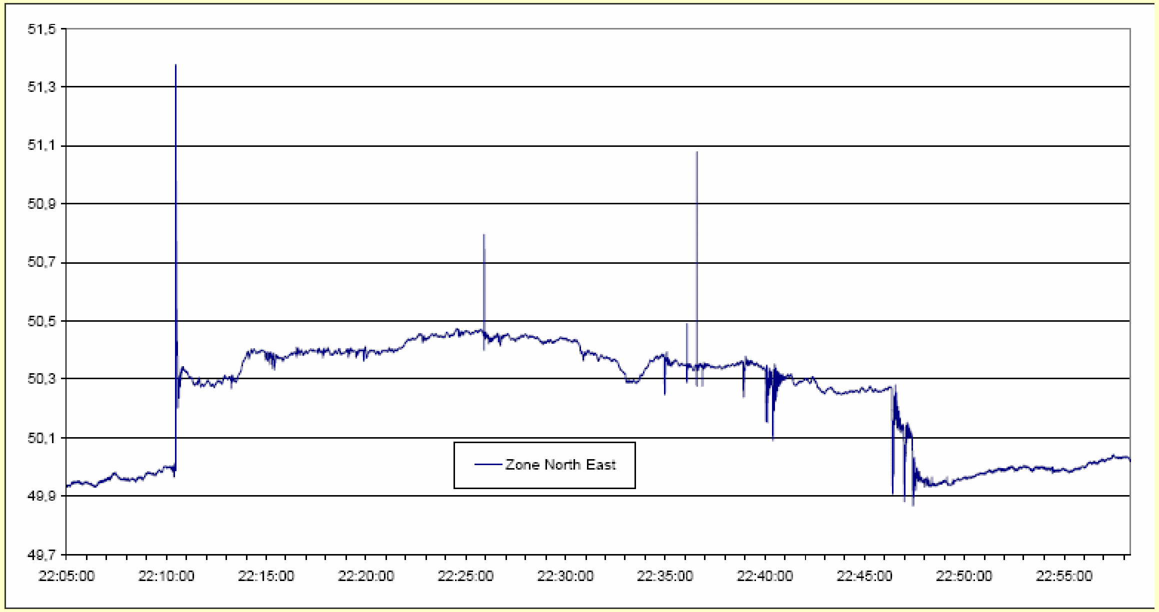


Source: UCTE

Western Europe: 8.9 GW deficit

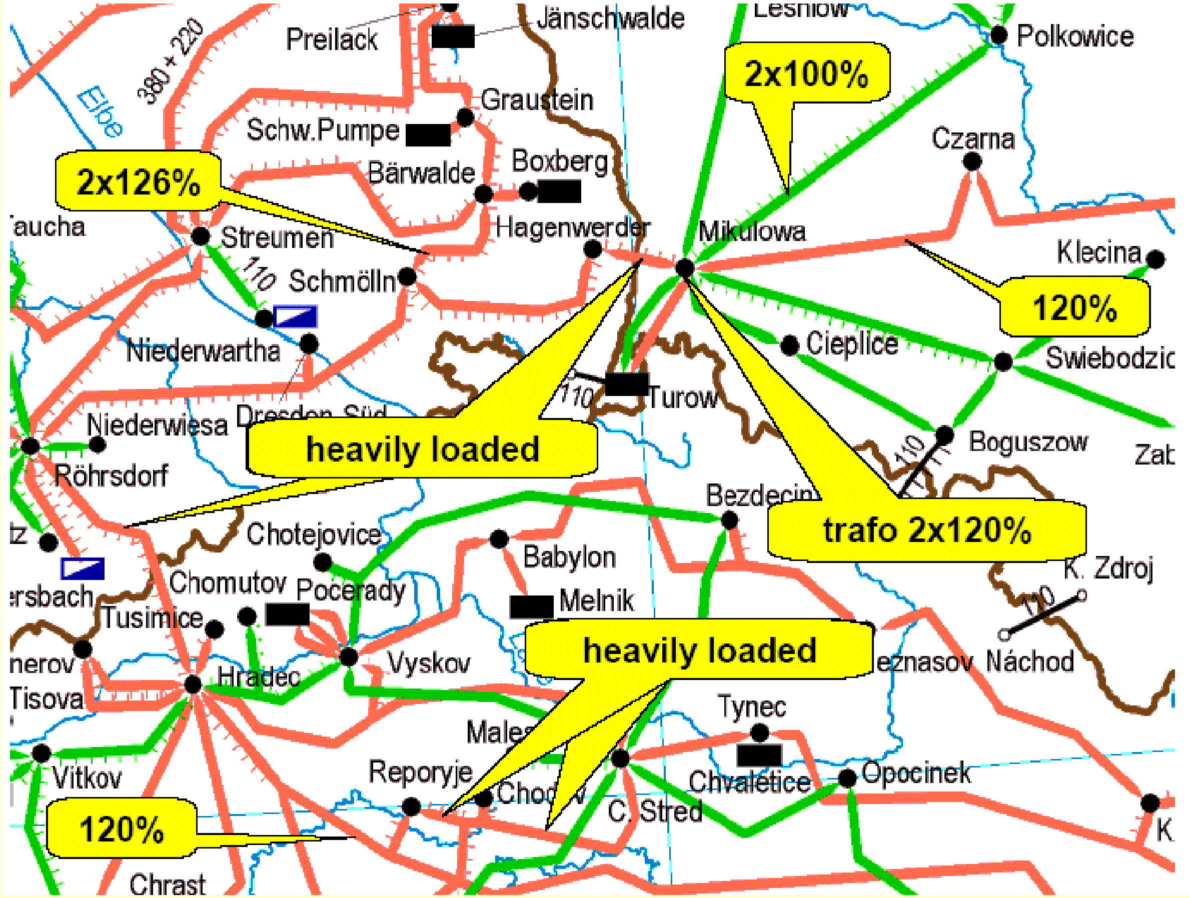
- Drop of frequency caused tripping of 10.7 GW of generation
- 40% of generation lost was wind
- 60% of wind plants and 30% of CHP tripped
- Continued export from France to the UK despite the deficit! (unconfirmed)

North-Eastern Europe: 10 GW surplus



- Initial rise of frequency halted by automatic frequency control and tripping of frequency-sensitive generation (mainly wind – 6.2 GW tripped)
- As frequency started to drop, windmills started to reconnect automatically worsening the situation

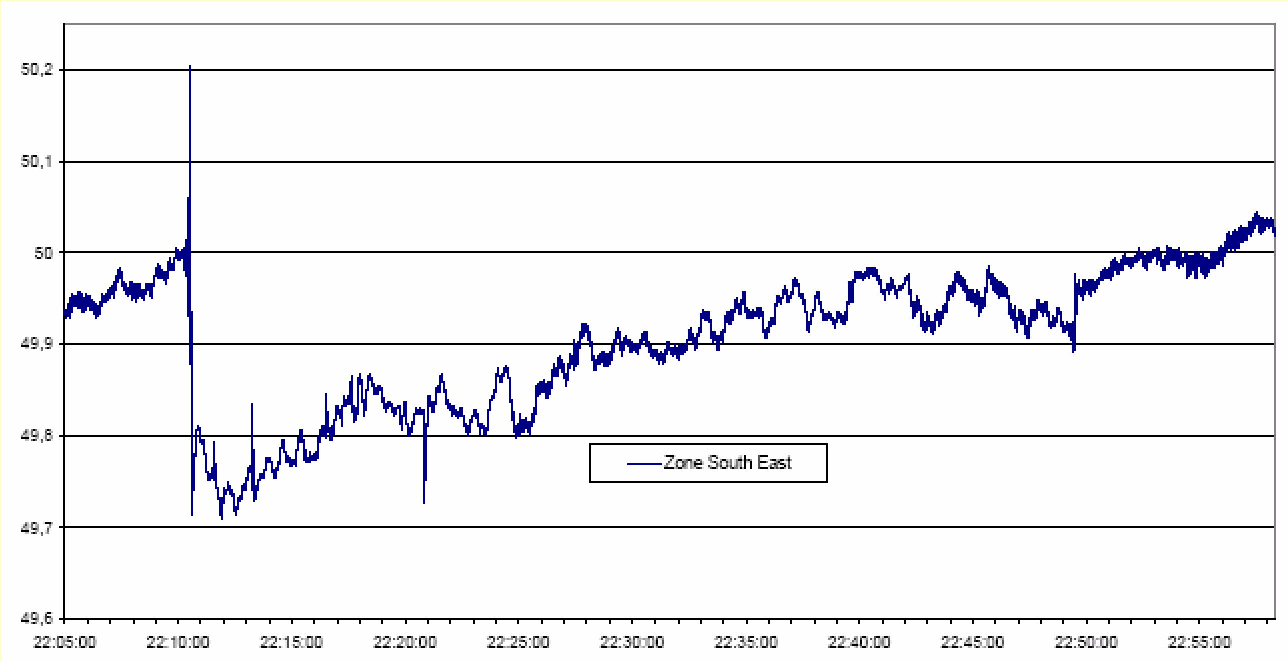
Source: UCTE



- Heavy flows threatened further cascaded trips
- Situation stabilised by manual action of TSOs: instructing central plants to decrease output or stop, starting pumps

Source: UCTE

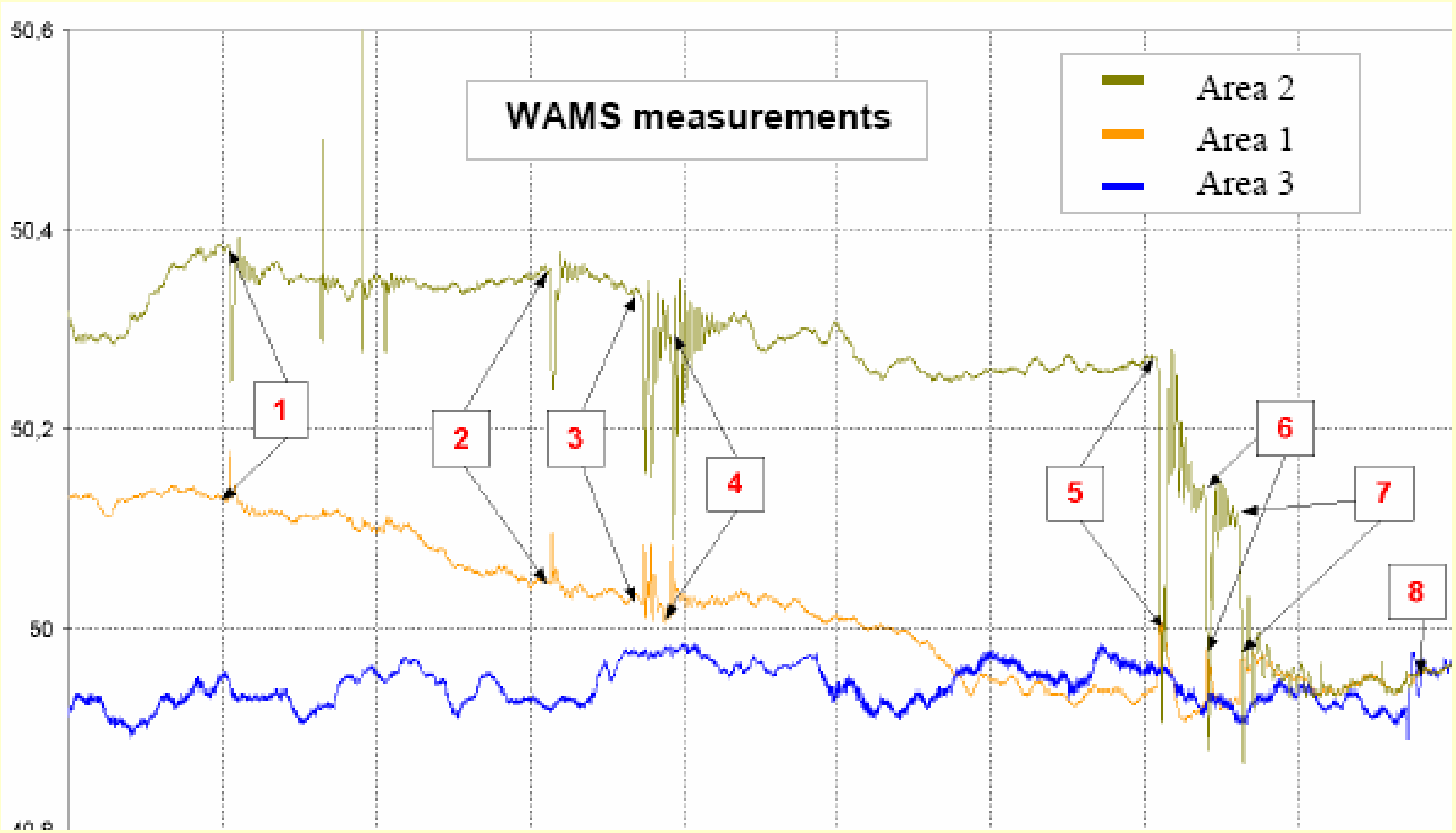
South-Eastern Europe: modest 0.8 GW deficit



- No load shedding activated
- Subsystem (N-1) secure

Source: UCTE

Resynchronisation



- A number of uncoordinated unsuccessful attempts made without knowledge of the overall UCTE situation
- Full resynchronisation after 38 minutes

Source: UCTE

Interim UCTE conclusions: root cause analysis

- Main points:
  - (N-1) criterion security rule
  - Inter TSO coordination
  - Other factors

N-1 criterion security rule

- EON decided to go ahead with the planned outage based on empirical, rather than simulation-based, assessment of (N-1) criterion. In fact, the outage was not (N-1) secure
- EON decided to the topology change in Landesbergen substation which worsened the situation and caused the first line trip. The decision had not been preceded by numerical analysis due to the rush

Inadequate inter TSO co-ordination

- Bringing forward the planned line outage was communicated very late by EON to other TSOs
- It was not checked by EON or prepared properly taking into account the actual situation
- Despite high load at the time, no efficient remedial action was prepared by EON
- No coordination between EON and other TSOs just before the triggering action (substation coupling)
- Unawareness by EON of lower protection settings at the critical line at RWE end

Other critical factors

- Uncontrolled DG trips due to low frequency (mostly wind) worsened situation in power deficit areas
- Uncontrolled reconnection of wind worsened situation in the surplus area
- Most of TSOs did not have real-time information about DG units connected to their grids
- German TSOs had to manage a number of actions defined in the German Energy Law and internal procedures
- Uncoordinated resynchronisation actions by TSOs
- Re-connection of customers by DNOs without coordination with TSOs
- Training of dispatchers

Conclusions

- The UCTE blackout of 4 November 2006 was due to the same underlying reasons as the 2003 blackouts
- Lessons about underlying institutional and organisational causes have not been really learned. It is easier to play the blame game
- Likely significant policy impact
- My conclusions from 2003 are still valid

Conclusions from 2003

- Blackouts were no coincidence; they were disasters waiting to happen
- Underlying common reason: utilities have not fully adapted to liberalisation, open-access and cross-border trades
- New framework of decentralised yet fully coordinated operation needed
- Many technical challenges which may be overcome
- Legal, political and organisational obstacles are the most difficult to overcome