The Disruption in the European Power Grid on 4 November 2006

A Why-Because Analysis

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Overview

The European Blackout 4 November 2006

- 15 Millionen cut off from electricity
- European grid split into three parts
- Triggered by turning off of a 380kV line across the river Ems
- Line turned off to let cruise ship pass

Sources

- Bericht der Bundesnetzagentur für Elektrizitat, Gas, Telekommunikation, Post und Eisenbahnen über die Systemstörung im deutschen und europäischen Verbundsystem am 4. November 2006
  - German (authoritative) and English versions
- Final Report System Disturbance on 4 November 2006 by the UCTE (Union for the Co-ordination of Transmission of Electricity

Sequence of Events

- Meyerwerft Papenburg asks E.ON to turn off high-voltage line across river Ems to allow cruise ship to pass
- E.ON gives provisional approvement and informs other affected carriers
- Meyerwerft asks to move shutdown time to an earlier hour
- E.ON approves earlier time without checks and without informing other carriers

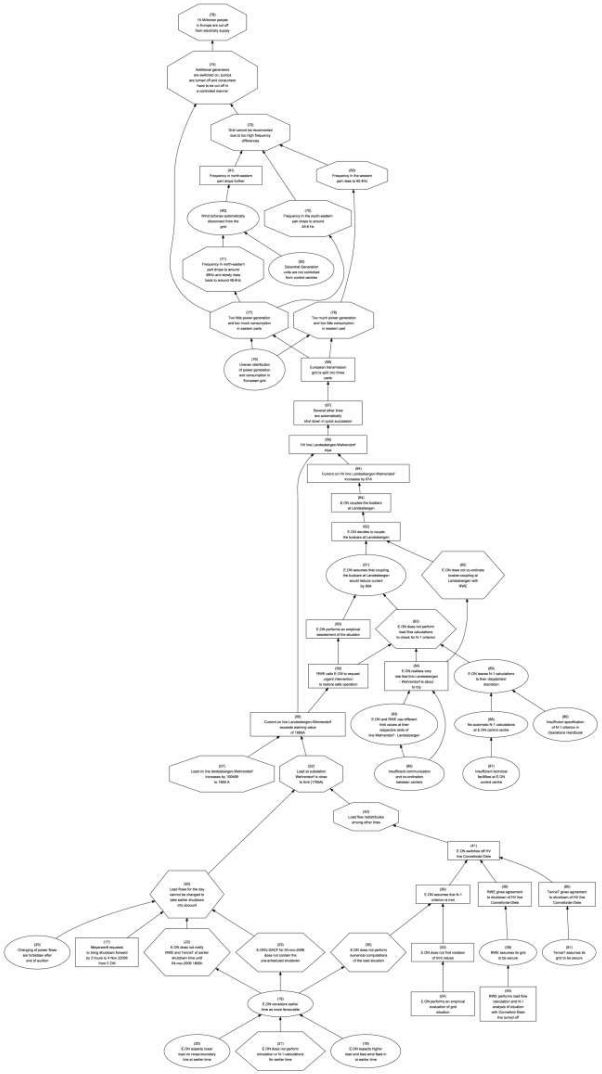
Sequence of Events II

- RWE and TenneT performs load flow calculations prior to shutdown, E.ON does not
- E.ON turns off double-circuit 380kV line across EMS at 21:30h, other lines take the load
- Line Wehrendorf-Landesbergen is close to limit
- Load on line Wehrendorf-Landesbergen increases
- E.ON couples busbars at Landesbergen switching point to decrease load
- Load increases on line Wehrendorf-Landesbergen and it trips
- Load distributes on other lines, many of which also trip in quick succession

Sequence of Events III

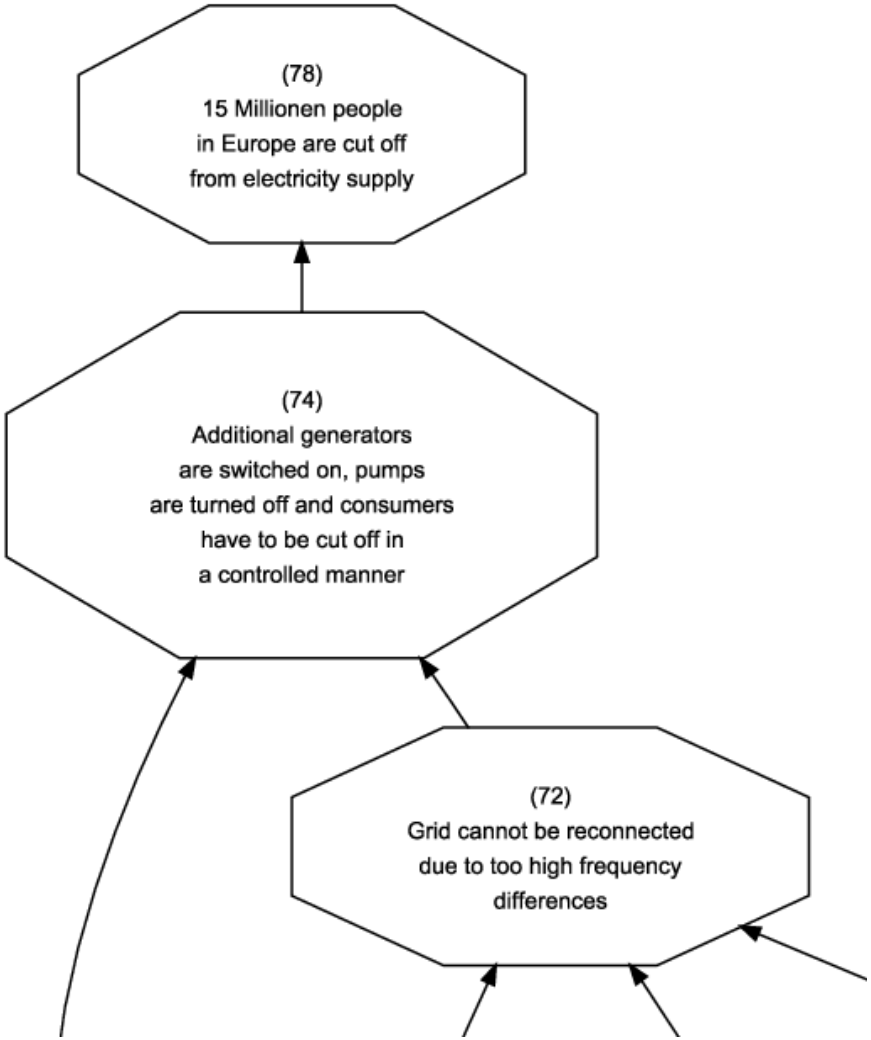
- Grid is split in three, frequencies drift apart
- Consumers in part with under-production have to be disconnected

WB-Graph



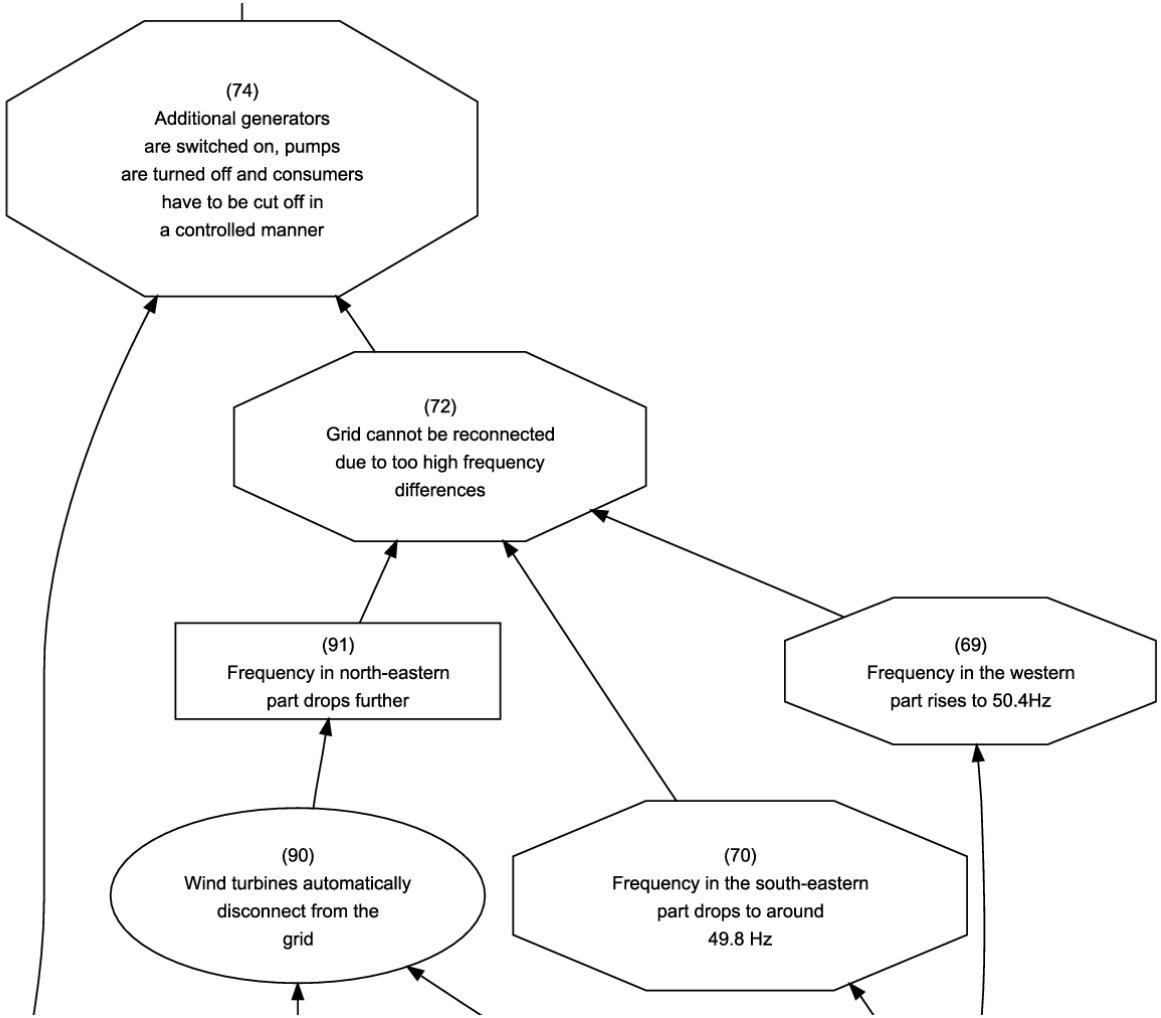
WB-Graph — Blackout

Consumers have to be disconnected in a controlled manner in regions with under-production



WB-Graph — Frequencies

The entire net has to be synchronized to work. Before any resynchronisation can be done, the split parts have to be brought to matching frequency.



Frequencies — Oscillation, Split, Drift

Prior to the final tripping of the lines frequencies oscillate

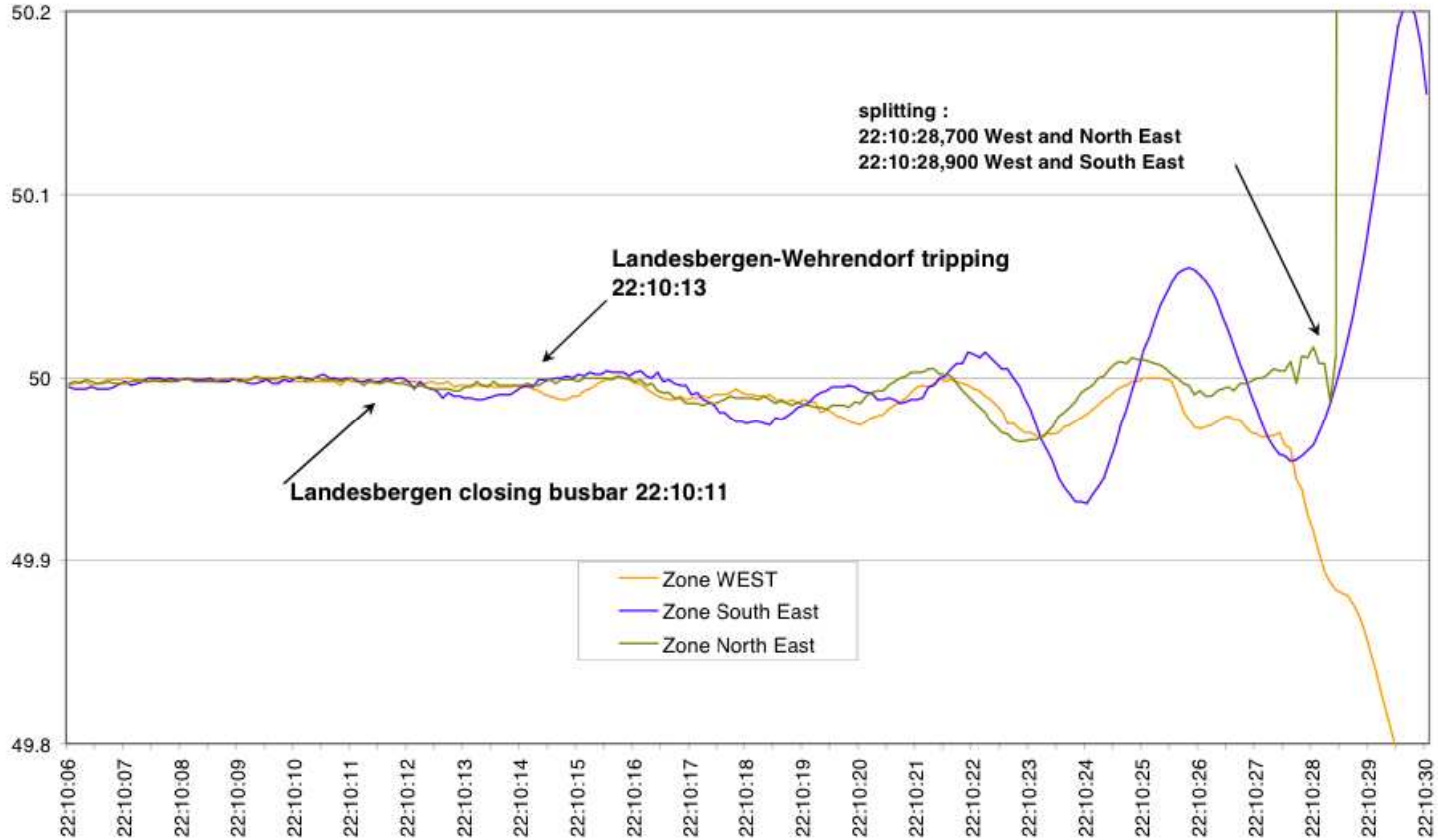


Figure 5: Frequency recordings until area splitting

Figure 6 is presenting frequency recordings as retrieved by Wide Area Measurement Systems (WAMS) in the three areas from 22:09:30 to 22:20:00

Frequencies — Oscillation, Split, Drift

Just after the split, frequencies quickly drift apart from the nominal 50Hz, precluding a quick reconnection.

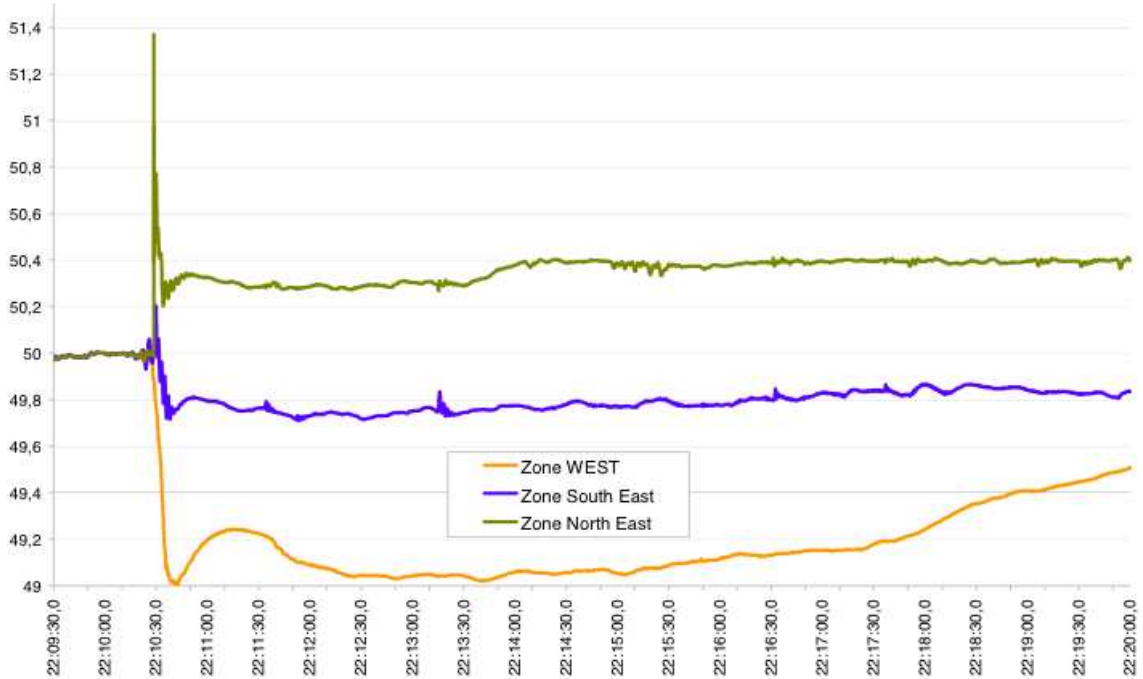
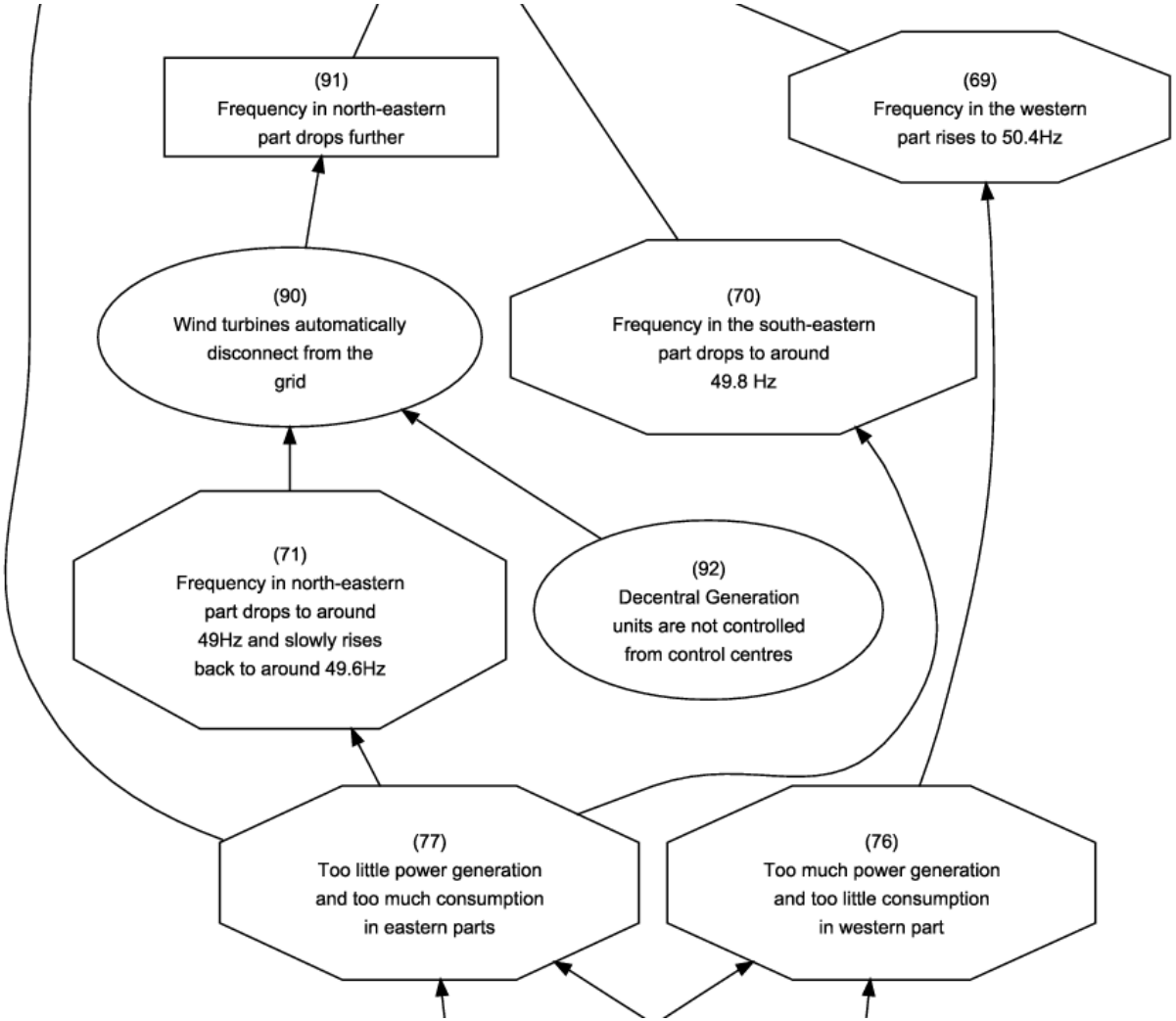


Figure 6: Frequency recordings after the split

WB-Graph — Wind Power

- Wind turbines are not centrally controlled
- Disconnect automatically when parameters deviate too far
- exacerbates underfrequency and underproduction problem



Wind Power — Infeed around the split time

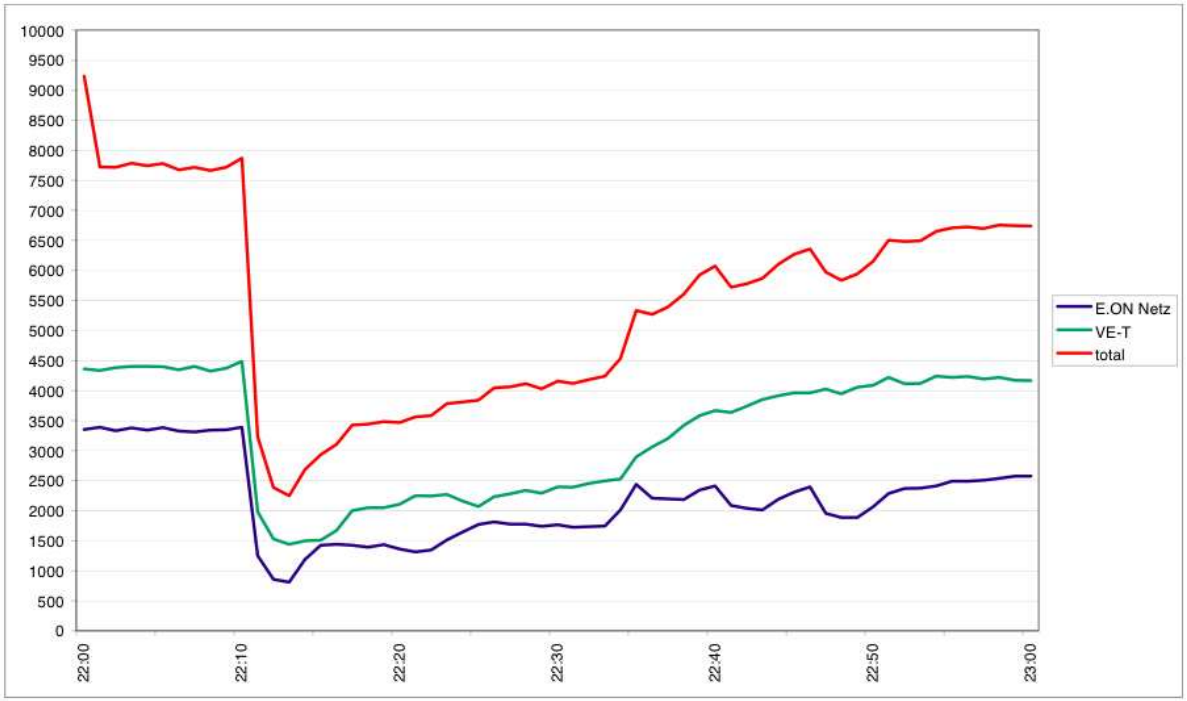
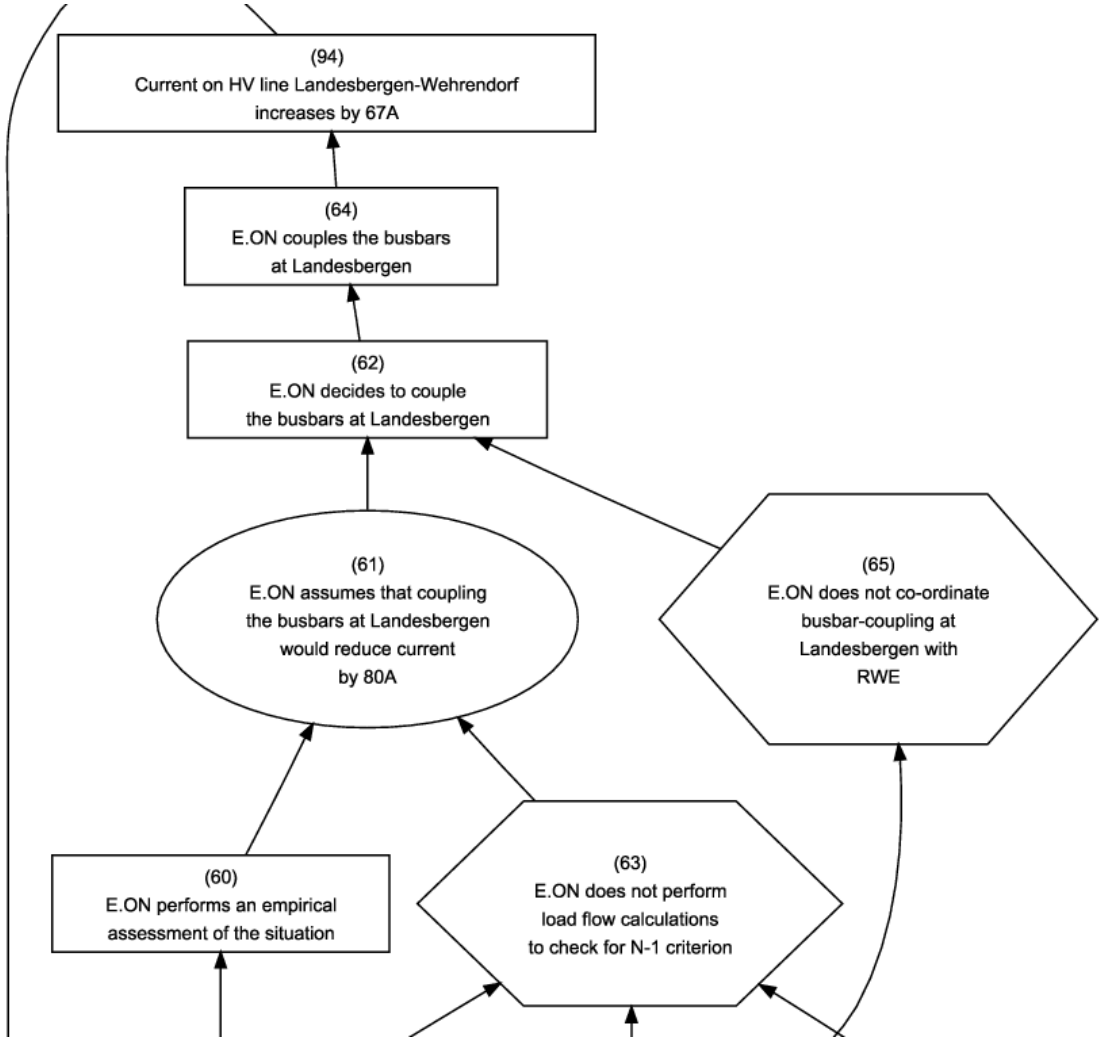


Figure 13: Output of windmills (VE-T, E.ON Netz, from 22:00 to 23:00

WB-Graph — Busbar Coupling

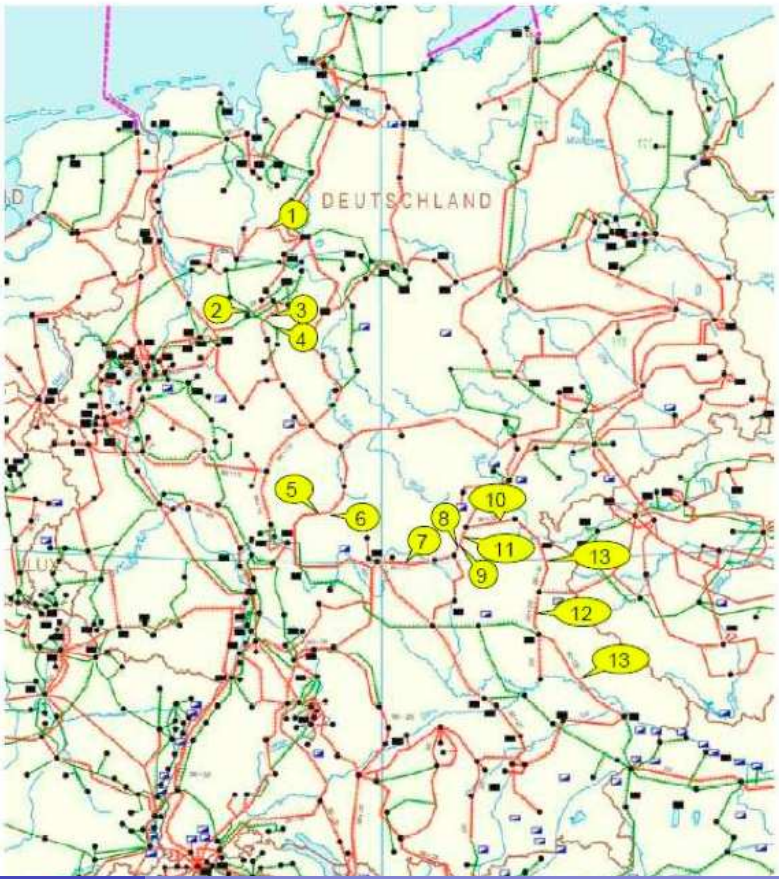
- E.ON did not perform load flow analyses
- Erroneously assumed busbar coupling would reduce load
- Coupling did increase load instead!



Busbar Coupling — Consequences

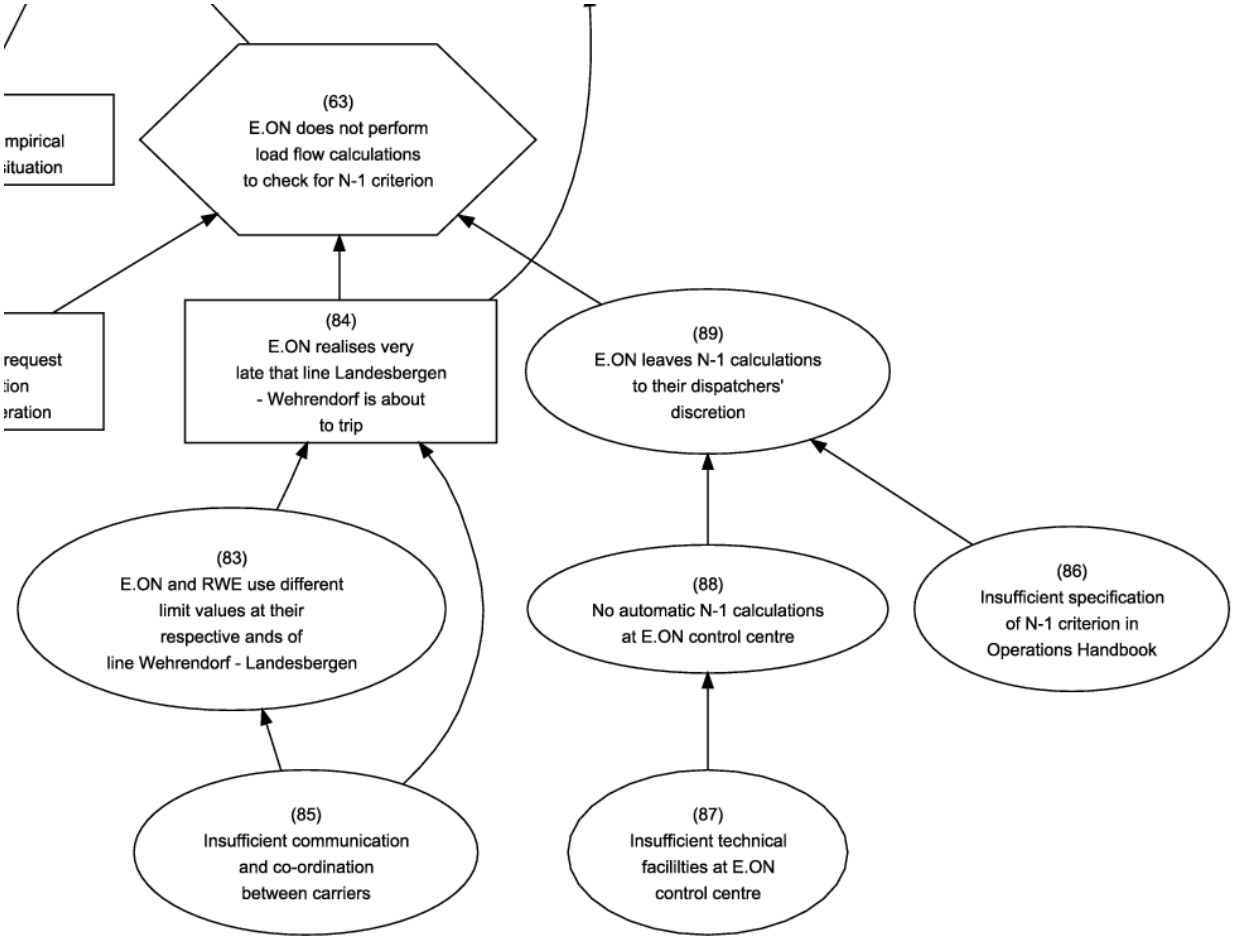
- Overloaded line Landesbergen Wehrendorf trips
- Other lines trip in an unstoppable cascade within seconds of each other
- First 14 lines tripped within 14 seconds
- Total 33 lines tripped within 1 min 20s

Nr.	Zeit	kV	Leitung
1	22:10:13	380	Wehrendorf-Landesbergen
2	22:10:15	220	Bielefeld/Ost-Spexard
3	22:10:19	380	Bechterdissen-Elsen
4	22:10:22	220	Paderborn/Süd-Bechterdissen/Gütersloh
5	22:10:22	380	Dipperz-Großkrotzenburg 1
6	22:10:25	380	Großkrotzenburg-Dipperz 2
7	22:10:27	380	Oberhaid-Grafenrheinfeld
8	22:10:27	380	Redwitz-Raitersaich
9	22:10:27	380	Redwitz-Oberhaid
10	22:10:27	380	Redwitz-Etzenricht
11	22:10:27	220	Würgau-Redwitz
12	22:10:27	380	Etzenricht-Schwandorf
13	22:10:27	220	Mechlenreuth-Schwandorf
14	22:10:27	380	Schwandorf-Pleinting

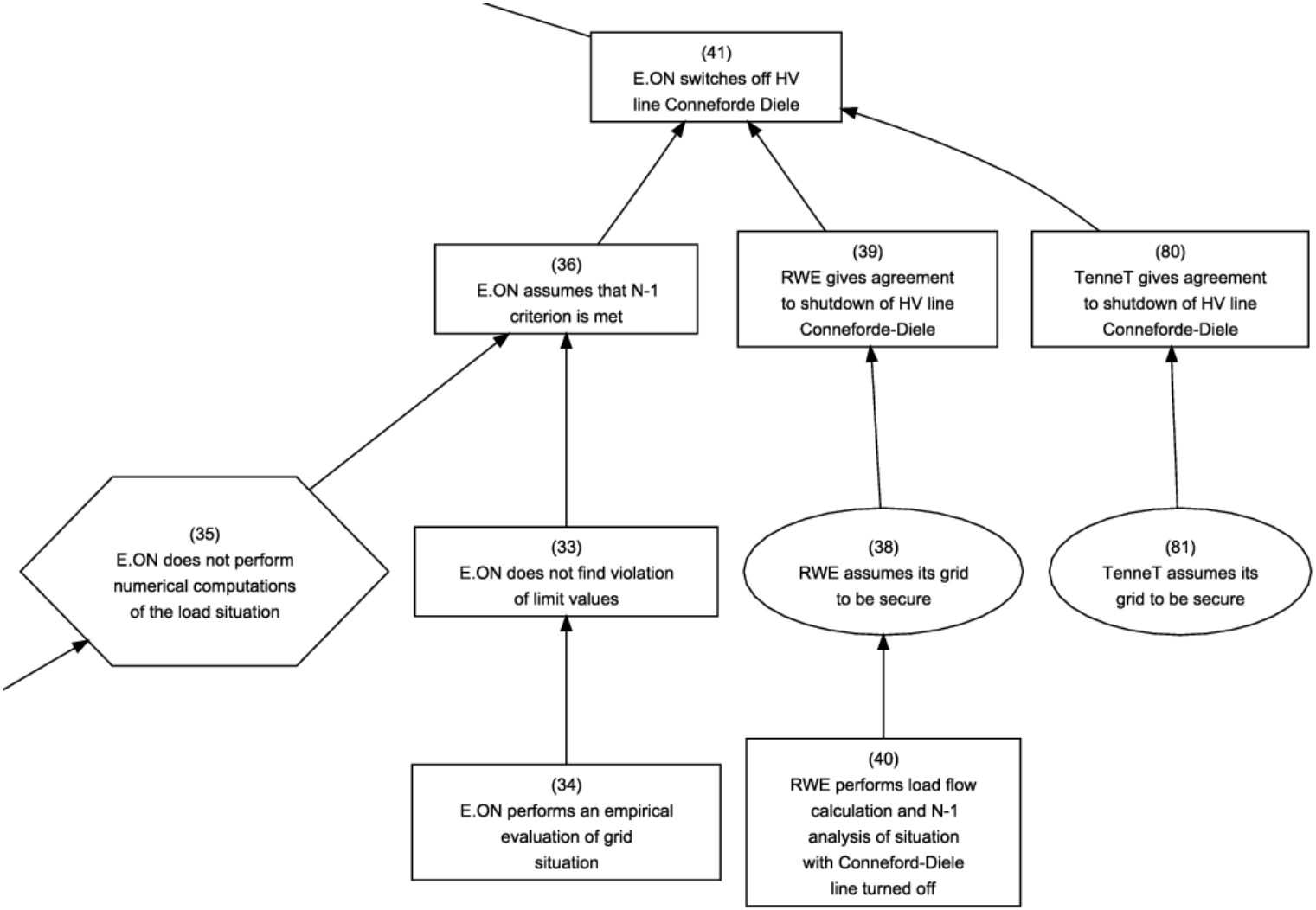


WB-Graph — N Minus One

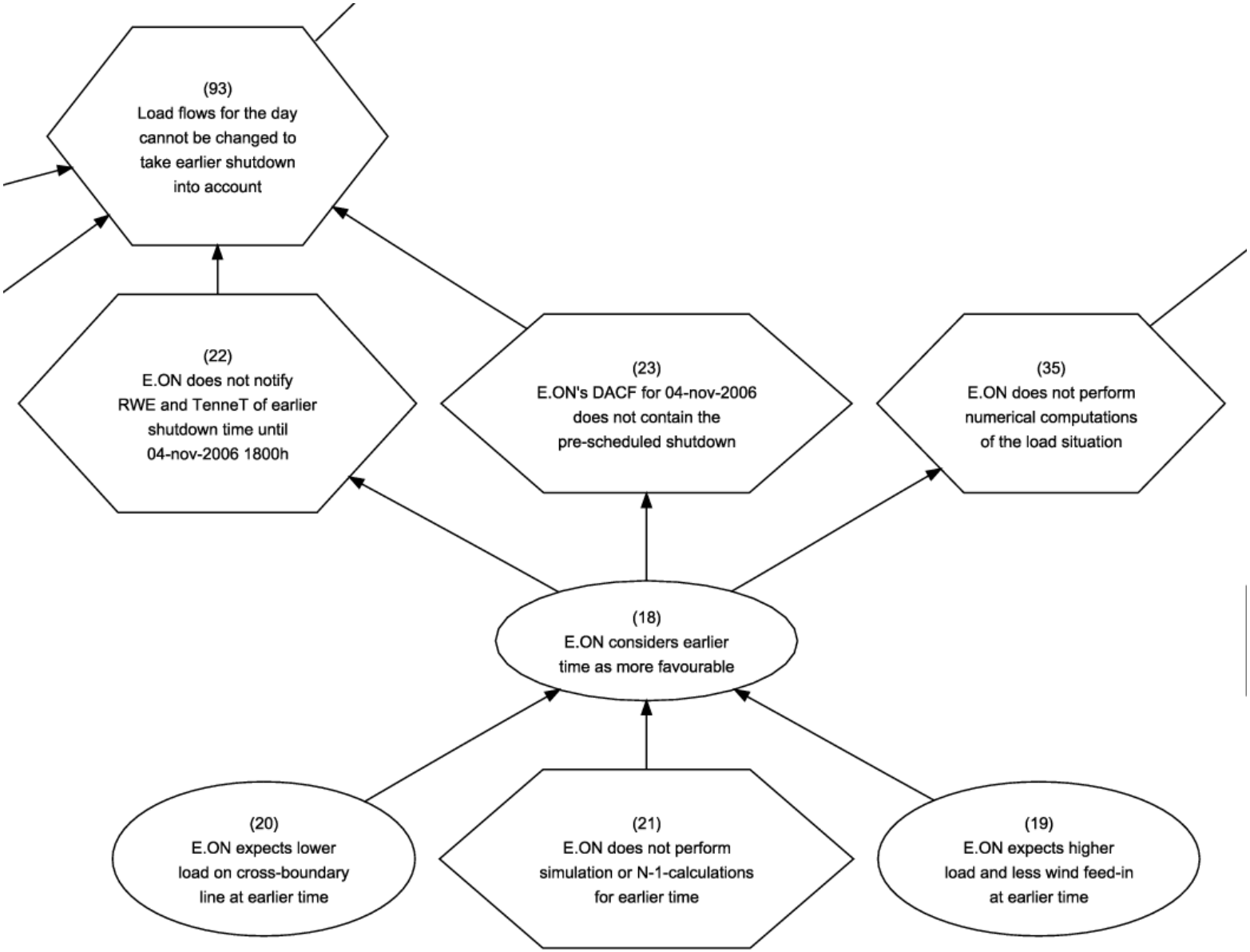
- E.ON does not check for N-1 criterion
- RWE does, in regular intervals and before switching operations



WB-Graph — N Minus One, Take 2



WB-Graph — N Minus One, Take 3



The N-1 Criterion

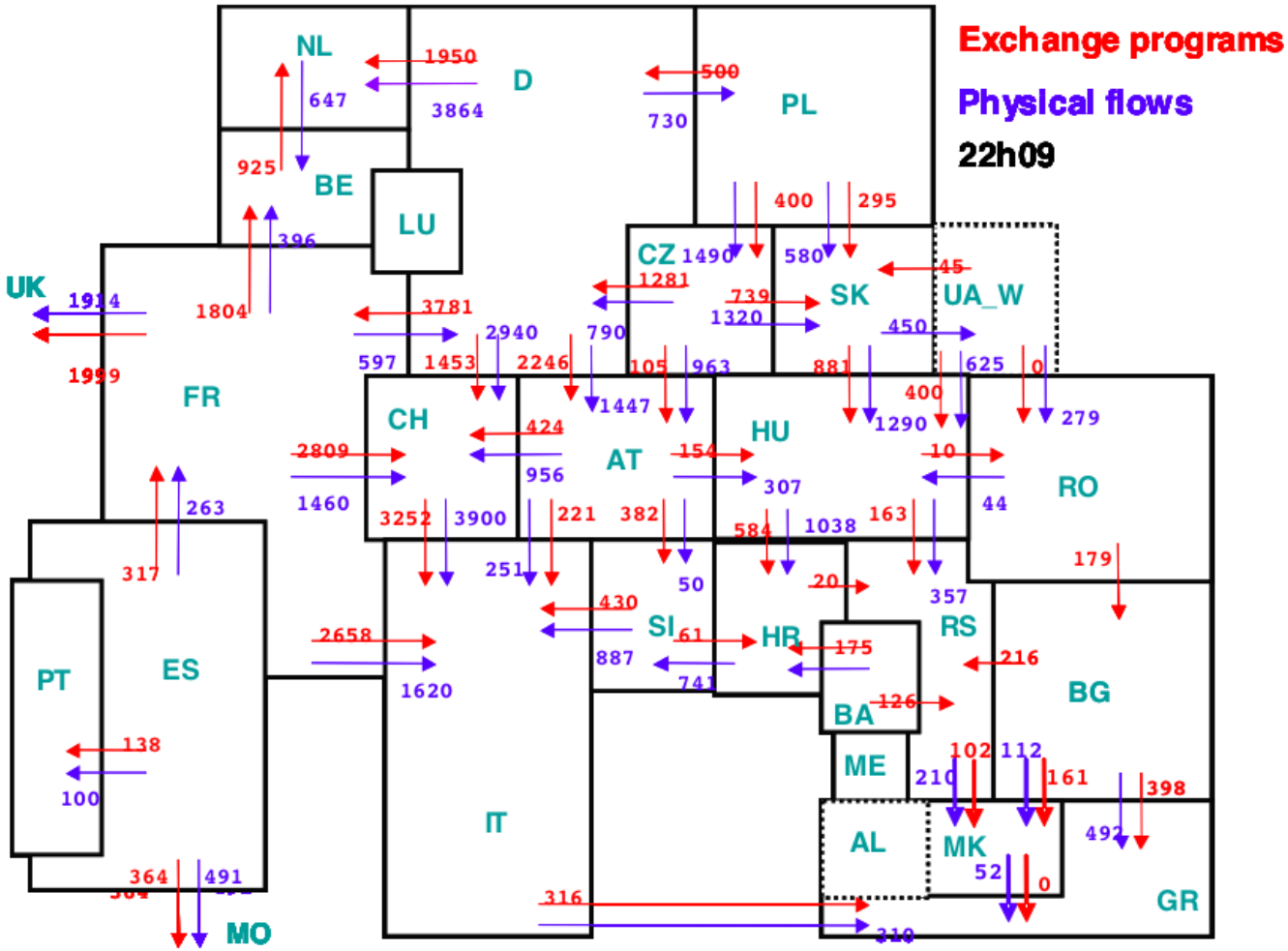
- Described in Operations Handbooks
- States that the net must tolerate failure of one major component and still work securely
- Regulations stipulate that N-1 criterion has to be met at all times
- No detailed description how to guarantee N-1 safety, or how often to perform calculations
- Insufficient specification

Checking for N-1 Safety

- RWE
  - has automated system that performs N-1 calculations every 15 minutes automatically
  - Personnel can easily trigger additional calculation runs
- E.ON
  - No automated system
  - Personnel have to initiate calculations manually
  - Left to Dispatchers' discretion when to perform calculations

Interconnected European Power Grid

- Unevenly distributed generation and consumption
- High-cross-boundary flows of power
- Use of AC requires frequency synchronisation



"Main Causes" in Official Reports

- Main Causes
  - Violation of N-1 criterion
  - Insufficient inter-TSO co-ordination
- Bundesnetzagentur and UCTE agree on these findings

UCTE recommendations

- Clarification of N-1 criterion in Operations Handbook
- Extend Emergency Operations Policy in OH with a "Master Plan"
- Develop standard criteria for inter-TSO co-ordination
- Set up information platform for TSOs to view global UCTE system state
- Adapt legal regulatory framework

Correspondence to Findings in WB-Graph

- 3 Occurences of failure to check for N-1 criterion
  (Caused by insufficient technical facilities at E.ON operations centre. Also identified by Reports)
- Failure to realise in time the different settings at line Wehrendorf-Landesbergen
  (Communications / Co-ordination failure between TSOs. Also identified by Report)

Thank you very much for your Attention

The solution: Build smaller ships:

The HV line Conneforde-Diele, which did not have to be switched off for the AIDA diva

Bundesnetzagentur:
Report on the disturbance in the German and European power system on the 4th of November 2006

Union for the Co-ordination of Transmission of Electricity (UCTE):
Final Report System Disturbance on 4 November 2006